3.1.2 Treatment

The raw water that is drawn from the RID Bangwad Reservoir through two 500 mm pipes is fed into the 1,000 cu.m/h treatment plant by raw water pumps. The treatment process consists of chemical flocculation, sedimentation, rapid sand filtration and chlorination. Alum is added at the rapid mixing basin and chlorine water is injected to the 400 mm filtrate pipe.

The treated water that is stored in the 6,400 cu.m clear water reservoir is distributed directly by the clear water pumps. The treated water needed by the Deep Sea Port is distributed by gravity due to low water demand at present. Water used for backwashing the rapid sand filter is obtained from a pipeline connected to the clear water pumps.

The elements comprising the treatment plant are summarized in Table 3-1-2. Figures 3-1-1 and 3-1-2 provide the schematic presentation and layout of the treatment plant, respectively.

3.1.3 Distribution System

(1) Description of Existing Distribution Network

The distribution system of the Phuket Waterworks covers the area as shown in Figure 3-1-3. The distribution system consists of three lines for Patong, Kathu and the Deep Sea Port. The pipelines for these three areas are installed separately from the clear water reservoir at the Bangwad Treatment Plant. Out of the three lines, only one pipeline for Patong is pressurized by a high pump while the two lines operate by gravity at present.

Patong area is supplied water via a booster pumping station which is located in the middle in the distribution main. This area is also supplied with water by gravity from the old treatment plant at the north end of Patong Beach. Water pressure in this area is extremely high since the direct pumping system was adopted. When the booster pump is operated, pressure at the house connection is raised up to 3.0 to 5.0 kg/sq cm. On the other hand, some areas located higher than 15.0 m (AMSL) suffer water interruptions when the booster pump is turned off. This is because the old plant can not produce the sufficient head for distributing water because of its location and the lack of distribution pumps.

The booster pump is turned on two to three times a day; therefore, water pressure fluctuates drastically.

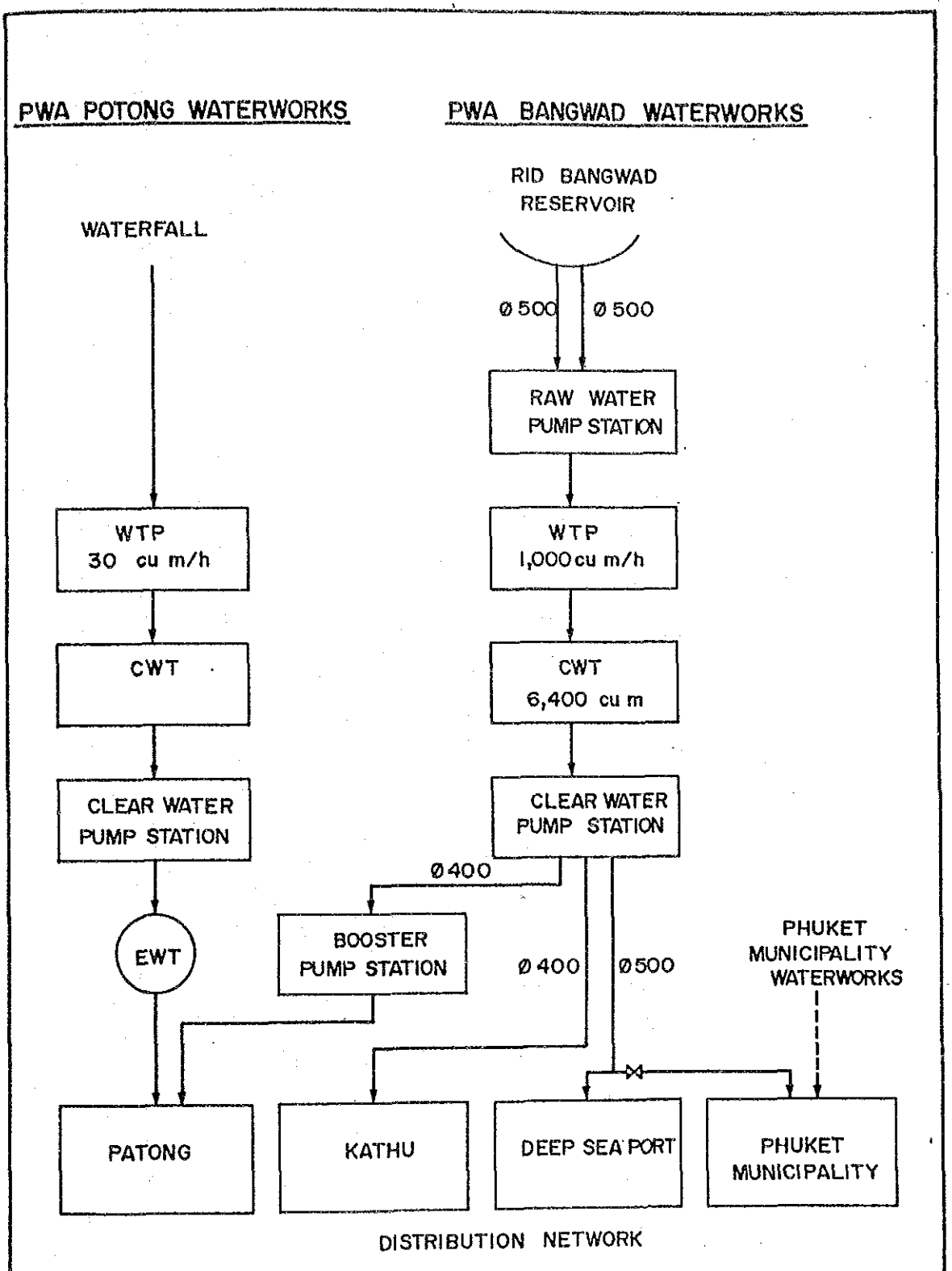
As described above, the distribution pipes in the service area in Patong receive intermittent high pressure at the time of the booster pump's operation. Repeated high and low pressure in the distribution line is considered to be a serious problem that needs immediate solution since this could damage the asbestos cement pipe itself and at its joints.

The distribution pipe may even burst and this could occur in the near future at various points in the network. The problem could be solved

Table 3-1-2 Outline of Water Treatment Facilities

Facility	Bangwad	Patong
Water Source	Bangwad Reservoir	Waterfall
Treatment Capacity	1,000 cu.m/h	20 cu.m/h
Raw Water Pump	600 cu.m/h x 26 m x 100 hp x 2units M/D 600 cu.m/h x 26 m x 100 hp x 2 units ME/D	None
Flocculation Basin		
No. of Units	4 units	1 unit
Dimensions	7.28 m x 7.28 m x 3.40 m	0.30 m x 1.80 m x 0.40 m x 50 channels
Flocculation Time	43.2 min	32.4 min
Sedimentation Basin		
No. of Units	4 units	1 unit
Dimensions	7.28 m x 54.78 m x 3.10 m	2.40 m x 6.36 m 3.40 m
Detention Time	4.9 h	2.6 h
Rapid Sand Filter		
No. of Units	8 units	1 unit
Dimensions	6.70 m x 6.60 m	2.40 m x 1.80 m
Filtration Rate	67.8 m/d	111.1 m/d
Clear Water Reservoir		
No. of Units	1 unit	1 unit
Capacity	6,400 cu.m	
Detention Time	6.4 h	
Elevated Water Tank	None	
No. of Units		1 unit
Capacity		
Detention Time		
Clear Water Pump	250 cu.m/h x 45 m x 70 hp x 2 units M/D 250 cu.m/h x 45 m x 74 hp x 1 unit E/D 300 cu.m/h x 20 m x 37 hp x 1 unit M/D	
Backwash Water Pump	1,400 cu.m/h x 15 m x 150 hp x 1 unit M/D	
In-plant Water Pump	5 cu.m/h x 20 m x 2 hp	

M/D:motor-driven E/D:engine-driven ME/D:motor-/engine-driven



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

FIGURE 3 - 1 - 1
PHUKET EXISTING WATER TREATMENT SYSTEM

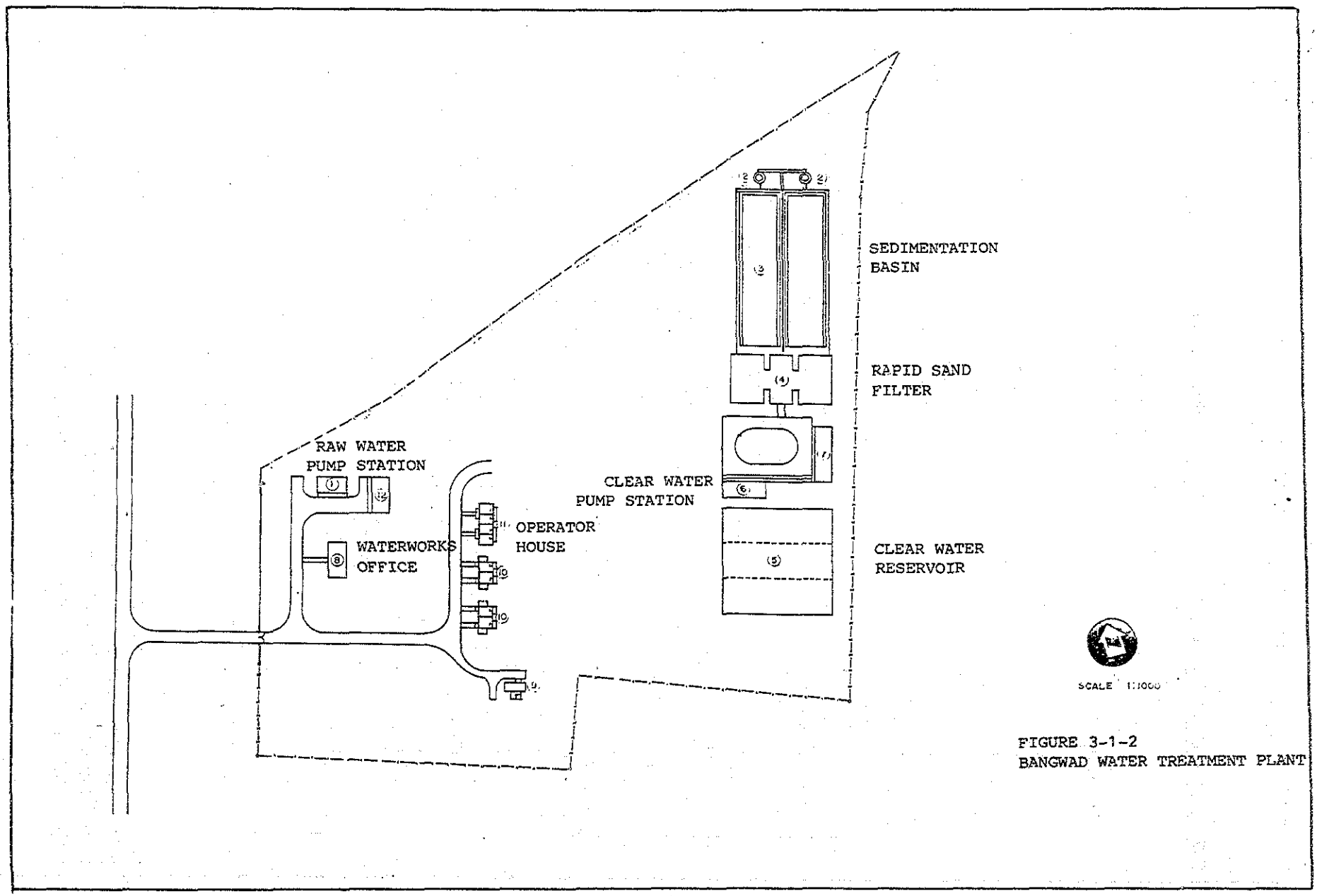


FIGURE 3-1-2
BANGWAD WATER TREATMENT PLANT

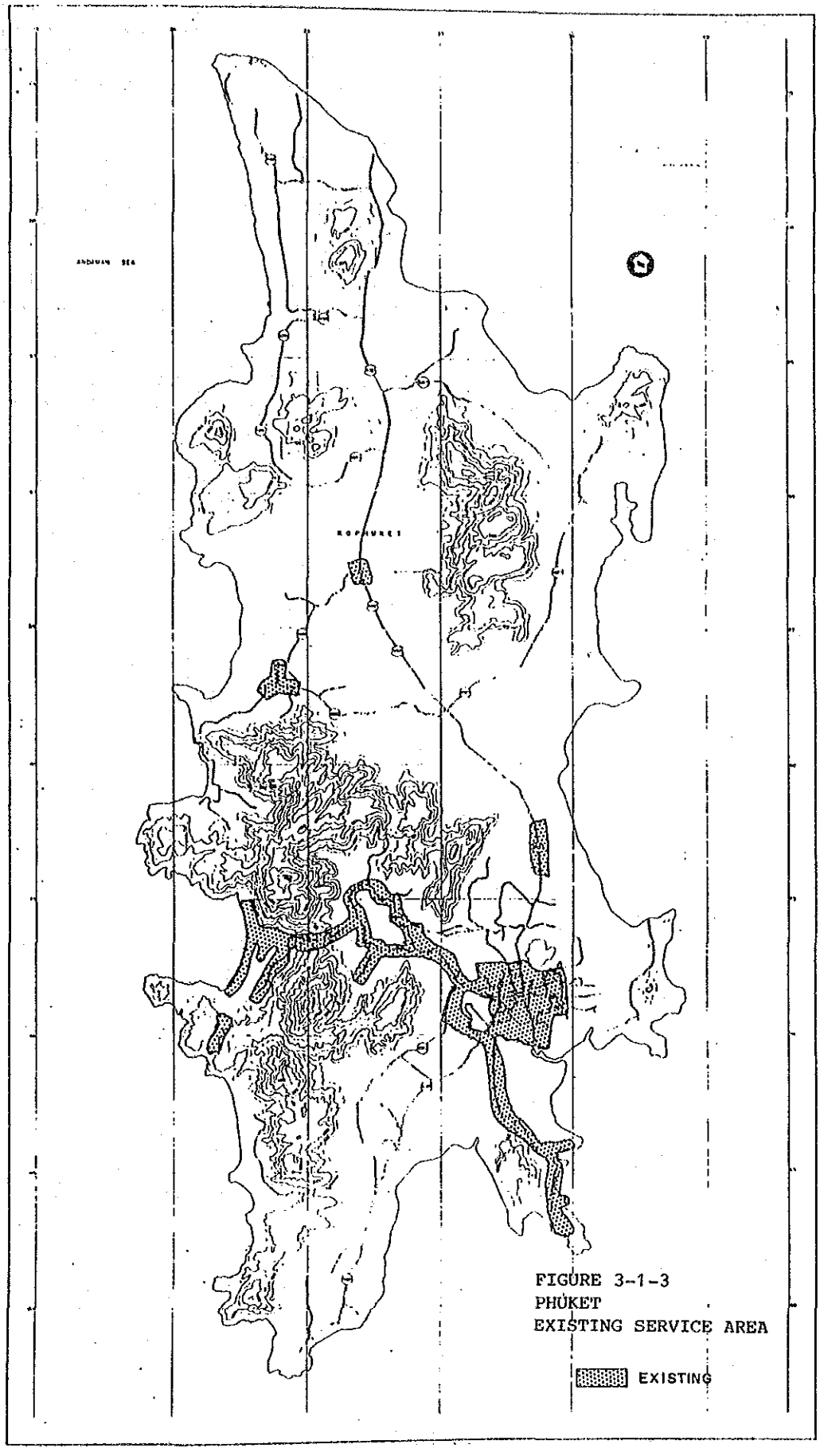


FIGURE 3-1-3
PHUKET
EXISTING SERVICE AREA

immediately by providing proper pressure reducing measures, such as the provision of a receiving tank at the proper elevation and/or installation of the most effective type of pressure reducing valve. If any measures to be undertaken, a careful hydraulic study should be carried out.

The Kathu area is supplied water by gravity from the Bangwad Treatment Plant. The distribution pipeline forms a single loop along the main road in the community. This area has the proper pressure range; but its problem is in water quality.

The distribution line for the Deep Sea Port is now scarcely used considering its big water conveying capacity. This is because the planned big two consumers for this line have not been connected yet. These are the Phuket Municipality and the Deep Sea Port. Therefore, the size of the pipe for the present water demand on this line is causing another water quality problem - high pH value of more than pH 10.0. This problem is described further in Appendix A-3-1.

The schematic plan of the network is shown in Figure 3-1-4. A breakdown of the pipeline of the PWA Phuket Waterworks is tabulated in Table 3-1-3.

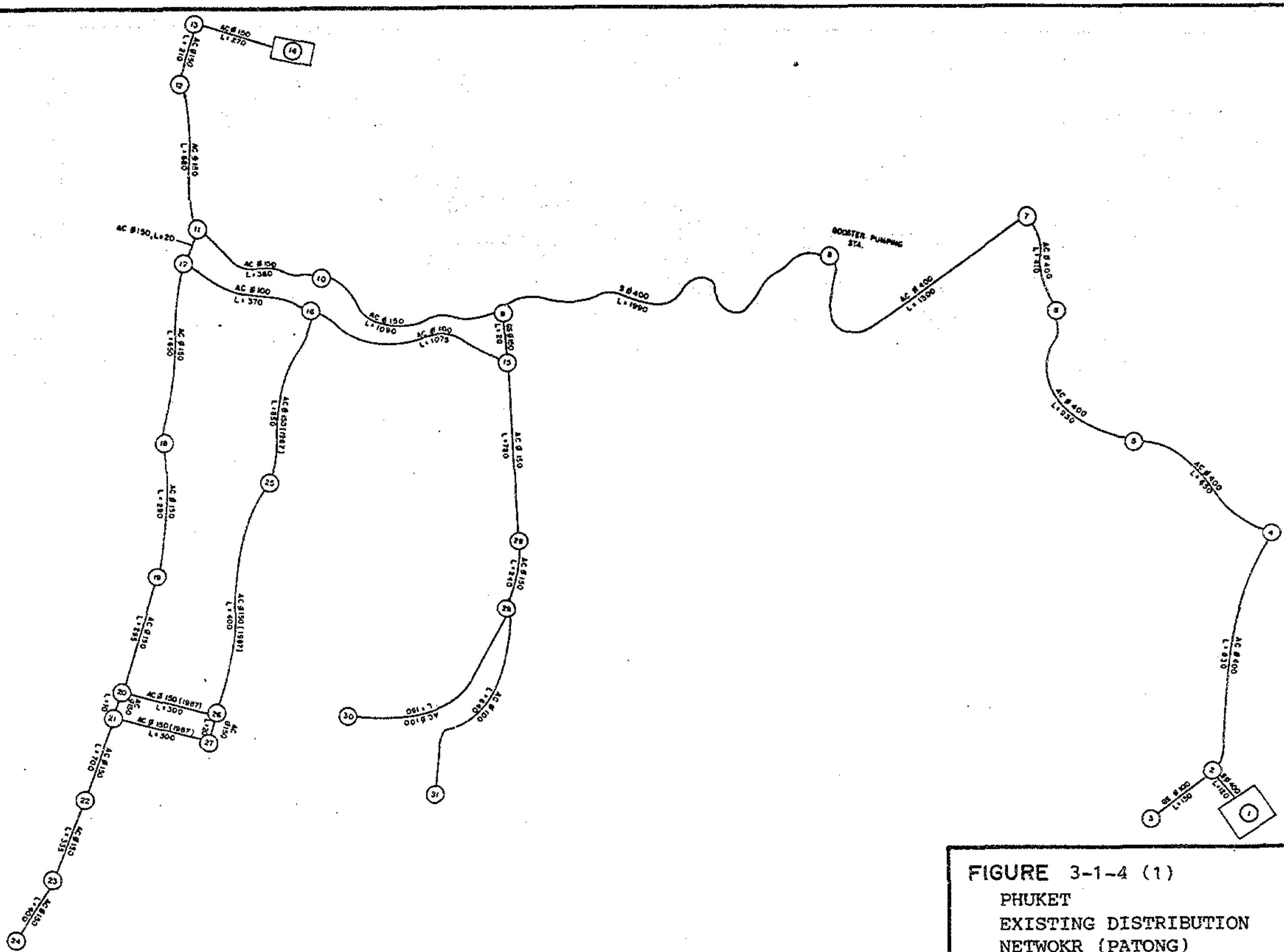


FIGURE 3-1-4 (1)
PHUKET
EXISTING DISTRIBUTION
NETWOKR (PATONG)

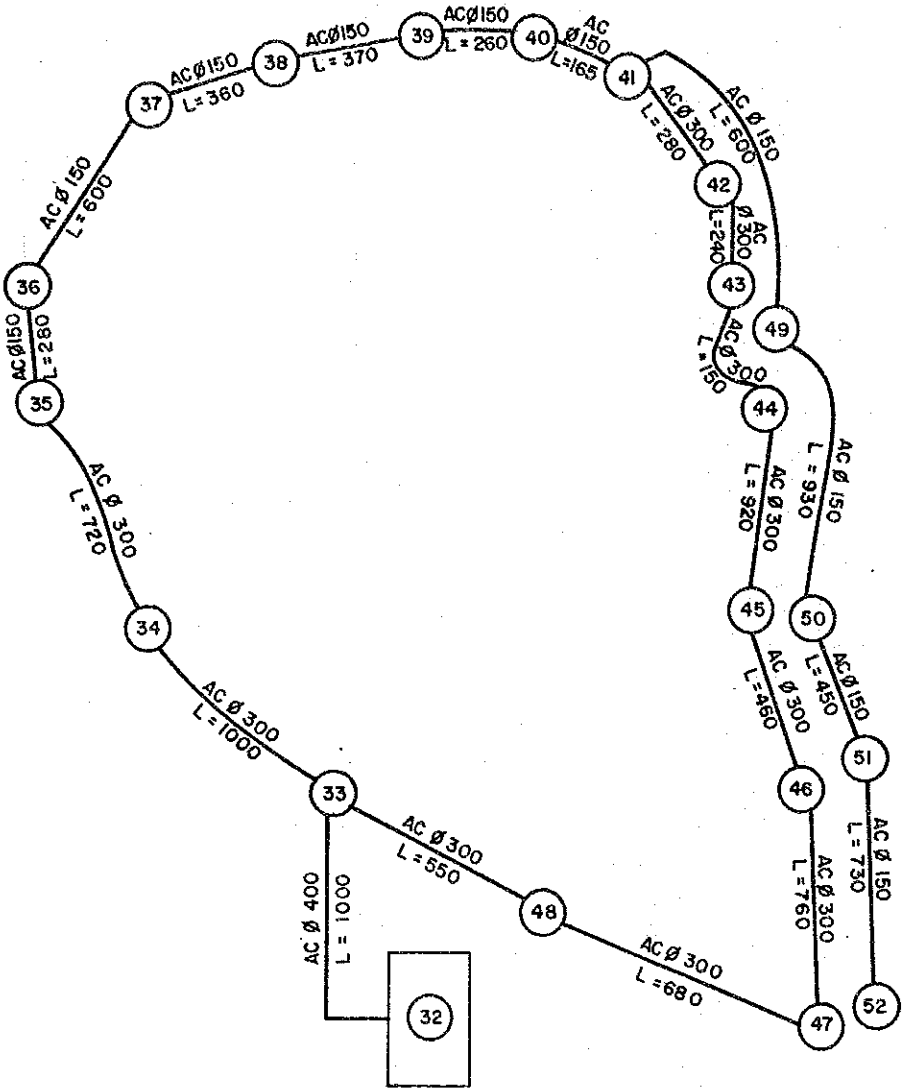


FIGURE 3-1-4 (2)
PHUKET
EXISTING DISTRIBUTION NETWORK
(KATHU)

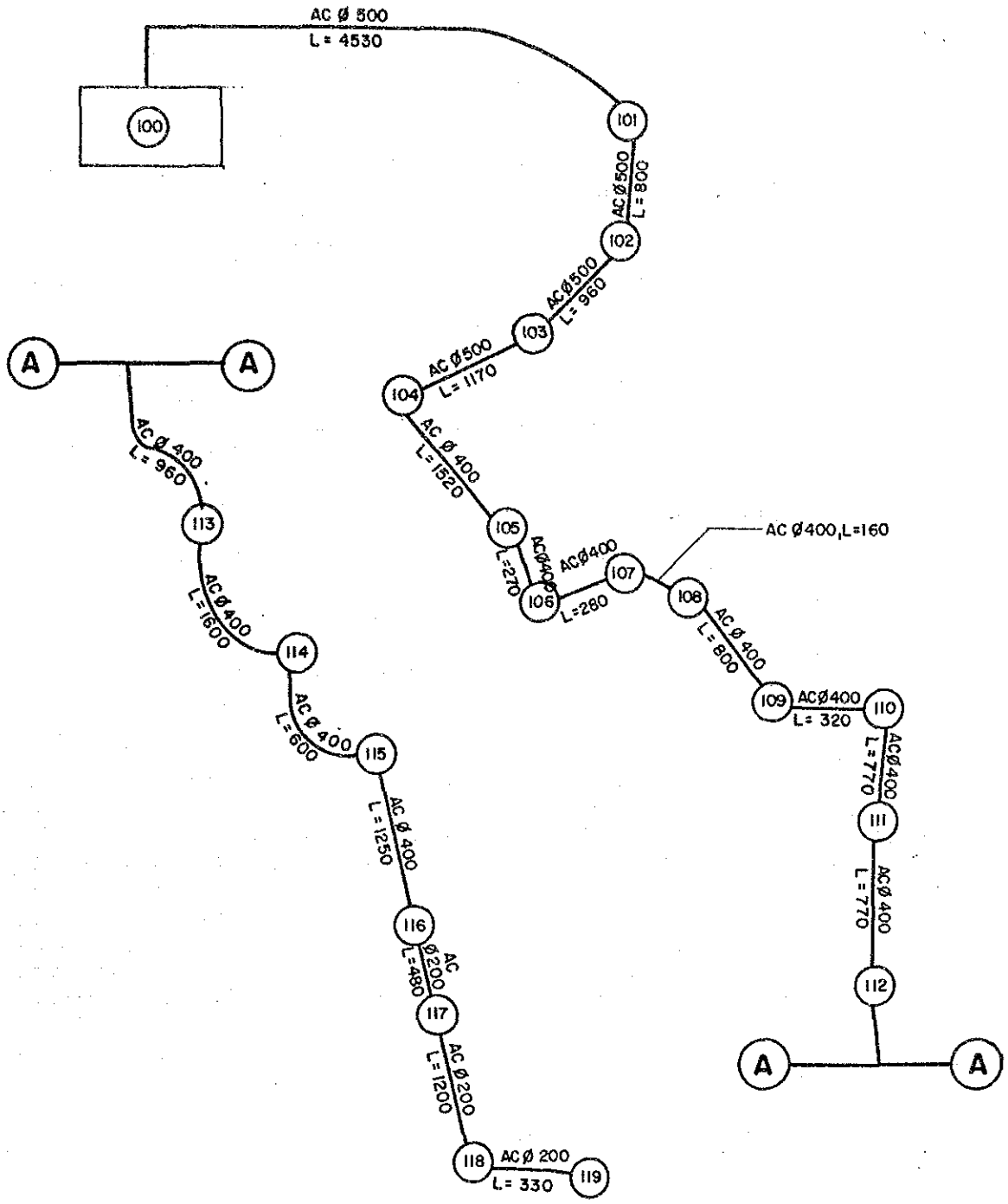


FIGURE 3-1-4 (3)
PHUKET
EXISTING DISTRIBUTION NETWORK
(DEEP SEA PORT)

Table 3-1-3 Distribution Pipe

Dia. (mm)	Approximate Length (m)			
	Patong	Kathu	D.S.P.	Total
500			7,460	7,460
400	1,990	1,000	9,300	12,290
300		5,160		5,160
200			2,090	2,090
150	7,210	4,750		11,960
100	2,240			2,240
Total	11,440	10,910	18,850	41,200

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

Table 3-1-4 Number of Connections

Year	No. of Connection
1987	888

Although all of the house connections are metered, some meters seem to be defective or have a measuring errors. Also observed during the site investigation was that some of meters were rotating backwards in case of negative pressure and that air was introduced from the open faucets. The reverse rotation results in the loss in meter reading.

Another defect of most of the meters is that it 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 distribution system and to determine the improvements necessary to satisfy the projected water demand. The model uses a standard Hardy-Cross network analysis tech nique where head losses are calculated using the Hazen-Williams equation. An interactive process is used in the model to balance the hydraulic grade line at each pipe junction in the network, with adjustment made in the hydraulic grade line to satisfy the continuity equation at each junction.

(b) Hazen-Williams Discharge Coefficients ("C" values)

Estimates of the Hazen-Williams discharge coefficients for existing pipeline are made based on the age of pipe, which was obtained from

the Phuket Waterwork 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 adapted 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 and hourly maximum water 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 2 m in water column is required at the existing water treatment plant.

Patong Beach Pipeline

Three operation system were set and analyzed.

- Case I.

When the booster pump and the old plant are operated, pressure at each node shows a extremely high at the hourly maximum demand conditions.

A half of the water demand flows into the old plant.

This means that the old plant can not supply water to the system while the booster pump is operated.

- Case II.

If the old plant is only operated, some area locating at the high ground elevation indicates a low pressure less than 1.0 kg/sq.cm. A capacity of the old plant is 20 cu.m/h, but the simulation model shows about 74 cu.m/hr. It means that the old plant is not able to supply the sufficient amount of water to meet demand.

- Case III.

In case that the booster pump is operated without the old plant, an extremely high pressure at more than 8.0kg/sq.cm covers a whole distribution system.

Kathu Pipeline

The results show that this system has a proper pressure range.

Deep Sea Port Pipeline

As same as Kathu pipeline, there are adequate pressure throughout the existing distribution system.

The results indicating pressure contour lines are shown in Figures 3-1-5 to 3-1-7, and the results of network analysis are presented in the separate volume.

The results of the pressure measurement in the existing distribution system described in Appendix A-3-2 confirm such a high pressure area and also identified by the waterworks official.

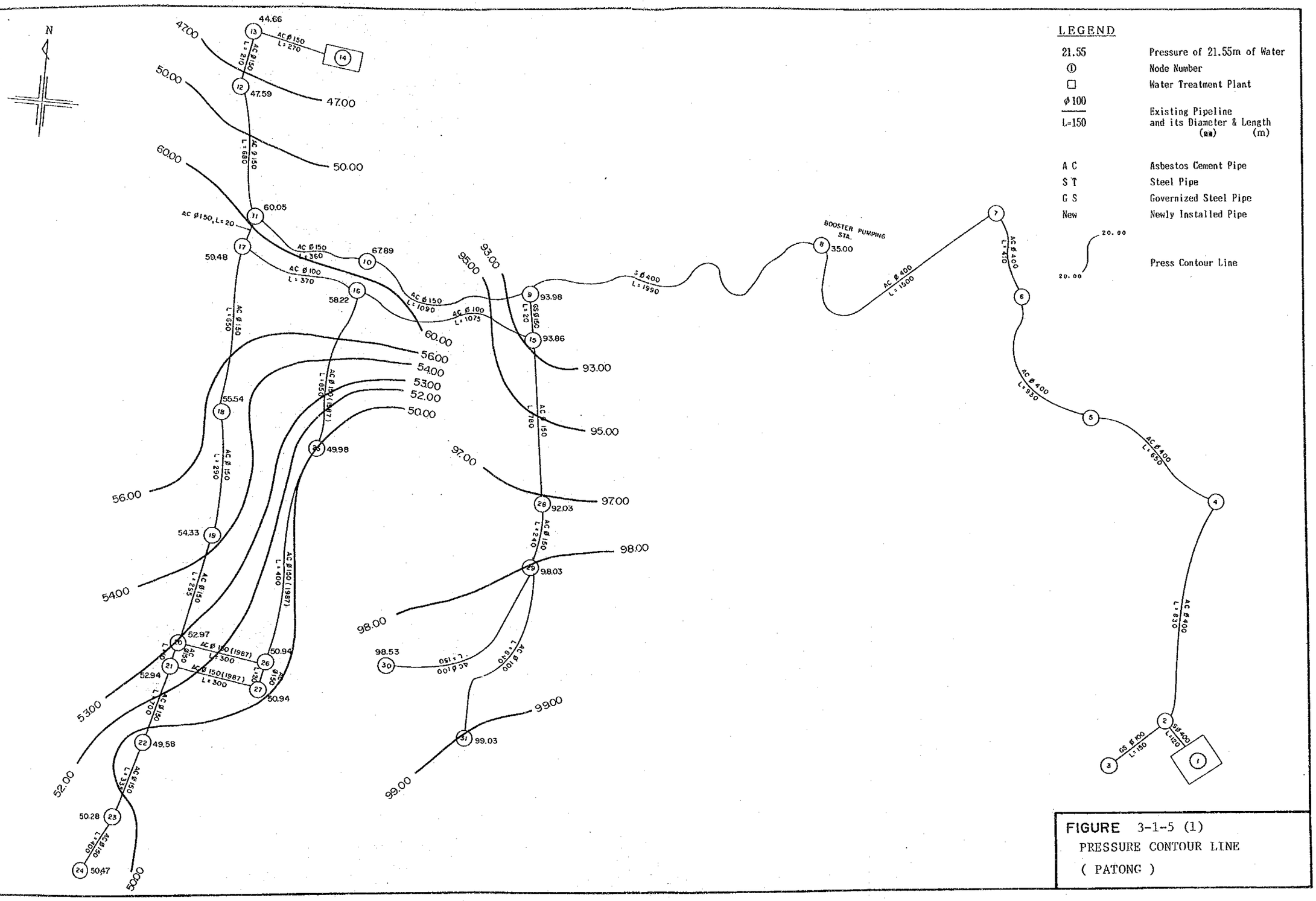


FIGURE 3-1-5 (1)
PRESSURE CONTOUR LINE
(PATONG)

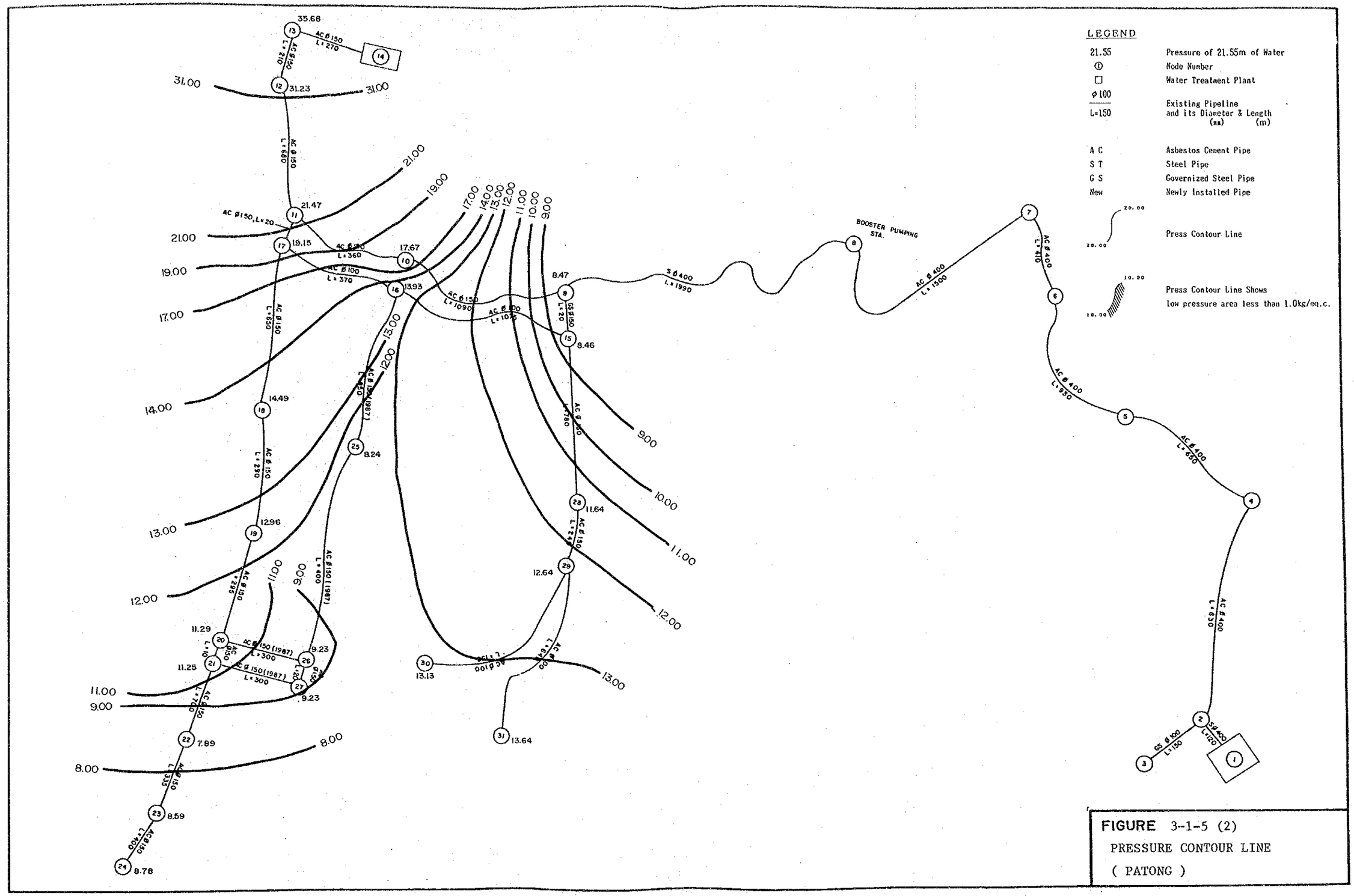


FIGURE 3-1-5 (2)
PRESSURE CONTOUR LINE
(PATONG)

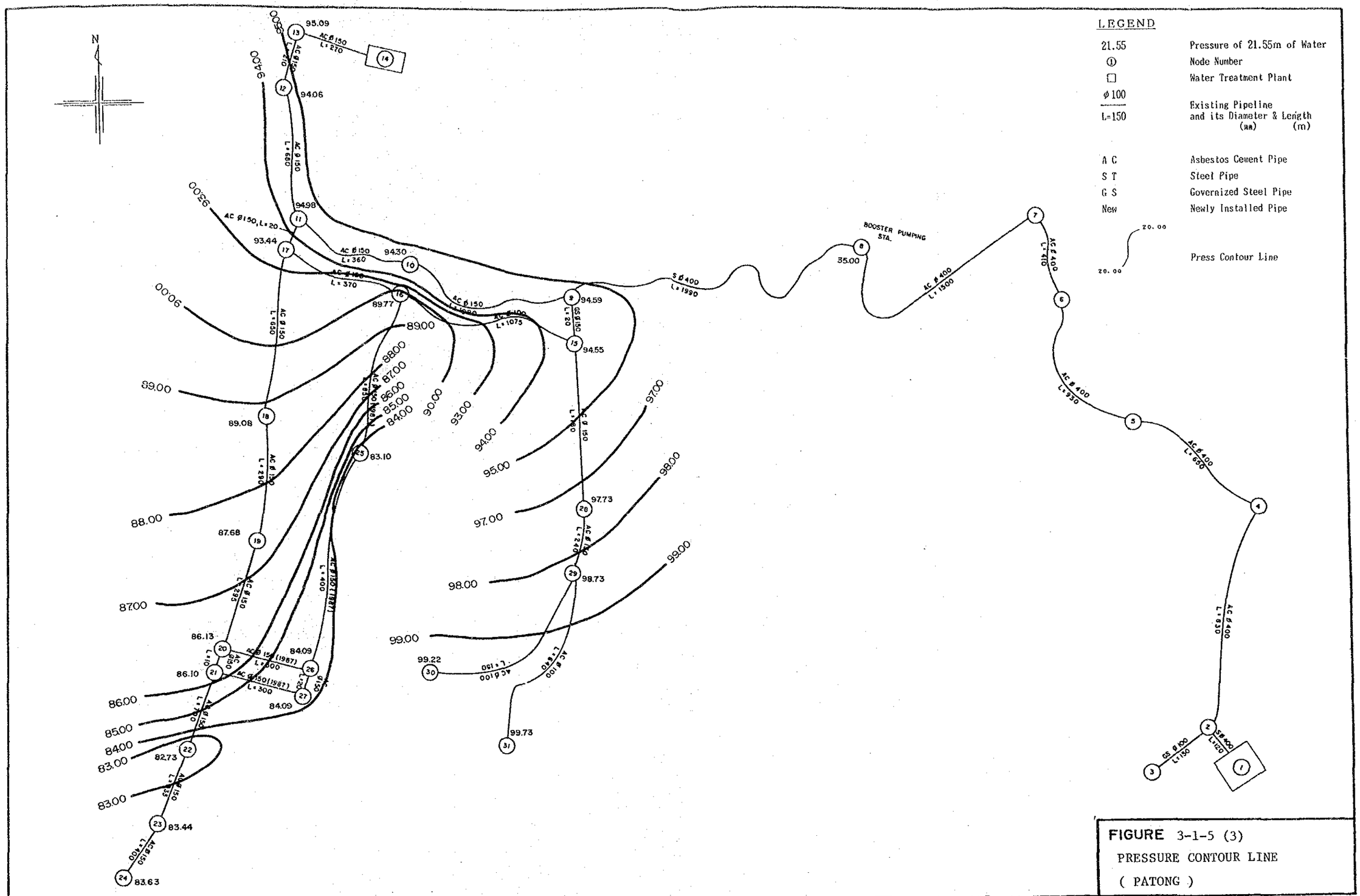
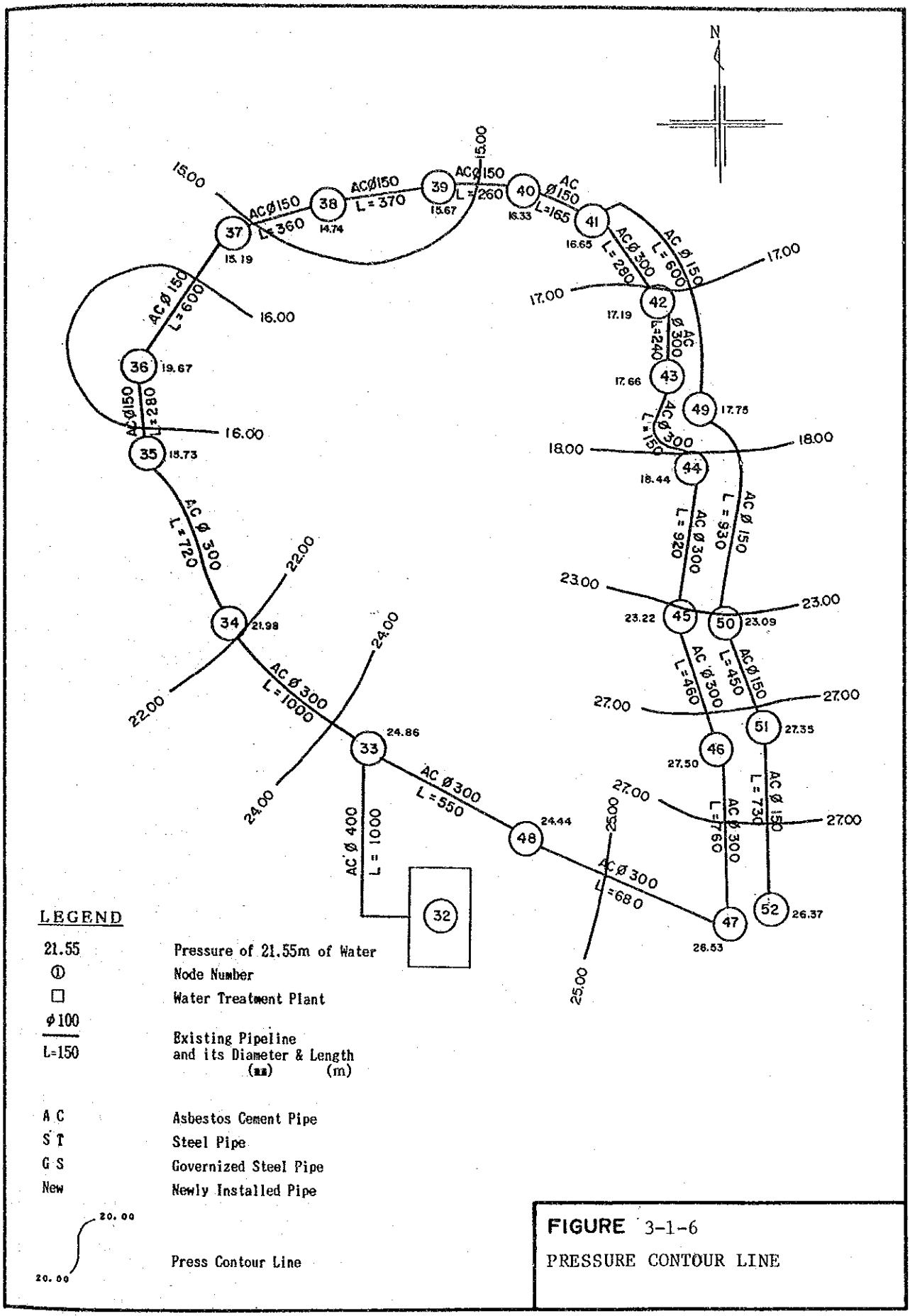


FIGURE 3-1-5 (3)
PRESSURE CONTOUR LINE
(PATONG)



LEGEND

21.55	Pressure of 21.55m of Water
①	Node Number
□	Water Treatment Plant
ϕ100 / L=150	Existing Pipeline and its Diameter & Length (mm) (m)
A C	Asbestos Cement Pipe
S T	Steel Pipe
G S	Governized Steel Pipe
New	Newly Installed Pipe
20.00 / 20.00	Press Contour Line

FIGURE 3-1-6

PRESSURE CONTOUR LINE

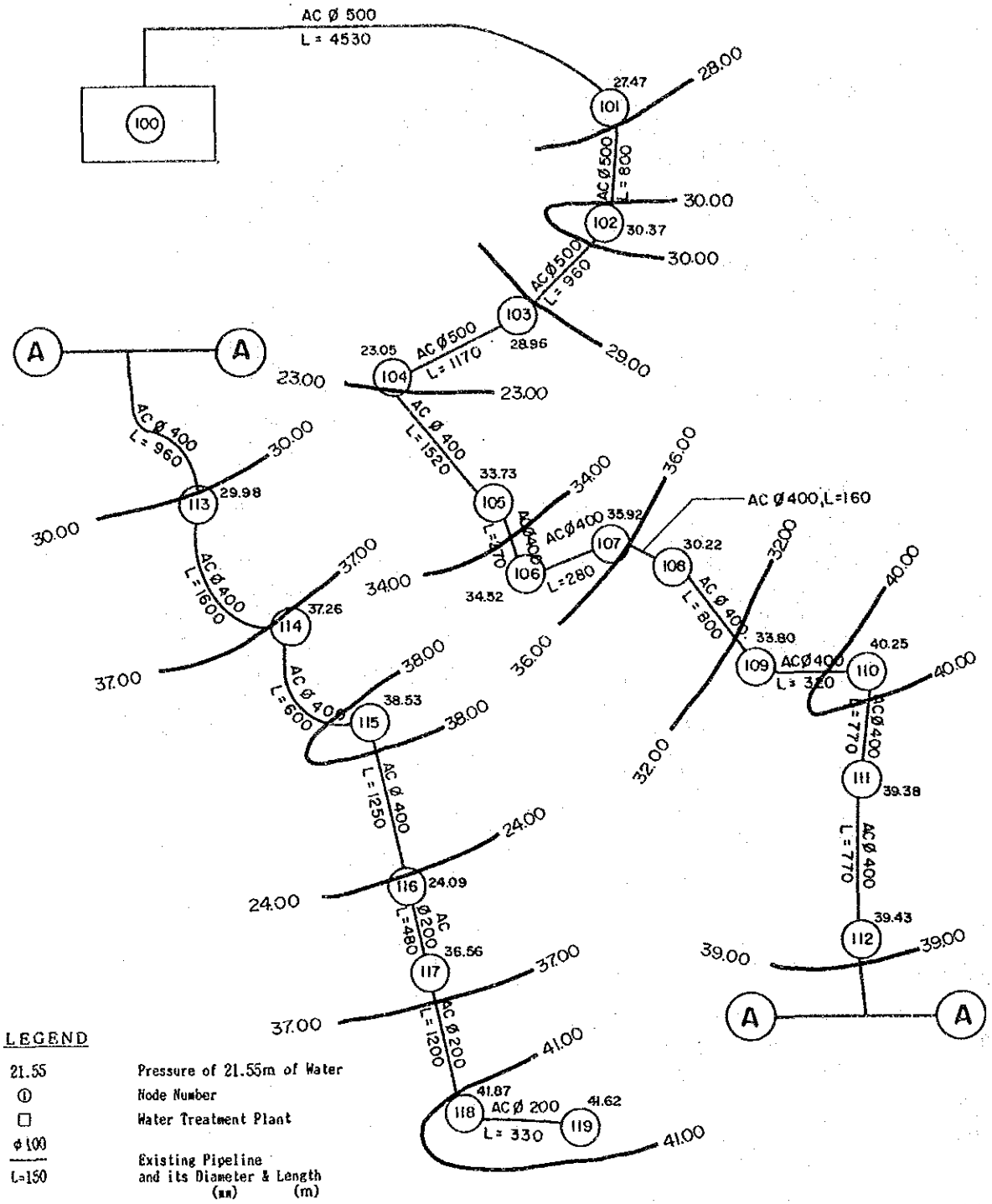


FIGURE 3-1-7

PRESSURE CONTOUR LINE

(DEEP SEA PORT)

3.2 Operation and Maintenance

The operations status during the past one year from August 1987 to July 1988 is shown in Table 3-2-1.

The treated water distribution was measured by separate master meters for each area as shown below.

Month 1988	Patong cu.m/mo	%	Kathu cu.m/mo	%	Deep Sea Port cu.m/mo	%	Total cu.m/mo	%
Jan	-	-	36,060	95.2	1,838	4.8	37,898	100
Feb	20,913	38.4	28,421	52.1	5,189	9.5	54,523	100
Mar	35,130	51.1	27,182	39.6	6,422	9.3	68,734	100
Apr	57,373	50.1	24,894	21.7	32,373	28.2	114,640	100
May	35,808	39.1	24,219	26.4	31,709	34.5	91,736	100
Jun	50,370	61.4	26,539	32.3	5,141	6.3	82,050	100
Jul	35,004	57.2	21,648	35.4	4,545	7.4	61,197	100

Some irregularities were found on the total distribution and on the distribution for each area. The operating condition has not yet been stabilized.

The present operating rate of the treatment plant vis-a-vis the nominal treatment capacity is in the range of 5.1% and 15.4%, neglecting the amount of clear water used in the plant. Therefore, the treatment plant did not operate continuously to save the energy cost. However, all modules were used during operation.

According to the operations record at the PWA Phuket Waterworks, the average daily operation time was 4.1 hours in May, 4.2 hours in June and 3.1 hours in July, including the days when the plant was not in operation. Such batch operation may cause the stiffening of alum solution in the alum mixing tank, surface hardening of the sand layer in the rapid sand filters and ineffective flocculation in the sedimentation basins, although these are not serious problems at present due to the good quality of raw water.

Treatment loss caused by water used in the plant was abnormally high, 18.1% on the average with a minimum of 5.1% and a maximum of 32.5%. Cleaning of the sedimentation basins is carried out periodically, or every three months after emptying the basins.

The backwash to the rapid sand filters is made once everyday. The amount of backwash water also shows some irregularities.

The rate of alum dosage varies between 15.5 mg/l and 80.2 mg/l. According to the result of the jar test, conducted on the field in August 1988, the optimum alum dosage rate was 5 mg/l. Taking into account the stable condition of raw water, it seems that the dosage rate is too high.

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

Item	Aug	Sep	Oct	Nob	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total	Ave
A) Raw Water	47680	72600	58500	40210	65230	75820	83010	106740	152320	130860	109070	79530	1021570	85131
Bangwad	46180	61800	43500	23710	44930	48320	71010	106740	152320	127360	109070	79530	914470	76206
Patong	1500	10800	15000	16500	20300	27500	12000	0	0	3500	0	0	107100	8925
*Variation	0.560	0.853	0.687	0.472	0.766	0.891	0.975	1.254	1.789	1.537	1.281	0.934	-	-
B) Raw Water Used	200	22750	750	950	750	1400	2200	2200	23030	25600	16000	10400	106230	8853
Sedimentation Basin	0	21500	0	0	0	0	1200	1200	14030	13500	0	0	51430	4286
Drainage	120	800	450	500	450	600	1000	1000	5800	7600	8500	6500	33320	2777
Waste	80	450	300	450	300	800	0	0	3200	4500	7500	3900	21480	1790
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.004	0.313	0.013	0.024	0.011	0.018	0.027	0.021	0.151	0.196	0.147	0.131	0.104	-
C) Treated Water	47480	49860	57750	39360	64430	74420	80810	104540	129290	105260	93070	69130	915400	76283
*Variation	0.622	0.654	0.757	0.516	0.845	0.976	1.059	1.370	1.695	1.380	1.220	0.906	-	-
D) Treated Water Used	2070	990	2074	874	1456	2160	1437	4186	16231	9720	11540	5510	57042	4854
Filter Washing	1500	350	1500	474	845	1500	1037	3308	13040	6700	10500	4500	45254	3771
Chemical Mixing	350	120	350	400	350	400	400	600	1540	1500	500	500	7010	584
Engine	60	60	60	0	60	60	0	60	520	350	300	300	1830	153
Sedimentation Basin	0	300	0	0	0	0	0	0	950	950	0	0	2200	183
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	40	40	40	0	45	80	0	80	43	80	150	150	748	62
Used in Houses	120	120	124	0	156	120	0	138	138	140	90	60	0	101
*(D)/(C)	0.044	0.020	0.036	0.022	0.023	0.029	0.018	0.040	0.126	0.092	0.124	0.080	0.062	-
E) Distributed Water	45250	48990	55970	38356	63830	66408	64203	70051	111096	97297	81024	63403	805878	67157
*Variation	0.674	0.729	0.833	0.571	0.950	0.989	0.956	1.043	1.654	1.449	1.206	0.944	-	-
F) Sold Water	16977	18250	18210	18414	23594	38418	35215	36940	43232	47893	42906	54265	394314	32860
Connection Meters	16977	18250	18210	18414	23594	38418	35215	36940	43232	47893	42906	54265	394314	32860
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	0.517	0.555	0.554	0.560	0.718	1.169	1.072	1.124	1.316	1.458	1.306	1.651	-	-
G) Unaccounted-for Water	28273	30740	37760	19942	40236	27990	28988	33111	67864	49404	38118	9138	411564	34297
*(G)/(E)	0.625	0.627	0.675	0.520	0.630	0.421	0.452	0.473	0.611	0.508	0.470	0.144	0.511	-
H) No. of Conn. (nos.)	660	666	685	711	717	741	774	804	813	819	837	845	-	-
I) Per Conn. Consumption	71.94	74.86	84.31	55.36	89.86	100.43	104.41	130.02	159.03	126.52	0.00	0.00	998.74	83
*Variation	0.864	0.900	1.013	0.665	1.080	1.207	1.911	1.562	1.911	1.544	0.000	0.000	-	-
J) Chemical (kg)														
Alum	4000	2000	2700	2000	1000	1200	3100	3050	3830	5175	2800	2950	33805	2817
Bleaching Powder	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorine Gas	0	0	100	100	100	100	100	0	300	200	200	2	1202	100
Lime	0	0	40	40	40	200	80	300	0	160	80	160	1100	92
K) Dosage Rate (mg/l)														
Alum	84.25	40.11	46.75	50.81	15.52	16.12	38.36	29.18	29.62	49.16	30.08	42.67	-	36.93
Bleaching Powder	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
Chlorine Gas	0.00	0.00	1.73	2.54	1.55	1.34	1.24	0.00	2.32	1.90	2.15	0.03	-	1.31
Lime	0.00	0.00	0.69	1.02	0.62	2.69	0.99	2.87	0.00	1.52	0.86	2.31	-	1.20

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

The Bangwad Water Treatment Plant was constructed in 1987 and has enough capacity to supply water for the present service area as well as for the Phuket Municipality. Therefore, there is no expansion plan as of now.

However, the improvement plan for the distribution system for Patong is presently being prepared to solve the high pressure problem in the area. As stated earlier in this report, extremely high pressure (as high as 5.0 kg/sq cm) in the distribution pipeline is due to its topographical and system characteristics. This problem comes from an absence of the proper pressure reducing scheme on the pipeline.

The countermeasure being considered by PWA is the provision of a receiving tank at the highest elevation of the pipeline. However, to reduce the pressure in the Patong area, a precise hydraulic study should be conducted to determine how both the dynamic and static hydraulic gradients would be for the recommended scheme.

3.4 Existing Constraints

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

(1) Water Source

- Small catchment area and steep slope
- Flow is insufficient in the dry season
- Flooding occurs in the wet season
- No potential aquifer

(2) Intake and Raw Water Transmission Pipe

- Mining pits are insufficient in capacity in the dry season
- The Bangwad Reservoir water is frequently spilled in the wet season.
- Many of shallow wells are contaminated

(3) Treatment

- A large amount of water is consumed inside the treatment plant. Treatment loss reaches 32.5 percent at maximum.
- Jar test results shows that raw water requires less amount of alum than that actually dosed.

(4) Distribution

- Pipeline to Patong is pressured too high and conveys water within a limited time only.
- In a pipeline to the Deep Sea Port high pH value is occurred due to small amount of consumption.

(5) Operation and Maintenance

- Operation is intermittently made.

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 Phuket 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 & Accounting Section

A 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.

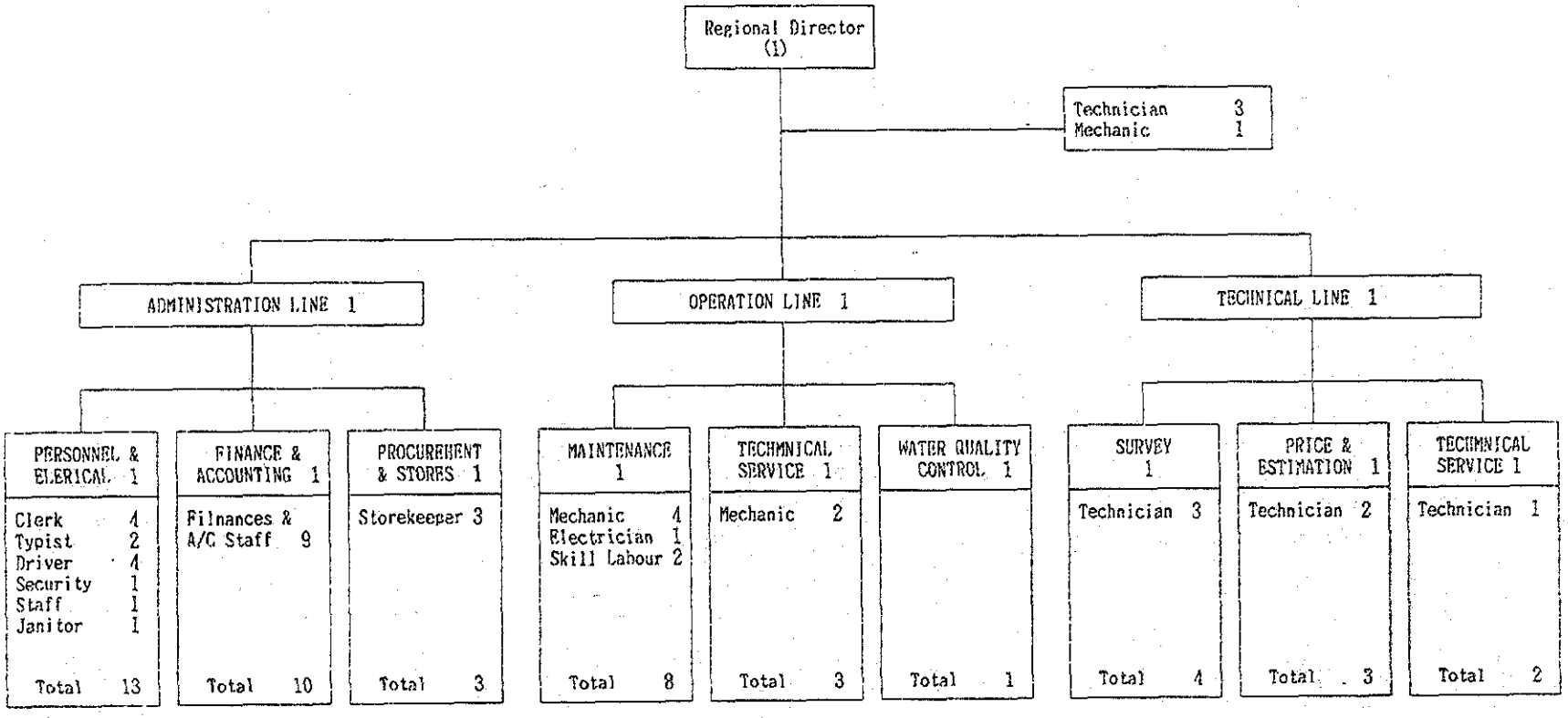


FIGURE 3-5-1
ORGANIZATION CHART OF REGIONAL OFFICE 4

(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 Phuket 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.

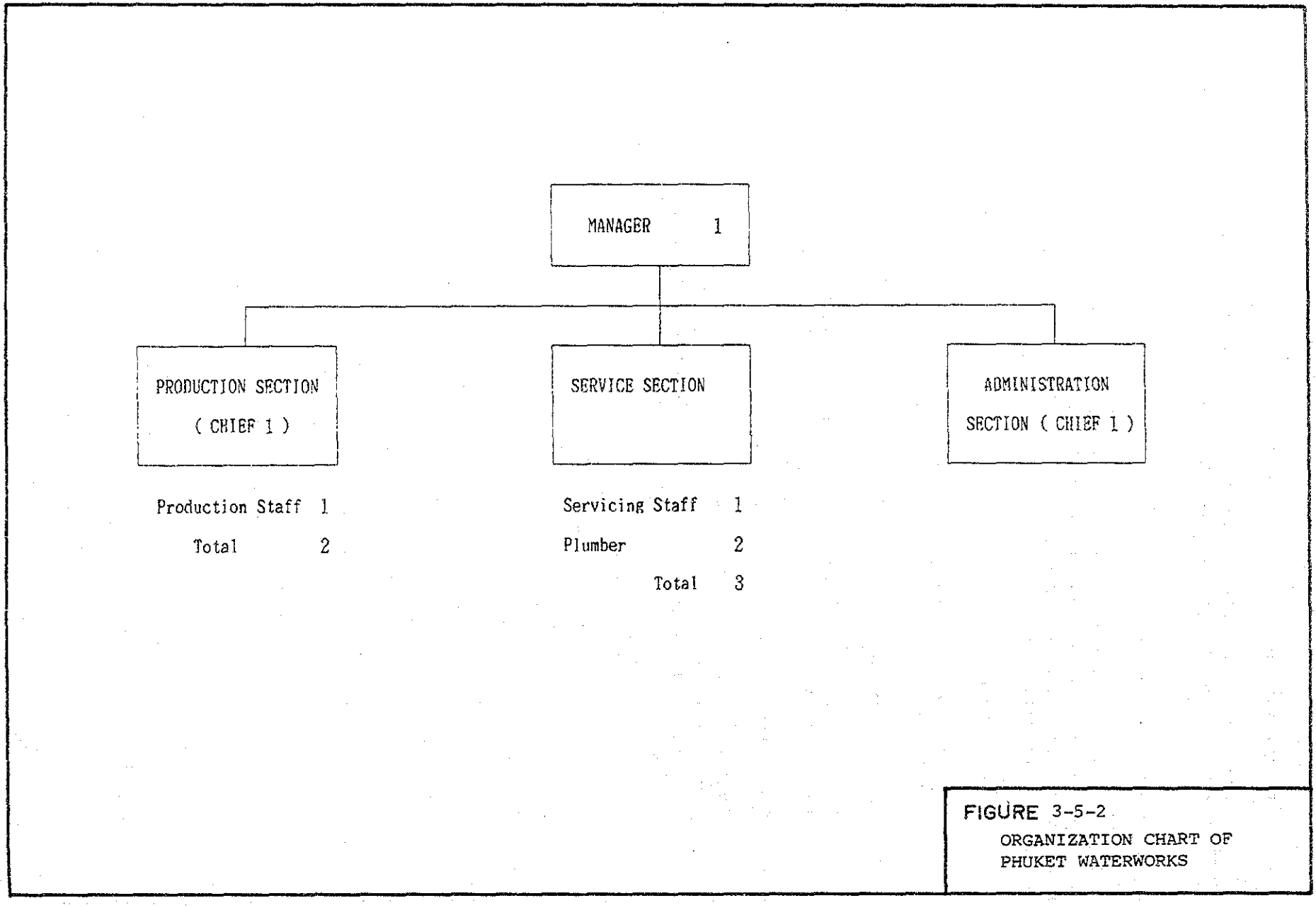


FIGURE 3-5-2
ORGANIZATION CHART OF
PHUKET WATERWORKS

3.6 Financial Status

3.6.1 Present System

As of 1987, Phuket Waterworks has 666 connections. The water production and sales in 1987 were 262,296 cu.m and 140,202 cu.m, respectively.

PWA has three major sources of tariff revenue: namely water sales, service charges and connection fees, details of which is described in Section 7.1.

3.6.2 Revenue and Expenditure

The annual revenue and expenditure of the waterworks in the last two years are shown below:

Table 3-6-1 Revenue and Expenditure

(Unit : 1,000 ฿)

Year	Revenue	Expenditure	Profit(loss)
1986	862	503	359
1987	1,572	1,225	347

In the accounting system of PWA, all the revenues of the waterworks are transferred to the PWA Head Office. All the expenses are also allocated by the PWA Head Office. However, as shown in Table 3-6-3, 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 the waterworks, one of the financial ratios (revenue/expenditure) is computed as shown below:

Table 3-6-1 Ratio of Revenue to Expenditure

	1985	1986	1987
PWA Head Office	1.45	1.72	1.76
Phuket Waterworks	-	1.71	1.28

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

As shown above, the waterworks earned a net profit on its annual operations. The ratio is greater than 1.0, but lower than the average rate of all PWA waterworks.

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

Table 3-6-3 Revenue and Expenditure of Phuket Waterworks

(Unit : Baht)

Description	1985	1986	1987
Water Production cu.m		-	262,296
Water Sales cu.m		-	140,202
No. of Connections		516	666
Revenue			
Water Sales		517,008.25	1,171,677.75
Service Charge		69,610.00	86,230.00
Connection Fee		274,080.50	308,604.00
Other Revenue		877.75	5,024.18
Total Revenue (A)		861,576.50	1,571,535.93
Expenditure			
Salaries		275,529.97	414,772.00
Remuneration		43,138.50	56,140.50
Chemical		12,378.75	67,298.72
Material & Maintenance		32,177.25	299,944.83
Oil & Fuel		29,717.60	97,845.08
Office Supplies		4,085.30	11,342.12
Hired Service		617.50	16,488.12
Other Operating Expense		39,010.10	30,167.00
Public Utilities		1,958.00	5,514.00
Electricity		-	140,125.41
Connection Cost		64,050.06	84,626.23
Material Sold		-	280.00
Total Expenditure (B)		502,662.93	1,224,504.01
Profit (Loss)		358,913.57	347,031.92

4. POPULATION AND WATER DEMAND

4.1 Project Horizon

The study area is the main island of Phuket Province consisting of three amphoes and one Municipality as shown in Table 4-1-1 and Figure 4-1-1. The total area of the island is approximately 550 sq.km.

Table 4-1-1 Administrative Hierarchy of Phuket

Amphoe/Municipality	Share of Area (%)	No. of Tambons
Amphoe Thalang	39	6
Amphoe Kathu	47	3
Amphoe Muang Phuket	14	6
Phuket Municipality		2

4.2 Population

4.2.1 Historic Population

The population of the study area was 153,600 in 1987 as shown in Table 4-2-1. Population of the province has increased steadily at 2.3% per annum on average since 1980. The growth rate is nearly equal to the natural growth rate of 2.4% in the southern region during 1980 to 1985.

The average annual growth rate of Amphoe Muang since 1980 was high at 4.1%, while that of the Municipality was low at 0.5%. One of the reasons for the difference is thought to be the urban expansion from the Municipality to the neighboring tambons.

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

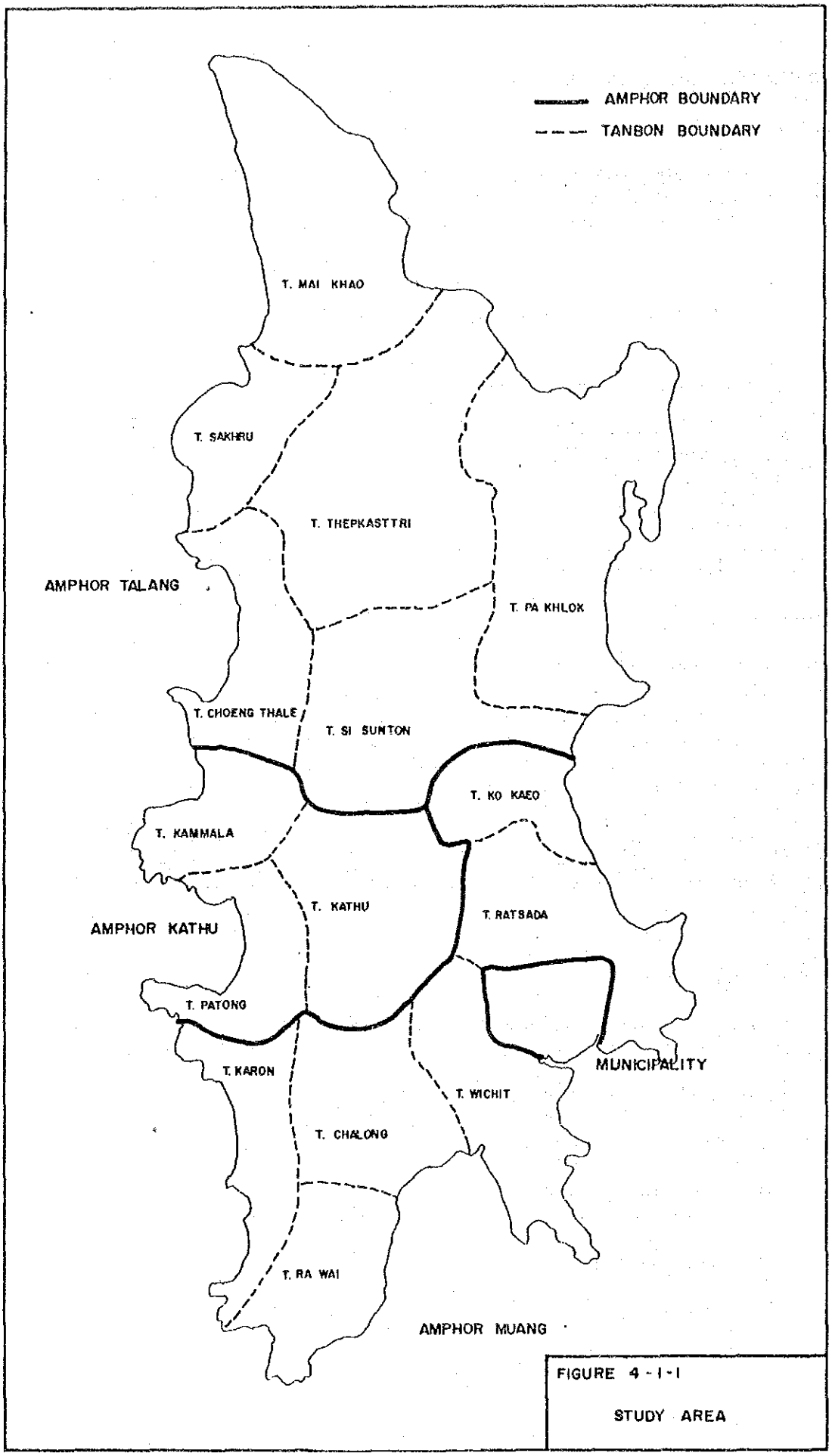


FIGURE 4 - 1 - 1

STUDY AREA

Table 4-2-1 Population Projection of Phuket Island

Zone Year	1980	1981	1982	1983	1984	1985	1986	1987	1991	1996	2001	2006	2011
Phuket Island	130995	136286	138627	141863	145229	147204	150218	153574	166600	179900	191800	203300	213700
Amphoe Thalang	38919		43020	43917	45001	45423	45889	46518	50446	54737	58204	61273	63717
T1 Thee Kasattri						12046	12242	12380	13191	14309	15203	16008	16634
T2 Si Sunton						8383	8435	8565	9126	9900	10518	11075	11508
T3 Choeng Thale						8094	8073	8245	9946	10837	11505	12173	12618
T4 Pa Khlok						6583	6648	6741	7183	7791	8278	8717	9057
T5 Mai Khao						7741	7792	7861	8157	8824	9417	9862	10307
T6 Sakhu						2651	2699	2740	2843	3076	3283	3438	3593
Amphoe Kathu	12621		13780	14055	14161	14428	14802	15023	14608	15855	16867	17818	18473
T1 Kathu						7271	7336	7483	6585	7142	7605	8007	8316
T2 Patong						4379	4621	4719	4569	4950	5267	5584	5775
T3 Kammala						2830	2845	2863	3454	3763	3995	4227	4382
Amphoe Muang	33785	35176	36399	37974	39408	40469	42174	44698	41146	44608	47429	49909	52010
T1 Ko Kaeo	4704	4880	5158	5208	5349	5616	5684	5567	5102	5533	5893	6204	6444
T2 Ratsada	7189	7625	7985	8918	9510	9976	10709	11141	9613	10425	11103	11689	12141
T3 Wichit	8404	8820	9146	9410	9787	9913	10417	11364	10700	11600	12300	12900	13500
T4 Chalong	5745	5907	5957	5945	6094	6330	6505	5530	6708	7272	7732	8142	8501
T5 Ra Wai	5518	5686	5822	6031	6159	5878	6198	6055	6392	6928	7368	7758	8099
T6 Karon	2216	2258	2331	2461	2509	2560	2661	2718	2631	2850	3033	3216	3325
Municipality	45671	45421	45437	46917	46659	46884	47353	47335	60400	64700	69300	74300	79500

Note : Amphoe Muang does not include the municipality.
The municipality's population of and before 1987 is for the administrative boundary and the population after 1987 is for DTCP town planning boundary.
Population decrease in some Tambon before 1991 is due to the difference of the boundaries and data sources.
Other minor inconsistencies are due to the difference of data sources.

Source : Data from Offices of Phuket Province, Amphoe and Municipality
Analysis and Estimation by the Study Team

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, future population of the study area is estimated based on the following assumptions. Therefore, mathematical models are used only for comparison.

(1) At the levels of the province and the town planning areas, the population projection of "The Study on Potential Tourism Area Development for the Southern Region in Thailand" conducted by JICA was adopted. The tourism study calculated the population at the province level according to NESDB reports. And at the town planning area level, DTCP forecasts were modified taking into consideration the recent and future development trends.

(2) Population of each tambon is calculated assuming the present share in the town planning area.

(3) Population of the amphoe is calculated by adding up tambon population.

(4) Then the population of the DTCP town planning area of Phuket Municipality is replaced by the estimation of "Feasibility Study on Sewerage and Drainage Improvement Project for Phuket Municipality" by JICA.

Population of the main island of Phuket in 2011 is estimated at 213,700 as presented in Table 4-2-1.

Figures 4-2-1 to 4-2-5 show the population projection by amphoe for reference. In these figures, legends "A" to "E" correspond to the formulae mentioned above and legend "T" shows the adopted estimates. It should be noted here that data in the past are all according to the administrative boundaries, but in the future the municipal area does not mean the administrative boundary but means DTCP boundary, causing jumps of the graph.

Presently the average family and house sizes are estimated at approximately 4.82 and 4.90, respectively. 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. Following the decreasing trend, the family and house sizes of the island are estimated at 3.44 and 3.50, respectively as in Table 4-2-2.

Accordingly the number of families in 2011 is estimated at 62,100 and the number of houses at 61,100.

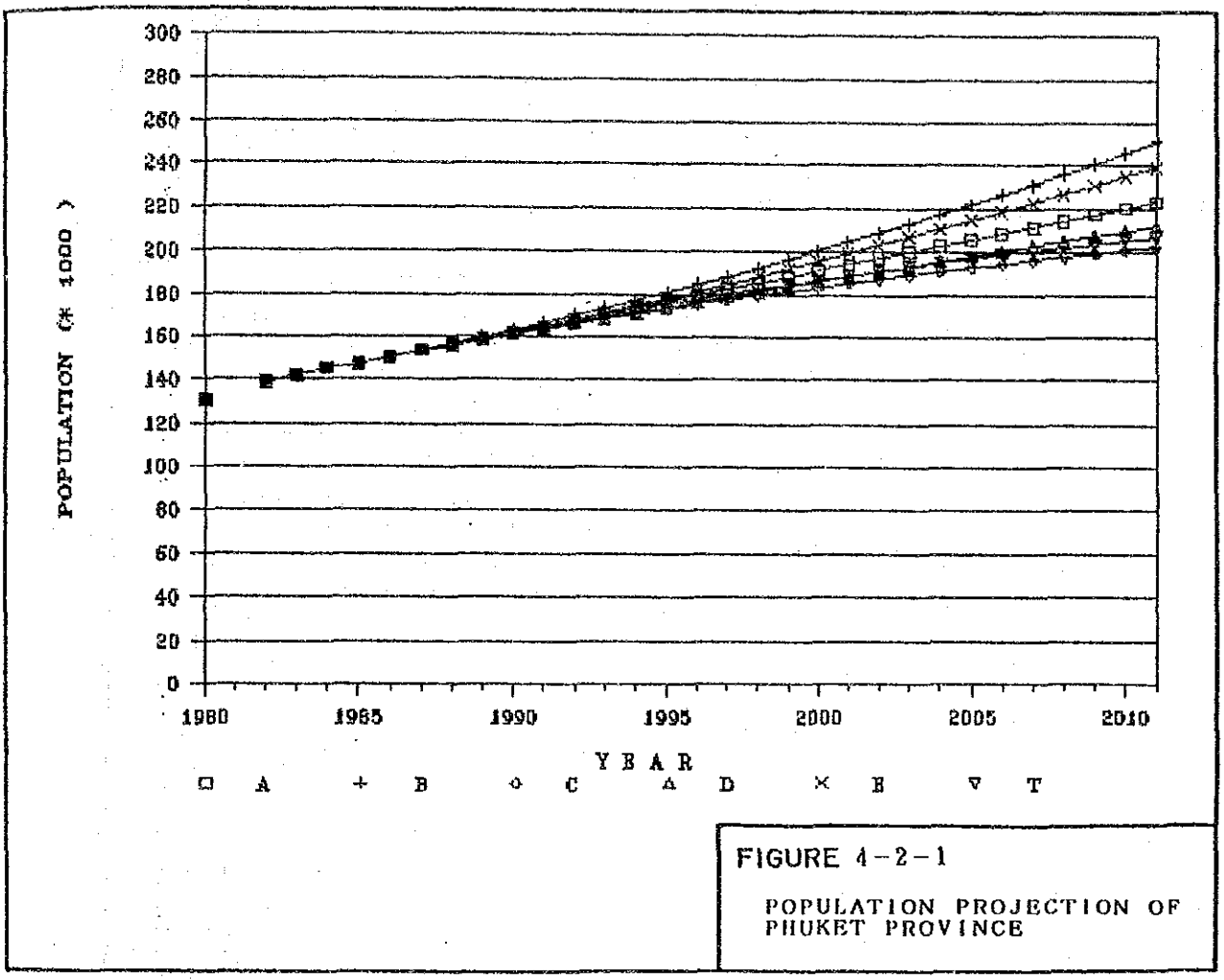


FIGURE 4-2-1

POPULATION PROJECTION OF PHUKET PROVINCE

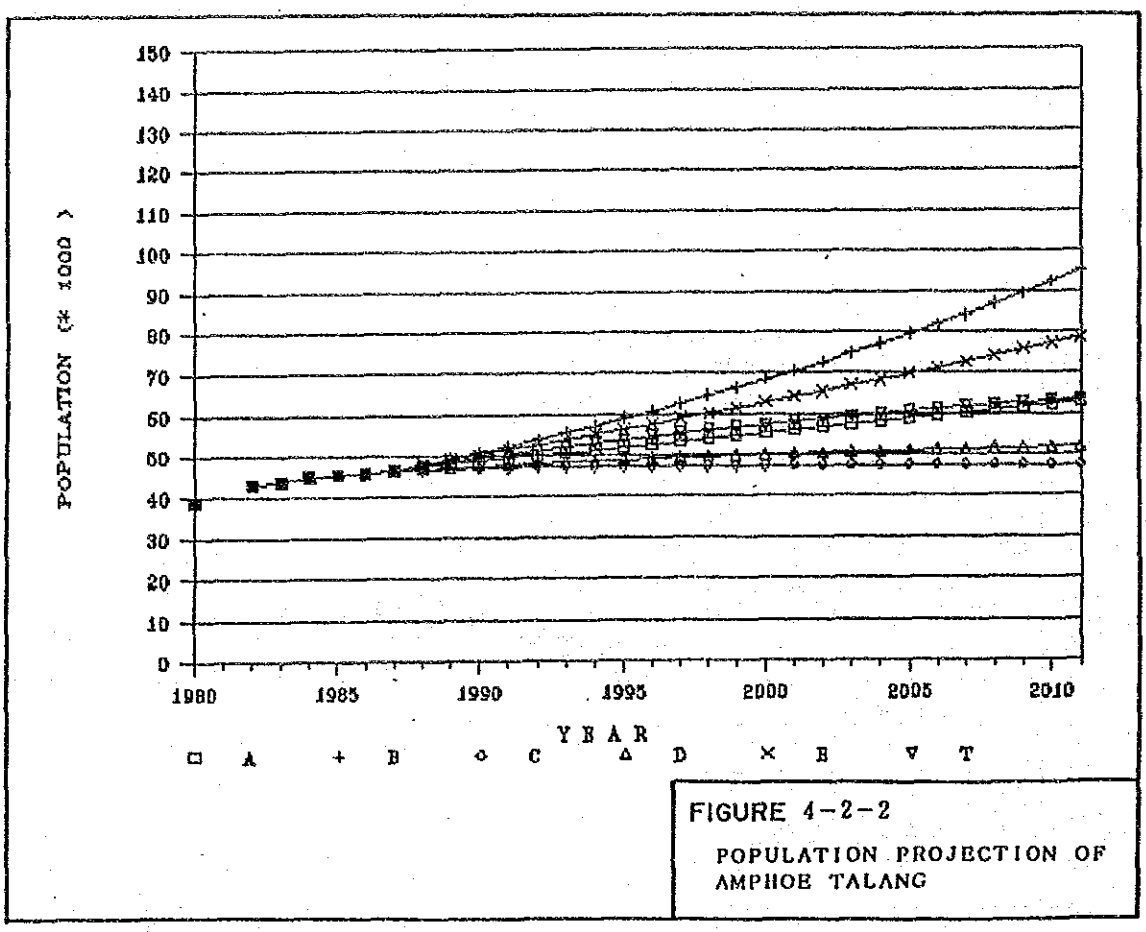


FIGURE 4-2-2

POPULATION PROJECTION OF AMPHOE TALANG

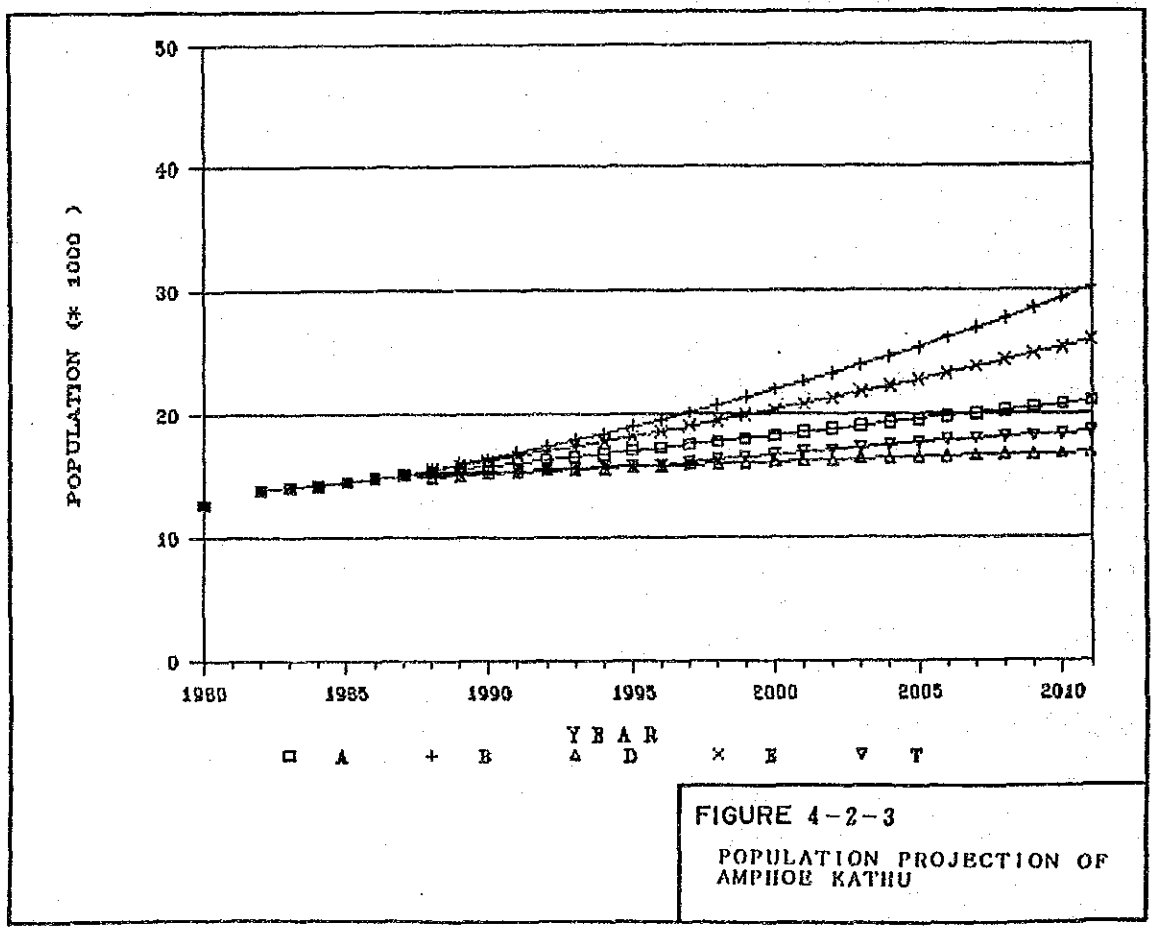


FIGURE 4-2-3

POPULATION PROJECTION OF AMPHOE KATHU

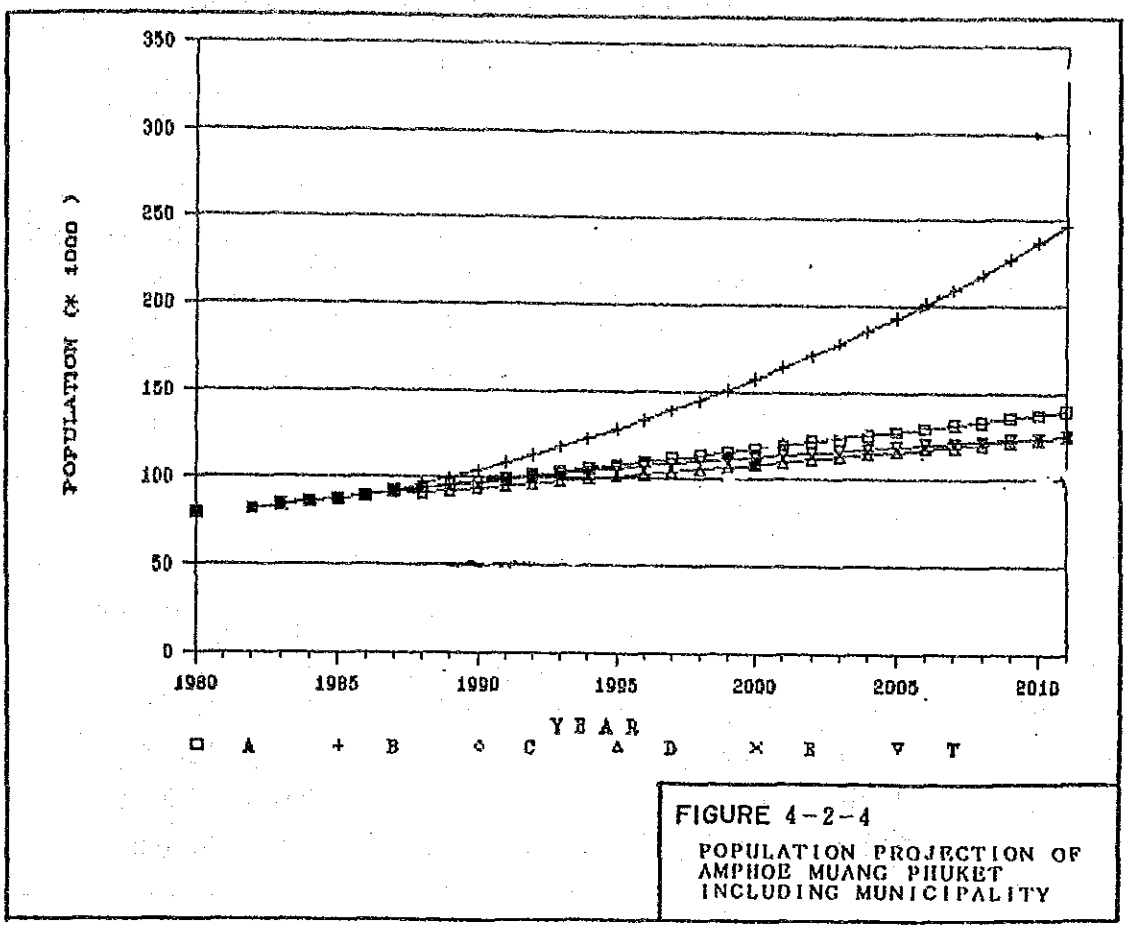
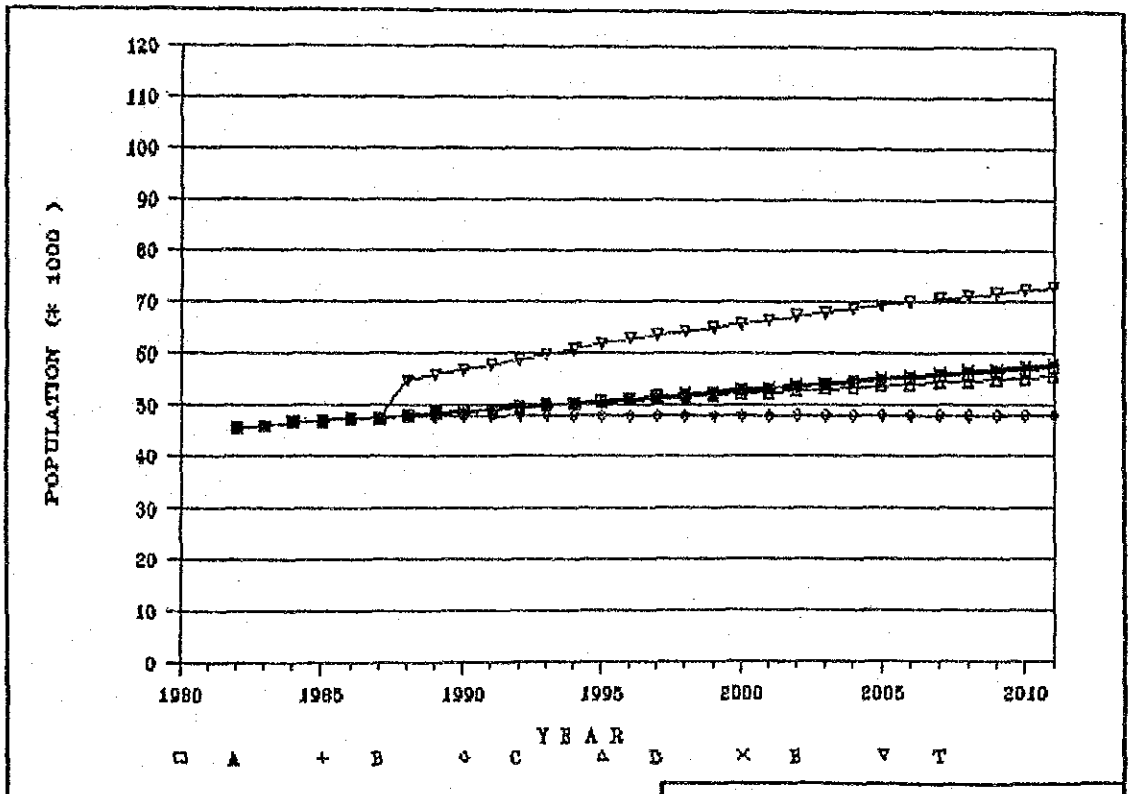


FIGURE 4-2-4
POPULATION PROJECTION OF AMPHOE MUANG PHUKET INCLUDING MUNICIPALITY



NOTE: DATA OF AND BEFORE 1987 ARE FOR ADMINISTRATIVE BOUNDARY AND DATA AFTER 1987 ARE FOR DTCP TOWN PLAN BOUNDARY.

FIGURE 4-2-5
POPULATION PROJECTION OF PHUKET MUNICIPALITY TOWN PLANNING AREA

Table 4-2-2 Projection of Numbers of Families and Houses

Nation							
Year	1985	1990	1995	2000	2005	2010	2015
Household Size	4.98	4.62	4.27	3.96	3.7	3.49	3.31
Year	1987	1991	1996	2001	2006	2011	
Household Size	4.84	4.55	4.21	3.91	3.66	3.45	
Index	1	0.941	0.870	0.808	0.756	0.714	

Phuket Study Area						
Year	1987	1991	1996	2001	2006	2011
Population	153,574	166,600	179,900	191,800	203,300	213,700
Family Size	4.82	4.53	4.19	3.89	3.64	3.44
No. of Families	31,877	36,800	42,900	49,300	55,800	62,100
House Size	4.90	4.61	4.26	3.96	3.70	3.50
No. of Houses	31,370	36,200	42,200	48,500	54,900	61,100

Source : HOMES Research Report, November 1987
Data from Offices of Phuket Province, Amphoe and Municipality
Analysis and estimation by JICA Study Team

4.2.3 Higher and Lower Growth Cases

In order to compare effects of the assumptions adopted in the method of estimation, higher and lower growth cases are shown in Table 4-2-3.

In the higher growth case, annual population growth rate of the Municipality and each amphoe is 1% higher than the original case and in the lower growth case, the growth rate is 1% lower.

In the higher growth case, the population of the province is 27% more than the original case, while in the lower growth case, it is 21% less.

Table 4-2-3 Population Projection in Higher and Lower Growth Cases

Year	1987	1991	1996	2001	2006	2011
Higher Growth Case						
Phuket	153574	168510	189397	213073	239933	270434
A. Thalang	46518	50986	57180	64127	71917	80654
A. Kathu	15023	16176	17741	19459	21342	23408
A. Muang	44698	47690	51714	56078	60809	65940
Municipality	47335	53658	62761	73410	85864	100432
Lower Growth Case						
Phuket	153574	155720	158583	161656	164949	168475
A. Thalang	46518	47115	47873	48643	49425	50219
A. Kathu	15023	14942	14842	14742	14643	14544
A. Muang	44698	44046	43244	42457	41684	40926
Municipality	47335	49617	52624	55814	59198	62786

4.2.4 Population Distribution

At present, tambons with over 10,000 population are Thep Kasattri, Ratsada and Wichit in addition to the Municipality as shown in Figure 4-2-6. Among the five sanitary districts (S.D); namely, Thep Kasattri, Choeng Thale, Kathu, Patong, and Karon S.D's, population of Kathu S.D is the largest at 14,700.

Future population distribution is estimated as in Figure 4-2-7. The numbers of tambons over 10,000 population in 2011 are four in Amphoe Thalang and two in Amphoe Muang as well as the DTCP town planning area for the Municipality, of which the population is estimated at 79,500.

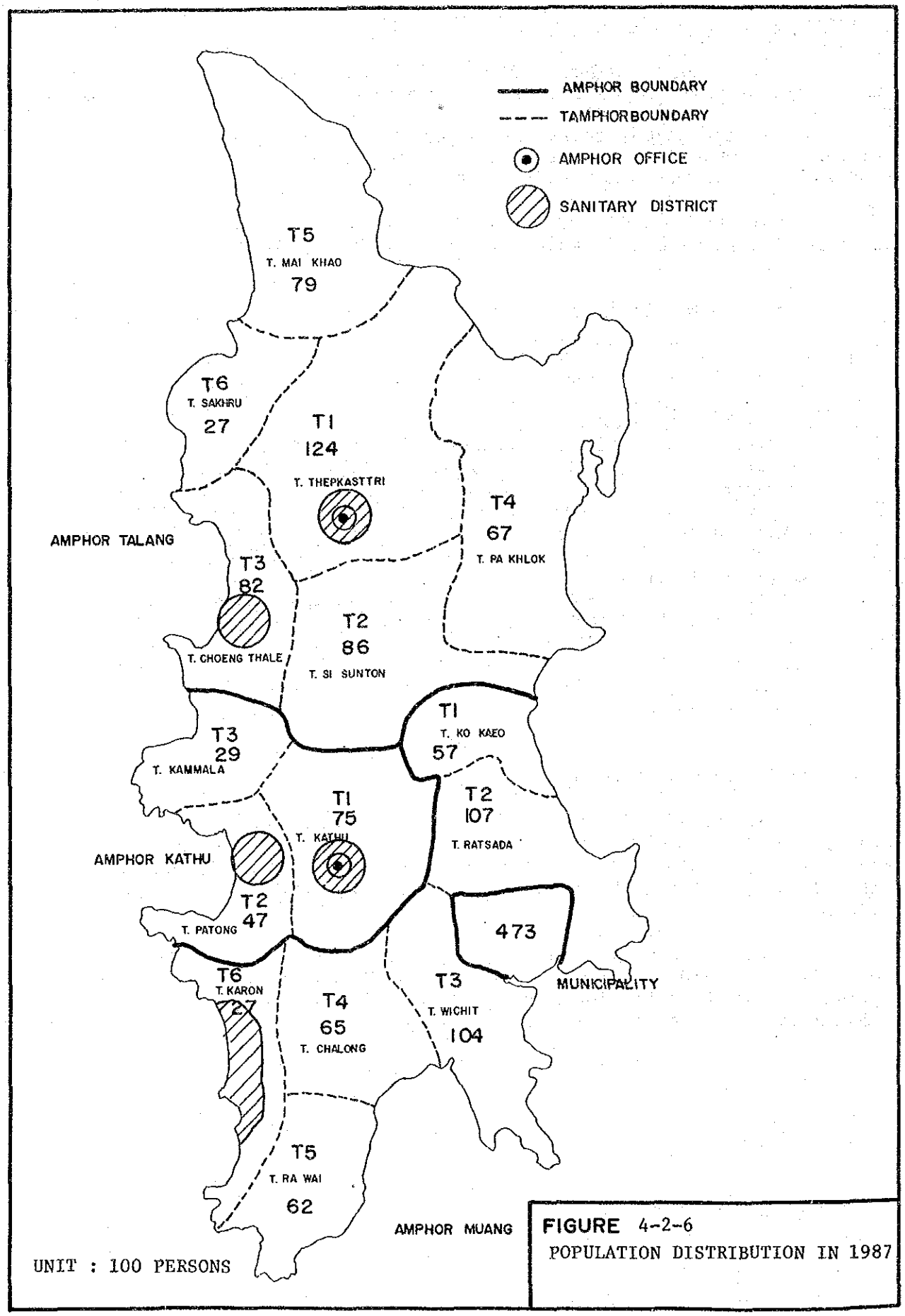


FIGURE 4-2-6
POPULATION DISTRIBUTION IN 1987

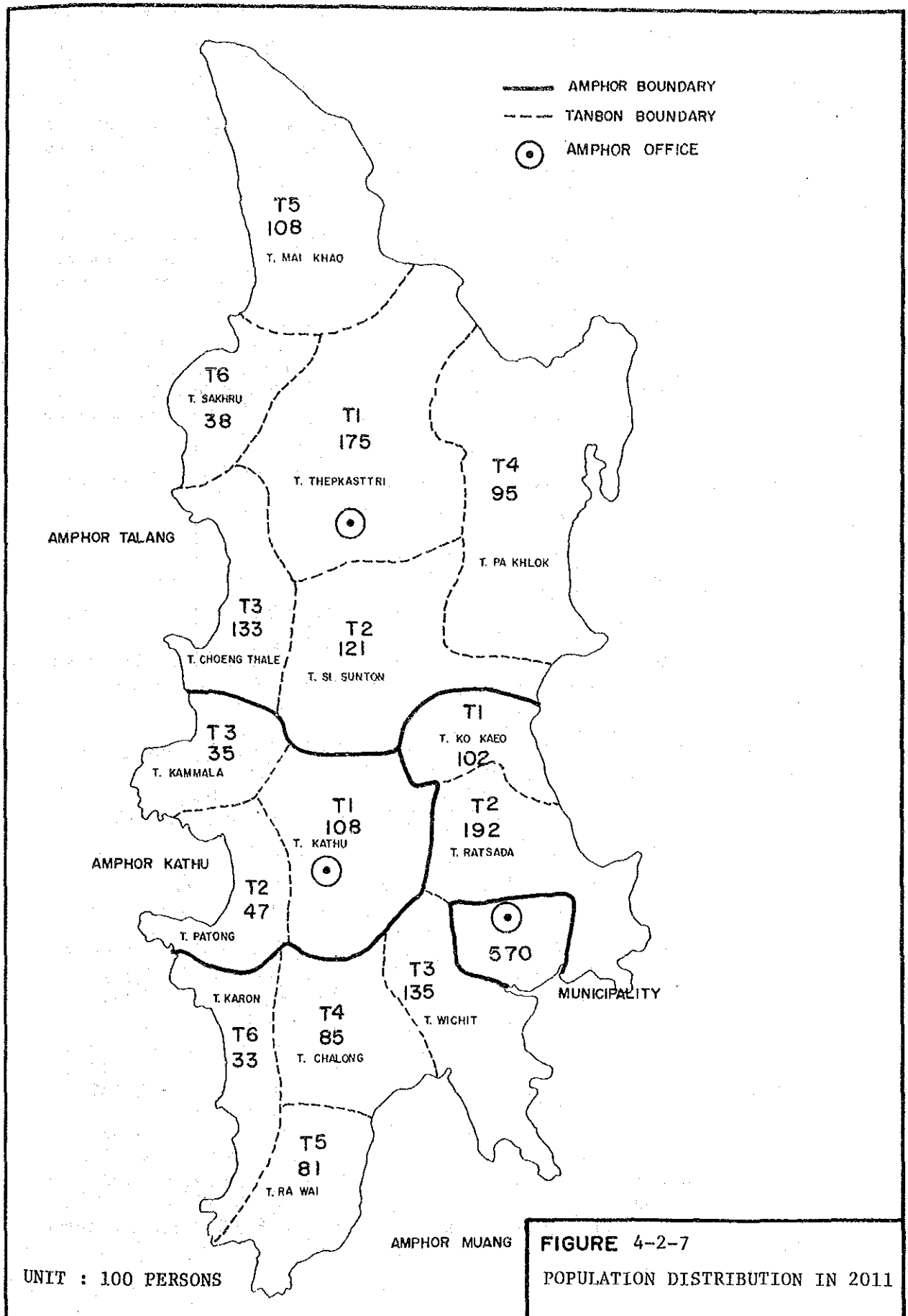


FIGURE 4-2-7

POPULATION DISTRIBUTION IN 2011

4.3 Service Area and Served Population

4.3.1 Service Area

The present service area of the Phuket Waterworks consists of Tambons Kathu, Patong and Wichit. For the Phuket Municipality PWA agreed to sell tap water to the Municipality with a limit of 6,000 cu.m/d at a rate of 4 ฿/cu.m in July 1989.

For the expansion of the services area in the future, taken into account are the DTCP's development plan and the PWA's development strategy. Consideration was made with future land use, population growth and tourism prospect.

Tourism development is the most important factor in determining the future service area, in other words, water supply for the resort beaches has the highest priority. The implementation for these areas should therefore be commenced in the earlier stage as shown in the extent of the service area for 2001.

The extent of the service area in years 2001 and 2011 are as shown in Figure 4-3-1.

4.3.2 Served Population

(1) Estimated Served Population

As the waterworks has started its operation at the Bangwad Treatment Plant in 1987, historical data on the water consumption and number of connections are not accumulated.

Served population was estimated from the number of connections in 1987 and the number of members per household.

Table 4-3-1 shows the result of estimation of served population.

Table 4-3-1 Estimation of Served Population

Area	No. of Conn. (a)	No. of Conn. for Domestic Use (b)	Pop./ No. of Houses (c)	Population Served (d)
Kathu	524	518	5.7	2,953
Patong	320	40	6.3	252
Wichid	44	38	4.8	182
Total	888	596		3,660

(b) Estimated from the meter reading records from Sep. 1987 to Aug. 1988
(c) Calculated from population data by tambon and Snitary District
(d) = (b) x (c)
Figure 4-3-1

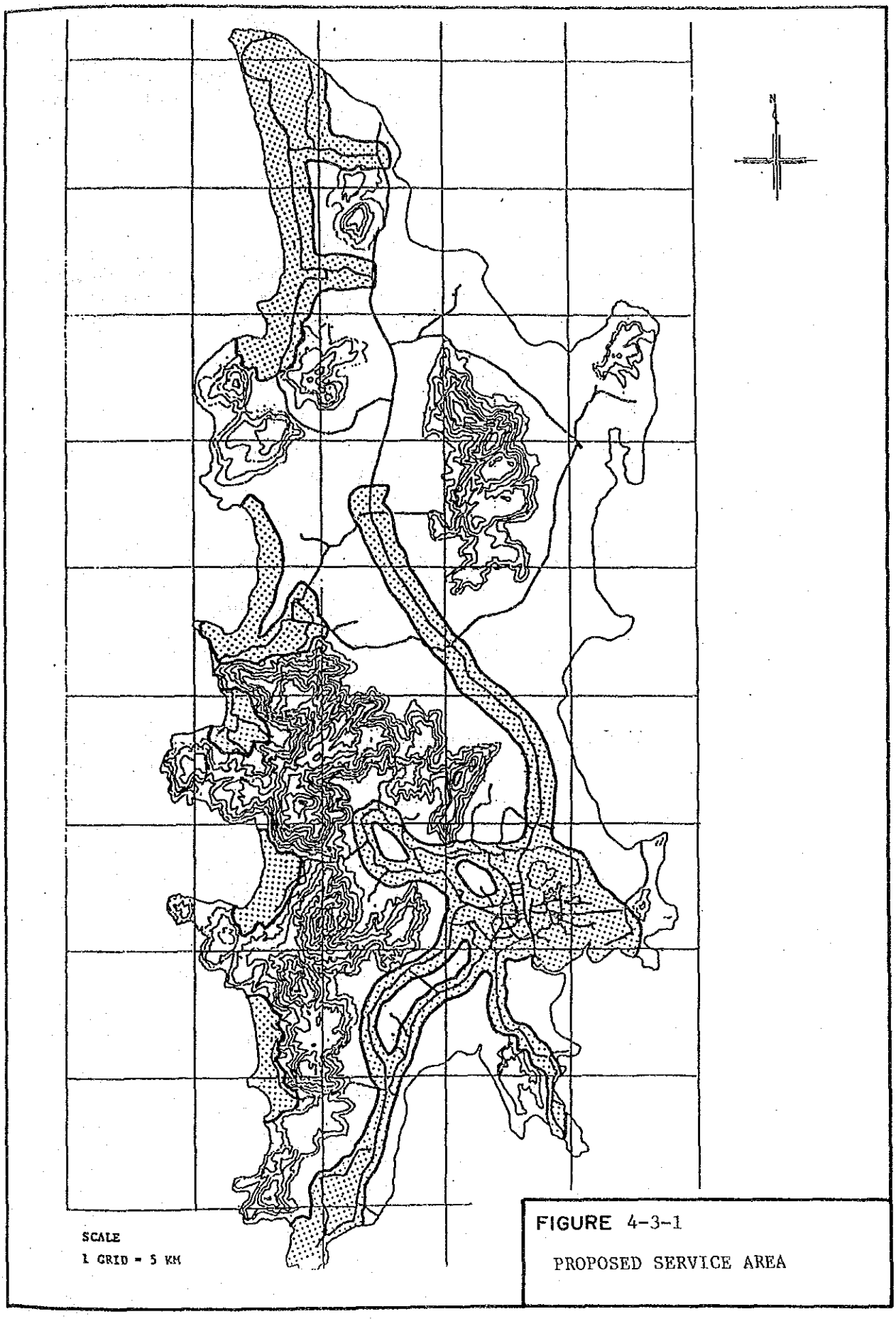


FIGURE 4-3-1

PROPOSED SERVICE AREA

(2) Service Ratio

According to the PWA's statistical data, the total population in the service area is 7,446 in 1987. Service ratio is calculated as follows:

3,660 / 7,446 = 49.2%

(3) Future Service Ratio

The future service ratio are set for three different categories of the area: (1) the Phuket Municipality, (2) the existing service area by PWA and tourism spots (hereinafter referred to as "tourism spot", (3) and areas other than (1) and (2). The ratios of these areas are as shown in Table 4-3-2.

Table 4-3-2 Future Service Ratio

(Unit : %)

Year	Municipality	Tourism Spot	Other Area
1991	57	15	-
1996	65	30	15
2001	73	40	25
2006	82	55	40
2011	90	70	50

(4) Future Served Population

Future served populations are calculated by area using the future service ratios and projected population therein as shown in Table 4-3-3.

Table 4-3-3 Future Served Population

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

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

The served population are calculated by tambon with the ratio of the served population against the total population in each tambon, the breakdown of which is shown in Table 4-3-4.

Table 4-3-4 Breakdown of Population by Tambon

Amphoe & Tambon	Type of Area	1991 Pop. in Study Area	1991 Ratio (a)	1991 Pop. in Service Area	1991 Ratio (b)	1991 Served Pop.	1996 Pop. in Study Area	1996 Ratio (a)	1996 Pop. in Service Area	1996 Ratio (b)	1996 Served Pop.	2001 Pop. in Study Area	2001 Ratio (a)	2001 Pop. in Service Area	2001 Ratio (b)	2001 Served Pop.	2006 Pop. in Study Area	2006 Ratio (a)	2006 Pop. in Service Area	2006 Ratio (b)	2006 Served Pop.	2011 Pop. in Study Area	2011 Ratio (a)	2011 Pop. in Service Area	2011 Ratio (b)	2011 Served Pop.
Thalang																										
T1	Low	13191	40	5276	0	0	14309	40	5724	15	859	15203	40	6081	25	1520	16008	40	6403	40	2561	16634	40	6654	50	3327
T2	Low	9126	30	2738	0	0	9900	30	2970	15	446	10518	30	3155	25	789	11075	30	3323	40	1329	11508	30	3452	50	1726
T3	Low	9946	60	5968	0	0	10837	60	6502	15	975	11505	60	6903	25	1726	12173	60	7304	40	2922	12618	60	7571	50	3786
T4	Low	7183	0	0	0	0	7791	0	0	15	0	8278	0	0	25	0	8717	0	0	40	0	9057	0	0	50	0
T5	Low	8157	50	4079	0	0	8824	50	4412	15	662	9417	50	4709	25	1177	9862	50	4931	40	1972	10307	50	5154	50	2577
T6	Low	2843	50	1422	0	0	3076	50	1538	15	231	3283	50	1642	25	411	3438	50	1719	40	688	3593	50	1797	50	899
Kathu																										
T1	Med.	6585	70	4610	15	692	7142	70	4999	30	1500	7605	70	5324	40	2130	8007	70	5605	55	3083	8316	70	5821	70	4075
T2	Med.	4569	70	3198	15	480	4950	70	3465	30	1040	5267	70	3687	40	1475	5584	70	3909	55	2150	5775	70	4043	70	2830
T3	Low	3454	70	2418	0	0	3763	70	2634	15	395	3995	70	2797	25	699	4227	70	2959	40	1184	4382	70	3067	50	1534
Muang																										
T1	Low	5102	30	1531	0	0	5533	30	1660	15	249	5893	30	1768	25	442	6204	30	1861	40	744	6444	30	1933	50	967
T2	Med.	9613	50	4807	15	721	10425	50	5213	30	1564	11103	50	5552	40	2221	11689	50	5845	55	3215	12141	50	6071	70	4250
T3	Med.	10700	70	7490	15	1124.6	11600	70	8120	30	2436	12300	70	8610	40	3444	12900	70	9030	55	4967	13500	70	9450	70	6615
T4	Low	6708	60	4025	0	0	7272	60	4363	15	654	7732	60	4639	25	1160	8142	60	4885	40	1954	8501	60	5101	50	2551
T5	Low	6392	60	3835	0	0	6928	60	4157	15	624	7368	60	4421	25	1105	7758	60	4655	40	1862	8099	60	4859	50	2430
T6	Med.	2631	60	1579	15	237	2850	60	1710	30	513	3033	60	1820	40	728	3216	60	1930	55	1062	3325	60	1995	70	1397
Municipal.																										
	High	60400	100	60400	57	34428	64700	100	64700	65	42055	69300	100	69300	73	50589	74300	100	74300	82	60926	79500	100	79500	90	71550
Total		166600	68.1	113376	33.2	37682	179900	67.9	122167	44.4	54203	191800	68	130408	53.4	69616	203300	68.2	138659	65.4	90619	213700	68.5	146468	75.5	110514
Breakdown																										
High		60400		60400		34428	64700		64700		42055	69300		69300		50589	74300		74300		60926	79500		79500		71550
Med.		34098		21684		3254	36967		23507		7053	39308		24993		9998	41396		26319		14477	43057		27380		19167
Low		72102		31292		0	78233		33960		5095	83192		36115		9029	87604		38040		15216	91143		39588		19797

(5) Prediction of Number of Tourists

The study on Potential Tourism Area Development for Southern Region in Thailand for TAT by JICA predicts the number of hotel rooms and tourists as shown in Table 1-3-1.

The study defines the two types of accommodation: the high and low class hotels. These two types are assumed to have different pattern of water use because of the level of facilities and equipment. The breakdown of the number of rooms for each type are shown in Table 4-3-5.

Table 4-3-5 Prediction of Number of Hotel Rooms

(Unit : Rooms)

Area	1991	1996	2001	2006	2011
Inside Mun.	3,500	3,500	3,500	3,500	3,500
Outside Mun.	12,683	16,172	18,421	18,421	18,421
Northern Area					
High	2,078	4,472	5,618	5,618	5,618
Low	11	255	300	300	300
Sub-Total	2,089	4,727	5,918	5,918	5,918
Southern Area					
High	6,770	7,387	8,034	8,034	8,034
Low	3,824	4,058	4,469	4,469	4,469
Sub-Total	10,594	11,445	12,503	12,503	12,503

Although the TAT report also gives the number of hotel rooms inside the Municipality, another report on the "Feasibility Study on Sewerage and Drainage Improvement Project for Phuket Municipality" for the Public Works Department by JICA which conducted the detailed survey in the Municipality and counted the number of all hotel rooms in ent figure which is adopted in Table 4-3-4 on the asumption that it will have no change until 2011.

The number of tourists is predicted by assuming the occupancy ratio and average number of guests per hotel room. These figures are:

Occupancy ratio = 60%

Number of guests per hotel room = 1.8 persons

The total number of tourists of stay is, therefore calculated as follows:

Table 4-3-6 Number of Tourisrs

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

4.4 WATER DEMAND

4.4.1 Historical Water Consumption

The annual water production and sales in 1987 are shown in Table 4-4-1.

Table 4-4-1 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)
1987	805,878	394,314	888	1.217

4.4.2 Future Water Consumption

As previously mentioned, the detailed survey was conducted in the Feasibility Study on Sewerage and Drainage Improvement Project for Phuket Municipality in which future water demand is also predicted for sewerage scheme. This report mostly refers the results of the above study regarding the future water demand in the Municipality.

(1) Domestic Water Consumption

The estimated per capita consumptions in the Phuket Municipality are 291 lpcd for 1988 and 300 lpcd for 2011, respectively. For the tourism spots and other areas per capita consumption in 2011 are assumed to be 150 and 100 lpcd, respectively.

Table 4-4-2 Unit Domestic Water Consumption

(Unit : lpcd)

Year	Municipality	Tourism Spot	Other Area
1991	292.5	100	-
1996	295.0	110	70
2001	297.5	125	80
2006	300.0	140	90
2011	302.5	150	100

Beside the above basic demand, there is an additional water demand of 3,494 cu.m/d by big consumers with an annual water consumption of more than 1,500 cu.m for domestic and commercial purpose except for restaurants. This additional water demand is assumed to be stable until 2001.

Table 4-4-3 shows the domestic water consumption in every five years to 2011.

Table 4-4-3 Future Domestic Water Consumption

(Unit : cu.m/d)

Year	Inside Mun.			Outside Mun.		
	Basic	Add.	Total	Tourism	Other	Total
1991	10,070	3,494	13,564	325	-	325
1996	12,406	3,494	15,900	797	357	1,154
2001	15,050	3,494	18,544	1,250	722	1,972
2006	18,278	3,494	21,772	1,998	1,369	3,367
2011	21,644	3,494	25,138	2,875	1,980	4,855

(2) Governmental/Institutional Water Consumption

The governmental/institutional water consumption includes the consumption of such institutions as governmental offices, hospitals, schools and temples. Water consumptions of each institution is predicted separately as they are different in nature.

(a) Governmental Office

It is assumed that the activities of governmental facilities correlate the population of the area which these facilities are governing. For example, the staff of the police department will be increased as the population grows up.

Considering this concept, future water consumption of the governmental facilities is predicted from the ratio to the population in the service area of each year.

The per population consumption was 7.31pcd in the Munipality in 1988 and is assumed to be 10 lpcd.

(b) School

Prediction of water consumption of school is made by assuming the number of students from the proportion of that against the total population. The number of students is assumed to increase along with the total population with a rate of 35%.

The per student consumption was 11.7 lpcd in the Municipality in 1988 and is assumed to be 12 lpcd through years.

(c) Hospital

Most of hospitals in the study area are equipped with their own water sources, mainly deep wells, as well as treatment facilities. This fact makes it difficult to identify the unit consumption and the actual total consumption of hospitals.

Regarding the statistical data of the number of beds against population, the "Population and Health" report of TDRI shows the following historical data with predictions in 1991 and 2006.

Table 4-4-4 Ratio of Population to Hospital Bed

(Unit : pop./bed)

Year	Whole Kingdom	BMA	Provincial Area
1980	805.85	341.48	955.66
1981	801.35	361.22	952.75
1982	793.46	365.63	934.51
1983	761	376	888
1984	749	354	879
1985	748	336	882
1986	744	354	862
1991			(700)
2006			(600)

There are one public hospital with 207 beds and four private hospitals with 149 beds in the municipal area.

In consideration of the province population in 2011 which is 213,700, and a national target of 600 pop./bed at the public sector level, 356 beds is required to be provided. The balance is allocated to the outside of the Municipality.

In accordance with this idea, the number of beds is calculated from the total population and population per bed as shown in Table 4-4-5.

Table 4-4-5 Bed Requirement in Phuket Island

Item	1991	1996	2001	2006	2011
Population	166,000	179,900	191,800	203,300	213,700
Per bed Population	600	600	600	600	600
Bed Requirement	277	300	320	339	356
Existing No. of Bed (Inside Mun.)	207	207	207	207	207
Balance (Outside Mun.)	70	93	113	132	149
Additional (Inside Mun.)	149	149	149	149	149
No. of Beds					
Inside Mun.	356	356	356	356	356
Outside Mun.	70	93	113	132	149

A unit water consumption per bed is assumed to be 1.5 cu.m/d/bed through the years.

(4) Summary of Governmental/Institutional Consumption

The total of governmental/institutional consumption are summarized as shown in Table 4-4-6.

Table 4-4-6 Summary of Governmental/Institutional Consumption

Item	1991	1996	2001	2006	2011
1. Government					
o per pop. consump. (lpcd)	10	10	10	10	10
o pop. in service area	113,376	122,167	130,408	138,659	146,468
o consump. (cu.m/d)	1,134	1,222	1,304	1,387	1,465
inside mun.	604	647	693	743	795
outside mun.	530	575	611	644	670
2. School					
o per student consump. (lpcd)	12	12	12	12	12
o no. of student	39,682	42,758	45,643	48,531	51,264
o consump. (cu.m/d)	476	513	548	582	615
inside mun.	254	272	291	312	334
outside mun.	222	241	257	270	281
3. Hospital					
o per bed consump. (cu.m/d/bed)	1.5	1.5	1.5	1.5	1.5
o no. of bed	427	449	469	488	505
o consump. (cu.m/d)	641	674	704	732	758
inside mun.	534	534	534	534	534
outside mun.	107	140	170	198	224
Total Consump. (cu.m/d)	2,251	2,409	2,556	2,701	2,838
inside mun.	1,392	1,453	1,518	1,589	1,663
outside mun.	859	956	1,038	1,112	1,175

(3) Tourism water consumption

The tourism water consumption is defined as the water required by hotels and other accommodations.

The tourism water consumption is estimated by multiplying the per room consumption by the number of rooms for the Municipality and by multiplying the per capita consumption by the number of tourists for the resort area.

The per room consumption was 1.2 cu.m/d in the Municipality and assumed to be fixed until 2011. For the per capita consumption, 640

and 500 lpcd are applied for high and lowr classes, respectively.

Total consumption by tourists is, therefore calculatedn as shown in Table 4-4-7

Table 4-4-7 Tourism Water Consumption

(Unit : cu.m/d)

Area	1991	1996	2001	2006	2011
Inside Mun.	4,200	4,200	4,200	4,200	4,200
Outside Mun.	8,187	10,527	12,012	12,012	12,012
Northern Area					
High	1,436	3,091	3,883	3,883	3,883
Low	6	138	162	162	162
Sub-Total	1,442	3,229	4,045	4,045	4,045
Southern Area					
High	4,680	5,106	5,553	5,553	5,553
Low	2,065	2,192	2,414	2,414	2,414
Sub-Total	6,745	7,298	7,967	7,967	7,967

(4) Commercial Water Consumption

Commercial water consumption is defined to be the consumption of private businesses such as shops, restaurants, bars, and markets. Consumption derived from the commercial activities is regarded to closely relate to the urban activities in the Munitcipality and the tourism activities in the tourism spot.

In the Municipality, restaurants is categorized into the urban activity, the consumption of which is equivalent to 5% of the basic consumption, while figures of Pattaya Water Supply Development Plan and Feasibility Study is applied to the tourism spot as shown in Table 4-4-8.

Table 4-4-8 Commercial Consumption

(Unit : cu.m/d)

Year	Municipality		Tourism Spot		Comm. Total
	Basic (a)	Comm. (b)	Tourism (c)	Comm. (d)	(e)
1991	13,564	678	8,187	3,029	3,707
1996	15,900	795	10,526	3,895	4,690
2001	18,544	927	12,012	4,444	5,371
2006	21,772	1,089	12,012	4,444	5,533
2011	25,138	1,257	12,012	4,444	5,701

(b) = (a) x 0.05
(d) = (c) x 0.37
(e) = (b) + (d)

(5) Industrial Water Consumption

There are two areas in Phuket which need industrial water supply: namely, the Deep Sea Port and the Phuket Municipality. The Deep Sea Port is planned to use an amount of 1,000 cu.m/d for industrial use. This amount is fixed until 2011. Another industrial zone is planned to be developed in the eastern area of the Municipality, the water demand of which is estimated at the same amount of 684 cu.m/d as the presnt industrial consumption in the Municipality, since the posibility of industrial development in the municipality is regarded to be less.

Municipality	684 cu.m/d
Deep Sea Port	1,000 cu.m/d

(6) Unaccounted-for Water Ratio

The unaccounted-for water ratio is in the range of 10 to 15 percent in these five years according to the Phuket Municipal Waterworks, although the distribution amount is estimated based on the operation time and rated discharge of pumps, while that of the PWA Phuket Waterworks was 46.5% rather high in 1987.

This ratio is supposed to be improved lower by implementing the daily maintenance works such as replacement of old pipes, leakage detection and replacement of water meters with more sensitive and anti-reverse rotation type.

PWA set a target of reducing the unaccounted-for water as one of measures for cost recovery at 25 and 20 percent in 1995 and 2010, respectively. Implementing program of leakage controls presently on going at various waterworks under PWA.

The said target is adopted in this study with intermittent figures as shown below:

Table 4-4-9 Future Unaccounted-for Water Ratio

(Unit : %)

Year	Municipality & New Service Area	PWA Existing Service Area
1991	20	37
1996	20	33
2001	20	28
2006	20	24
2011	20	20

4.4.3 Future Water Consumption

(1) Peak Factors

Data for determining the peak factors from the present water use pattern was not found. In this study, peak factors are set separately for tourism and commercial use and other use.

For peak factor of tourism use, 1.40 is adopted from the past record of monthly fluctuation of number of tourist. Considering the other planning of PWA's water supply projects, a value of 1.25 is applied for other use.

(2) Future Water Demand

Future water demand is calculated from the water consumption, unaccounted-for water ratio, and peak factors. Table 4-4-10 shows the average and maximum daily water demand.

Table 4-4-10 Future Water Demand

(Unit : cu.m/d)

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

Table 4-4-11 Demand by Zone

(Unit : cu.m/d)

Zone No.	1991	1996	2001	2006	2011
Zone 1	0	350	476	687	882
Zone 2	164	277	384	556	754
Zone 3	1,246	1,420	1,584	1,846	2,160
Zone 4	0	846	1,002	1,173	1,336
Zone 5	20,359	22,883	25,736	29,209	32,830
Zone 6	151	258	361	525	715
Zone 7	0	3,432	4,328	4,446	4,560
Zone 8	0	1,355	1,728	1,860	1,981
Zone 9	0	664	750	803	852
Zone 10	6,314	6,897	7,584	7,700	7,831
Zone 11	1,984	2,179	2,405	2,463	2,527
Total	30,217	40,561	46,338	51,268	56,427

5. Design Criteria

5.1 Raw Water Intake

Amount of raw water to be taken should be 105 percent of daily maximum water demand.

5.2 Treatment and Pipe Design

Design criteria for the design of the treatment system and pipeline was established on the basis of the various design standards having been employed in Thailand or other countries, and with consideration on the conditions of the project site and raw water quality to be taken from dams.

The design criteria is summarized in the followings:

(1) Water Loss

Treatment Loss : 3 % of production capacity for filter washing and in-plant use.

Raw water has low turbidity so that amount of backwashing water can be smaller than other cases of surface water treatment.

(2) Pipeline

Formula for Flow Rate Calculation :

Hazen-William's Formula, C = 110

C-value for pipes are usually defined as 130 for new pipes. For planning purpose, 110 is adopted considering miscellaneous loss in line at valves, bends etc.

Velocity : Maximum 3.0 m/s

Minimum 0.3 m/s

Pipe Material: Material should be decided considering pressure, soil condition, pipe profile, etc. However, material is generally selected in accordance with the principle below:

Steel Pipe:for diameter 400 mm or larger

A/C Pipe: for diameter 300 mm or smaller

(3) Treatment Plant Facilities

a. Receiving Well

Retention Time : 1.5 min

b. Mixing Tank

Type of mixing	:	Hydraulic
Mixing time (min)	:	1 - 5
Intensity, G (1/sec)	:	500 - 1,000

c. Flocculation

Type of mixing	:	Hydraulic
Stage	:	3 or more
Intensity, G (1/sec)	:	10 - 75
Flocculation time (min)	:	20 - 40

d. Sedimentation Basin

Type of sedimentation	:	by Gravity
Type of basin	:	Rectangular Horizontal flow
Flow velocity (cm/min)	:	less than 40
Retention time (hour)	:	3 - 5
Effective depth (m)	:	3 - 4
Length/Width ratio	:	3 - 8
Sludge removal	:	by manual or suction pipe

e. Filter

Type of filtration	:	Rapid sand filtration Gravity down flow
Surface loading (m/d)	:	120 - 150
Filter media		
type	:	Single media
depth (cm)	:	60 - 70
effective size (mm)	:	0.45 - 0.70
Underdrain		
gravel layer	:	100- 150 mm x 4 layers
underdrain type	:	Bored pipe
Surface washing		
type	:	fixed nozzle
jet pressure(kg/cm2)	:	1.5 - 2.0
washing time (min)	:	4 - 6
rate (m3/m2/min)	:	0.2
Backwashing		
rate (m3/m2/min)	:	0.6 or larger
washing time (min)	:	5 - 10

f. Clear Water Reservoir

Retention time (hour)	:	6.0

Big hotels have storage tanks so that hourly fluctuation is considered small.

Depth (m)	:	3 - 6

g. Chemical feeding

Alum

coagulant	:	Solid aluminum sulfate
mixing	:	Batch mixing
dosage rate	:	5 - 10

Lime (as necessarily)

objective	:	pH control for coagulation
chemical type	:	Slaked lime (Ca(OH)2)

h. Chlorination

Chemical type	:	Chlorine gas
Minimum storage	:	1 month
Type of injector	:	Vacuum type injector
Dosage rate (ppm)	:	2.0

i. Instrumentation

General concept

Centralized operation not to be introduced;

Operation to be manual control at plants of smaller than 10,000 cu m/d;

Operation to be automatic control at each facility at plants of 10,000 cu m/d or more.

Flows to be measured	:	Raw and treated water
Levels to be measured	:	Receiving well Clear water reservoir All pump pits Chemical tanks
Weights to be measured	:	Chlorine gas cylinder
Head to be measured	:	Filter loss

(4) Distribution Facilities

a. Service pressure

Minimum pressure (kg/cm2): 1.0 (for hourly maximum flow)

b. Distribution reservoir

Retention time : 6 hours of daily maximum flow

6. Basis of Cost Estimates

6.1 Construction Cost

(1) General

Construction cost of facilities to be built is calculated with prices in 1989 on the basis of the various unit costs.

The construction cost is calculated by different items in the manner as described below:

a. Pipelines : by linear meter for
- o Transmission pipes
- o Distribution pipes

b. Water Treatment Plant : by facilities for
- o Receiving well
- o Sedimentation basin
- o Sand filter
- o Clear water reservoir
- o Elevated tank
- o Pumping house
- o Chemical house
- o Mechanical works
- o Electrical works
- o Miscellaneous

c. Land Acquisition

These costs are separated in Foreign and Local Cost portion with the percentage by item as shown below:

Work 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

(2) Pipeline Construction

Pipelines are firstly separated into two major groups: (i) transmission pipeline for either raw water or clear water, but not for distribution, and (ii) distribution pipeline.

Unit costs for construction of transmission pipeline are calculated by linear meter, consisting of the material, transportation (two cases as more than 800 km, or smaller) and installation costs. Cost for fittings are assumed as 10 and 15 percent of pipe material cost for asbestos cement and steel pipes, respectively. These ratios are set smaller compared to that of the distribution pipes because of the simplicity in the pipeline components.

Unit costs of distribution pipeline are calculated in the same manner as that for the transmission pipeline. The ratios for fittings are set as 25 and 35 percent of the pipe material cost for asbestos cement and steel pipes, respectively.

(3) Treatment Plant

Cost for the treatment plant is calculated by the unit cost by facility of plant component of various capacity which has been used by PWA for planning purpose. Each cost is updated to meet the increased construction cost in 1989.

Unit costs for facilities, which are not included in the PWA's unit cost list, are calculated assuming the unit costs for the major items as follows:

- o Concrete works by concrete volume, including related works as reinforcement (assuming 100 kg/cu m of concrete), forming, scaffolding, supporting.
- o Earth works by soil volume for excavation and fill
- o Architectural works by unit area of building
- o Concrete piles by each pile, including material, transportation and driving cost

(4) Mechanical Works

Costs for the plant facilities included in the mechanical works are calculated on the basis of the number of unit of each equipment such as pump, flocculator, sludge remover, or chemical and chlorination dosage equipment. Additional percentage is assumed for the miscellaneous items as pipings and fittings.

(5) Electrical Works

Cost for the electrical works substantially varies depending on the instrumentation system. The records in the construction of the advanced water supply system shows it would share as much as 40 percent of the total construction cost if the sophisticated computer control system is employed. Employing the more simple system could reduce this cost much.

The system to be recommended in this study should be the simple one as described in the Design Criteria so that the cost for the system could be lowered. It is practical and common way to assume that the cost of the electrical works closely related to the cost of the mechanical works. In this study, the cost is therefore, calculated by percentage of the mechanical works.

(6) Land Cost

The land cost in the study area has been increasing very rapidly because of the booming investment therein. The escalation ratio is said to be more than 300 to 500 percent in one or two years. Considering this situation, the unit land cost is assumed as follows:

a. Flat area in the island : Baht 2,000,000 per rai
b. Hill side area in the beach in the island :
Baht 5,000,000 per rai
c. Rubber plantation area in the hill side in and outside od the island : Baht 500,000 rai
d. Hill side area in and outside the island :
Baht 300,000 per rai

The details of the unit cost are shown in the Appendix A-6-1.

6.2 Operation and Maintenance Cost

(1) General

Operation and maintenance cost is calculated on the basis of the price and rate in 1989, and consists of the following factors:

- o Energy Cost
- o Chemical Cost
- o Manning Cost
- o Repair Cost
- o Replacement

This cost is calculated in local currency only.

(2) Energy Cost

It is practical that the energy for the operation will be provided in the form of the electricity by Provincial Electricity Authority (PEA).

The Energy cost is calculated separately for the demand charge and energy charge with the PEA rate in 1989 which are:

Demand Charge : Baht 229 /KW/month

Energy Charge : Baht 1.23 /KWH

(3) Chemical Cost

Unit chemical costs are as follows:

Alum : Baht 3.9 /kg

Lime : Baht 1.25 /kg

Chlorine Gas : Baht 15.6 /kg (excluding gas container)

(4) Manning Cost

The unit manning costs of each year are calculated from the average manning cost in 1987, which is Baht 6,540 per person per month. The annual increment of the monthly salary is set to be 5 percent.

(5) Repair Cost

Repair cost should be counted for repairing and maintaining the

plant equipment. This cost is calculated as 0.3 percent of the construction cost of the mechanical and electrical works.

(6) Replacement

Each facility to be constructed should have a certain life time. The span for the life time is varying depending on its nature of the facility. The followings are the life time of the facilities to be taken in this study and concept for replacement:

Item	Life time span	To be replaced after life time
Pipeline		
A/C pipes	20 years	50 percent
Steel Pipes	30	50
Concrete Structures		
Treatment Plant	50	100
Reservoir	50	100
Mechanical Equipment	20	100
Electrical System	20	50

(7) Cost of the Head and Regional Office

Cost of the PWA's head office and the regional office are allocated and added, in the financial study in Chapter 17, to the direct operation costs above. The allocation is determined assuming the future increment of their costs in each office, detailes of which is explained in Chapter 17.

Part 2
DEVELOPMENT PLAN

Part 2 DEVELOPMENT PLAN

7. Consideration on the Development Plan

An extensive expansion of the service area and the water supply system should be required to cope with the present development and prospective future development of the resort areas in the island. This factor is the most important in considering the facility planning in the development plan.

In the facility planning, the balanced and effective layout is needed since the service area consist of the scattered zones and there are several water sources both in the island and Phang Nga province side.

Land acquisition is becoming a serious problem in this region as the investment by private sector has been extensively increasing. Such investment is making the land price to substantially uprise. Therefore, the land requirement should be minimized in the planning so that the implementation of the project would not be less hampered by the land acquisition problem.

The service area is separated into eleven blocks as shown in Figure 7-1. The zoning method is introduced since it has several advantages, such as:

(i) Distribution of the water demand

Service area will consist of the separated zones which have the separated water demand depending on the characteristics of the population and social aspects. This will help the implementation to be easily established by considering the priority of each zone.

(ii) Easy operation and maintenance

Operation and maintenance of the distribution system will be easier sine each block is separated and grouped into several systems depending on the location of the raw water source and treatment plant. The organization of waterworks will also become simple by the separated staff and responsibility.

Table 7-1 presents the features of each zone.

Table 7-1 Characteristics of Zones

Zone No.	Amphoe	Tambon	Served Population (in 2011)	Water Demand (in 2011) (cu m/day)	Characteristics of Zone
1	Muang	1			
	Thalang	1	6,020	1,103	Residential
		2			
2	Muang	2	4,250	943	Residential & Commercial
3	Muang	3	6,615	2,700	Residential & Deep Sea Port
4	Muang	4	4,981	1,670	Residential
		5			
5	Municipality		71,550	41,037	Commercial & Tourist Spot
6	Kathu	1	4,075	893	Residential
7	Thalang	5	3,476	5,700	Tourism Spot
8	Thalang	3	3,786	2,476	Tourism Spot
9	Khatu	3	1,534	1,065	Tourism Spot
10	Khatu	2	2,830	9,788	Tourism Spot
11	Muang	6	1,397	3,159	Tourism Spot
		Total	110,511	70,533	

Note: Water Demands show daily average demands.

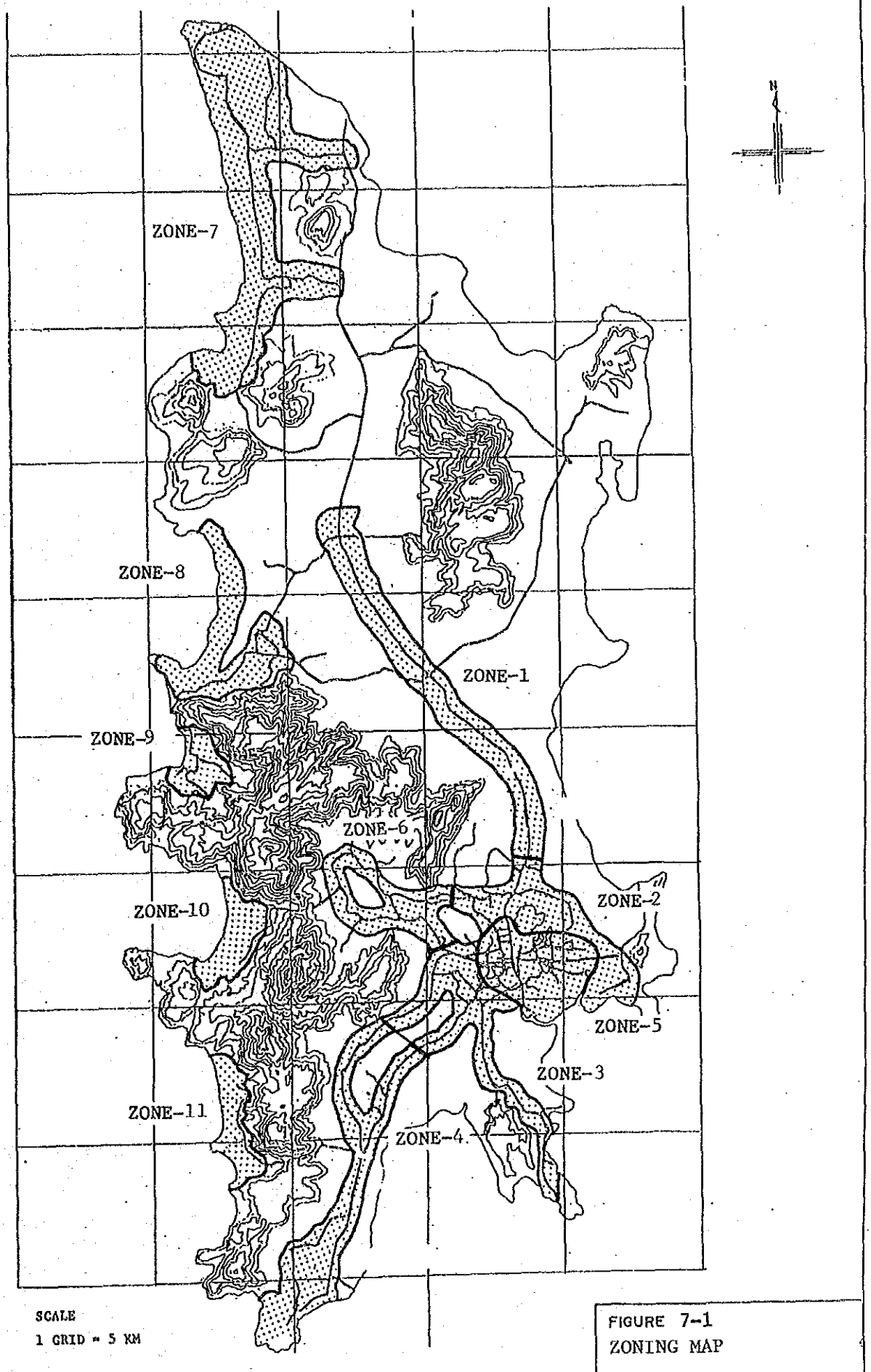


FIGURE 7-1
ZONING MAP

8. Definition and Evaluation of Alternatives

8.1 Water Sources

8.1.1 Proposed Water Sources

Five of new dams are proposed to be constructed for securing permanent water source for the water supply of the Island. The proposed dams are: Bang Tho Sung, Khlong Katha, Bang Nieo Dam, Khao Che Tra, and Khlong Lo Yung. Characteristics of each dam are described in Chapter 2. The raw water intake capacity is, therefore summarized as follows:

Table 8-1-1 Maximum Raw Water Intake Capacity

Water Source	Maximum Intake Capacity (cu m/d) (Daily Average Base) (1)	Maximum Amount for Water Supply (cu m/d) (Daily Average Base) (2) = (1)/1.05
1. Existing Source		
- Mining Pits	13,900	13,240
- Bangwat Dam	11,700	11,140
Sub-total	25,600	24,380
2. Proposed Source		
- Bang Tho Sung	10,900	10,380
- Khlong Katha	9,600	9,140
- Bang Nieo Dam	8,900	8,480
- Khao Che Tra	7,600	7,240
- Khlong Lo Yung	21,400	20,380
Sub-total	58,400	55,620
Total	84,000	80,000

Note: Maximum Amount for Water Supply (2) is less than Maximum Intake Amount by 5 percent as a total of the intake and treatment loss.

THese dams are designed on the basis of the design criteria of Bangwat Dam. Geological and dimensioning aspects for the proposed dams are described in Appendix A-8-1. The design drawings are presented in Appendix A-8-2.

8.1.2 Temporary Water Sources

For the period before the proposed dams will be constructed, the temporary measures should be made to help the shortage of water supply. The provable water sources for the temporary measures are existing streams, and mining pits.

Khlong Bang Yai is almost only stream in the island which could provide a substantial amount of water during the rainy season. Other streams seem to be too small to be used as a water source. Khlong Ban Yai is proposed to be used as a temporary source to supplement an intake capacity of Bangwat Reservoir.

The intake point is proposed to be located at the bridge in Kathu area where the two branched streams meet. The pumping station will be needed to pump water to the reservoir from the intake point. The pumping station will be able to send the enough amount of water to enable the use of a full capacity of the Bangwat Treatment Plant.

In the other area, however, there is few sources of raw water for the temporary use. Available sources for the temporary use are the mining pits in the island which have been abandoned. The followings are two prospective mining pits and their approximate capacities.

Table 8-1-2 Proposed Mining Pits for Temporary Sources

Location	Estimated Storage Capacity (MCM)	Catchment Area (km2)	Water Supply Capacity (cu m/d)
Khao Na Bon	1.65	2.6	7,600
Ban Tan Muang	1.40	5.0	6,500

Note: Water supply capacity is estimated as calculated in Appendix A-8-3.

The further investigation and study are recommended to be made by PWA for the use of these mining pits to verify the detailed volume of the pits and the necessary facilities for the water supply from these sources.

8.1.3 Water Source Development Plan

In order to meet the increasing water demand, the construction of the proposed dams should be carried out in the earliest time. However, the number of the proposed dam is counted to be five which are rather large to be implemented quickly. It is assumed that a term of the dam project including the design and construction is four years on the basis of the schedules proposed by RID.

The priority of the dam construction should, therefore be firstly studied. In this respect, from the present information regarding the land acquisition and the local people's attitude for dam construction project, the construction of the Khlong Lo Yung dam is considered to have more difficulty compared to the other dams. Therefore, it should be scheduled in the later part.

Several alternatives are proposed for this study. The comparison study is, however described in the Chapter 9 since it should be made with a study on the water supply system.

8.2 Water Supply System

In consideration of the water supply system, there are three major items to be studied: (i) Water demand prediction by zone, (ii) the total facility layout, and (iii) the facility planning of each component. These issues are studied separately as follows:

8.2.1 Water Demand Prediction by Zone

Water demand in each zone is calculated from the served population and unit consumption, by assuming the water supply service ratio of each Tambon in every year. The service ratios of each year and Tambon were set following the implementation schedule of the proposed dams. Various kind of other demands such as tourism, industrial, commercial, and governmental use are calculated in the same manner of predicting the water demand in the total service area.

Figures 8-2-1 shows a water demand prediction by zone. Detailed calculation is shown in Appendix A-8-4.

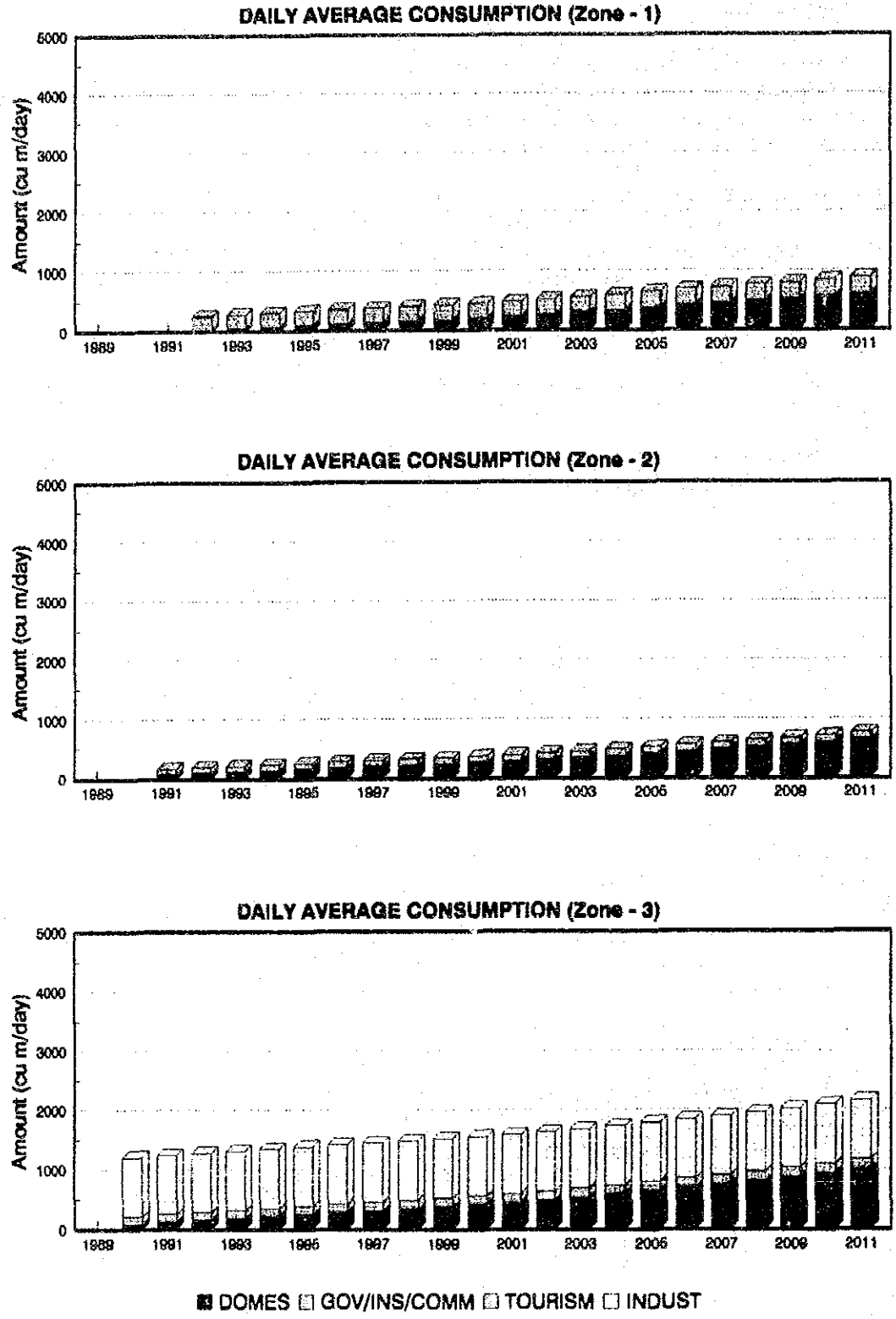


FIGURE 8-2-1
Water Demand Prediction
(Zones 1 - 3)

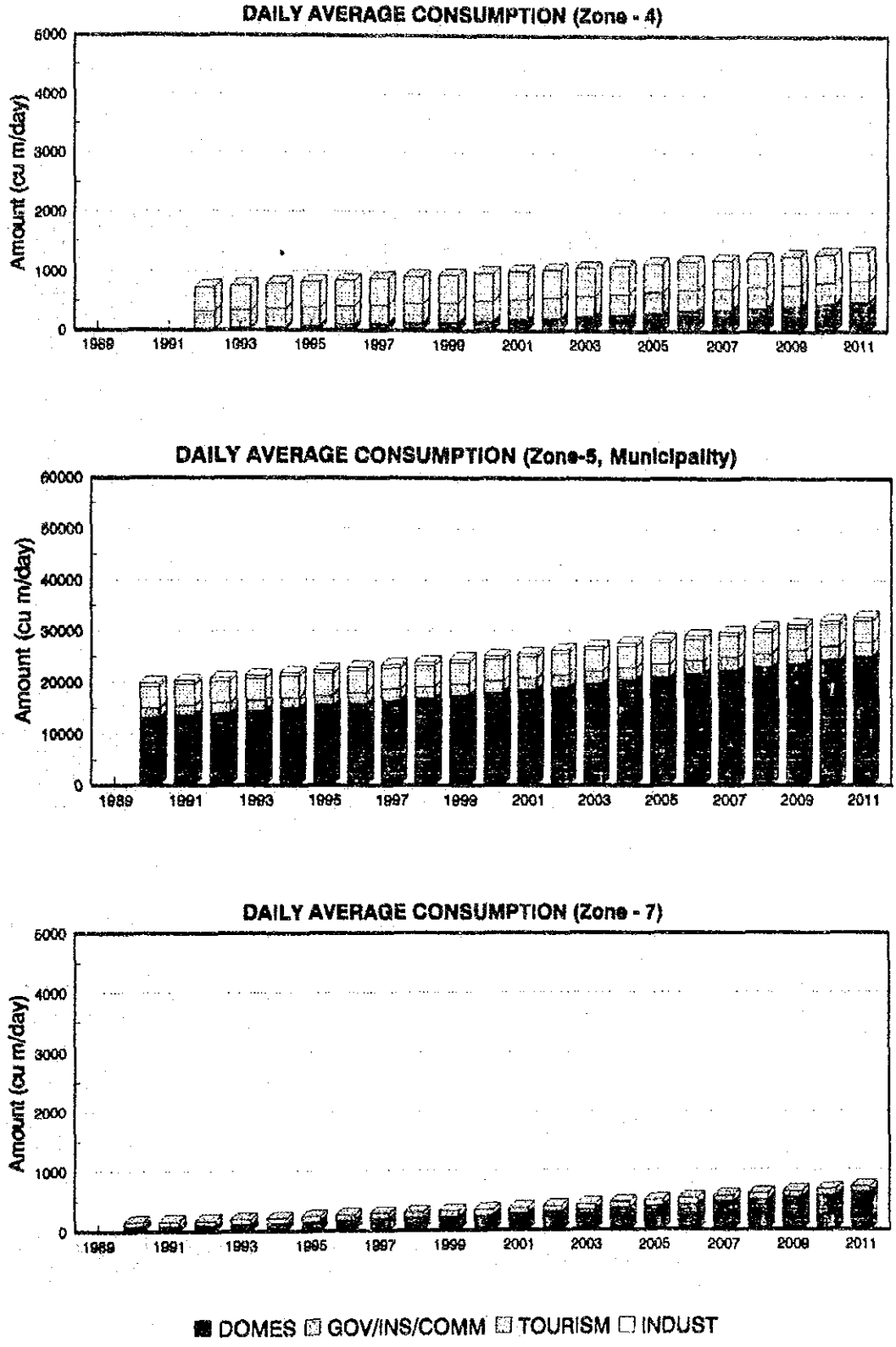


FIGURE 8-2-1 (Cont'd)
Water Demand Prediction
(Zone 4 - 6)

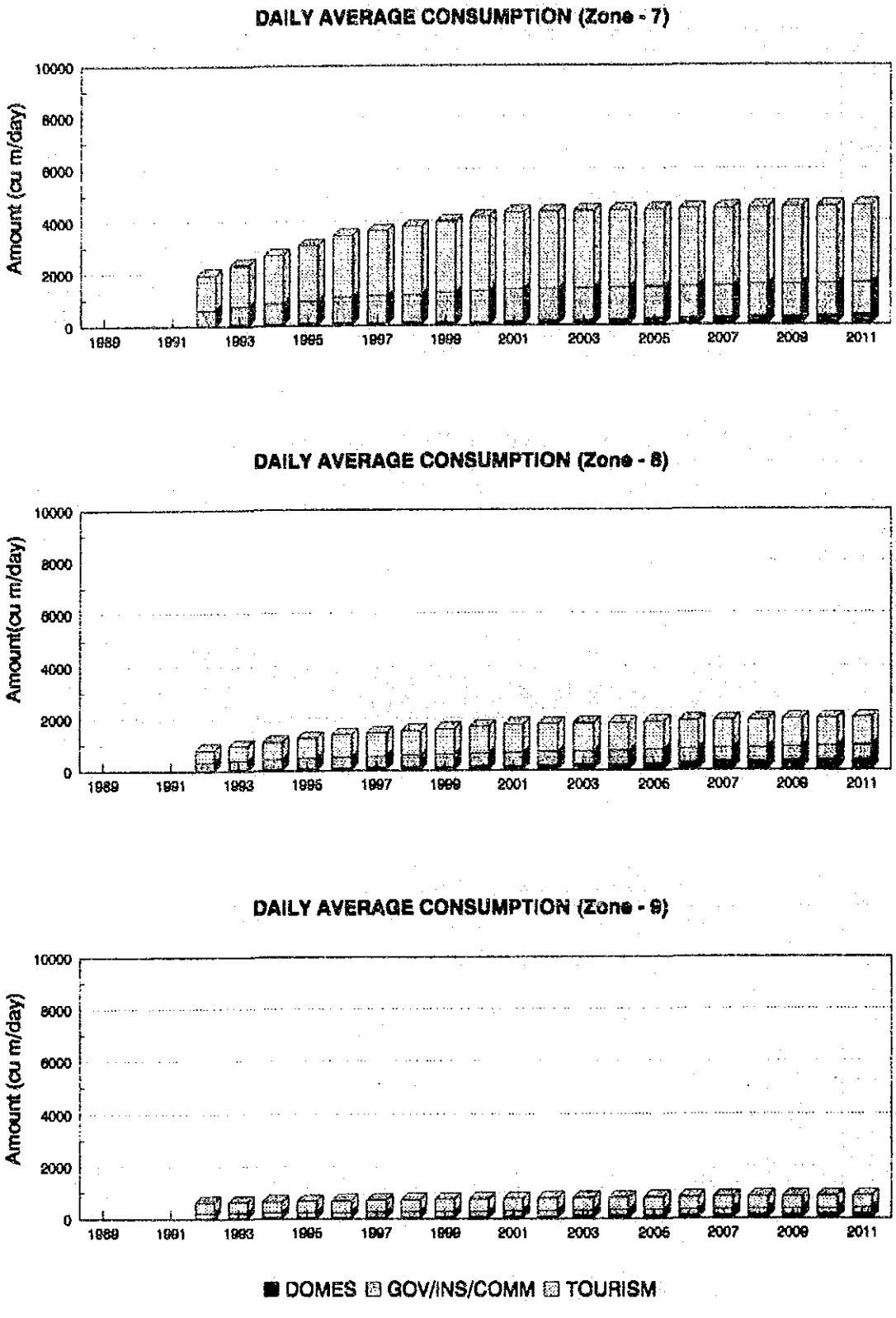
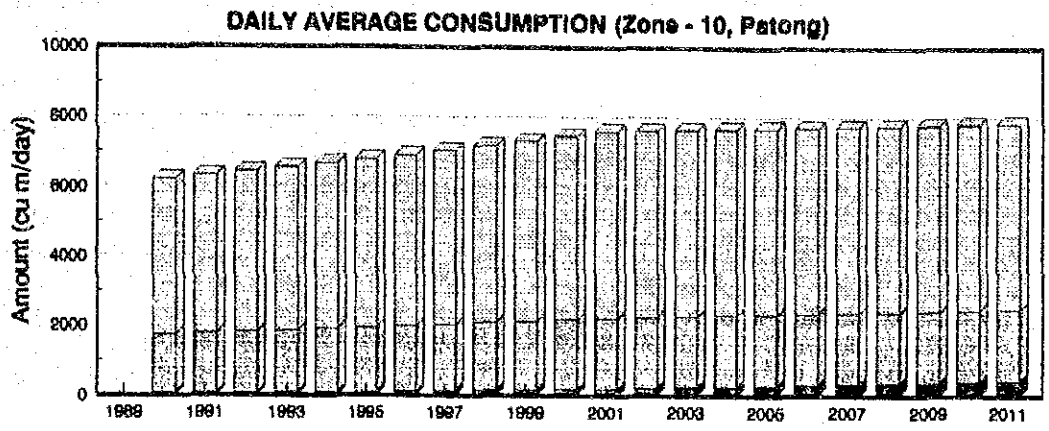


FIGURE 8-2-1 (Cont'd)
Water Damand Prediction
(Zones 7 - 9)



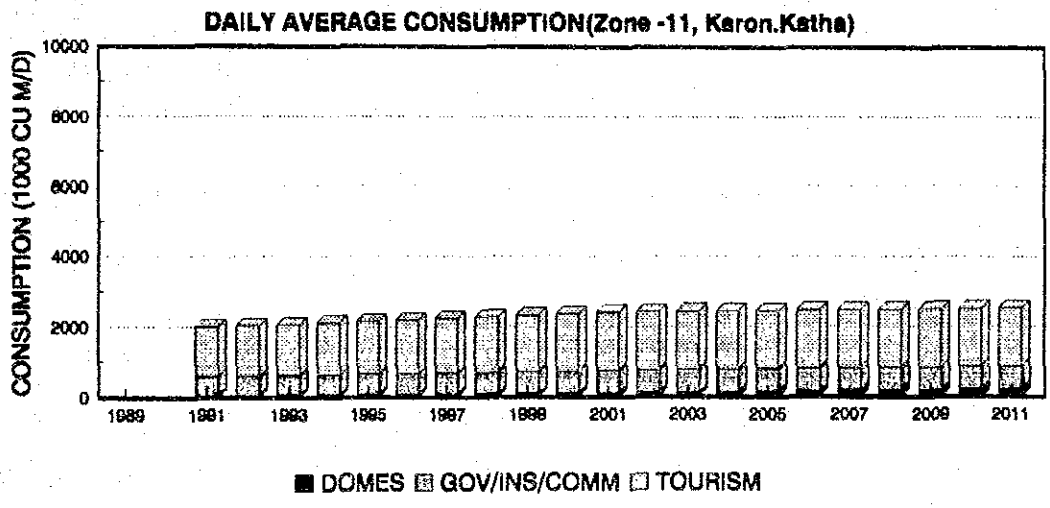


FIGURE 8-2-1 (COnt'd)
Water Demand Prediction
(Zone 11)

8.2.2 Total Facility Layout

The layout of the total water supply system depends on the components of the system, and their locations. The location of the dams and reservoirs for the raw water supply are discussed in the previous sub-section. Of the system components, particularly the number and location of treatment plants should firstly be selected.

It is recommended that several treatment plants are constructed close to the proposed dam sites since the service zones are scattered in the wide area and further each other. This concept will enable to reduce the length of the transmission pipeline between zones as well as to facilitate the easy operation of water transmission and distribution. Another advantage of this concept is that the implementation of the proposed water supply system will be able to follow the order of the dam construction so that it will be carried out area by area. This point is important since the dam construction will be affected by the land acquisition which is an unknown factor as of now.

As an order of dam construction is fixed to set the yearly water demand prediction, the selection of the location of the treatment plants will be limited as described below:

(1) Location and Zoning of Water Supply System

Since the service areas are scattered in the island, the water supply system is also separated in some groups consisting of some zones. It is proposed that each group of water supply system consists of one treatment plant and several service areas, and is named as shown in Table 8-2-1.

As shown in the Table, Zone 5 (Municipality) will be supplied water from several sources. This is because the water demand of the municipality is so large that several sources are needed.

To reduce a number of the treatment plant less than this is not practical from the topographical feature of the service area.

(2) Location of the proposed treatment plants

Out of three of the proposed plants, T3 and T4 are recommended to be located near each dam site since the dam sites are close to the service areas. The locations of the treatment plants will be, therefore near the service areas.

The treatment plant T5 will be located either at the Khlong Lo Yung dam site in Phang Nga Province or near the service areas in the island.

Table 8-2-1 Proposed Group of Treatment Plants and Dams

Treatment Plant	Raw Water Source: Dam	Raw Water Source: Supply Capacity (Day Ave.)	Zone Supplied	Amount Supplied (Day Ave.)
(1) Bangwat System				
T1 (Exis.)	Bangwat	11,700 cu m/d	Zone 6	893 cu m/d
(Bangwad)	Bang Tho Sung	9,600	10	9,788
			11	3,159
			5	4,622 2)
	(total)	21,300		18,462 1)
(2) Municipality System				
T2 (Exis.)	Mining Pits	13,900	Zone 5	13,200 1)
(Municipality)				
(3) Khlong Katha System				
T3	Khlong Khata	10,900	Zone 3	2,700
			4	1,670
			5	6,010 2)
	(total)	10,900		10,380 1)
(4) Bang Nieo Dam System				
T4	Bang Nieo Dam	8,900	Zone 1	1,103
	Che Tra	7,600	2	943
			8	2,476
			9	1,065
			5	10,127 2)
	(total)	16,500		15,714 3)
(5) Zone 7 System				
T5	Khlong Lo Yung	21,400	Zone 7	5,700
			to T4 System	7,078 4)
	(total)	21,400		12,778
			Balance for Thai Muang	8,622

Note : 1) (Supplied Amount) : Calculated from the treatment capacity of Bangwat WTP as follows:
Maximum Effective Capacity (Qmax) = 24,000 cu m/d
Equivalent Daily Average Capacity = 18,462 cu m/d (Qmax/1.3)

2) (Amount for Zone 5) =
(Total Supplied Amount, 1).) - (Other Zone's Amount)

3) (Supply Amount) = (Dam capacity 16,500 cu m/d)/1.05
= 15,714 cu m/d

4) (Amount for T4 System) = Total of Zone 5 demand (41,037 cu m/d) minus total of supplied amounts from T1 to T4

(3) Proposed Alternatives for the System Layout

Considering the above conditions for the location of the treatment plants, the two alternatives are proposed for Khlong Lo Yung System as summarized below.

Alternative 1 : Treatment Plant T5 will be located in the island.

Alternative 2 : Treatment Plant T5 will be located near Khlong Lo Yung dam in Phang Nga side.

Figures 8-2-2 and 8-2-3 show schematic plans for the two alternatives. To be different between two alternatives is only the location of the treatment plant T5. Required major facilities related to the plant T5 and their characteristics for each alternative are as shown in Table 8-2-2.

Figure 8-2-4 shows hydraulic profiles of the water transmission from Khlong Lo Yung for two alternatives.

Table 8-2-2 Major Facilities for Alternatives
(Zone 7 System)

Item	Alternative 1	Alternative 2
1. Raw Water Source	Khlong Lo Yung Dam High water level +46.00 AMSL Low water level +32.00 AMSL	
2. Treatment Plant	in Zone 7 (T5) Qda=10,940 cu m/d in Thai Muang (future) Qda= 9,440 cu m/d	near the dam site Qda= 20,380 cu m/d (incl.supply for Thai Muang,9,440 cu m/d)
3. Transmission method	by pumping (from dam to T5)	by pumping (from T5 to Zone 7)
4. Transmission pipe	Steel Pipe, Dia = 500 mm L = 34 km Design flow Qdm = 14,222 cu m/d (Qdm = 1.3 * Qda)	
5. End of the Transmission pipe	Water Treatment Plant T5	Service Reservoir

Note : Water supply amount for Thai Muang (9,440 cu m/d) in the above Table means a surplus supply amount of Khlong Lo Yung Dam. The prospective demand in Thai Muang (10,000 cu m/d) need an additional water source development for about 5,000 cu m/d.

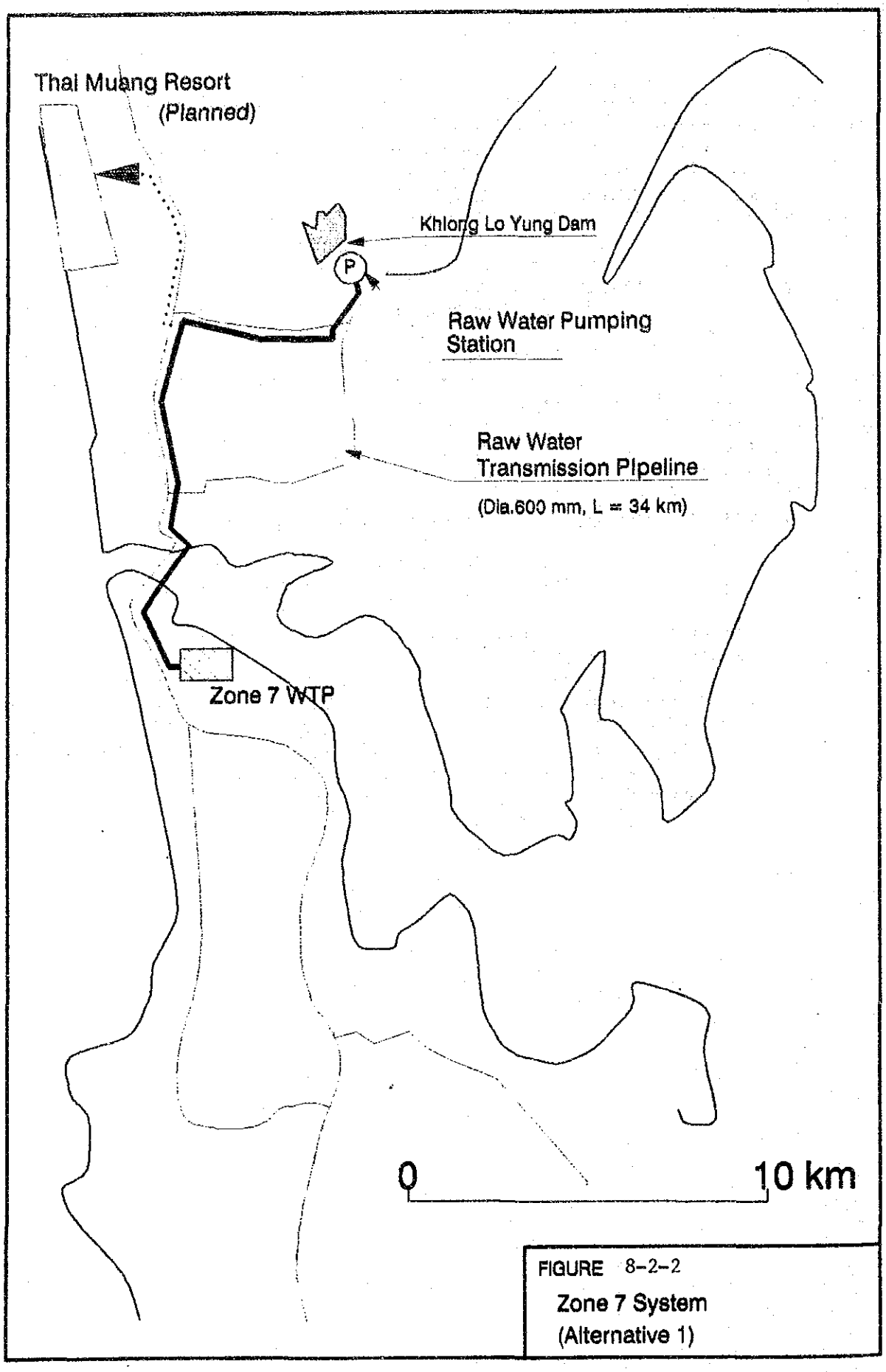


FIGURE 8-2-2
Zone 7 System
(Alternative 1)

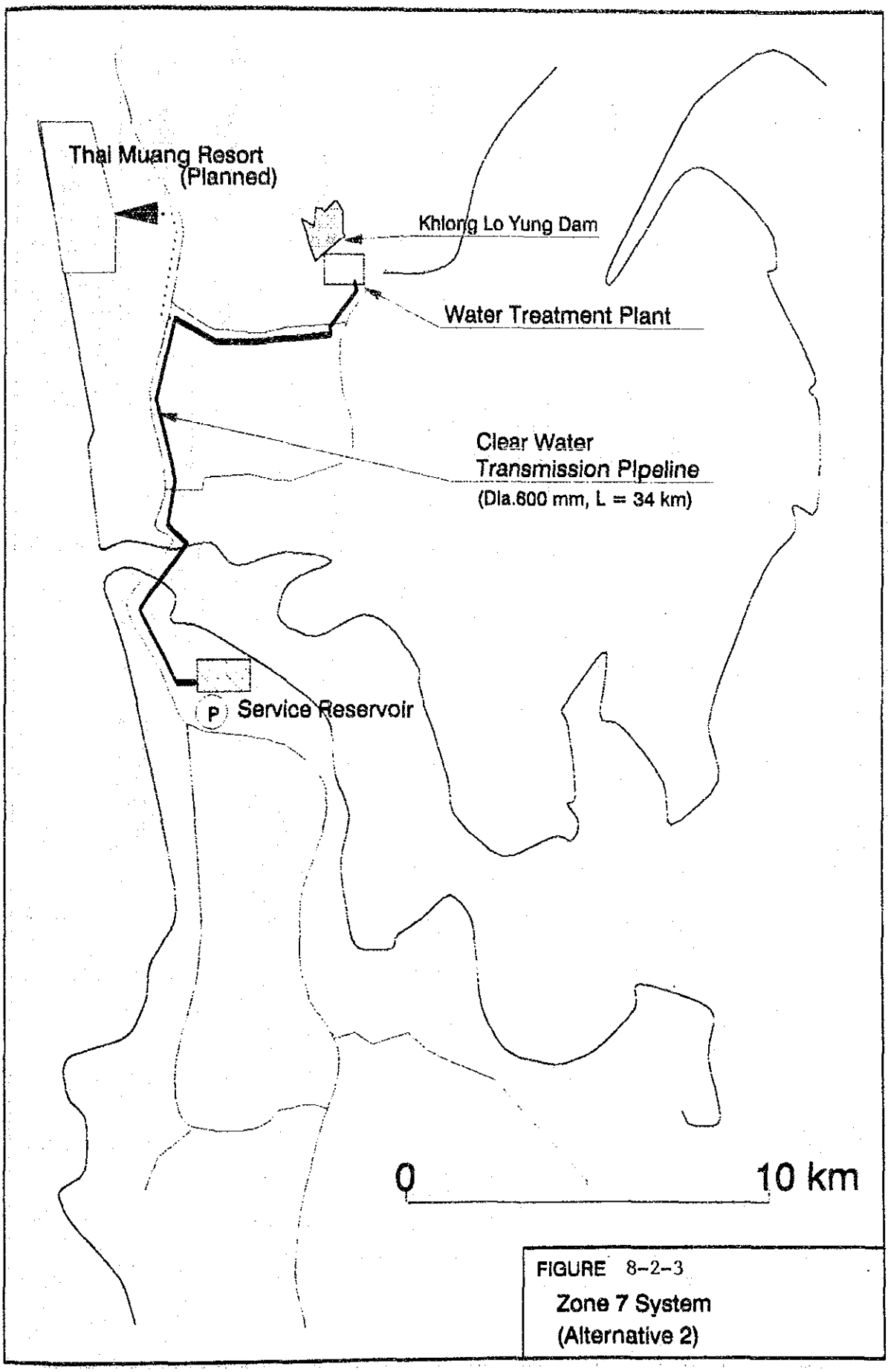


FIGURE 8-2-3
Zone 7 System
(Alternative 2)

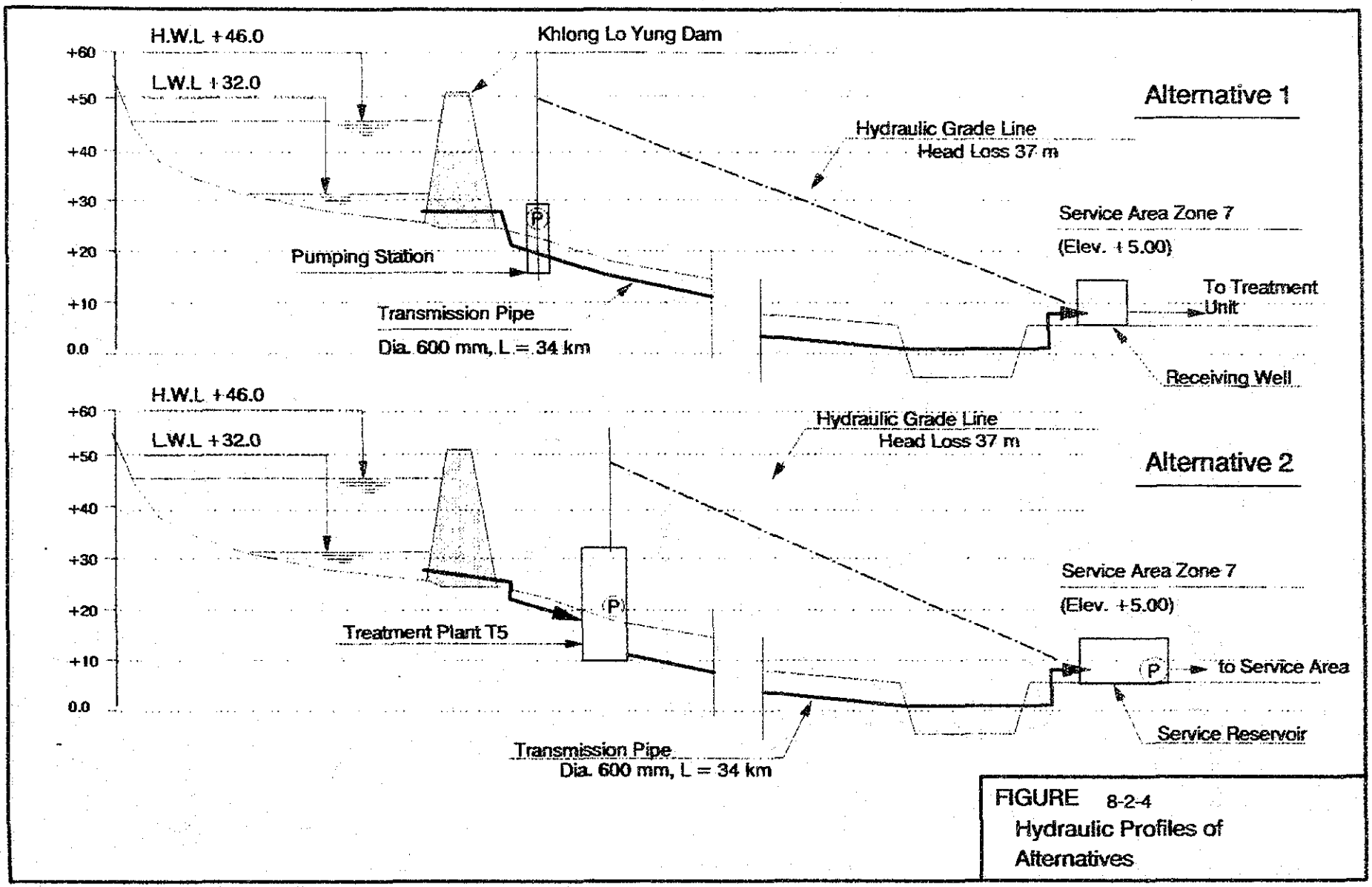


FIGURE 8-2-4
Hydraulic Profiles of Alternatives

(4) Comparison of Alternatives

Table 8-2-3 shows a summary of the comparison for the two alternatives. The details of the cost are shown in Table 8-2-4.

Table 8-2-3 Comparison of Alternatives

Item	Alternative 1	Alternative 2
System Requirement		
Transmission volume control	- need a telecommunication between service area and the treatment plant	- same as Alternative 1
Pumping Facility	-one station at dam site -one station at plant T5 -one station at Thai Muang	- one station at plant T5 - one station at Zone 6 - one station at Thai Muang
Cost Effectivity (Cost Baht 1000)		
Construction	(for Khlong Lo Yung system only)	
	Treatment Plant	
	57,350	43,840
	Transmission Pipeline (same condition)	
	Pumping Facility (same condition)	
	Service Reservoir	Service Reservoir
	0	16,240
Land Cost	3,300	9,300
	Total of a & b 60,650	69,380
Operation	(for water transmission from Khlong Lo Yung only)	
Energy Cost	(same condition)	
Manning Cost	2 plant system needs double number of staff	
Treatment Cost	same condition	

Table 8-2-4 Cost Comparison of Two Alternatives

Item	Alternative 1		Alternative 2	
Treatment Plant		Cost		Cost
	T5, Qdm = 14,300 m3/d (at Zone 6)	(Baht 1000)	T5, Qdm = 26,500 m3/d (at Khlong Lo Yun	(Baht 1000)
	Receiving Well (15 m3)	30	Receiving Well (30 m3)	60
	Sedimentation Basin (600 m3/d)	12,000	Sedimentation Basin (1,100 m3/d)	22,000
	Sand Filter (600 m3/d)	7,200	Sand Filter (1,100 m3/d)	13,200
	Clear Water Reservoir(4,800m3)	11,520	Clear Water Reservoir (3,300 m3)	8,580
	Sub-total	30,750	Sub-total	43,840
	Thai Muang Plant, Qdm = 12,300 m3/d		(Clear water reservoir is for 3 hours	
	Receiving Well (15 m3)	30	retention. Service reservoirs have 5	
	Sedimentation Basin (510 m3/d)	10,200	hours retention each.)	
	Sand Filter (510 m3/d)	6,120		
	Clear Water Reservoir(4,100m3)	10,250		
	Sub-total	26,600		
	Total	57,350		
	(Clear water reservoir is for 8 hours retention)			
				Cost (Baht 1000)
Service Reservoir	None		for Zone 6, V = 3,000 m3	8,700
			for Thai Muang V = 2,600 m3	7,540
			Sub-total	16,240
Land Acquisition	Raw Water Intake (1 rai)	300	Plant T5 (30 rai)	9,000
	*)Plant T5 (15 rai)	0	Service Reservoir at Zone 7 (1 rai)	0
	Thai Muang Plant (10 rai)	3,000	Service Reservoir at Thai Muang (1 rai)	300
	Total 11 rai =	3,300	Total 28 rai =	9,300

*) Land cost for Plant T5 in Alternative 1 is not counted since it is belonging to Government
**) Unit land cost = 300,000 Baht/rai

Result of the comparison shows that the Alternative 2 needs higher total cost. The difference between the total costs is so extensive (40 million Baht) that the additional expenses for the manning cost for maintaining two treatment plants can not fill the gap of the costs. Assuming that 10 people are additionally needed in Alternative 1 and that average salary is 10,000 Baht per person per month, total manning cost will be about 18 million Baht in 15 years.

In this cost comparison, the construction costs of two alternatives are nearly same. However, there is a substantial gap in the land cost. This is because the land cost for the treatment plant T5 in Alternative 1 is not counted by the reason that this land is belonging to the Government. The total land cost may, however be turned up if PWA should pay for this land.

From the technical point of view, there is no difference between two alternatives.

In case of Alternative 2, the treatment plant T5 will be put under the jurisdiction of Phang Nga Province so that the necessary arrangement should be made for the management of the waterworks.

As shown in the comparison, Alternative 1 is advantageous because of its lower total cost. Therefore, this alternative is recommended.

The system diagram and schematic plan of the total water supply ystem are shown in Figures 8-2-5 (A) and 8-2-5 (B), respectively.

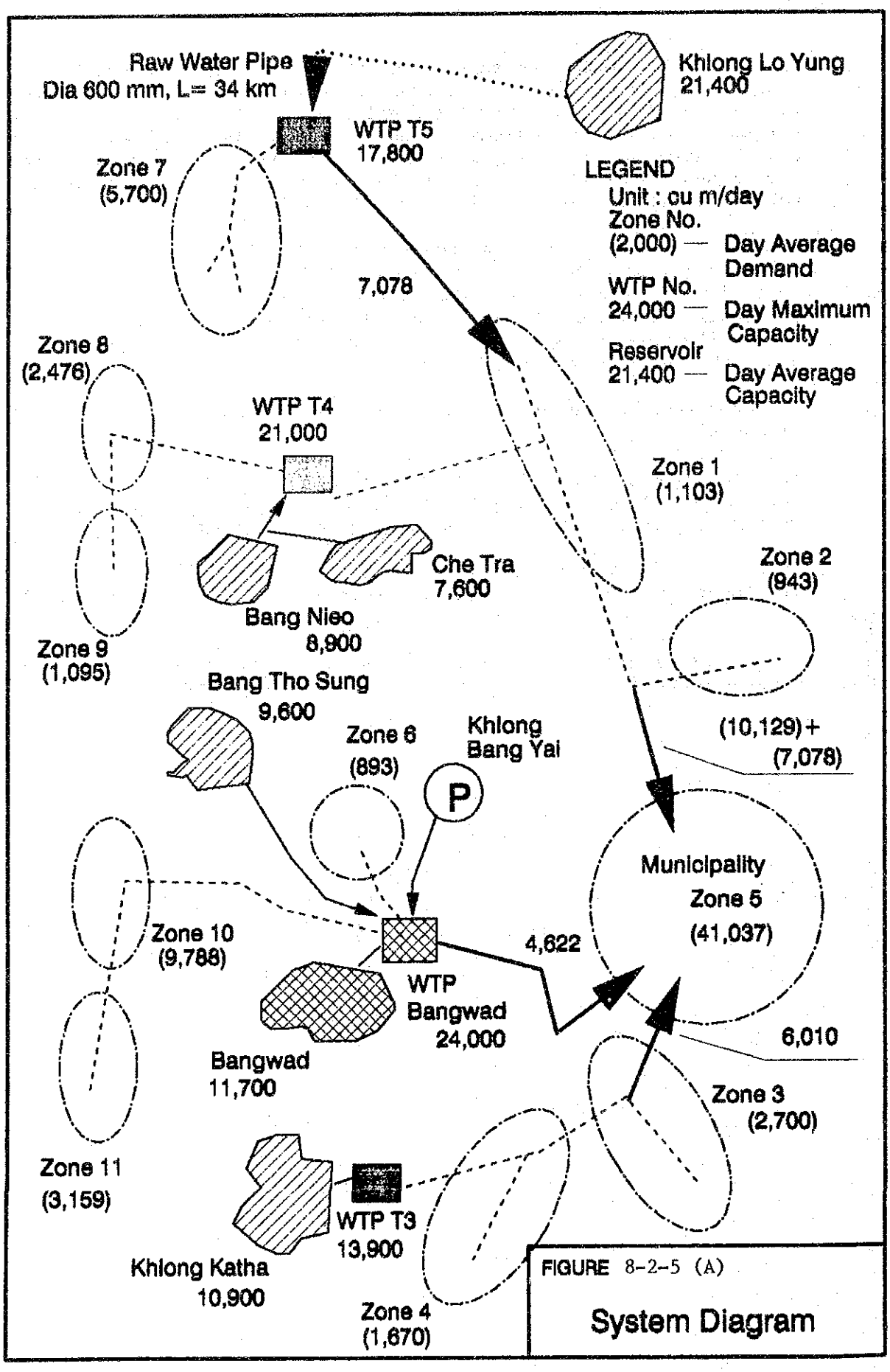


FIGURE 8-2-5 (A)

System Diagram

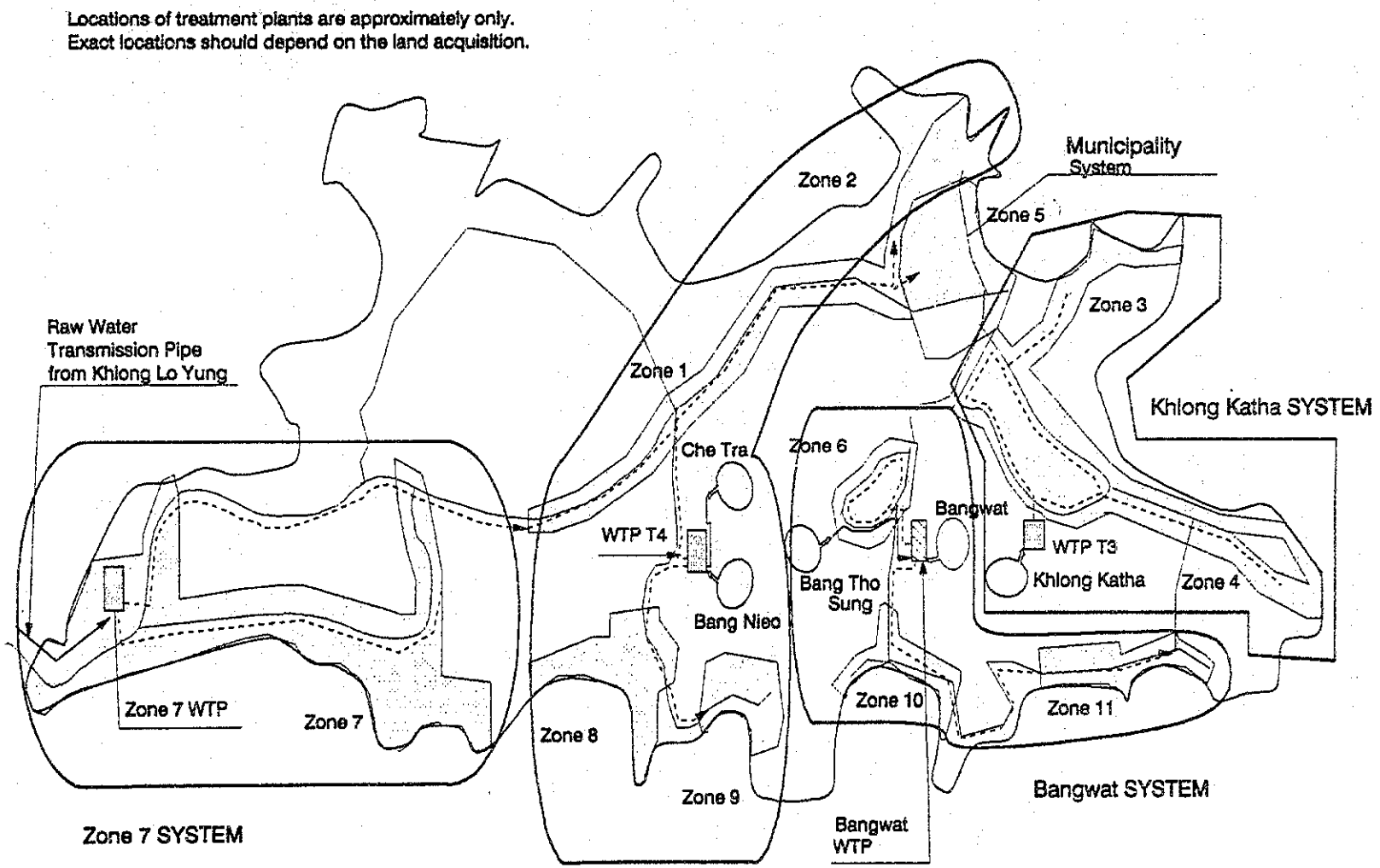


FIGURE 8-2-5 (B)

TOTAL SYSTEM LAYOUT

8.2.3 Facility Planning

On the basis of the system layout selected in the previous subsection, the detailed planning is prepared for the facilities as follows:

(1) Raw Water Sources

(2) Treatment plants

(3) Transmission and Distribution Pipelines

(1) Raw Water Sources

Raw water sources for the proposed water supply system are as proposed in Section 8.1, and Table 8-2-1. A temporary water intake from Khlong Bang Yai will be made by use of a pumping station before Bang Tho Sung Dam will be constructed.

For the other systems, it is assumed that the water supply facilities will be constructed on the same timing of the completion of the proposed dams.

(2) Treatment Plant

The record show that the raw water of the Bangwat reservoir is quite clear so that the slow sand filtration may be used when raw waters are taken from the same type of reservoirs. However, the rapid sand filtration is recommended because of its small land requirement considering the recent difficulty of land acquisition in the Phuket Island.

The followings are the proposed facilities as the major treatment plant components which can commonly be applied for each treatment plant.

a. Receiving well
b. Mixing tank
c. Flocculator
d. Sedimentation basin
e. Rapid sand filter
f. Clear water reservoir (with pumping station)

Sludge lagoon and drying bed are not recommended since the amount of the sludge will be so small that the drained water and backwashing water may be discharged to the nearby waters without causing environmental problem.

Some buildings and housings, such as administration building, chemical storage, staff houses, warehouses will be incorporated in the facility planning of the treatment plant.

The characteristics of the major facilities of the treatment plant are summarized as shown in Table 8-2-5.

Table 8-2-5 Major Facilities of Treatment Plant

Item	Khlong Katha	Bang Nieo Dam	Zone 7
(1) Treatment Capacity			
Maximum Capacity	13,900 cu m/d	21,000 cu m/d	17,800 cu m/d
Maximum Effective Capacity	13,494	20,428	17,284
Equivalent Daily Average Capacity	10,380	15,714	13,295
(2) Major Facilities			
Receiving Well	Dia. 2.5 m D = 3.0 m	Dia. 3.0 m D = 3.0 m	Dia. 3.0 m D = 3.0 m
Mixing Tank	L W D N 1.2x1.5x1.5 x 4	L W D N 1.5x2.0x1.5 x 4	L W D N 1.5x2.0x2.0 x 2
Flocculator	L W D N 1.5x20.0x2.5 x 2	L W D N 2.0x24.0x2.5 x 4	L W D N 2.0x20.0x2.5 x 4
Sedimentation Basin	L W D N 5.0x30.0x4.0 x 4	L W D N 6.0x38.0x4.0 x 4	L W D N 6.0x32.0x4.0 x 4
Sand Filter	L W N 3.0 x 4.5 x 8	L W N 4.0 x 5.0 x 8	L W N 3.5 x 5.0 x 8
Clear Water Reservoir	L W D N 32 x 15 x 5 x 2 V = 4,800 cu m	L W D N 35 x 20 x 5 x 2 V = 7,000 cu m	L W D N 30 x 20 x 5 x 2 V = 6,000 cu m
Clear Water Pump	Dia. 200 mm P = 50 kw N = 4 units	Dia. 200 mm P = 80 kw N = 4 units	Dia. 200 mm P = 70 kw N = 4 units

Note: Capacity calculations of the treatment plants are presented in Appendix A-8-5.

(3) Transmission and Distribution Pipelines

Design of the pipes should follow the design criteria described in Chapter 5.2. Route and location of the pipelines are determined from the location of the treatment plant. Sizes of pipes are calculated from the water demand by zone and distribution of the water demand in each zone depending on demand by Tambon.

Appendix A-8-6 shows calculation of network analysis and plan of the proposed distribution pipes.

8.2.4 Immediate Improvement Project for Patong, Karon, and Katha

The existing water supply from the Bangwat Treatment Plant to Patong Beach has a problem of high pressure, and leaking and bursting of pipe derived from its high pressure. Since the pipeline reaches Patong Beach over the mountain, the elevation at the highest point in the line is as high as +126 meters (AMSL). This topographic characteristic and the present transmission system is a cause of the serious problem of too high pressure in the Patong service area.

However, this high pressure will help water to be conveyed from Patong side to Karon beach. There is a existing pipeline extended to Le Meridien Hotel with a branch from the main transmission pipe (400 mm steel pipe) before the pressure reducing valve. This pipe is, however too small in size so that it is not practical to use this pipe. Additional pipeline should be laid for this purpose.

A plan of the proposed water supply system is shown in Figure 8-2-6. Figures 8-2-7 to 8-2-9 show a system diagram, and hydraulic profiles of distribution system for Patong area, and Karon and Kata area, respectively.

The following shows the hydraulic study for water transmission for Karon and Kata:

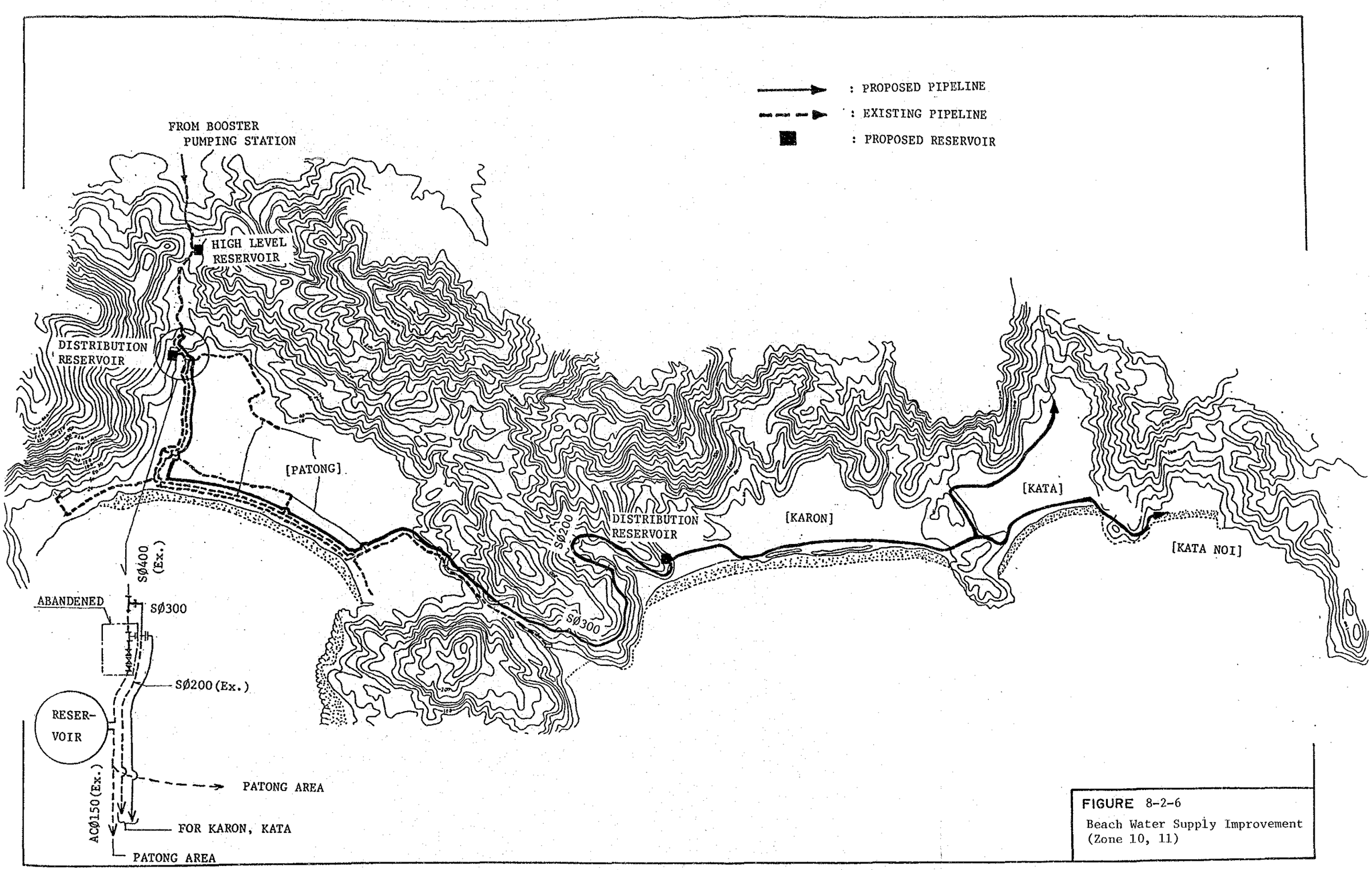


FIGURE 8-2-6
Beach Water Supply Improvement (Zone 10, 11)

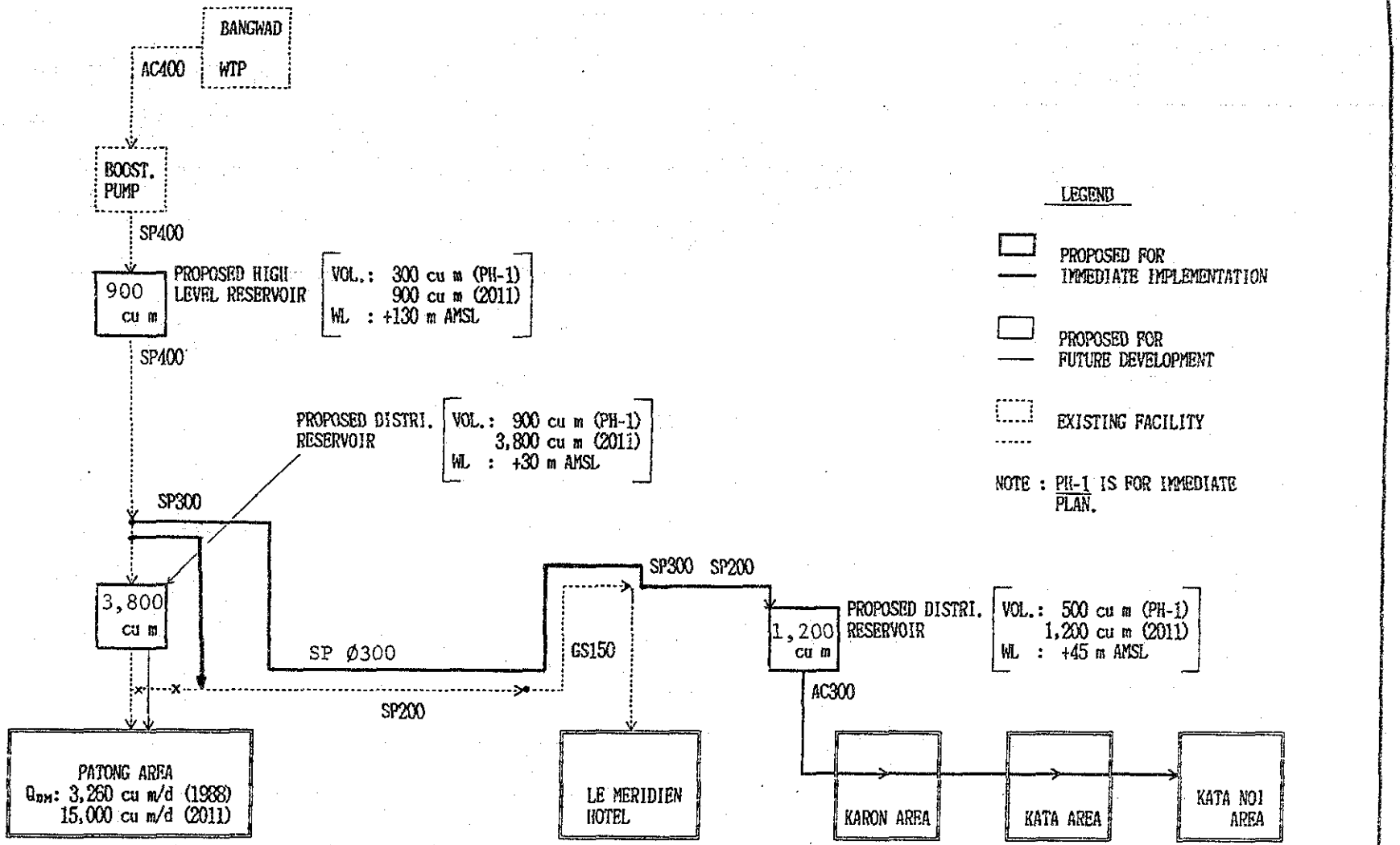


FIGURE 8-2-7

Schematic Plan of Zone 10 and Zone 11 System

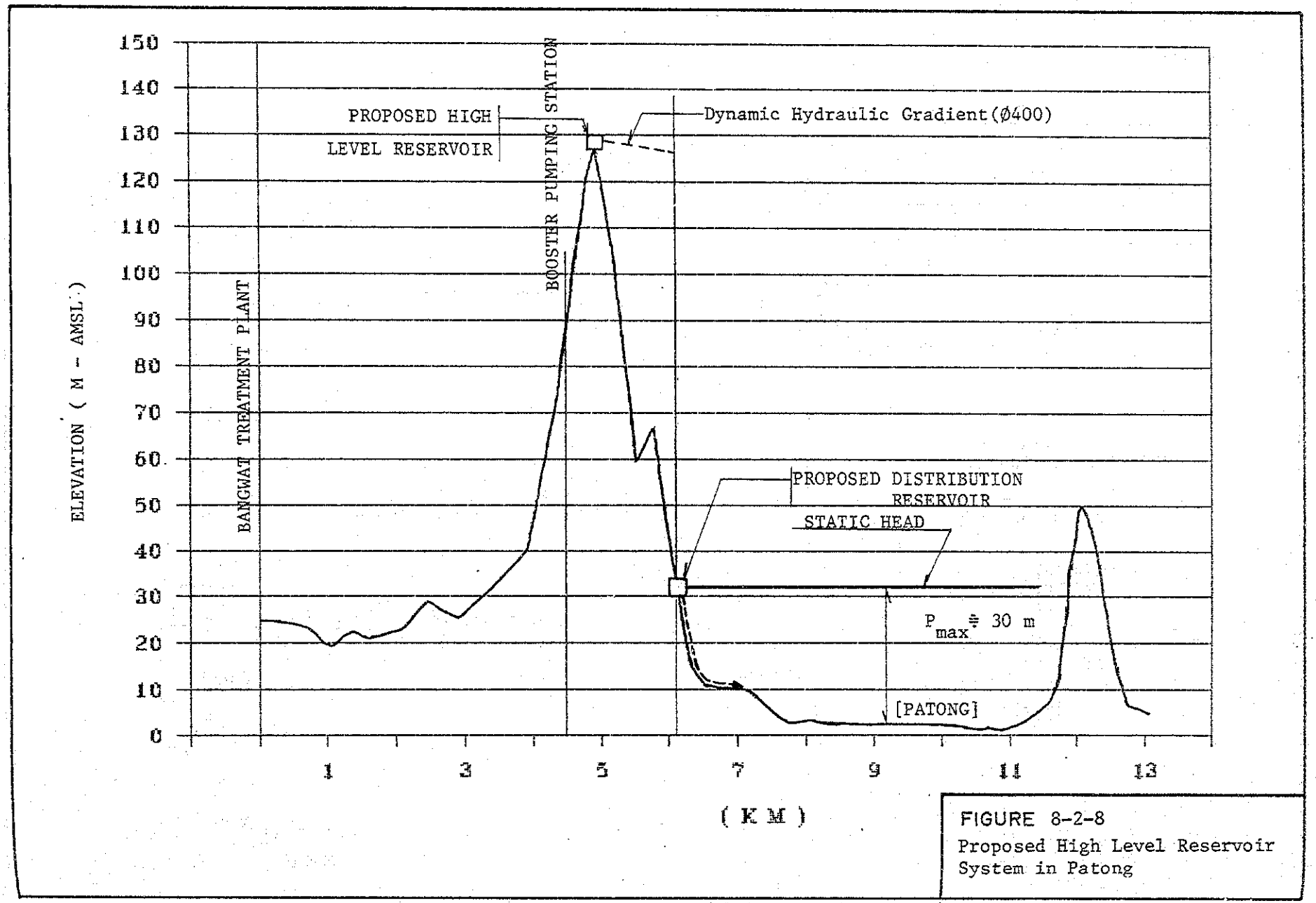
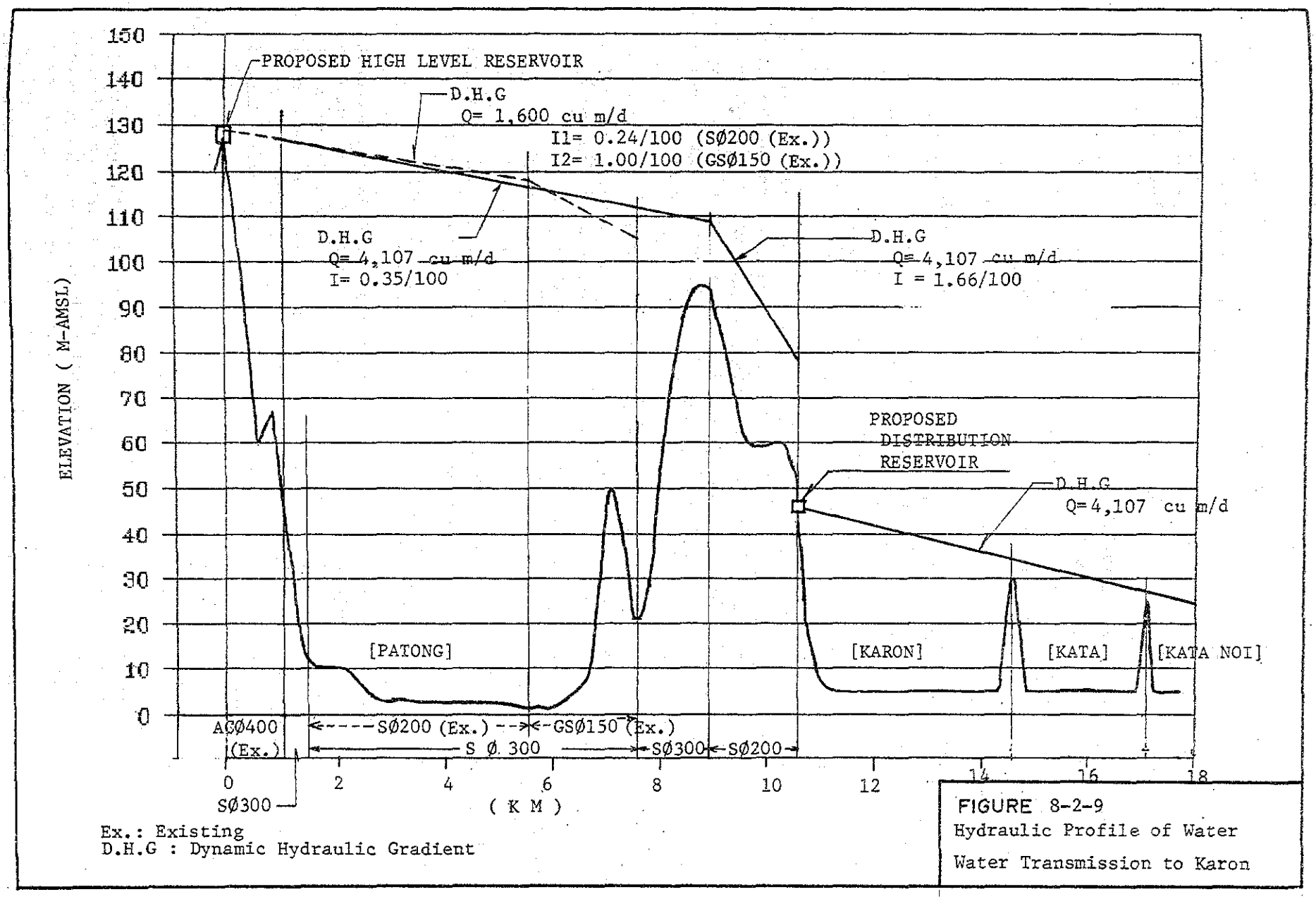


FIGURE 8-2-8
Proposed High Level Reservoir System in Patong



Ex.: Existing
D.H.G : Dynamic Hydraulic Gradient

FIGURE 8-2-9
Hydraulic Profile of Water
Water Transmission to Karon

(1) Water Demand

Table 8-2-6 shows the predicted water demands in the area.

Table 8-2-6 Water Demand in Patong, Karon and Kata

Item		Patong (Zone-10)	Karon, Kata (Zone-11)
Demand in 1991	Qda	10,022	2,480
	Qdm	13,029	3,224
Demand in 2001	Qda	10,533	3,007
	Qdm	13,693	3,909
Demand in 2011	Qda	9,788	3,159
	Qdm	12,725	4,107

Note: Q(da) : Daily Average Demand (cu m/d)
Q(dm) : Daily Maximum Demand (cu m/d)

(2) Capacity of the Pipeline

Dotted line in Figure 8-2-9 shows a hydraulic gradient in the existing pipeline (dia. 200 and 150 mm) extended to Le Meridien Hotel. As shown in this figure, a possible maximum amount conveyed to Karon side by the existing pipe is 1,600 cu.m/d only. This amount is limited by the hill top between Patong and Karon unless additional pumping is provided.

Because of a lack of the transmission capacity of the existing pipe, a new pipeline should be constructed. As shown in Figure 8-2-9, new pipeline should have a diameter of 300 mm to convey an amount of daily maximum demand for Karon and Katha (Zone 11).

(3) Proposed Transmission System

In the proposed scheme, three reservoirs are proposed to be constructed. Roles of each reservoir are described as follows:

o High Level Reservoir

This reservoir is proposed to receive water from the existing booster pumping station and to supply water to the following two distribution reservoirs. A volume of this reservoir can be designed rather small since it works as a receiving tank only. Although there is no criteria for designing the volume of receiving tank, a volume equivalent for one hour retention time is recommended.

o Distribution Reservoir for Patong Area

A distribution reservoir is proposed to regulate the distribution pressure at the area. Pressure regulation by a reservoir is much more reliable and stable compared to control by the pressure reducing valve since pressure reducing valve have no effect in pressure reduction when water flow is very small. (Effect in pressure reduction by valve is also varied by type of valves: such as sleeve type, needle type, orifice type etc. Gate valve or

butterfly valve is less effective for pressure reduction in big range.)

The reservoir can also work to absorb the fluctuation of water demand in the area so that the operation of the booster pump will be made stable in pumping amount.

Elevation of the reservoir should be determined so that the whole service area can be supplied water with sufficient but not too high pressure. Considering that the existing road in the area is in the lower level than +15 meters (AMSL), the elevation of the proposed reservoir is recommended to be approximately +30 meters (AMSL).

A volume of the reservoir should be as big as six hours retention time to absorb the hourly fluctuation. Recommended herein is stage construction to save initial cost for immediate implementation.

Land acquisition, however may be the problem to solve since this area is hilly and lacking flat area.

o Distribution Reservoir for Karon and Kata Area

This reservoir is proposed to supply water to Karon, Kata, and Kata Noi Beaches with proper pressure. Water conveyed by gravity with the transmission pipeline is received in the reservoir and supplied to the service area. The reservoir will also be effective to absorb a fluctuation in water demand so that water transmission pipe can be designed only for daily maximum demand: consequently, pipe size can be designed smaller than that designed for hourly maximum demand.

Elevation of the reservoir should high enough to supply water to Kata Noi Beach. Detailed topographic survey should, however be conducted for detailed design of the reservoir to determine the elevations of hills between Karon and Kata, and Kata and Kata Noi, which are assumed +30 to +25 meters (AMSL) from reading maps.

A volume of the reservoir is recommended to have six hours retention time as well as the reservoir for Patong area.

(4) Proposed Facilities

The improvement of the existing distribution pipelines and new construction are also incorporated in the immediate improvement project. Proposed facilities are summarized as shown in Table 8-2-7.

Table 8-2-7 Proposed Facilities for Immediate Improvement

Facility		Size
High Level Reservoir	Volume	900 cu.m
Distribution Reservoir for Patong area	Volume	3,800 cu m
Distribution Reservoir for Karon and Kata area	Volume	1,200 cu m

Pipeline

Transmission Pipeline from High Level Reservoir to Karon Reservoir

SP Dia. 300 mm, L = 8,000 m
AC Dia. 200 mm, L = 1,200 m

Distribution Pipeline

(i) Patong (Zone-10)

(Replacement)

AC Dia. 200 mm, L = 1,390 m
AC Dia. 250 mm, L = 360 m
AC Dia. 300 mm, L = 5,715 m

(New Construction)

AC Dia. 150 mm, L = 800 m
AC Dia. 200 mm, L = 1,940 m
SP Dia. 400 mm, L = 150 m

(ii) Karon and Katha (Zone-11)

(New Construction)

AC Dia. 150 mm, L = 800 m
AC Dia. 200 mm, L = 9,550 m
AC Dia. 300 mm, L = 1,600 m