3.5.2 Groundwater

Groundwater in the Ubon area is available from the Alluvial and terrace deposits and from aquifers of the Mesozoic continental sedimentary rocks, mostly formed in shale, siltstone and sandstone. Fig-3.7 summarized the hydrogeological conditions indicating the availability of the area's groundwater, based on the published hydrogeological map by DMR, 1973, 1978 and 1983, and other relevant information.

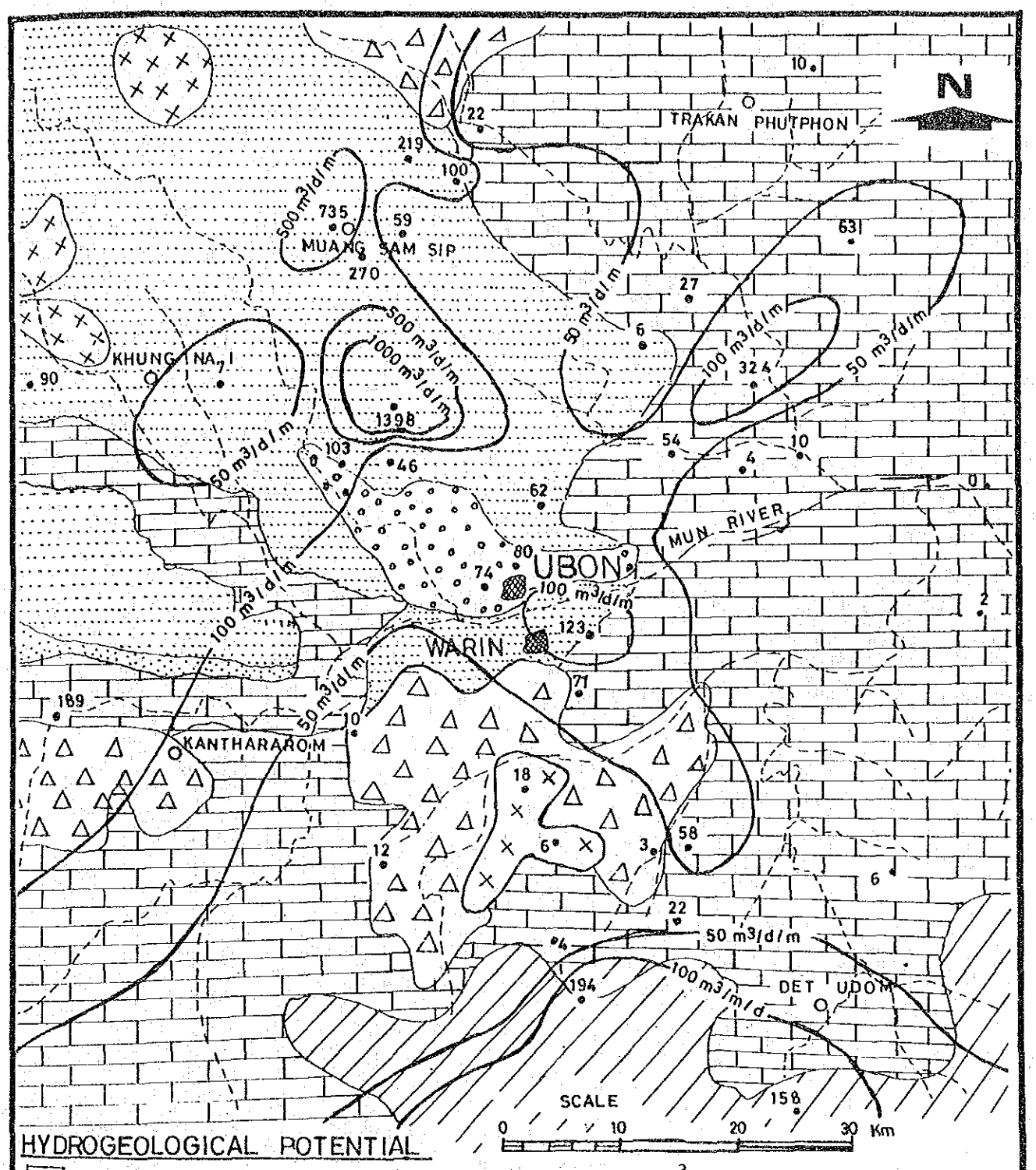
Groundwater development was made mostly for domestic uses since 1950, by HD (Housing Development), DMR and ARD which are responsible for providing water wells of domestic uses for the communities. During 1958 to 1981, it is said that in the area of Ubon, more than 300 deepwells were drilled. Most of the deep wells are about 20 to 65 m deep and the static water level ranges from 2 m to 13 m.

The specific capacity ranges from 46 to 735 cu m/d/m and it is high rated in some wells. However, the usual discharge of productive aquifers consisting of sandstone, siltstone and karstic limestone are ranges from 250 to 500 cu m/d.

In addition to the deepwells, water can also be obtained from the unconfined aquifer of alluvial and terrace deposit, by means of shallow or dug wells. Most wells have depth of 10 m to 15 m and water level of about 2 to 5 m below the ground surface. The groundwater level fluctuates seasonally within a range of 3 m to 7 m usually, and sometimes as much as 10 m, corresponding similar change of the Mun river level. The aquifers are thought to be recharged through percolation of rainwater and from the flows in the Mun and Chi rivers. The peak level usually occurs in the period from August to November, while the minimum level in the months of April-June.

However, many of shallow wells are dried during the dry period in many places. Hydrochemical analysis on groundwater from unconfined and confined aquifers, based on the reconnaissance survey and existing information, salty water and high iron content of water have been encountered in the area.

It is reported that a Salt Formation of upto 250 m thickness lies at about



HYDROGEOLOGICAL POTENTIAL

- Unconsolidated Aquifer(Sands & Gravel), 250-500m^3/d, Good quality of Water (90%)
- Productive Aquifer, 250-500m^3/d, Good quality of Water (80%)
- Productive Aquifer, 250-500m^3/d, Good quality of Water above 65m(95%) .Lower Parts(Salty)
- Karstic or Limestone Aquifer, 250-500m^3/d
- Less Productive Aquifer, 0-100m^3/d, Fresh Water(80%)
- Flood Plain, Fresh Water (Less 50%)
- Flood Plain Salty Water(90%)

(m3 / d / m)

.90 = Specific Capacity

DATA : DMR, 1973, 1978 and 1983

FIGURE 3.7 HYDROGEOLOGICAL MAP OF UBON AREA

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30 m below the ground near the Ubon city. Groundwater of more than 20 m depth is generally saline in some area near Ubon. Therefore, groundwater development should be carefully studied.

Groundwater has not been used by the Ubon and Warin waterworks till now and in future, it will not be recommendable for the public water supply, - because the yield of wells, estimated at about 250 to 500 cu m/day, is too small for the size of supply. Also, salty water containing almost 3,000 ppm chlorine and 0.4 to 5.0 ppm iron is obviously unsuitable as the raw water of the supply.

Details of the water quality are reported in Appendix 4.

3.6 Water Resources Development Plan

Fig-3.8 concludes the existing water source and water resources development plan up to the year of 2010.

The Ubon and Warin waterworks depend their water sources on the Mun and Mun Noi rivers which have abundant discharge throughout the year. At present (1986), the waterworks intake rate is 27,840 cu m/day or about 10.2 MCM/year, a minute portion of the runoff of 19,500 MCM/year.

Groundwater is also available from the Alluvial deposits and Mesozoic sedimentary rocks. Most of the wells are about 20 m to 65 m deep and yield about 250 to 500 cu m/day. However, salty water and high iron contents are detected, due to the existence of salt formation at about 30 m below the ground.

The demand for expansion in the year of 2010 is 52,160 cu m/day (0.60 cu m/s). It is still a fraction of about 40 cu m/s droughty flow of the river.

WATER RESOURCES DEVELOPMENT PLAN OF UBON

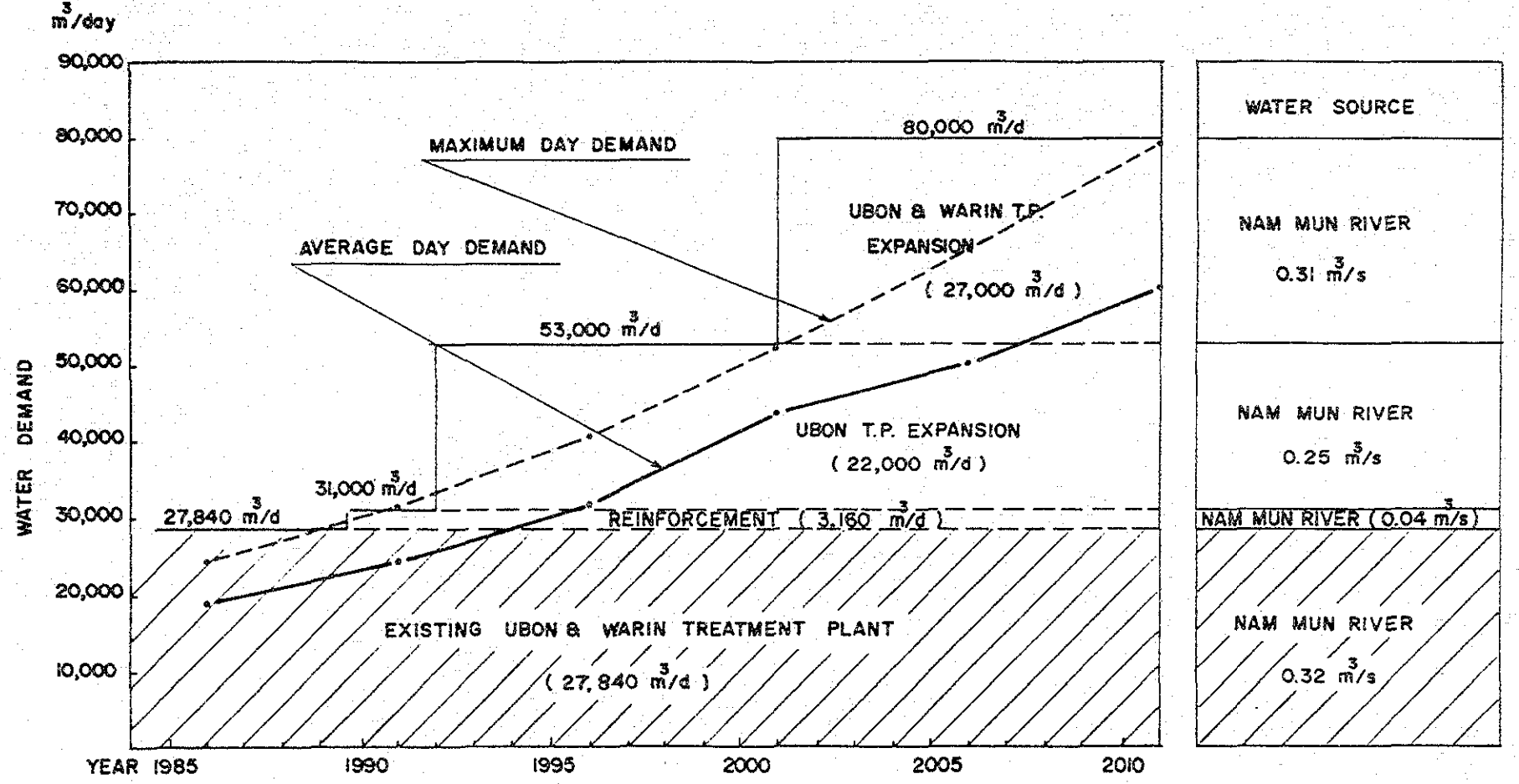

FIGURE	WATER RESOURCES DEVELOPMENT PLAN OF UBON
3.8	
JAPAN INTERNATIONAL COOPERATION AGENCY	

The recommendable water source development program is shown as follows.

I. Present Water Source (1986)

1) Mun / Mun Noi River : 27,840 cu m/d

II. Water Resources Development (up to 2010)

1) The Year of 1991
Mun / Mun Noi River : 3,160 cu m/d

2) The Year of 1992
Mun / Mun Noi River : 22,000 cu m/d

3) The Year of 2001
Mun / Mun Noi River : 27,000 cu m/d

3.7 List of References

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Environmental and Ecological Investigation of Pak Mun Project
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3) PWD, Nov. 1985
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4) MEA, 1971
1968 Hydrologic Data Vol-I and Vol-II

5) National Statistical Office, 1983
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7) RID Nov. 1983
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8) EGAT, July 1985
Guide Book for Accessing Hydrologic Data

9) EGAT, August 1984
Key Maps for River Basins in Thailand

10) EGAT, December 1980
Surface Runoff and Specific Yield of River Basins in Thailand

11) RID, April 1983
Mean Annual Flow, Instantaneous Peak Discharge, Average Yield of Runoff and Specific Yield of flood Flow for Rivers in Thailand

12) Royal Thai Survey Department, 1974
Hydrography (Atlas of Thailand)
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13) Royal Thai Survey Department, 1974
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-Mun River at Seri Prachathipatai Bridge, Ubon Ratchathani

APPENDIX 4

STUDY ON WATER QUALITY

APPENDIX 4

APPENDIX 4 STUDY ON WATER QUALITY

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APPENDIX 4 STUDY ON WATER QUALITY

4.1 Water Sources

4.1.1 Mun River and Mun Noi River

The Warin Treatment Plant takes water from the Mun River while the Ubon Treatment Plant trakes it from the Mun Noi River. The Mun Noi River, a bypass flow of the mainstream Mun River, branches off at the 6 km upstream point of the Ubon Treatment Plant's intake and joins at the 3 km downstream point thereof. Therefore, the two rivers' water quality is very similar.

The results of water quality analysis of the Mun Noi and Mun Rivers, made by PWA and the study team, are shown in Table-4.1.

1) Characteristics of water

a) Color

The value, ranging from 10 to 35 Pt. Co units, is moderate to relatively high and stays at the higher side in the rainy season and the beginning of the dry season.

b) Turbidity

The value varies from 2.4 to 54 SiO2 units by the PWA analysis and from 8 to 18 NTU by the team's analysis. It tends to rise in the rainy season and the beginning of the dry season.

c) pH

The value ranges from 6.71 to 8.05 satisfying DWS and it is on the lower side in the rainy season.

d) Alkalinity

The value is low to moderate ranging from 10 to 84 mg/l as CaCO3, and it is on the lower side in the rainy season.

Table-4.1 WATER QUALITY OF THE MUN NOI RIVER

Item	Unit	1	2	3	4	5	6	MUN RIVER 7	MUN RIVER 8	9	PWA STANDARD
Date		4/2/'85	8/7/'85	29/8/'85	24/9/'85	21/10/'85	15/11/'85	30/12/'85	4/2/'86	4/2/'86	
Temperature	°C	-	-	-	-	-	-	23.4	28	29	-
Color	Pt-Co units	10	35	35	30	25	30	12	15	15	5
Turbidity	NTU	2.4	-	53	48	54	51	18	8	10	5
pH		7.4	6.71	7.34	6.55	6.75	7.38	7.6	8.05	7.64	6.5-8.5
Conductivity	micromhos/cm	-	113	59	81	173	227	336	600	530	-
Total solids	mg/l	-	-	-	-	-	-	207	-	-	500
Alkalinity	mg/l as CaCO3	28	30	10	10	17	23	54	84	70	-
Hardness	mg/l as CaCO3	70	22	15	19	33	47	78	57	54	-
Calcium	mg/l	16	5.6	4.8	6.4	10	13.6	-	25	19	75
Magnesium	mg/l	7.2	1.9	0.7	0.5	1.9	3.1	-	6	6	50
Iron	mg/l	-	-	-	-	-	-	0.25	0.17	0.22	0.5
Manganese	mg/l	-	-	-	-	-	-	<0.1	<0.1	<0.1	0.3
Sulfate	mg/l	-	-	-	-	-	-	4.5	9	8	200
Chloride	mg/l	100	24	18	18	40	50	69	135	114	250
Ammonia-N	mg/l	-	-	-	-	-	-	<0.2	<0.2	<0.2	-
Nitrite-N	mg/l	-	-	-	-	-	-	-	<0.01	<0.01	-
Nitrate-N	mg/l	-	-	-	-	-	-	-	0.5	0.3	45 NO3
Coliform group	N/100ml	-	-	-	-	-	-	100	100	800	<2.2
Total colonies	N/ml	-	-	-	-	-	-	27	41	170	500

DATA SOURCE : 1-6 PWA 7-9 STUDY TEAM

e) Hardness

The value ranges from 15 to 78 mg/l as CaCO3 and it is very low in the rainy season.

f) Iron and Manganese

The value is within DWS in the dry season. Iron concentration tends to rise in the rainy season, while manganese is steady through the year, judged by the 1980 data, as recent years' data are not available.

g) Chloride

The value ranges from 18 to 135 mg/l, and it is on the higher side in the dry season. Even the highest value is within DWS, 250 mg/l.

h) Organic pollution

A small amount of nitrate is detected, and also ammonia and nitrite, but in far smaller amounts. Coliform group, though detected, is low in number. They indicate that the pollution is not fresh and heavy.

2) Evaluation

Both the Mun and Mun Noi Rivers can be used for the public water supply in future. However, attention should be paid to treating the raw water of which quality changes in the dry and rainy season.

4.1.2 Other Sources

Even in the public service's service area, a substantial number of household and commercial users are found to be using shallow wells, about 10 m deep. People in the surveyed five villages are relying on rain water and/or well water.

Fig-4.1 shows the location of sampled wells and the result of quality analysis is shown in Table-4.2.

Ubon and Warin Area (ST.1 to ST.5)

As seen in the table below, all wells sampled were found unsuitable for the public water supply, because all of them were unacceptable regarding some of the itemized conditions.

UNACCEPTABLE CONDITIONS

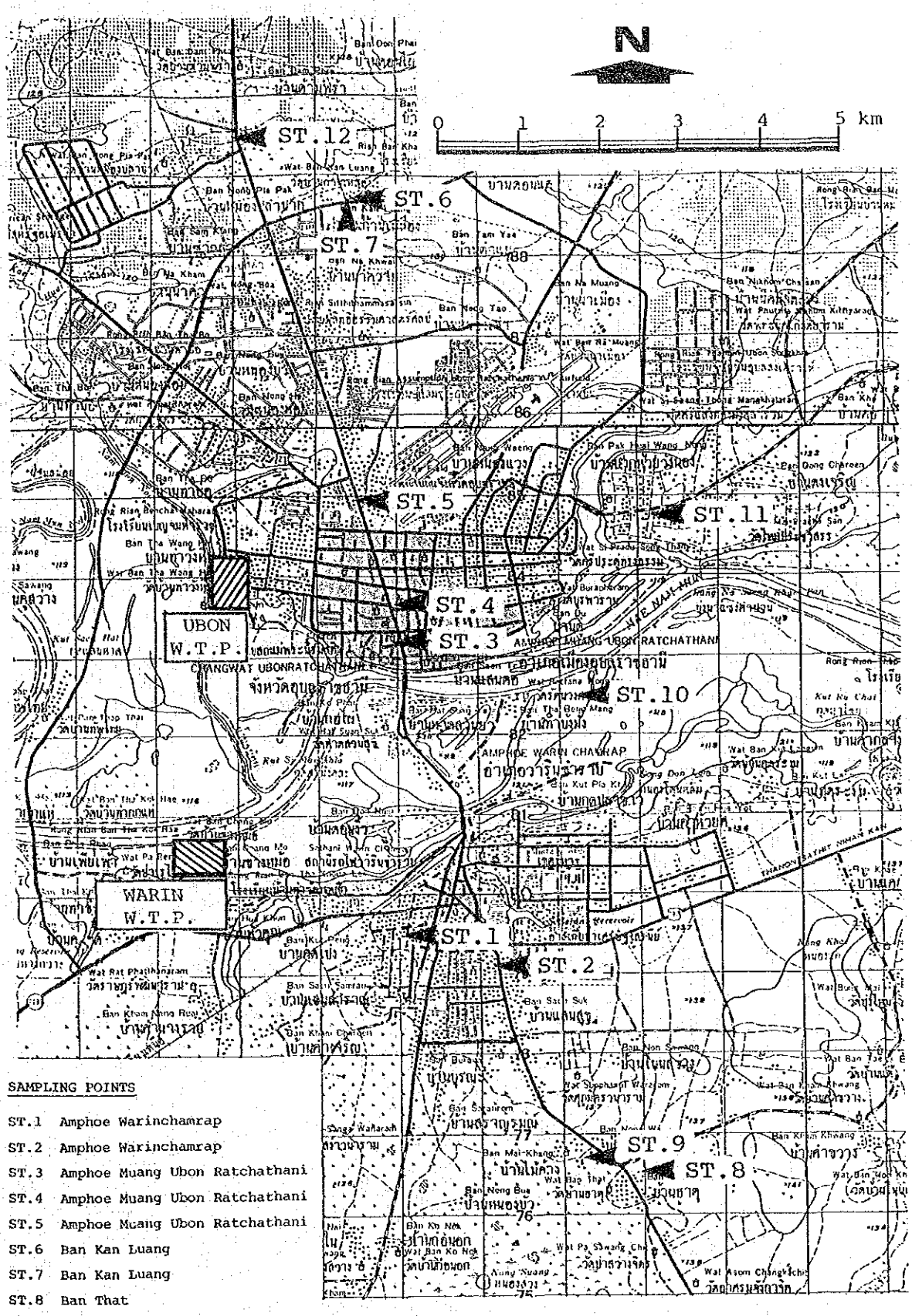
	ST.1	ST.2	ST.3	ST.4	ST.5
Low pH (<6.5)	*	*	*	*	*
High Iron (>1.0 mg/l)			*		
High Ammonia (>0.5 mg N/l)	*		*	*	*
High Nitrate (>10 mg N/l)		*		*	

NOTE: ST: Sampling station
*: Yes

Villages (ST.6 to ST.12)

Manually dug wells are widely used in the surrounding villages of Ubon and Warin. But these wells are not protected properly from possible contamination caused by unsanitary conditions of unclean rope and bucket, absence of adequate cover of the wells, and absence of an apron surrounding the wells to prevent seepage of wastewater.

As shown in Table-4.2 it is presumed that most of the wells analyzed are contaminated bacteriologically. The water is not suitable for human ingestion unless disinfected, though it can be used for other domestic purposes.



SAMPLING POINTS

ST.1 Amphoe Warinchamrap
ST.2 Amphoe Warinchamrap
ST.3 Amphoe Muang Ubon Ratchathani
ST.4 Amphoe Muang Ubon Ratchathani
ST.5 Amphoe Muang Ubon Ratchathani
ST.6 Ban Kan Luang
ST.7 Ban Kan Luang
ST.8 Ban That
ST.9 Ban Mai Klang
ST.10 Ban Tha Bong Mang
ST.11 Ban Pak Huai Wang Nong
ST.12 Ban Don Klang

FIGURE	GROUNDWATER SAMPLING POINTS
4.1	

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Table-4.2 WATER QUALITY OF GROUNDWATER

Item	Unit	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	ST.7	ST.8	ST.9	ST.10	ST.11	ST.12
Date		6/2/'86	6/2/'86	26/12/'85	5/2/'86	26/12/'85	5/2/'86	5/2/'86	27/12/'85	27/12/'85	27/12/'85	27/12/'85	6/2/'86
Well depth	m	3	7	15	13	30	17	4.5	10	14	14	5	5
Temperature	°C	24	27	27	28.2	29.4	29	26	25.6	25.9	27.7	25.2	21
Color	Pt•Co units	<1	<1	2	<1	2	<1	<1	<1	<1	<1	<1	<1
Turbidity	N T U	<1	<1	6	<1	9.2	12	3	1.4	2	2.8	3.5	10
pH		4.2	4.74	5.6	4.78	6.3	6.58	6.76	5.2	5.8	5.6	5.9	5.34
Conductivity	micromhos/cm	850	780	400	500	482	440	192	32	259	162	191	600
Alkalinity	mg/l as CaCO3	0	6	38	7	28	178	84	10	20	18	34	15
Hardness	mg/l as CaCO3	43	130	28	51	116	120	76	36	80	28	84	55
Iron	mg/l	0.14	0.04	1.2	0.13	3.46	0.1	0.12	0.28	0.2	0.78	0.08	0.38
Manganese	mg/l	<0.1	<0.1	0.119	<0.1	0.21	<0.1	<0.1	<0.1	0.14	0.12	<0.1	<0.1
Chloride	mg/l	220	96	71	50	79	25	1	9	45	36	69	112
Sulfate	mg/l	1	9	26	35	6	2	8	<1	<1	2	<1	20
Ammonia-N	mg/l	0.5	<0.2	10	7.2	2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrite-N	mg/l	-	0.07	-	0.3	-	<0.01	<0.01	-	-	-	-	0.01
Nitrate-N	mg/l	1.3	45	-	22	-	0.2	1	-	-	-	-	7
Coliform group	N/100ml	-	-	200	-	0	0	300	3400	300	200	1200	2000
Total colonies	N/ml	-	-	>300	-	0	280	>300	220	>300	230	>300	>300

DATA SOURCE : STUDY TEAM

4.2 Treated Water

4.2.1 Existing Conditions

Table-4.3 shows the results of water quality analysis made by PWA on the raw and treated water. Fig-4.2 shows the monthly average dosage of alum and chlorine.

Present conditions of the treated water quality are described below based on the data.

a) Of the tested 6 samples of the Ubon Treatment Plant and 3 samples of the Warin Treatment Plant, the cases exceeding DWS are numbered as follows respectively.

	Ubon Plant	Warin Plant
Color :	1	-
Turbidity :	2	3
pH :	4	3

These conditions are due to the absence of alkali treatment and improper alum dosage. Judging from the present raw water quality, it is not difficult to meet the DWS requirements, if the alkali and alum dosage are controlled and the filters are operated properly.

b) To treat the raw water of low pH, low alkalinity and high turbidity in the rainy season, alkali together with alum dosage is indispensable.

Because of the low alkalinity, coagulation effect is remarkably lessened in treating the high turbidity which demands relatively high dosage of alum. Poor coagulation may have led to the turbidity break-through in treated water.

Table-4.3(1) WATER QUALITY OF THE UBON TREATMENT PLANT

Item	Unit	RAW / TREATED		RAW / TREATED		RAW / TREATED		RAW / TREATED		RAW / TREATED		RAW / TREATED		PWA STANDARD
Date		4/2/'85		8/7/'85		29/8/'85		24/9/'85		21/10/'85		15/11/'85		
Color	Pt-Co units	10	5	35	6	35	5	30	2	25	5	30	4	5
Turbidity	NTU	2.4	0.7	-	-	53	5.8	48	3	54	5.8	51	4	5
pH		7.4	7.3	6.71	4.74	7.34	4.9	6.55	4.74	6.75	6.1	7.38	7.00	6.5-8.5
Conductivity	micromhos/cm	-	-	113	138	59	76	81	102	173	181	227	228	-
Alkalinity	mg/l as CaCO3	26	20	30	3	10	4	10	3	17	2	23	16	-
Hardness	mg/l as CaCO3	70	64	22	22	15	15	19	18	33	34	47	46	-
Calcium	mg/l	16	17.6	5.6	6	4.8	4.4	6.4	4.8	10	9.2	13.6	12.4	75
Magnesium	mg/l	7.2	4.8	1.9	1.7	0.7	1	0.5	1.7	1.9	2.6	3.1	3.6	50
Chloride	mg/l	100	97	24	26	18	16	18	22	40	45	50	50	250
Coliform group	MPN/100ml	-	-	-	-	-	<2.2	-	<2.2	-	-	-	-	<2.2
Total colonies	N/ml	-	-	-	-	-	1	-	0	-	-	-	-	500
Feacal coliform		-	-	-	-	-	Negative	-	Negative	-	-	-	-	Negative

DATA SOURCE : PWA

Table-4.3(2) WATER QUALITY OF THE WARIN TREATMENT PLANT

Item	Unit	RAW / TREATED		RAW / TREATED		RAW / TREATED		RAW / TREATED		RAW / TREATED		RAW / TREATED		PWA STANDARD
Date		4/2/'85		8/7/'85		29/8/'85		24/9/'85		21/10/'85		15/11/'85		
Color	Pt-Co units	10	-	35	-	35	-	30	3	25	4	30	2	5
Turbidity	NTU	2.4	-	-	-	53	-	48	6.5	54	9.2	51	8	5
pH		7.4	-	6.71	-	7.34	-	6.55	4.05	6.75	4.16	7.38	5.95	6.5-8.5
Conductivity	micromhos/cm	-	-	113	-	59	-	81	141	173	221	227	250	-
Alkalinity	mg/l as CaCO3	28	-	30	-	10	-	10	1	17	4	23	5	-
Hardness	mg/l as CaCO3	70	-	22	-	15	-	19	21	33	33	47	41	-
Calcium	mg/l	16	-	5.6	-	4.8	-	6.4	5.6	10	9.2	13.6	11.2	75
Magnesium	mg/l	7.2	-	1.9	-	0.7	-	0.5	1.7	1.9	2.4	3.1	3.1	50
Chloride	mg/l	100	-	24	-	18	-	18	19	40	47	50	61	250

DATA SOURCE : PWA

NOTE : As the raw water is not sampled at the Warin Treatment Plant, the raw water was sampled at the Mun Noi River, identical with Table-4.3(1).

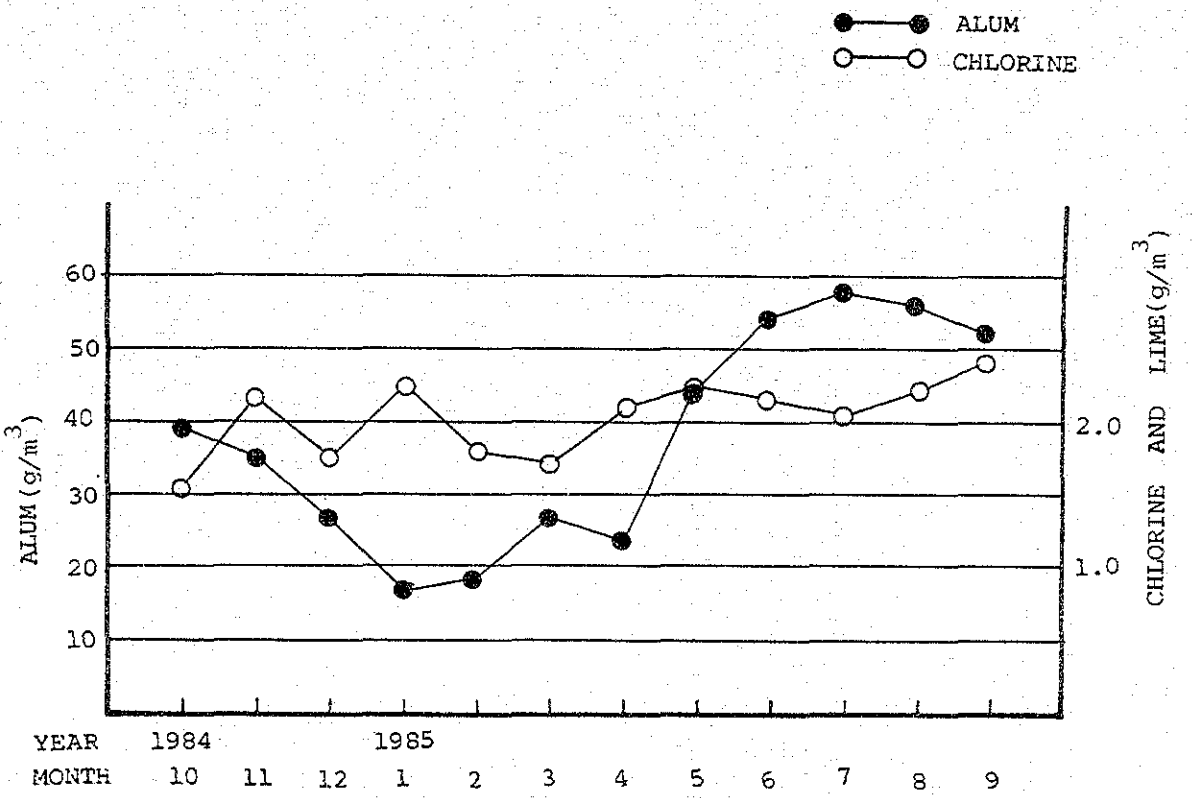

FIGURE	CHEMICAL DOSAGE MONTHLY AVERAGES
4.2	

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The low pH, further lowered by the alum dosage, will possibly cause pipe corrosion.

To deal with these problems, alkali dosing should be done only when necessary.

c) The aforementioned alkali dosing will be needed only in the rainy season and not in the dry season when alkalinity and pH of the raw water are high, in addition to low turbidity. In order to decide the optimum alkali and alum dosing, a jar test should be made carefully and regularly.

d) The chlorine dosage fluctuated through the period recorded in Fig-4.2 and averaged 2.02 mg/l. The reason of fluctuation is inexplicable. To keep the water quality safe and palatable, attention should be paid to dosing a constant rate of chlorine, unless necessitated otherwise.

As seen in Fig-4.3, residual chlorine was detected at all taps in the surveyed area, proving safety of the water. However, residual chlorine, above 1 mg/l detected in the whole Ubon area and as high as 1.8 mg/l found at many spots in Warin area, indicates obvious uneconomical over-dosing. Control of chlorine dosage with continuous monitoring of the residual should be practiced. While, investigation should be made to find the cause of the low residual at several points in Warin area.

Periodic monitoring should be strengthened in the whole water supply area in order to maintain a certain level of chlorine residue as well as to prevent over-dosing.

4.2.2 Improvement of Treatment Method

To improve the treated water quality, rectifying chemical dosing and filter operation is needed.

No.	Residual Chlorine (mg/l)	No.	Residual Chlorine (mg/l)
1	> 1	26	> 1
2	> 1	27	> 1
3	> 1	28	1.8
4	> 1	29	1.8
5	> 1	30	1.8
6	> 1	31	1.8
7	> 1	32	1.8
8	> 1	33	1.8
9	> 1	34	1.8
10	> 1	35	1.8
11	> 1	36	0.4
12	> 1	37	0.2
13	> 1	38	1.3
14	> 1	39	0.1
15	> 1	40	0.2
16	> 1	41	0.1
17	> 1	42	1.4
18	> 1	43	1.8
19	> 1	44	1.8
20	> 1	45	1.8
21	> 1	46	1.8
22	> 1	47	1.8
23	> 1	48	1.8
24	> 1	49	1.8
25	> 1	50	1.8

DATA SOURCE : STUDY TEAM

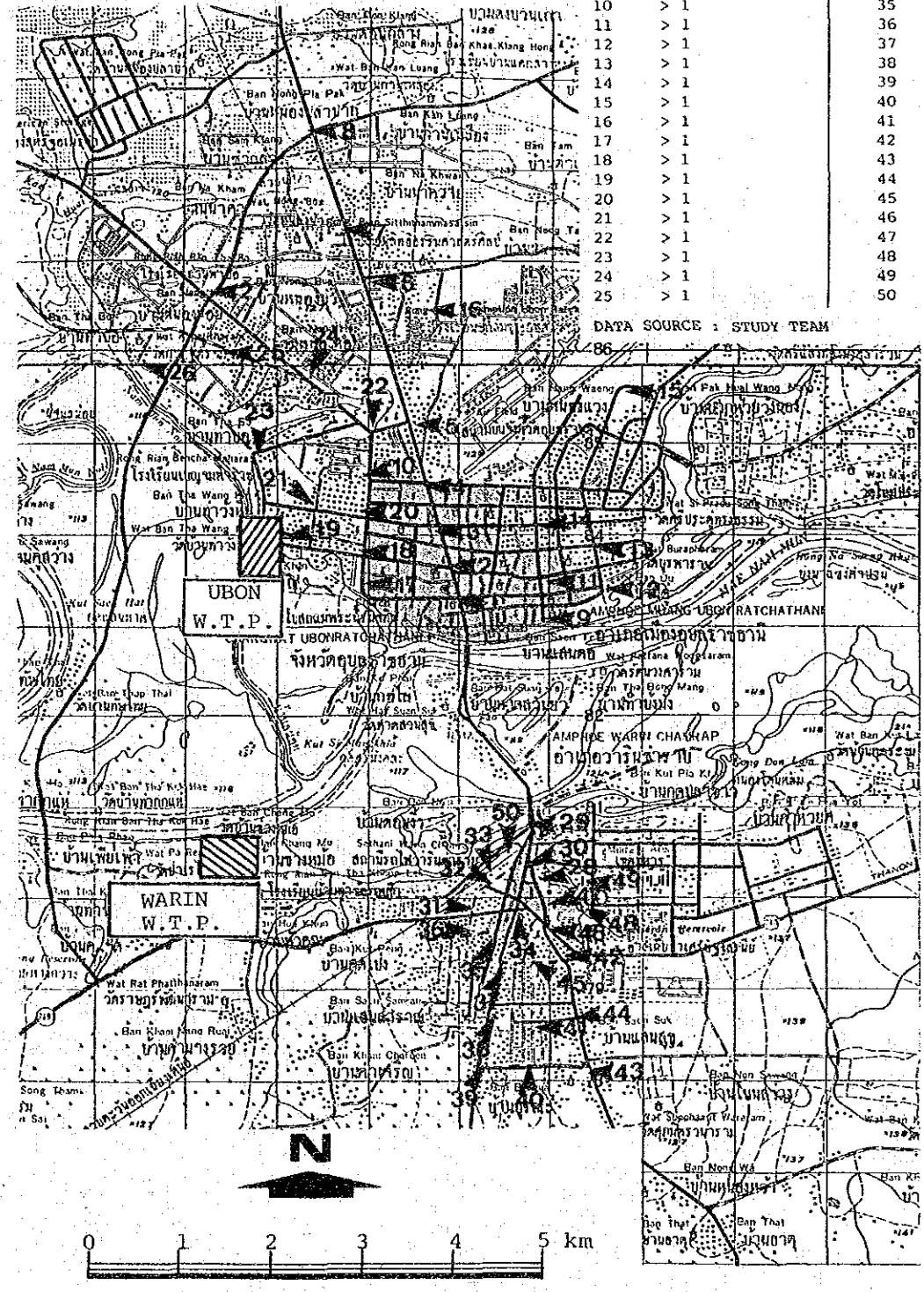

FIGURE 4.3

RESIDUAL CHLORINE SAMPLING POINTS

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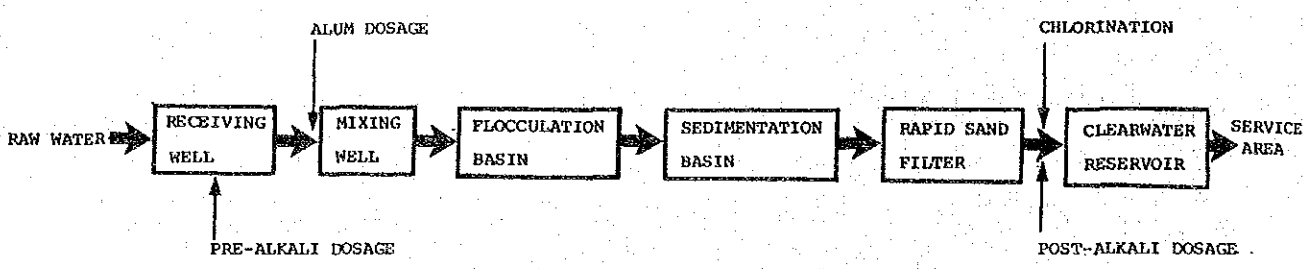
Fig-4.4 shows the proposed treatment operation practice considering the characteristic of raw water and practice of the existing treatment plant.

Fig-4.4 FLOW SHEET OF TREATMENT PROCESS



a) Pre-alkali dosage is useful in optimizing coagulation effect in the rainy season. It will not be needed in the dry season when alkalinity and pH of raw water are high and turbidity is low.

b) Alum and pre-alkali dosage should be determined by jar testing

c) Chlorine dosage is subject to chlorine demand test and chlorination should be checked of its performance by surveying residual chlorine of the dead end of service pipe.

d) Post-alkali dosage is effective in inhibiting corrosion of pipes.

e) The timing of filter backwashing shall be judged by the head loss and turbidity of filtered water.

f) Filter sand should be checked of cleaness occasionally, by sampling sand of different depth and scrubbing it by hand in clear water.

APPENDIX 5

QUESTIONNAIRE SURVEY

APPENDIX 5

APPENDIX 5 QUESTIONNAIRE SURVEY

APPENDIX 5 QUESTIONNAIRE SURVEY

5.1 Objective

The JICA Study Team conducted a door-to-door questionnaire survey as a part of the Development Plan and Feasibility Study on the Provincial Water Supply Projects in the Kingdom of Thailand, in cooperation with the counterparts of the Provincial Waterworks Authority.

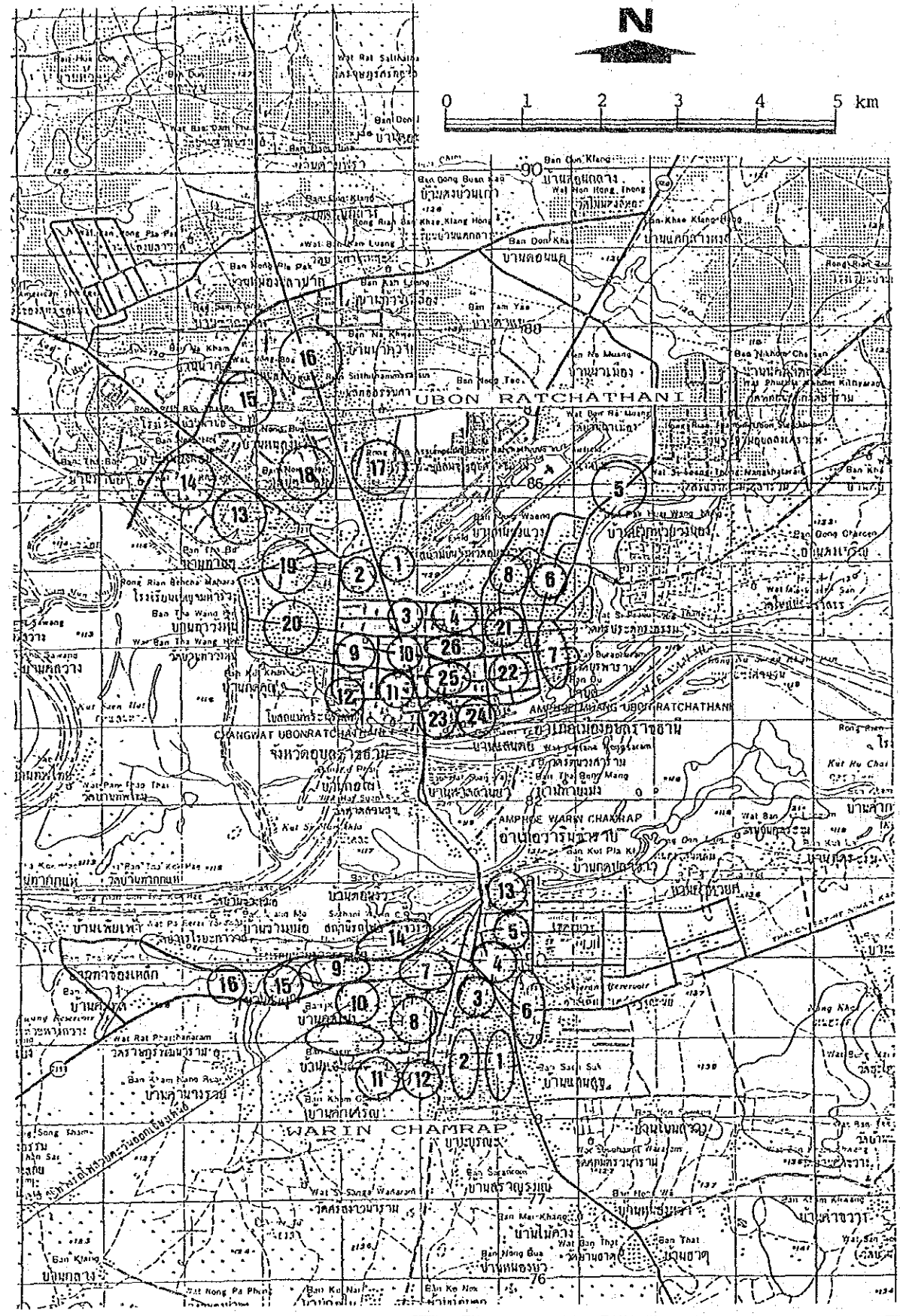
This survey was intended to obtain the basic and direct information on the present water use pattern of the inhabitants in the project area including their willingness for house-connection supply. These results of survey will be used for preparing the Development Plan and Feasibility Study.

5.2 Survey Areas and Interviewees

The survey area covered all districts in the project areas, inclusive of both the served and unserved area. The points where the questionnaire survey was conducted are listed as follows and shown in Fig-5.1 (1) and (2).

1) Ubon and Warin
2) Ubon Sanitary District
3) Five villages (Ban Don klang, Ban Pak Huai Wang Nong, Ban Tha Bong Mang, Ban Suan Ya and Ban Mai Klang)

The interviewees included not only the present consumers of the PWA service but also the people using other water sources.



NO. Surveyed points

FIGURE	MAP OF SURVEYED ZONE
5.1(1)	UBON-WARIN

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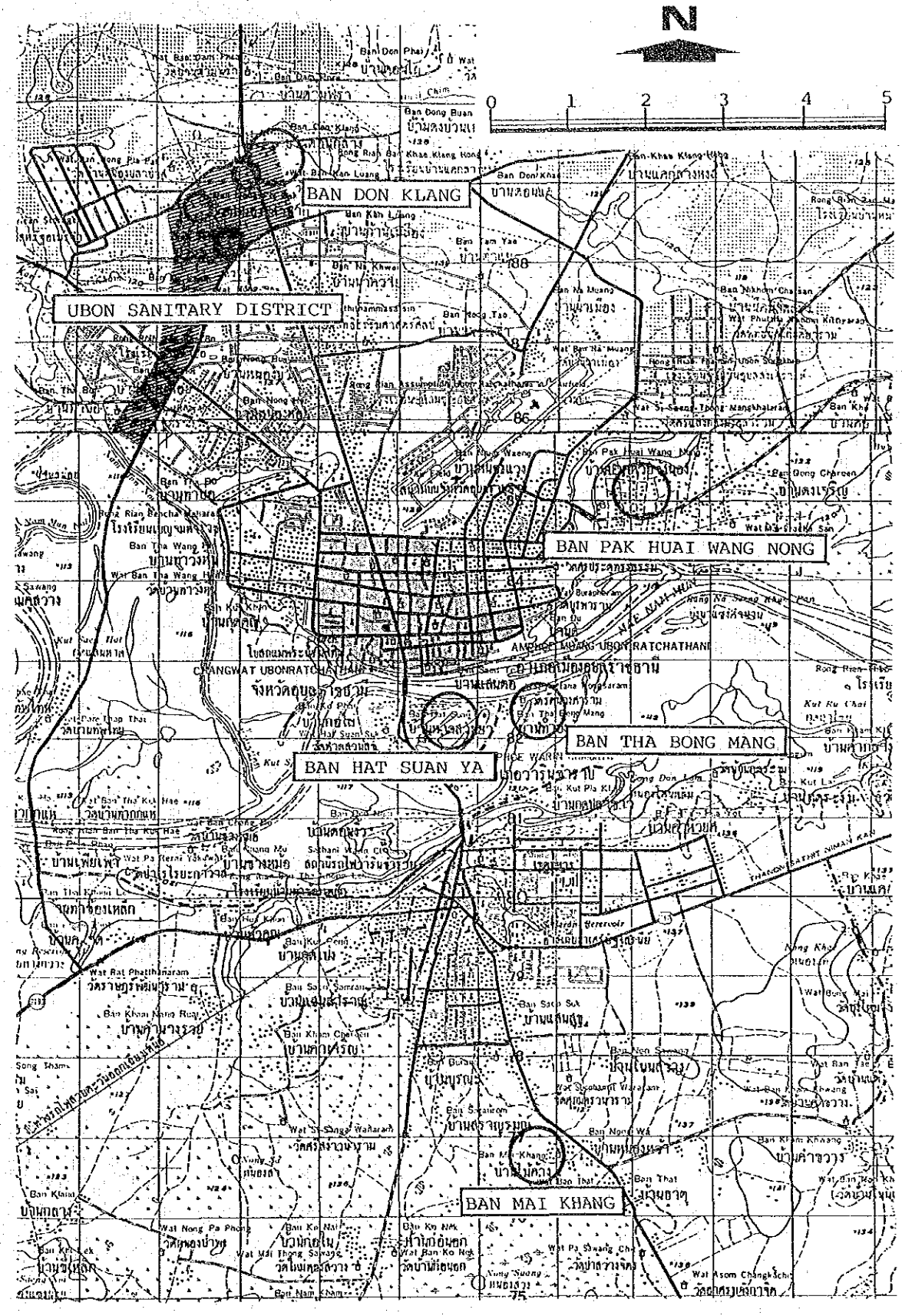


SURVEYED POINTS

FIGURE	MAP OF SURVEYED ZONE
5.1(2)	(FIVE VILLAGES AND SANITARY DISTRICT)

JAPAN INTERNATIONAL COOPERATION AGENCY

5.3 Survey Items

As seen in Table-5.1(1) and (2), the questionnaire form used for the survey consists of the following ten items:

Ubon and Warin Municipalities (Table-5.1 (1))

- Q-1 Type of Building Surveyed
- Q-2 Type of Water Supply Source
- Q-3 Number of Persons per Connection
- Q-4 Number of Persons per Household
- Q-5 Current Status of Water Supply
- Q-6 Monthly Average Water Consumption
- Q-7 Average Cost of Water per Month
- Q-8 Willingness to be Connected to Municipal System
- Q-9 Willingness to Pay for Water per Month
- Q-10 Average Monthly Income per Household

For Ubon Sanitary District and five villages

- Q-1 to Q-7 in Table-5.1 (1)
- Q-8 to Q-10 in Table-5.1 (2)

5.4 Survey Method

The survey team consisted of staff members of the JICA team, three officials from the PWA Head Office, personnel of the PWA Regional Office and the Ubon-Warin Waterworks.

The total of 48 local people, employed as interviewers, were engaged in the survey and the interviewees, numbering 1475 in total, were selected randomly.

Questioning was made by the interviewer, assisted by the local PWA personnel, under the guidance of PWA Head Office Staff.

The survey was conducted on the 4th through 6th of February, and the 24th of July, 1986.

Table-5.1(1) QUESTIONNIRE FORM

QESTIONNAIRE

FOR

PROVINCIAL WATER SUPPLY PROJECT

Ward No. :

Interviewer :

Date : / / 19

				Enumeration No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Census Reference No.																												
Name of Street																												
House/Building No.																												
Q-1. Type of Building Surveyed (Check appropriate one)	Pure Residential																											
	Residential & Commercial																											
	Pure Commercial																											
	Institutional																											
	Industrial																											
Q-2. Type of Water Supply Source (Check appropriate one/ones)	Municipal System																											
	Sources Other Than Municipal System	Rain/River Water																										
		Spring																										
		Water Vendor																										
		Ground-water	Shallow Well																									
			Deep Well																									
			Well depth	1 - 10 m																								
				10 - 20 m																								
				20 - 50 m																								
				50 - 100 m																								
				100 - 200 m																								
				over 200 m																								
			Water level	1 - 5 m																								
				5 - 10 m																								
				10 - 20 m																								
				20 - 50 m																								
				over 50 m																								
			Fluctuation (Dry and Rainy)	1 - 3 m																								
				3 - 5 m																								
				over 5 m																								
	drinking																											
	not drinking																											
	colored																											
	smell																											
Q-3. Number of Persons Per Household (Should not include neighbors)																												
Q-4. Number of Persons Per House Connection (Applicable only to those being supplied by Municipal System. Should include neighbors using same house connection)																												
Q-5. Current Status of Water Supply (Check appropriate one. If unsatisfactory, check appropriate reason/reasons)	Satisfactory																											
	Unsatisfactory	Poor Quality																										
		Low Pressure																										
		Unstable																										
		Expensive																										
Q-6. Average Monthly Water Consumption (Check appropriate one)	Less than 15 m3																											
	15 - 30																											
	30 - 50																											
	50 - 75																											
	75 - 100																											
	100 - 150																											
	150 - 200																											
	200 - 300																											
	over 300																											
Q-7. Average Cost of Water Per Month (Check appropriate one)	Less than 50 Baht																											
	50 - 100																											
	100 - 150																											
	150 - 200																											
	200 - 300																											
	300 - 500																											
	500 - 1,000																											
	1,200 - 5,000																											
	5,000 - 10,000																											
	over 10,000																											
Q-8. Willingness to be connected to Municipal System (Applicable only to those not being supplied by Municipal System. Check 'Yes' or 'No')	Yes																											
	No																											
Q-9. Willingness to pay for Water Per Month (Applicable to only those who answered 'Yes' to Q-8. Check appropriate one)	Upto 50 Baht																											
	100																											
	200																											
	500																											
	1,000																											
	2,000																											
	5,000																											
	10,000																											
Q-10. Average Monthly Income Per Household (Check appropriate one)	Less than 2,000 Baht																											
	2,000 - 3,000																											
	3,000 - 4,500																											
	4,500 - 6,000																											
	6,000 - 7,500																											
	7,500 - 10,000																											
	10,000 - 13,000																											
	13,000 - 30,000																											
	over 30,000																											

Table-5.1(2) QUESTIONNAIRE FORM

QUESTIONNAIRE FOR PROVINCIAL WATER SUPPLY PROJECT

NAME OF VILLAGE_____

ADDRESS

(1)_____ (9)_____

(2)_____ (10)_____

(3)_____

(4)_____

(5)_____

(6)_____

(7)_____

(8)_____

1. (Q-8) Connection fee is set at about 2000 baht for the first 10 meter length of pipe installation and additional fee must be paid for longer pipe installation.

Do you want to be connected to municipal system ?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Yes										
No										

2. (Q-9) Willingness to pay for water per month. Applicable to those who answered "Yes" to the first question. (Baht/Month)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

3. (Q-10) Average monthly income per household. (Baht/Month)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

Note : If you answer "No" to the first question, please go to the third question.

5.5 Survey Results

5.5.1 Ubon and Warin

The survey results are summarized in Table-5.2 and shown in Fig-5.2 (1) to (6) graphically.

1) Type of Building Surveyed (see Table-5.2 and Fig-5.2 (1))

Of the 1,045 households answering the captioned question, 61.0 % lived in residential-only (purely residential) buildings while 23.4 % in residential -commercial buildings. Altogether 84.4 %, most of the 1,045, lived in the residential-purported buildings and consumed water for domestic uses.

2) Type of Water Supply Sources (see Table-5.2 and Fig-5.2 (1), (2))

Of the 1,049 households answering the captioned question, 63.1 % used the municipal system only, 5.4 % the municipal system and other sources and 31.5 % used other sources only. (Fig-5.2 (1)). Fig-5.2 (2) shows how the other sources were used. When the two graphs are combined, the ground-water's share is the largest, 350 of the total 387, or 90.4 %, followed by rain/river water's 3.9 % and the water buyer's 3.4 %. The groundwater is used by the overwhelming majority of the users of other sources.

3) Current Status of Water Supply (Table-5.2, Fig-5.2 (3))

Of the 657 households using the PWA system wholly or partly, 74.3 % were found to be dissatisfied with the service. Of the reasons, 51.8 % of the 488, pointed out combined reasons, 27.1 % instability, 19.3 % costliness and 1.2 % low pressure.

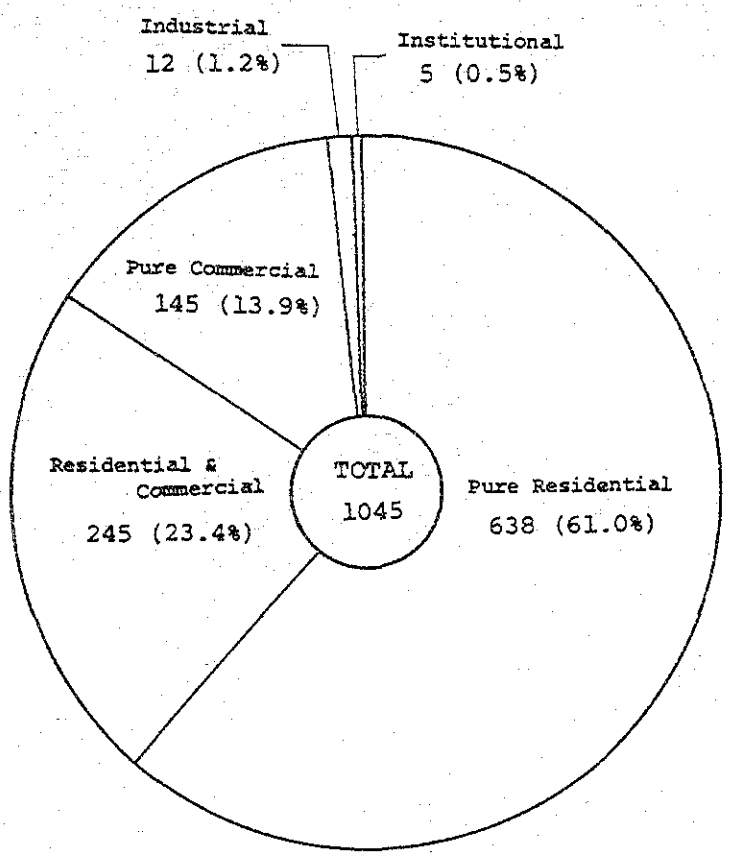
4) Monthly Average Consumption and Payment (Table-5.2, Fig-5.2 (4))

Consumption and payment are closely related. Of the 701 households surveyed, the less-than-15 cu m/month consumer, numbering 187 and comprising

Table-5.2 SURVEY RESULTS

UBON & WARIN

QUESTIONNAIRE	UBON	WARIN	TOTAL
Q-1 :Type of Building Surveyed			
Pure Residential	369	269	638
Residential & Commercial	164	81	245
Pure Commercial	113	32	145
Institutional	3	2	5
Industrial	5	7	12
No Anser	7	7	14
TOTAL Q-1	661	398	1059
Q-2 :Type of System Supply Sources			
A :Municipal System Only	470	192	662
B :Municipal System Plus Other Sources			
B-1 : Rain/River Water	8	4	12
B-2 : Pond / Reservoir Water	0	0	0
B-3 : Water Vender	6	1	7
B-4 : Groundwater	17	18	35
B-5 : Combined Sources	2	1	3
C :Sources Other Than Municipal System			
C-1 : Rain/River Water	2	1	3
C-2 : Pond / Reservoir Water	0	0	0
C-3 : Water Vender	0	6	6
C-4 : Groundwater	145	170	315
C-5 : Combined Sources	6	0	6
D :No Answer	5	5	10
Sub total (A + B)	503	216	719
Sub total (C)	153	177	330
TOTAL Q-2	661	398	1059
Q-5 :Current Status of Water Supply (Municipal System)			
A :Satisfactory	89	80	169
B :Unsatisfactory			
B-1 : Poor Quality	2	1	3
B-2 : Low Pressure	5	1	6
B-3 : Unstable	99	33	132
B-4 : Expensive	59	35	94
B-5 : Combined Reasons	211	42	253
C :No Answer	38	24	62
TOAL Q-5	503	216	719
Q-6 :Monthly Average Water Consumption			
1 :Less than 15 m3	99	88	187
2 :15 - 30	210	88	298
3 :30 - 50	126	31	157
4 :50 - 75	29	5	34
5 :75 - 100	15	0	15
6 :100 - 150	0	1	1
7 :150 - 200	4	0	4
8 :200 - 300	4	0	4
9 :Over 300	1	0	1
10 :No Answer	15	3	18
TOTAL Q-6	503	216	719
Q-7 :Average Cost of Water Per Month			
1 :Less than 50 Baht	69	57	126
2 :50 - 100	143	67	210
3 :100 - 150	87	38	125
4 :150 - 200	70	28	98
5 :200 - 300	63	14	77
6 :300 - 500	30	6	36
7 :500 -1,000	21	1	22
8 :1,000 - 5,000	4	0	4
9 :5,000 - 10,000	0	0	0
10 :Over 10,000	1	0	1
11 :No Answer	15	5	20
TOTAL Q-7	503	216	719
Q-8 :Willingness to be Connected			
1 :Yes	97	63	160
2 :No	56	91	147
3 :No Answer	5	28	33
TOTAL Q-8	158	182	340
Q-9 :Willingness to Pay for Water per Month			
1 :Upto 50 Baht	55	30	85
2 : 100	28	12	40
3 : 200	0	5	5
4 : 500	0	2	2
5 : 1,000	4	5	9
6 : 2,000	2	6	8
7 : 5,000	0	1	1
8 : 10,000	0	0	0
9 :No Answer	8	2	10
TOTAL Q-9	97	63	160
Q-10:Average Monthly Income per Household			
A :Sources Other Than Municipl System			
1 :Less than 2,000 Baht	64	66	130
2 : 2,000 - 3,000	46	67	113
3 : 3,000 - 4,500	24	23	47
4 : 4,500 - 6,000	10	5	15
5 : 6,000 - 7,500	4	7	11
6 : 7,500 -10,000	4	8	12
7 : 10,000 -15,000	1	1	2
8 : 15,000 -50,000	0	0	0
9 :Over 50,000	0	0	0
10 :No Answer	5	5	10
Sub total Q-10-A	158	182	340
B :Municipal System Plus Sources			
1 :Less than 2,000 Baht	77	48	125
2 : 2,000 - 3,000	139	68	207
3 : 3,000 - 4,500	119	50	169
4 : 4,500 - 6,000	57	20	77
5 : 6,000 - 7,500	43	13	56
6 : 7,500 -10,000	18	8	26
7 : 10,000 -15,000	9	4	13
8 : 15,000 -50,000	6	1	7
9 :Over 50,000	2	0	2
10 :No Answer	33	4	37
Sub total Q-10-B	503	216	719
TOTAL Q-10	661	398	1059



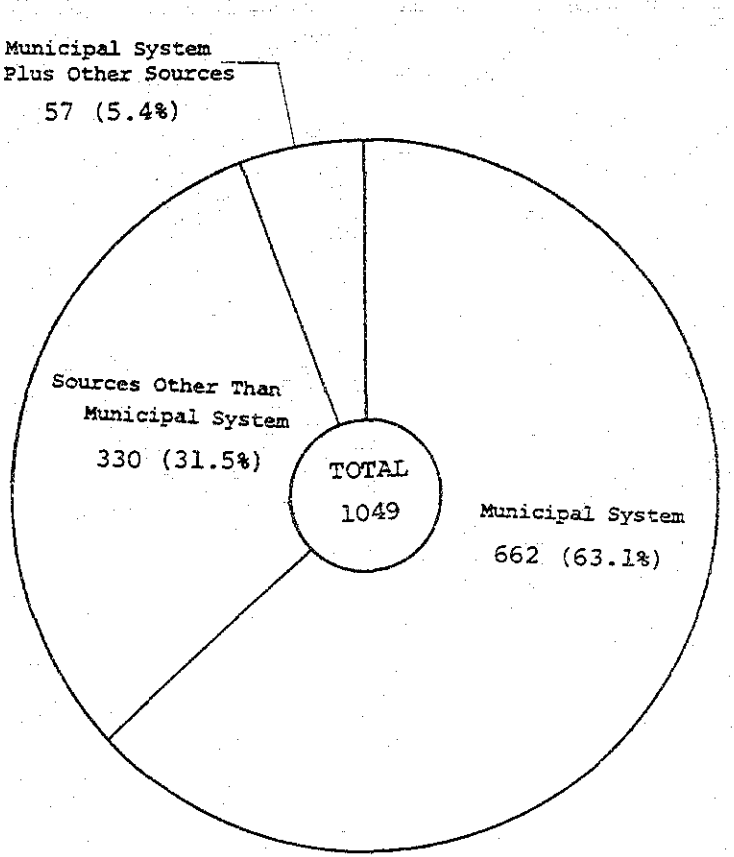


FIGURE	QUESTIONNAIRE SURVEY RESULTS (1)
5.2(1)	(UBON-WARIN)

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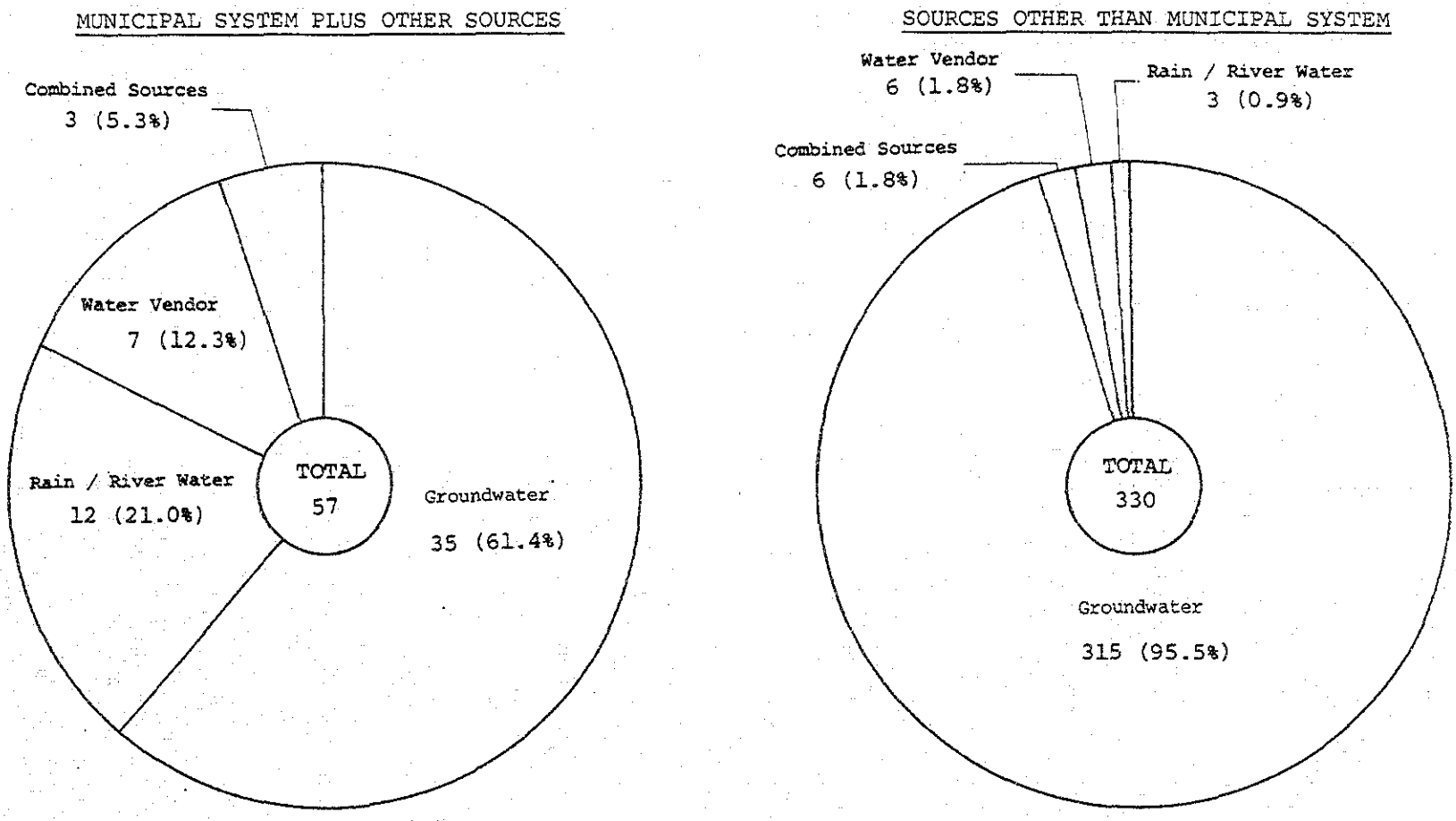

FIGURE	QUESTIONNAIRE SURVEY RESULTS (2)
5.2(2)	(UBON-WARIN)

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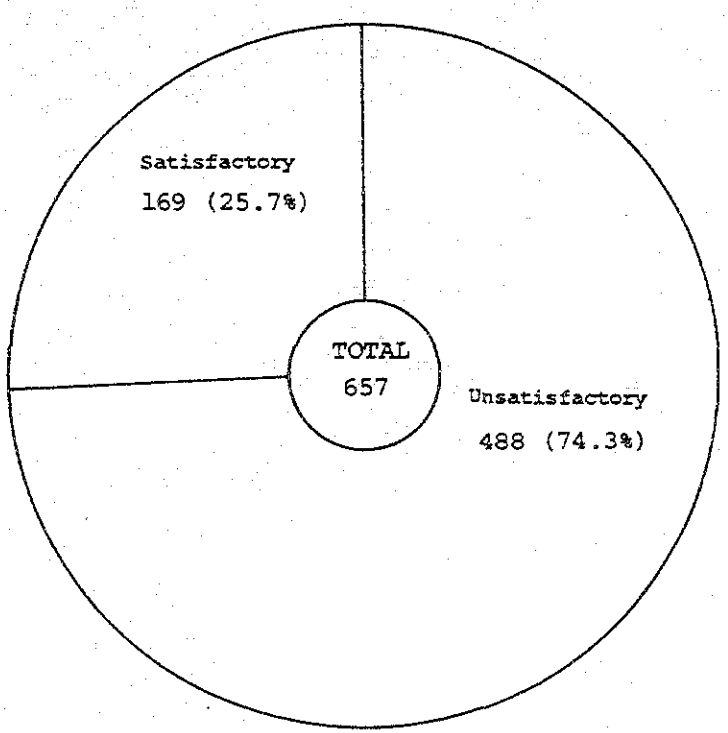
CURRENT STATUS OF WATER SUPPLY

MUNICIPAL SYSTEM



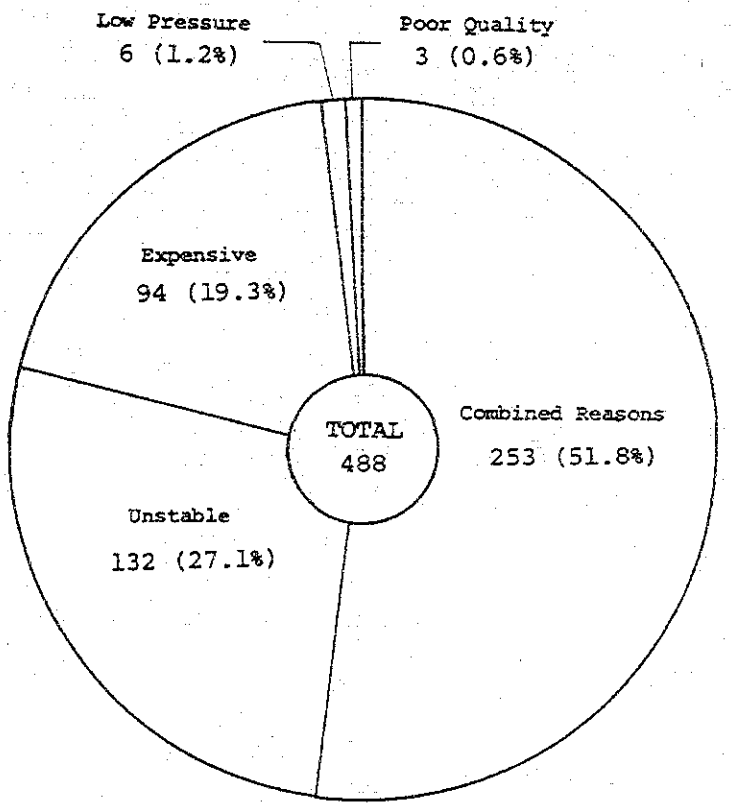


FIGURE	QUESTIONNAIRE SURVEY RESULTS (3)
5.2(3)	(UBON-WARIN)

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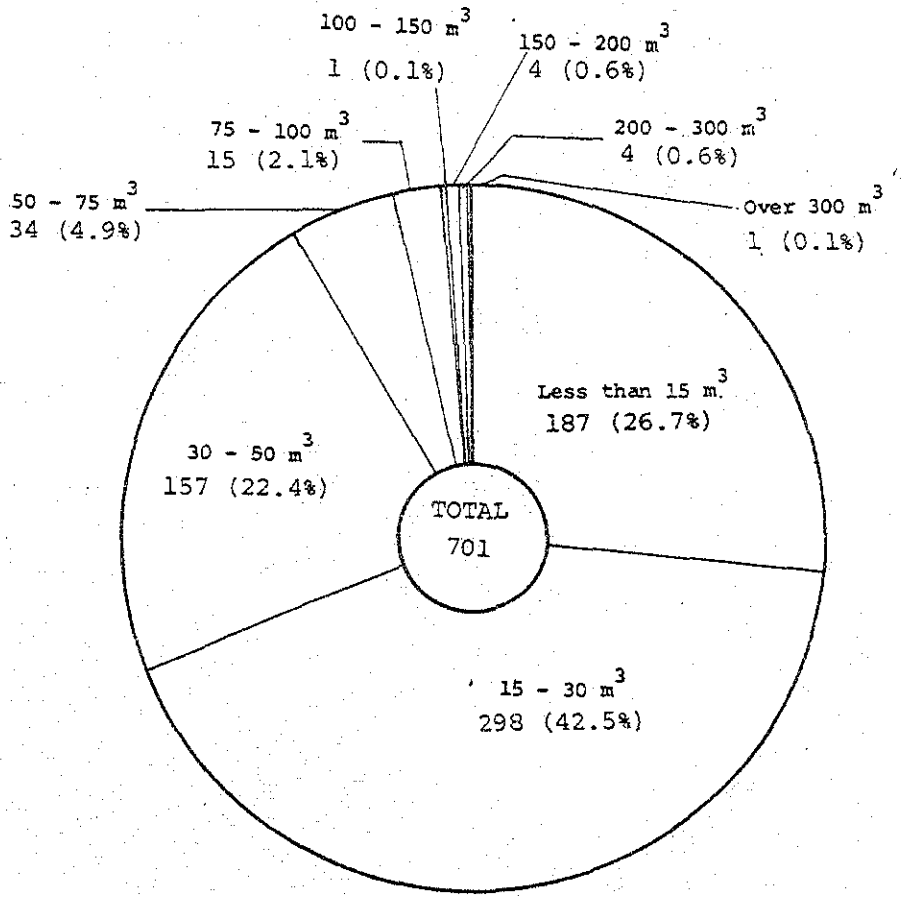
MONTHLY AVERAGE WATER CONSUMPTION



AVERAGE COST OF WATER PER MONTH

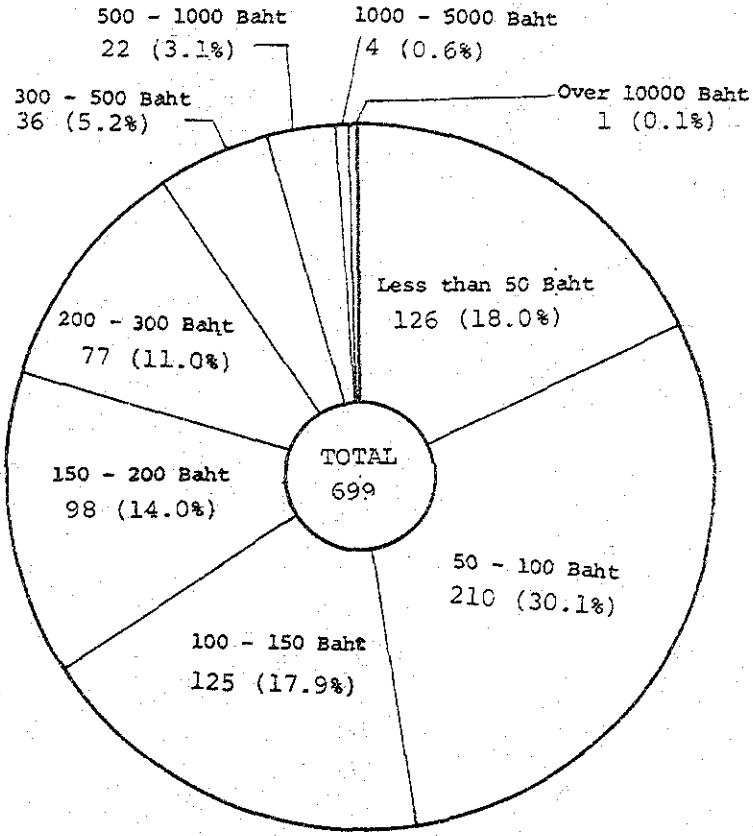


FIGURE	QUESTIONNAIRE SURVEY RESULTS (4)
5.2(4)	(UBON-WARIN)

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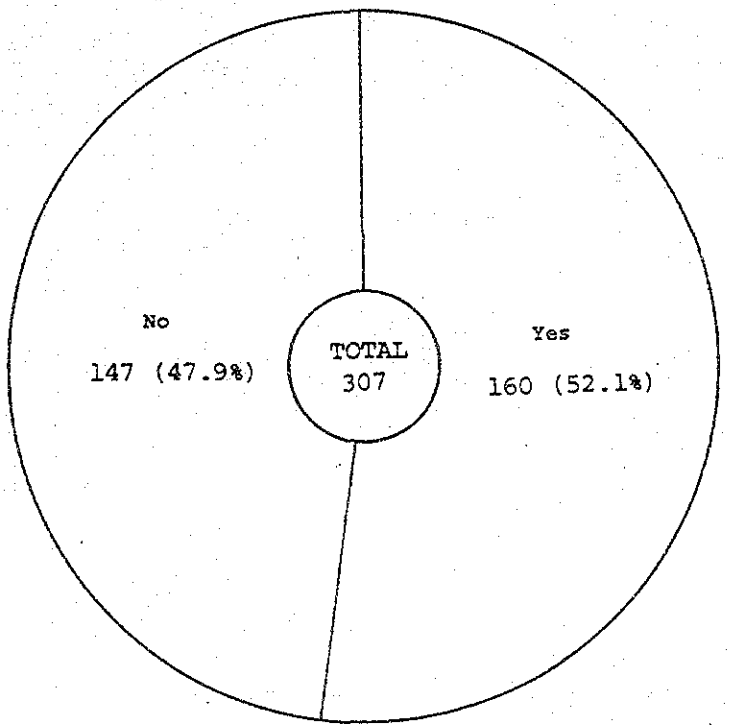
WILLINGNESS TO BE CONNECTED



WILLINGNESS TO PAY FOR WATER PER MONTH

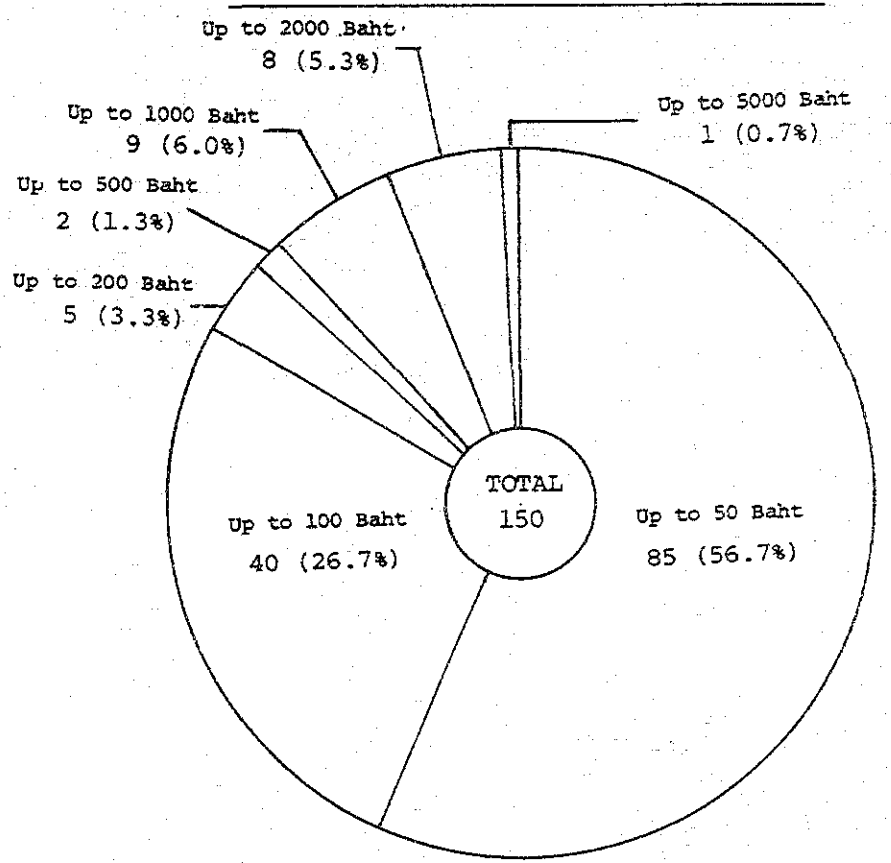
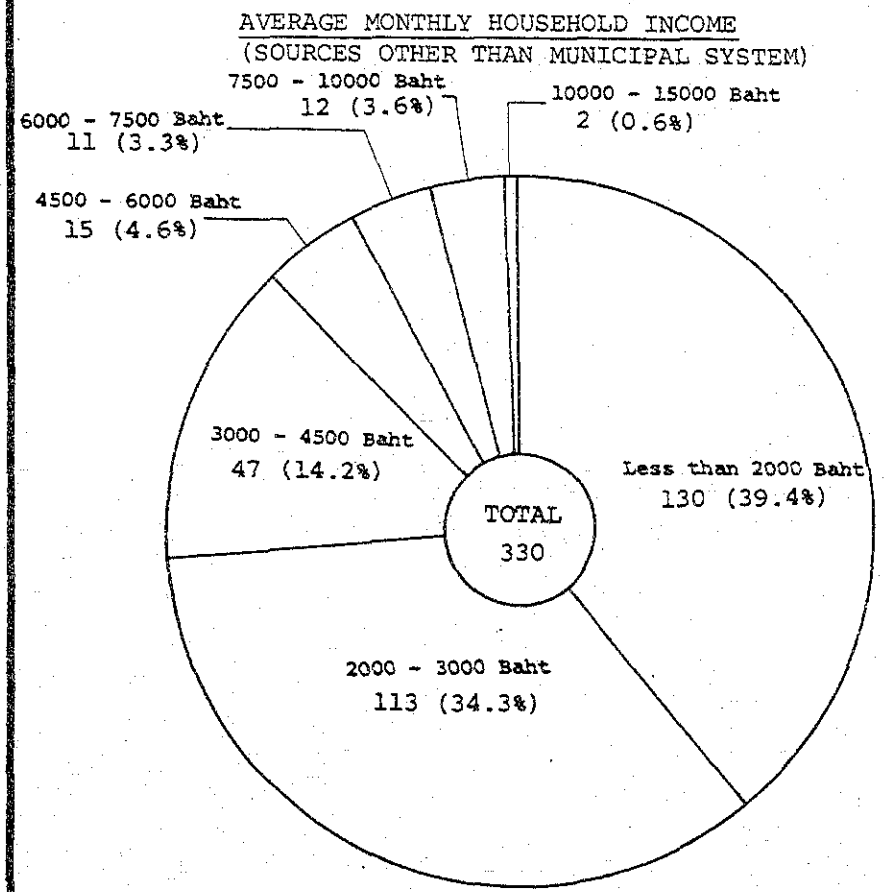


FIGURE	QUESTIONNAIRE SURVEY RESULTS (5)
5.2(5)	(UBON-WARIN)

JAPAN INTERNATIONAL COOPERATION AGENCY



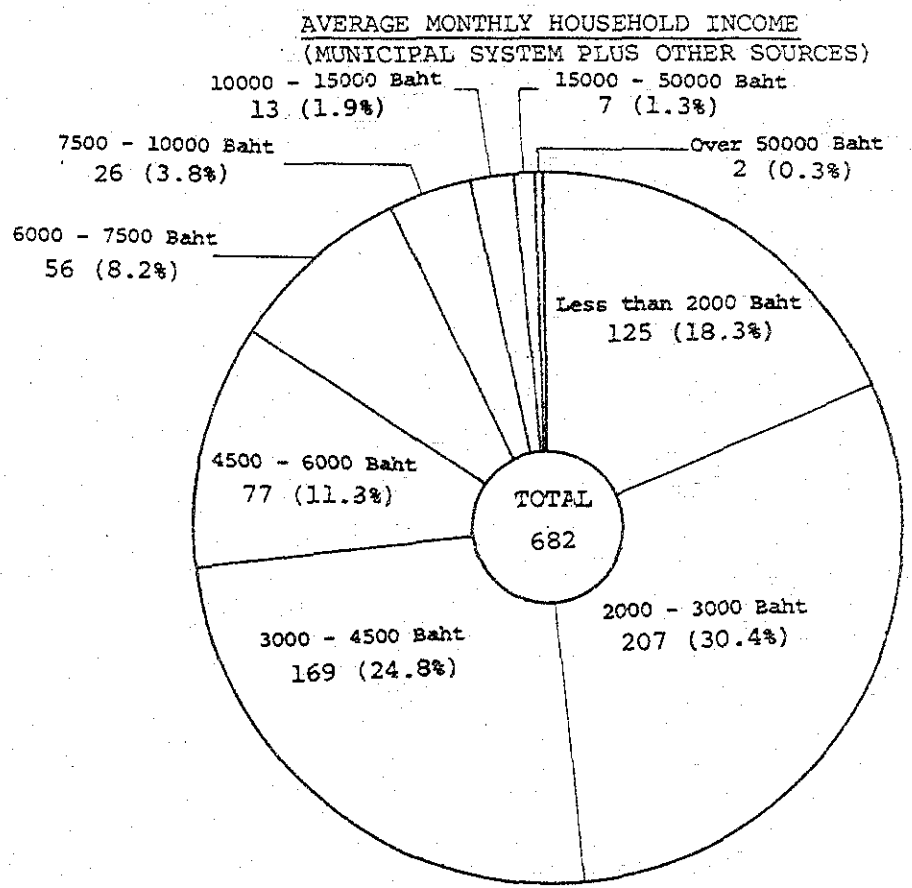


FIGURE	QUESTIONNAIRE SURVEY RESULTS (6)
5.2(6)	(UBON-WARIN)

JAPAN INTERNATIONAL COOPERATION AGENCY

26.7 %, corresponds to the less-than 50 Baht payer, numbering 126 and comprising 18.0 %. Likewise, the 15-30 cu m/month consumer corresponds to the payer of 50-150 Baht.

It also indicates that a limit in economizing consumption and payment exists at rather low level.

5) Willingness to be connected to Municipal System
(Table-5.2, Fig-5.2 (5))

By the people using sources other than the Municipal system, the captioned question was answered.

Nearly 52 %, or 160 of 307 of the answers, were positive.

The others, 47.9 %, were not willing to be connected, which might be due to use of groundwater and/or high water tariff.

6) Willingness to Pay for Water per Month (Table-5.2, Fig-5.2 (5))

Of those repliers willing-to-be-connected people, more than half i.e., 85 out of 150, answered 50 Baht or less as a willing-to-pay amount. This percentage contrasts with the finding that presently the less-than-50 Baht paying group comprises only 18.0 % of the total.

7) Average Monthly Household Income (Table-5.2, Fig-5.2 (6))

330 other sources-than-Municipal system users and 682 wholly-or-partly-Municipal-System users were questioned and the result is shown for each separately.

Obviously, the income levels differ between the two. The less-than-2,000 Baht income group comprises 39.4 % of the non-users and 18.3 % of the wholly-or-partly users. The 2,000-3,000 Baht class is 34.3 % and 30.4 % respectively. Seemingly, a separation line of income level between the affordable and not-affordable exists at around 2,000 Baht per month.

8) System Connection by Income Bracket (Fig-5.3)

To find the relationship between per capita income and individual house-connection ratio, screening of data, which was collected during the questionnaire survey, was made by taking the following steps:

a) Selecting all families having less than 20 family members,

b) Selecting all families in the residential-only dwellings and residential-commercial dwellings from selected families in step a),

c) Classifying the above selected families by per capita income brackets, and

d) Grouping the classified families whether they have services through individual house connections or not.

As shown in Fig-5.3, there is an apparent positive correlation between the per capita income and individual house connection services. It is also observed that nearly 70 % of families whose incomes are higher than 1,000 Baht have PWA services through individual house connections.

5.5.2 Sanitary District and Five Villages

The survey results are summarized in Table-5.3 and shown in Fig-5.4 (1) to (4) graphically.

1) Type of Building Surveyed (see Table-5.3 and Fig-5.4 (1))

Of the 299 households answering the captioned question, 84.9 % lived in residential-only (purely residential) buildings while the rest, 15.1 % in residential -commercial buildings. All of them lived in the residential-purported buildings and consumed water for domestic uses.

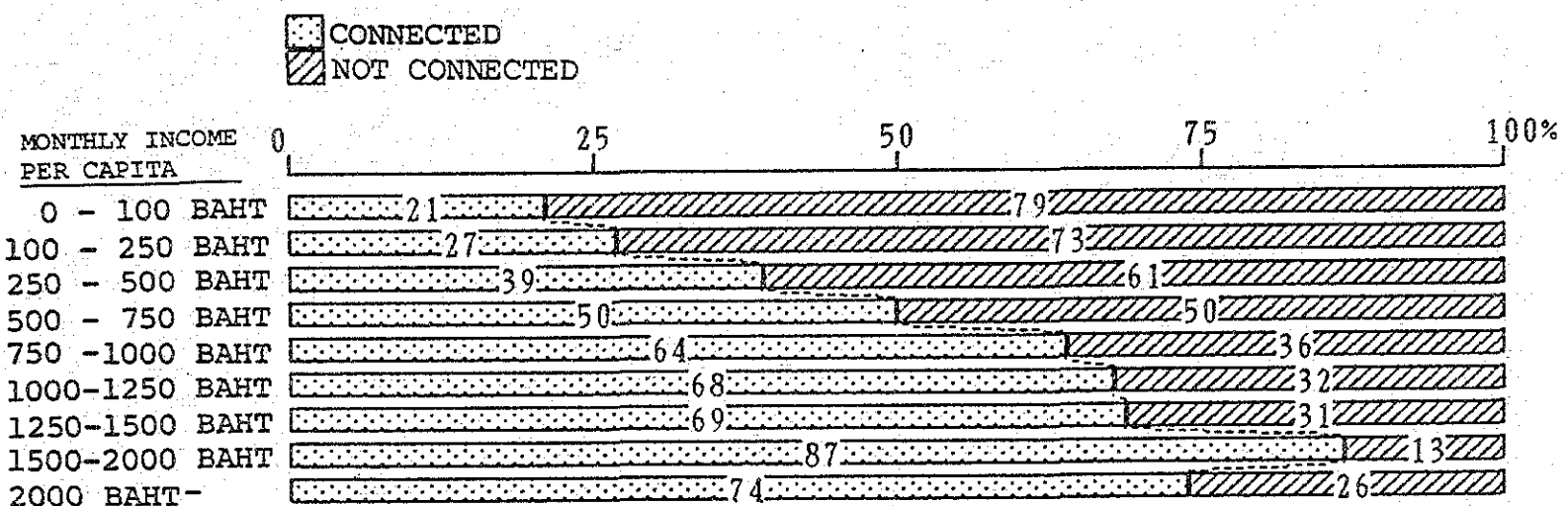


FIGURE	SYSTEM CONNECTION BY INCOME BRACKETS (UBON-WARIN)
5.3	

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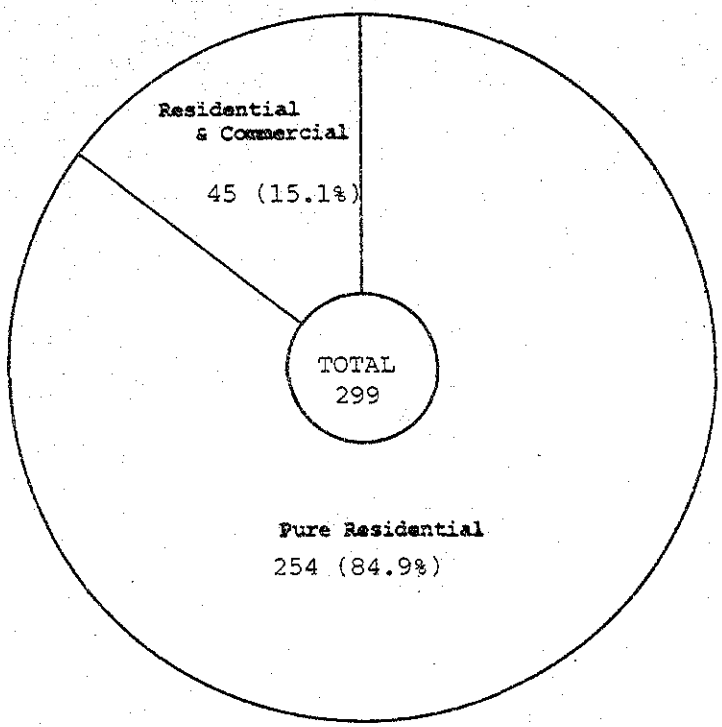
Table-5.3 SURVEY RESULTS

VILLAGES 8 UBON S.D

QUESTIONNAIRE	TOTAL
Q-1 :Type of Building Surveyed	
Pure Residential	254
Residential & Commercial	45
Pure Commercial	0
Institutional	0
Industrial	0
No Anser	1
TOTAL Q-1	300
Q-2 :Type of System Supply Sources	
A :Municipal System Only	5
B :Municipal System Plus Other Sources	
B-1 : Rain/River Water	0
B-2 : Pond / Reservoir Water	0
B-3 : Water Vender	0
B-4 : Groundwater	0
B-5 : Combined Sources	0
C :Sources Other Than Municipal System	
C-1 : Rain/River Water	5
C-2 : Pond / Reservoir Water	0
C-3 : Water Vender	2
C-4 : Groundwater	219
C-5 : Combined Sources	66
D :No Answer	3
Sub total (A + B)	5
Sub total (C)	292
TOTAL Q-2	300
Q-5 :Current Status of Water Supply (Municipal System)	
A :Satisfactory	2
B :Unsatisfactory	
B-1 : Poor Quality	0
B-2 : Low Pressure	0
B-3 : Unstable	1
B-4 : Expensive	0
B-5 : Combined Reasons	1
C :No Answer	1
TOAL Q-5	5
Q-6 :Monthly Average Water Consumption	
1 :Less than 15 m3	0
2 :15 - 30	4
3 :30 - 50	0
4 :50 - 75	1
5 :75 - 100	0
6 :100 - 150	0
7 :150 - 200	0
8 :200 - 300	0
9 :Over 300	0
10 :No Answer	0
TOTAL Q-6	5
Q-7 :Average Cost of Water Per Month	
1 :Less than 50 Baht	0
2 :50 - 100	2
3 :100 - 150	2
4 :150 - 200	0
5 :200 - 300	0
6 :300 - 500	1
7 :500 -1,000	0
8 :1,000 - 5,000	0
9 :5,000 - 10,000	0
10 :Over 10,000	0
11 :No Answer	0
TOTAL Q-7	5
Q-8 :Willingness to be Connected	
1 :Yes	122
2 :No	44
3 :No Answer	0
TOTAL Q-8	166
Q-9 :Willingness to Pay for Water per Month	
1 :Upto 50 Baht	42
2 : 100	43
3 : 200	30
4 : 500	7
5 : 1,000	0
6 : 2,000	0
7 : 5,000	0
8 : 10,000	0
9 :No Answer	0
TOTAL Q-9	122
Q-10:Average Monthly Income per Household	
A :Sources Other Than Municipl System	
1 :Less than 2,000 Baht	75
2 : 2,000 - 3,000	34
3 : 3,000 - 4,500	18
4 : 4,500 - 6,000	14
5 : 6,000 - 7,500	8
6 : 7,500 -10,000	12
7 : 10,000 -15,000	5
8 : 15,000 -50,000	0
9 :Over 50,000	0
10 :No Answer	0
TOTAL Q-10	166

TYPE OF BUILDING SURVEY



TYPE OF WATER SUPPLY SOURCE

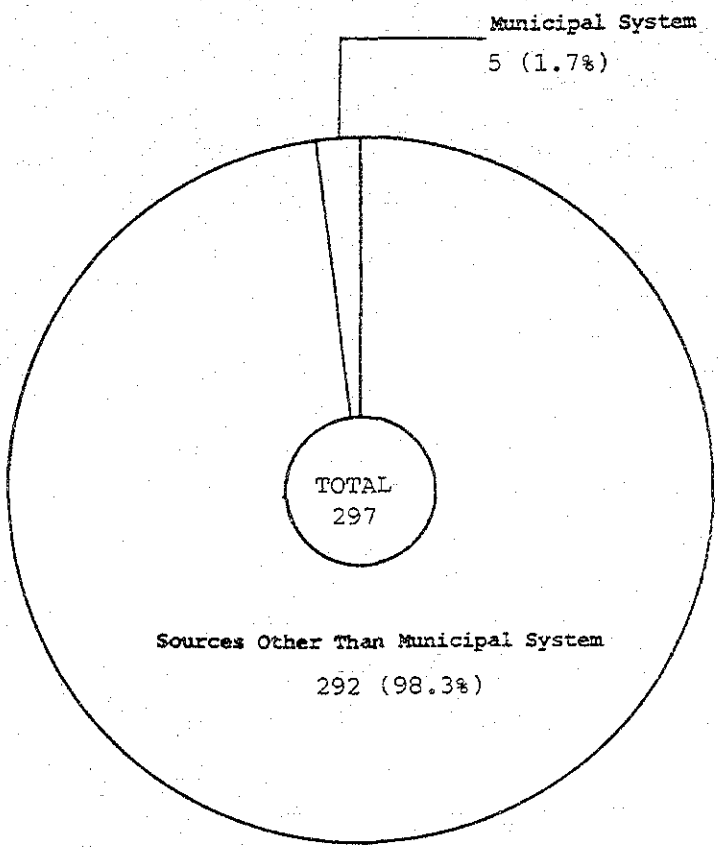


FIGURE	QUESTIONNAIRE SURVEY RESULTS (1)
5.4(1)	(5 VILLAGES AND UBON S.D.)

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SOURCE OTHER THAN MUNICIPAL SYSTEM

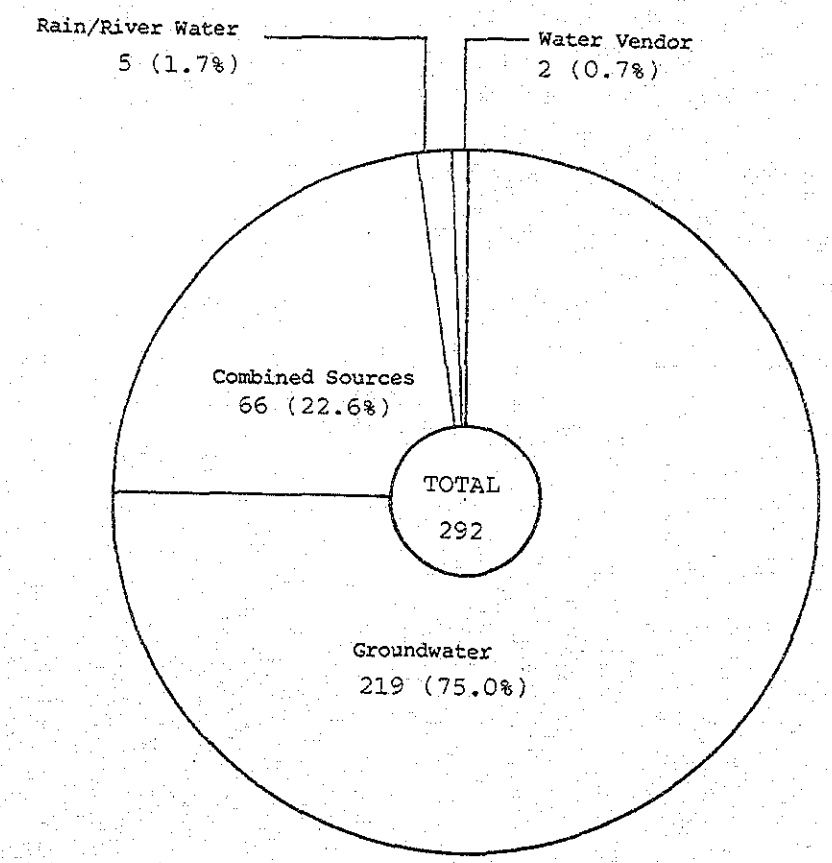

FIGURE	QUESTIONNAIRE SURVEY RESULTS (2)
5.4(2)	(5 VILLAGES AND UBON S.D.)

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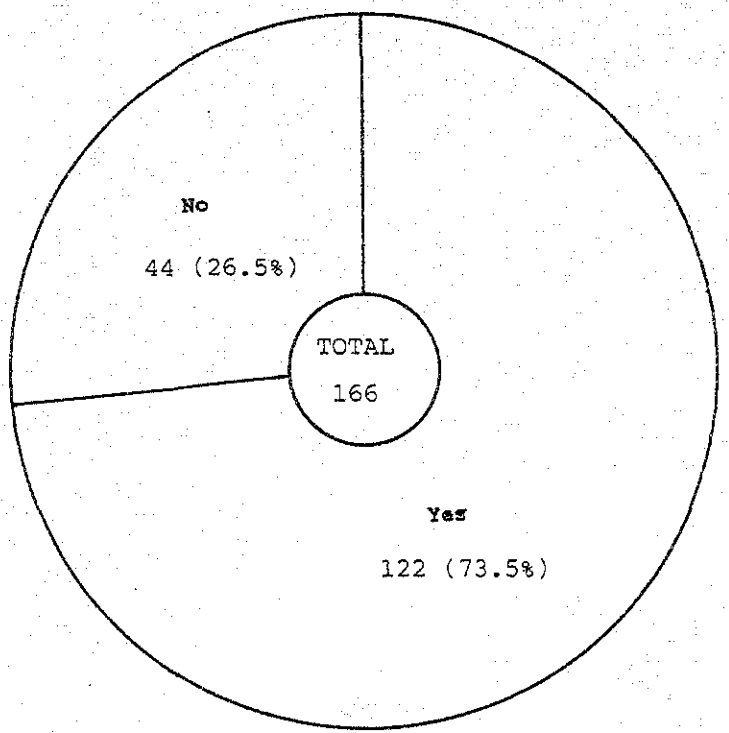
WILLINGNESS TO BE CONNECTED



WILLINGNESS TO PAY WATER PER MONTH

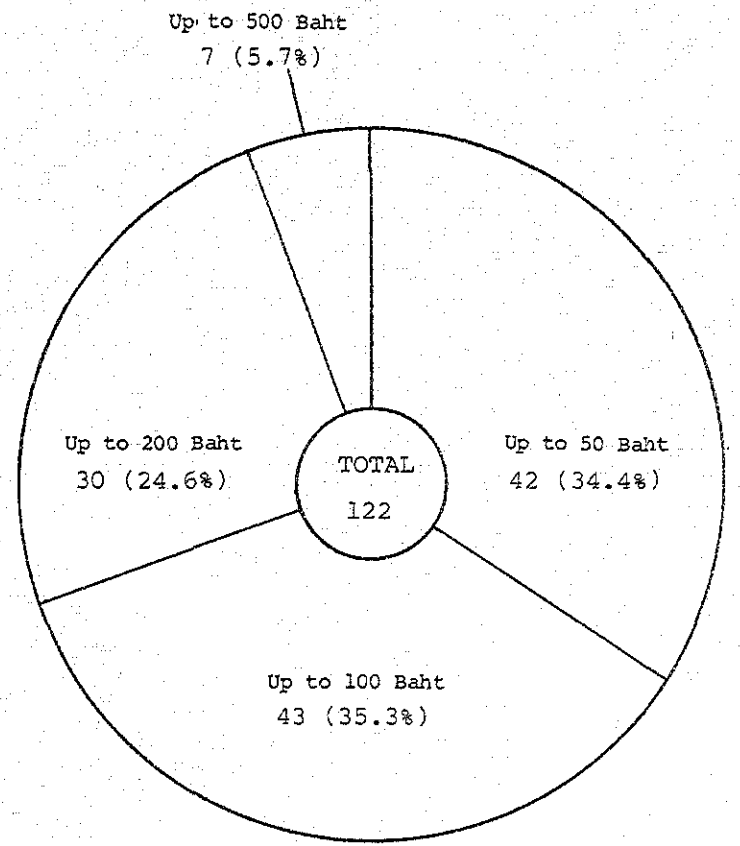


FIGURE	QUESTIONNAIRE SURVEY RESULTS (3)
5.4(3)	(5 VILLAGES AND UBON S.D.)

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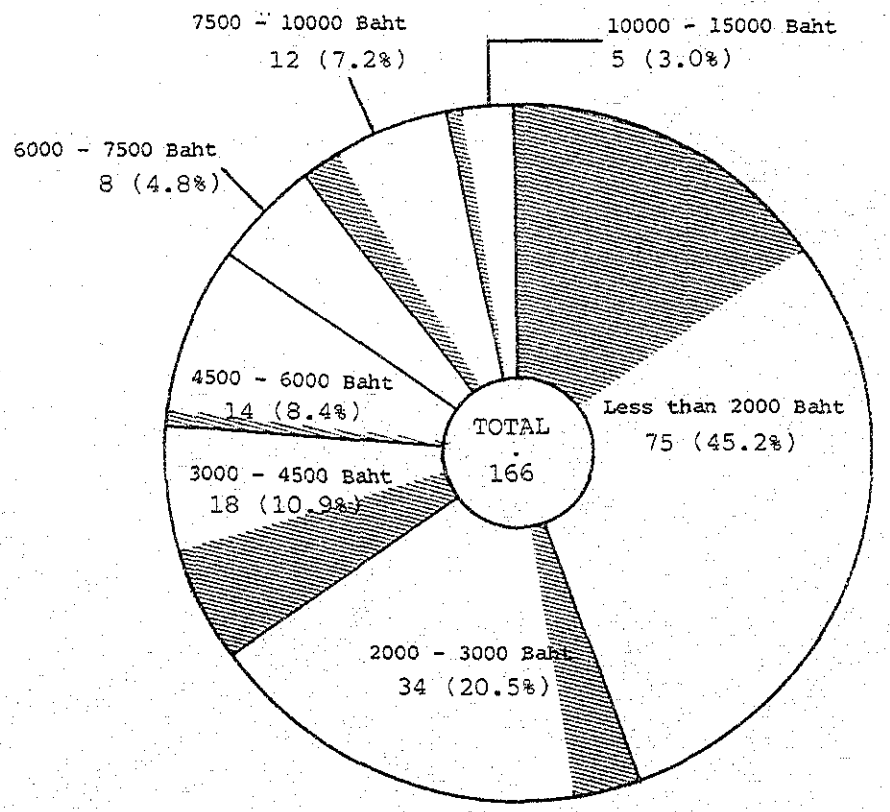
AVERAGE MONTHLY HOUSEHOLD INCOME
(SOURCE OTHER THAN MUNICIPAL SYSTEM)



LEGEND

: Willing to be connected

: Not willing to be connected

FIGURE 5.4(4)	QUESTIONNAIRE SURVEY RESULTS (4) (5 VILLAGES AND UBON S.D.)
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2) Type of Water Supply Sources (see Table-5.3 and Fig-5.4 (1), (2))

Of the 297 households answering the captioned question, only 5, or 1.7 %, are receiving the municipal water supply. The reason for the small percentage of receiving PWA services is that PWA services are now being offered in only a part of Ban Hat Suan Ya.

Fig-5.4 (2) shows how the other sources were used by the unserved. Of the 292 households, 75.0 % were using groundwater as the sole source. Those utilizing more than two of the four sources, i.e., (1) groundwater, (2) rain/river water, (3) pond/reservoir water and (4) water vendors, amounted to 22.6 %, with the majority using groundwater as a main source.

3) Willingness to be connected to Municipal System
(Table-5.3, Fig-5.4 (3))

By the people using other sources than the Municipal system, the captioned question was answered.

Of the 166 interviewees who are not receiving PWA services, 74 % are willing to be connected to the PWA water system. The breakdown is shown below.

Willingness to be connected

	Yes (%)	No (%)
Ubon Sanitary District	68	32
Ban Don Klang	48	52
Ban Pak Huai Wang Nong	68	32
Ban Tha Bong Mang	93	7
Ban Hat Suan Ya	73	27
Ban Mai Klang	85	15
Average	74	26

The willingness of inhabitants in Ban Don Klang is relatively low. The low percentage is due to economical reason, because 80 % of those unwilling repliers are grouped into the 2,000 Baht or less monthly income bracket.

4) Willingness to Pay for Water per Month (Table-5.3, Fig-5.4 (3))

Of those repliers willing-to-be-connected respondents, 34.4 %, i.e., 42 out of 122, answered 50 Baht or less as a willing-to-pay amount.

5) Average Monthly Household Income (Table-5.3, Fig-5.4 (4))

166 other sources-than-Municipal system users were questioned.

Nearly half of the households were grouped into the less-than-2,000 Baht income bracket, and two third of them are willing to be connected, as shown in Fig-5.4 (4). Regarding this question, they were reminded, before answering that a certain amount of connection cost would be charged.

Most of the 2,000-3,000 Baht income level gave positive answers, but in the 3,000-4,500 Baht income level, the willingness was about 50 %.

Most of the above 4,500 Baht income group showed willingness. Some of them, however, answered they were unwilling because they owned private wells.

Although the existence of wells and the present income level may affect it, the willingness of the questioned people is, as described before, 74 %. It obviously indicates the necessity of public water supply service in the area.

APPENDIX 6

DESIGN CRITERIA

APPENDIX 6

APPENDIX 6 DESIGN CRITERIA

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APPENDIX 6 DESIGN CRITERIA

The design criteria mentioned herein are applied to the preliminary design of the present project. They were concluded after studying the PWA design criteria and the concepts widely accepted in waterworks field and discussing them with PWA.

6.1 Peak Factors

The factors have not been established as criteria and the table below shows the peak factors planned for this project.

City/Town	Peak Factor by Day (Max Day/Ave Day)	Peak Factor by Hour (Max Hour/Ave Hour*)
Chiangmai	1.25	1.30
Ubon, Warin	1.30	1.40
Pattaya	1.30	1.20
Suphanburi	1.35	1.40
Five S.D.s in Chiangmai	1.35	1.50

* Ave Hour = 1/24 Max Day

The peak factor by day was estimated for each of the domestic and tourism demands separately and the listed figure is the average. Using the peak factors, the average day demand, maximum day demand and maximum hour demand are calculated.

These demands are used in making calculation mostly of:

Average Day Demand: financial and economic study
Maximum Day Demand: production facility design
Maximum Hour Demand: distribution facility design

6.2 Water Loss in Production

Water loss is counted in the design of treatment facilities. It is assumed to be 8 % of production capacity including filter washing and other in-plant consumptions

6.3 Concrete Structure

Concrete structures for production and distribution must be designed following the practiced design method prevailing in Thailand.

6.4 Pipeline

Pipelines must be designed based on consideration of hydraulic conditions, geologic conditions, pipe and joint material and others.

6.5 Treatment Plant Facilities

1) Flash Mixing

Type of mixing	:	hydraulic
Intensity, G (1/s)	:	500 - 1,000
Time of mixing, t (s)	:	1 - 3

2) Flocculation

Type of mixing	:	hydraulic
No. of stages	:	more than 3
Intensity, G (1/s)	:	10 - 70, tapered
Detention time (min)	:	20 - 40
Others	:	minimum of 2 basins, easy removal of scum and sludge

3) Sedimentation

Type	:	rectangular basin, one direction horizontal flow
Hydraulic loading	:	1 - 2 m3/m2/hr
Flow velocity (m/min)	:	0.3 - 1
Detention time (hr)	:	1.5 - 3
Water depth (m)	:	more than 3 plus sludge deposit thickness estimated on the interval of cleaning
Weir loading (m3/m.d)	:	less than 300 (less than 15 gpm/ft)
Length/width ratio	:	more than 5, dummy wall considered
Sludge collection	:	manual

4) Filtration

Type	:	gravity rapid sand filter
Filt. rate (m/hr)	:	less than 7, for declining rate filtration

Filter Bed

Type	:	single media
Minimum no. of filter	:	4
Minimum size of filter	:	3 m x 4 m
Effective size of sand	:	0.55 - 0.75 mm
Uniformity coefficient	:	1.7
Minimum depth	:	750 mm

Underdrains

Type	:	pipe lateral
No. of gravel layers	:	minimum 4
Thickness of each	:	more than 100 mm

Surface wash

Type	:	fixed nozzle
Rate (m/min)	:	0.12 - 0.17
Head (kg/cm2)	:	more than 1.0
Jet velocity (m/s)	:	6 - 7

Backwash

Rate (m/min)	:	more than 0.6

5) Clear Water Reservoir in Treatment Plant

Function	:	storage for in-plant consumption including backwashing
Type	:	elevated and/or ground level
For backwash	:	minimum storage for 2 filters consecutive backwashing

6) Chemical Feeding

Alum

No. of tank	:	more than 2
Feeder	:	metering pump or manual control with flow meter, recycle bypass, corrosion-resistant pump

Lime

Objective	:	pH control for coagulation and/or pipe protection against corrosion
No. of tank	:	more than 2

At least 1 stand-by feeder is to be provided for alum and lime. Gauges at outside of the tanks are preferable.

7) Chlorination

Chemicals form	:	chlorine gas and/or bleaching powder
Minimum storage	:	1 months
No. of standby chlorinator	:	more than 1
Scale	:	periodical recording of consumptions to be practiced

8) Instrumentation

Flow to be measured	:	raw water and treated water of treatment plant, chemicals, chlorine
Level to be measured	:	clear water reservoir, chemical tank
Weight to be measured	:	chlorine

In selecting the measuring devices, durability, robustness, easiness of operation and maintenance (changing parts, repair) are to be given priority to, for instance, high accuracy.

6.6 Distribution Facilities

1) Service Pressure

The minimum service pressure under the maximum hour flow is set at 1.0 kg/cm2 for general application, except for rural area where 0.7 - 0.8 kg/cm2 be tolerated.

2) Storage of Distribution Reservoir

When sufficient data regarding the characteristics of fluctuation area collected in future, the storage problems are to be studied.

Increasing the existing storage capacity is not considered in the rehabilitation/modification works, but in the expansion works, construction of a reservoir retaining 6 hour production volume for the expanded capacity is planned.

3) Pipe Material

In selecting pipe material, conditions such as strength against internal and external loads, suitability to ground conditions, workability in existing conditions and influence on water quality must be considered.

Asbestos cement pipes, anti-corrosion coated when necessary, are to be used preferably for economic reasons. For cases requiring pipe strength such as road crossing works and the like, ductile cast iron pipes are to be employed.

4) Pipe Size

Pipe size is to be selected pursuant to flow requirements. In this preliminary design, the maximum hour flow is employed for the pipe size selection.

5) Valves

The location of stop valves is selected upon consideration of convenience in operation and maintenance, such as:

- control of flow to equalize distribution or reduce excessive pressure
- isolation of a section of distribution area
- isolation of in-line facilities like railway, riverbed crossing and pipe-bridge

PWA criteria of 1 km minimum distance is observed.

The location of drain valves is selected upon consideration such as:

- emptying a pipeline in emergency like bursting
- draining wastewater in periodical cleaning works

Air valves are to be located at all the peaks in a pipeline's profile.

6) Fire Hydrant

The location of fire hydrants is selected upon consideration such as:

- existence of nearby natural and/or man-made water like streams, canals swamps, etc.
- characteristics of the area to be protected, for instance, existence of factories handling inflammable matters, congested wooden housings, etc.

7) Anchor Block

To prevent displacement or slip-off of bends and tees, anchor blocks are used where necessary.

6.7 Drinking Water Standard

Tables-6.1 and 6.2 show the PWA Drinking Water Standard of Surface Water Source and of Groundwater respectively.

The treatment facilities, preliminary designed on the basis of the design criteria in 6.5 for processing raw water of two surface water sources of Pattaya, are required to produce treated water conforming to the standard.

Table-6.1 DRINKING WATER STANDARD OF SURFACE WATER SOURCE

PHYSICAL PROPERTIES	MAXIMUM ACCEPTABLE CONCENTRATION (mg/l)	MAXIMUM ALLOWABLE* CONCENTRATION (mg/l)
Color (Platinum Cobalt Unit)	5	15
Taste	unobjectionable	unobjectionable
Odour	unobjectionable	unobjectionable
Turbidity (Silica Scale Unit)	5	20
pH	6.5 to 8.5	not over 9.2
CHEMICAL PROPERTIES		
Total Solids	500	1,500
Total Hardness as $CaCO_3$	300	500 (WHO 1971)
Iron (Fe)	0.5	1.0
Manganese (Mn)	0.3	0.5
Iron an Manganese	0.5	1.0
Copper (Cu)	1.0	1.5
Zinc (Zn)	5.0	15
Calcium (Ca)	75**	200
Magnesium (Mg)	50	150
Sulphate (SO_4)	200	250***
Chloride (Cl)	250	600
Fluoride (F)	0.7	1.0
Nitrate (NO_3)	45	45
Alkyl Benzyl Sulfonates (ABS)	0.5	1.0
Phenolic Substances as Phenol	0.001	0.002
TOXIC SUBSTANCES		
Mercury (Hg)	0.001	
Lead (Pb)	0.05	
Arsenic (As)	0.05	
Selenium (Se)	0.01	
Chromium Hexavalent (Cr)	0.05	
Cyanide (CN)	0.2	
Barium (Ba)	1.0	
Cadmium (Cd)	0.01	

Table-6.1 DRINKING WATER STANDARD OF SURFACE WATER SOURCE (cont'ed)

BACTERIOLOGICAL PROPERTIES	MAXIMUM ACCEPTABLE CONCENTRATION
Standard Plate Count (N/ml)	500
Most Probable Number Coliform Organisms (N/100 ml)	less than 2.2
Escherichia Coli	None

Notes:

* The maximum allowable concentration is allowable for waterworks and well used for human consumption temporarily only and the water property is between the maximum acceptable and maximum allowable and will not be entitled to use the standardized trademark.

** If the Calcium (Ca) is higher than the limit and the Magnesium (Mg) is lower, the standard shall be considerd as Ca and Mg in terms of total hardness. If the total hardness calculation in terms of $CaCO_3$ is lower than 300 mg/l, the water is according to the standard classification of water hardness in the following:

0 - 75 mg/l = Soft water
75 - 150 mg/l = Mean hard water
150 - 300 mg/l = Hard water
up 300 mg/l = Very hard water

*** If the Sulfate value reached 250 mg/l, the Magnesium (Mg) shall not exceed 30 mg/l.

Table-6.2 Drinking Water Standard of PWA (Groundwater)

PHYSICAL PROPERTIES	MAXIMUM ACCEPTABLE CONCENTRATION (mg/l)	MAXIMUM ALLOWABLE CONCENTRATION (mg/l)
Color (Platinum Cobalt Unit)	5	50
Turbidity (Silica Scale Unit)	5	20
pH	7.0 to 8.5	6.5 to 9.2
CHEMICAL PROPERTIES		
Iron (Fe)	0.5	1.0
Manganese (Mn)	0.3	0.5
Copper (Cu)	1.0	1.5
Zinc (Zn)	5.0	15
Sulphate (SO_4)	200	250
Chloride (Cl)	200	600
Fluoride (F)	1.0	1.5
Nitrate (NO_3)	45	45
Total Hardness as $CaCO_3$	300	500
Non Carbonate Hardness as $CaCO_3$	200	250
Total Solids	750	1,500
TOXIC SUBSTANCES		
Arsenic (As)	N.D.	0.05
Cyanide (CN)	N.D.	0.2
Lead (Pb)	N.D.	0.05
Mercury (Mg)	N.D.	0.001
Codmium (Cd)	N.D.	0.01
Selenium (Se)	N.D.	0.01

(N.D. : Not to be detected)

BACTERIOLOGICAL PROPERTIES	MAXIMUM ACCEPTABLE CONCENTRATION
Standard Plate Count (N/ml)	500
Most Probable Number (Coliform Organism/100 ml)	less than 2.2
Escherichia Coli	None

APPENDIX 7

COMPARATIVE STUDY

APPENDIX 7

APPENDIX 7 COMPARATIVE STUDY

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APPENDIX 7 COMPARATIVE STUDY ON LOCATION OF TREATMENT PLANT

7-1.1 Objective

The objective of this study is to select the location of new water treatment plant in the long term development plan, from technical and economical view points. Requirements and conditions to be met in the water supply plan for Ubon and Warin are described in Chapter 7 of the main report.

7-1.2 Basic Figures and Consideration

1) Water Demand of Stage I and Stage II

The following table shows the water demand.(Unit: cu m/d)

Demand Area	Stage I (2000)	Stage II (2010)
Ubon	40,400	60,800
Warin	12,000	18,300
Total	52,400	79,100

The demand in 2000 is more concentrated in Ubon than in Warin.

2) Capacity of Treatment Plant, after Rehabilitation and Modification works

Plant Location	Capacity (cu m/d)
Ubon	18,400
Warin	12,600
Total	31,000

3) Required Additional Capacity to be Developed

Stage	Required Capacity	Remarks
I (2000)	22,000	40,400 - 18,400 (in Ubon only)
II (2010)	26,100	79,100 - 40,400 - 12,600 (in Ubon and Warin)

The required production capacity in Ubon shall be fulfilled by construction of a new treatment plant under the Stage I in Ubon. The plant capacity will be 22,000 cu m/d, though the 600 cu m/d surplus of the Warin plant could be distributed to Ubon area, by the existing pipeline.

4) Water Sources

Presently the Mun River is the source of the Warin plant and the Mun Noi River that of the Ubon Plant. As the new plant(s) is to be located close to the existing, the water sources condition will be unchanged.

7-1.3 Treatment Plant Location

There are several possible locations for the treatment plant(s), including PWA premises of the existing Ubon and Warin treatment plants.

1) Stage I

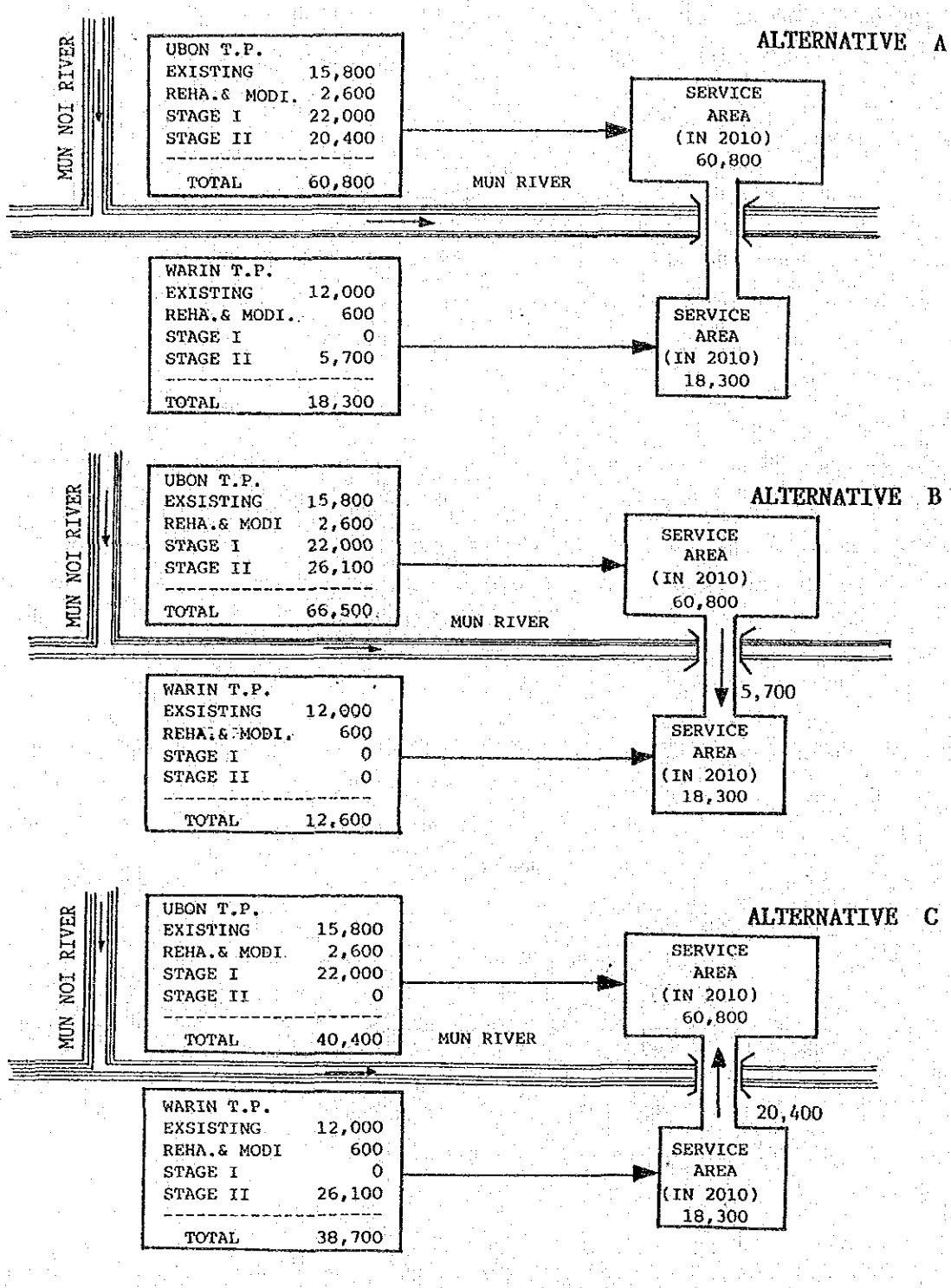
As mentioned before, a 22,000 cu m/d treatment plant shall be located in Ubon area and the site is to be sought near the existing plant for convenience of operation and maintenance.

2) Stage II

After the Stage I completion, the demand and supply capacity in each of Ubon and Warin are balanced. However, the incremental water demand in Ubon and Warin, 20,400 and 6,300 cu m/d respectively, shall be met by construction of treatment plant(s) in any one of the three following alternative plans:

Alternative	Concept and Location of Treatment Plant(s)
A	to supply each area separately by two plants, one 20,400 cu m/d capacity in Ubon and another 5,700 cu m/d (6,300 cu m/d incremental demand less 600 cu m/d surplus) capacity in Warin
B	to supply two areas by one plant, located in Ubon and capacitied for 26,100 cu m/d production
C	to supply two areas by one plant, located in Warin and capacitated for 26,100 cu m/d production

In the alternatives B and C, a pipeline for exclusive use of transmission is needed to deliver water to the opposite side service area of the Mun River, so as not to disturb the distribution pressure balance. The three alternatives are shown in Fig-7.1 schematically.



Unit : cu m/day

FIGURE 7.1	ALTERNATIVE PLANS

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Major facilities and total costs of the three Alternatives are presented in Table 7.1. However, the costs for distribution pipelines are excluded, since those costs are considered almost equal in all Alternatives.

Table-7.1 FACILITIES AND CONSTRUCTION COST

Item	Alternative A	Alternative B	Alternative C
1. Land Acquisition	10,000 sq m	15,000 sq m	*
2. Treatment Plant	20,400 cu m/d Ubon and 5,700 cu m/d in Warin	26,100 cu m/d in Ubon	26,100 cu m/d in Warin
3. Transmission Pipe	-	Dia.400mm x 9,000m	Dia.600mm x 8,000m
Total cost (x 1,000 Baht)	64,500	105,000	96,300

* land space available in the present plant site

The difference of pipeline length and diameter comes from the difference of flow rate delivered across the river. The transmission pipeline of Alternative B or C contains three river crossings, 200 m long in total, and at the Mun River crossing, the existing 250 mm dia. pipeline, installed on the bridge structure, is planned to be replaced by the new pipeline of above mentioned size.

As to the operation and maintenance cost, the three alternatives treat similar quality raw water employing similar process and no substantial difference will be incurred. Power consumption difference will be slight assumedly. O & M cost was not taken up for comparison, therefore.

7-1.4 Conclusions

In the Stage I, a capacity of 22,000 cu m/d treatment plant is proposed for construction at a site near the existing Ubon water treatment plant.

In the Stage II, a 20,400 cu m/d treatment plant in Ubon and the another at 5,700 cu m/d plant in Warin are proposed, as the Alternative A is lowest in the construction cost and possibly best in balancing the two area's distribution pressure. The two plants are to be located near the existing plant.

APPENDIX 7-2 COMPARISON OF UNIT PRICE AND COST OF WATER BETWEEN PWA AND PRIVATE FACILITIES

7-2.1 Basic Assumptions

1) Water Volume

This study of comparison was made of comparatively large sized consumers, whose monthly consumption volumes range at 50, 100, 200, 300, and 400 cu m per day.

2) PWA Price

The PWA price of water is assumed to include water tariffs, service charges and connection fees. Connection fees which are chargeable for the connection work prepared by PWA at the initiation of PWA service are assumed to be distributed to the PWA price of water for 20 years by equal monthly lot.

3) Cost of Water Produced by Private Facilities

Cost is assumed to include operation and maintenance cost, together with capital investment for construction of facilities. Investment cost is distributed for 240 months in terms of monthly depreciation.

7-2.2 Unit Cost of Water by Private Facilities

Raw water assumed to be lifted by a submersible pump, disinfected by dosed bleaching powder and, lifted to an elevated tank with the remaining pressure.

The details of the assumed facilities are shown in Table-7.1.

a. Water Source : deep well, 50 meter depth

b. Location of Well : in Ubon and Warin Municipalities

c. Raw Water Quality : 3.5 mg/l or less iron,
2.0 mg/l or less NH3-N
(medium values of varying data collected from existing wells)

d. Treatment Process : Oxidation of iron by breaching powder, filtration, disinfection by chlorine, by the dosed bleaching powder

e. Treatment Capacity : 50, 100, 300, 400 cu m/d

Construction Cost

Submersible pumps are assumed to be imported, but their installation and construction of wells, pipeworks and erection of elevated tanks are assumed to be made locally.

O/M costs

- a person is assumed to engage in the operation and maintenance of the system for 1.5 hr per day, doing other works in the remaining hours.
- repair cost is estimated at 0.5 % of the construction costs.
- electricity cost is estimated with 24 hrs' run throughout the year.
- 20 mg/l dosage of bleaching powder containing 30 % effective chlorine is assumed to be dosed constantly.

Table-7.1 PRIVATE WELL FACILITIES

Item	No.	50 cu m/d capacity Description	100 cu m/d capacity Description	300 cu m/d capacity Description	400 cu m/d capacity Description
1) Deep Well dia. x depth	1	125 mm x 50 m	125 mm x 50 m	200 mm x 50 m	200 mm x 50m
2) Submersible Pump dia. x capacity x head x motor rating	1	40 mm x 0.04 cu m/min 25 m x 1.1 KW	40 mm x 0.07 cu m/min 25 m x 1.1 KW	50 mm x 0.21 cu m/min 25 m x 2.2 KW	50 mm x 0.28 cu m/min 25 m x 2.2 KW
3) Pump House width x length	1	brick, 4 m x 4 m	brick 4 m x 4 m	brick, 4 m x 4 m	brick, 4 m x 4 m
4) Treatment Capacity	1	50 cu m/d	100 cu m/d	300 cu m/d	400 cu m/d
5) Elevated Tank Capacity	1	5 cu m	10 cu m	30 cu m	40 cu m
6) Pipeworks	L.S.	1 set, incl. pipes, valves, fittings	1 set, incl. pipes, valves, fittings	1 set, incl. pipes, valves, fittings	1 set, incl. pipes, valves, fittings
7) Miscellaneous Works	L.S.				

Note:
L.S. : lump sum
Treatment system incl. filter, bleaching powder feeding, backwash pump

Unit Cost of Water

The construction costs are distributed in equal monthly depreciation allowances for 20 years, and with the depreciation allowances and monthly O/M costs, unit (cubic meter) water cost is estimated as shown in Table-7.2.

Table-7.2 UNIT COSTS OF WATER, PRIVATE WELL

Item	Production Capacity (m3/d) 50	100	300	400
1. Construction Cost				
- Amount of Investment (x 1,000 Baht)	2,794	2,915	3,280	3,437
- Monthly Depreciation (20 years, Baht/month)	11,640	12,150	13,670	14,320
2. O/M Cost (Baht/month)	5,250	6,580	13,500	17,670
3. Monthly Cost (Baht/month)	16,890	18,730	27,170	31,990
4. Unit Cost of Water (Baht/m3)	11.26	6.24	3.02	2.67

7-2.3 Unit Price of Water by PWA

As the study is made on consumption volumes of 50 cu m per day or more, the water tariff is assumed to be charged at a flat rate of 8.5 Baht/cu m, together with service charges and connection fees as described in Table-7.3 below.