3.6.2 Groundwater Evaluation

The most productive aquifer in the Suphanburi area is the recent alluvium lying along the floodplains of Suphanburi river. Most deepwells drilled in the floodplain are under artesian conditions, due to the existence of thick clay, sand and gravel confining clay layers, and their yields are usually in the range of 2,000-3,000 cu m/day.

Many deep wells are used by the large water-consumers like hospitals, hotels, restaurants and temples. The aquifers lying 100 to 150 m underground can yield water sufficiently, 2,000 to 3,000 cu m/day per unit.

The analysis of collected samples in the existing 24 deepwells in the area indicates that the main aquifers are the Phra Pradaeng 100 m Aquifer and Nokhon Luang 150 m Aquifer. In addition to the above main aquifers, the Bangkok Lower 50 m Aquifer and Sam Khok 250 m Aquifer are also identified. The well depth ranges from 46 m to 277 m and the piezometric water level from 2 m to 15 m. Specific capacity is ranging from 1 to 1080 cu m/day/m, indicating very high potentiality of the Phra Pradaeng 100 m Aquifer. (Table-3.3)

The quality of groundwater is usually good for public water supply, domestic and other uses. Table-3.3 summarizes the water quality of the wells. In it, a well indicates high concentration of chloride and iron.

Fig-3.8 shows well log and well design of the PWA production well constructed in 1985 newly, and Fig-3.9 illustrates the Drawdown - Discharge Curve based on pumping test data. The critical point has been observed at the 100 cu m/hr (2,400 cu m/day) and drawdown about 10 m. The drawdown of the well is somehow high rated.

Based on the field survey and hydrogeological interpretation, the prospective aquifer systems in Suphanburi area were concluded in Table-3.4. There are 4 main aquifer systems which have been identified, namely the Bangkok Lower (50 m), Phra Pradaeng (100 m), Nakhon Luang (150 m) and Sam Khok (250 m) Aquifers.

Table-3.3 HYDROGEOLOGICAL EVALUATION OF DEEPWELLS

WELL NUMBER	DRILLING YEAR	TOTAL DEPTH (m)	PLUG(s) SET (m)	CASING USED (Inch) -(m)	RESULTS	STATIC WATER LEVEL (m)	Q YIELD (m3/day)	As DRAW-Down (m)	Specific Capacity (m3/d/m)	AQUIFER(s) DEPTH (m)	AQUIFER SYSTEM	pH	IRON ppm.	CHLORIDE ppm.	TOTAL DISSOLVED SOLID ppm.	TOTAL HARDNESS AS $CaCo_3$ ppm.	DATE METHOD OF
1	1979	137	-	-	Aban.	-	-	-	-	-	-	-	-	Salty	-	-	-
2	1979	198	-	6"-198	(Hand P.)	13.4	109	13.7	8.0	164-168 170-174	Nakhon Luang (150 m)	-	-	-	-	-	-
3	1979	277	268-277	6"- 88 5"-139	(Hand P.)	4.8	1,214	13.1	92.7	159-268	Nakhon Luang Sam Khok	8.6	0.19	13	579	32	1979
4	1979	152	138-152	5"-139	(Hand P.)	Flow	144	18.2	7.9	131-137	Nakhon Luang (150 m)	-	-	-	-	-	-
5	1979	46	-	5"- 46	(Hand P.)	-	55	42.6	1.3	36- 43	Bangkok (L) (50 m)	8.1	13	146	1,262	170	-
6	1980	271	225-271	6"-265	(Hand P.)	5.6	1,260	17.2	73.3	253-265	Sam Khok (250 m)	8.6	0.5	11	628	28	1981
7	1980	338	-	-	Dry	-	-	-	-	-	-	-	-	-	-	-	-
8	1980	204	42-204	5"- 42	(Hand P.)	4.0	109	20.6	5.3	30- 42	Bangkok (L) (50 m)	7.3	0.7	55	960	150	1981
9	1980	152	149-152	6"-149	(Hand P.)	4.5	171	21.1	8.1	140-146	Nakhon Luang (150 m)	8.5	1.6	16	308	37	1981
10	1981	177	106-177	5"-106	(Hand P.)	2.5	391	1.9	205.8	91-104	Phra Pradaeng (100 m)	8.2	0.1	63	326	70	1981
11	1981	125	94-124	6"- 94	(Hand P.)	3.1	1,634	-	-	85- 92	Phra Pradaeng (100 m)	8.3	0.2	41	248	112	1981
12	1985	150	120-150	12"- 91 8"- 91	Submers-ible P.	6.0	3,600	12.6	285.7	93-105 108-117	Phra Pradaeng -Nakhon Luaung	7.8	0.1	10	210	84	1985
13	1973	131	-	6"-131	Good	2.2	576	14.8	38.9	121-127	Nakhon Luang (150 m)	-	0.1	24	-	110	-
14	1976	116	-	6"- 30	Good	2.5	936	7.5	124.8	106-113	Nakhon Luang (150 m)	-	0.3	5.5	-	92	-
15	1977	98	-	6"- 31	Good	14.8	72	7.0	10.3	82- 94	Phra Pradaeng (100 m)	-	0.2	13	-	104	-
16	1978	144	-	-	Dry	-	-	-	-	-	-	-	-	-	-	-	-
17	1978	80	-	6" - 79	Good	3.5	336	8.0	42.0	76- 82	Phra Pradaeng (100 m)	-	0.1	11	-	60	-
18	1981	99	-	6"- 99	Good	5.0	432	3.0	144.0	90- 96	Phra Pradaeng (100 m)	-	0.1	6	-	70	-
19	1982	160	-	-	Dry	-	-	-	-	-	-	-	-	-	-	-	-
20	1982	107	-	-	Dry	-	-	-	-	-	-	-	-	-	-	-	-
21	1982	154	-	-	Dry	-	-	-	-	-	-	-	-	-	-	-	-
22	1982	100	-	6"-100	Good	3.0	432	0.8	540.0	90- 97	Phra Pradaeng (100 m)	-	-	24	-	118	-
23	1983	99	-	6"- 94	Good	7.0	432	0.4	1,080.0	93-100	Phra Pradaeng (100m)	-	0.1	5	-	80	-
24	1983	102	-	-	Aban.	-	-	-	-	-	-	-	-	Salty	-	-	-
												6.5 -9.2	0.5 -1.0	200 -600	500 -1,500	0 -300	WHO

DATA: PWA, PWD and DMR

SUPHANBURI , PWA PRODUCTION WELL , 1985

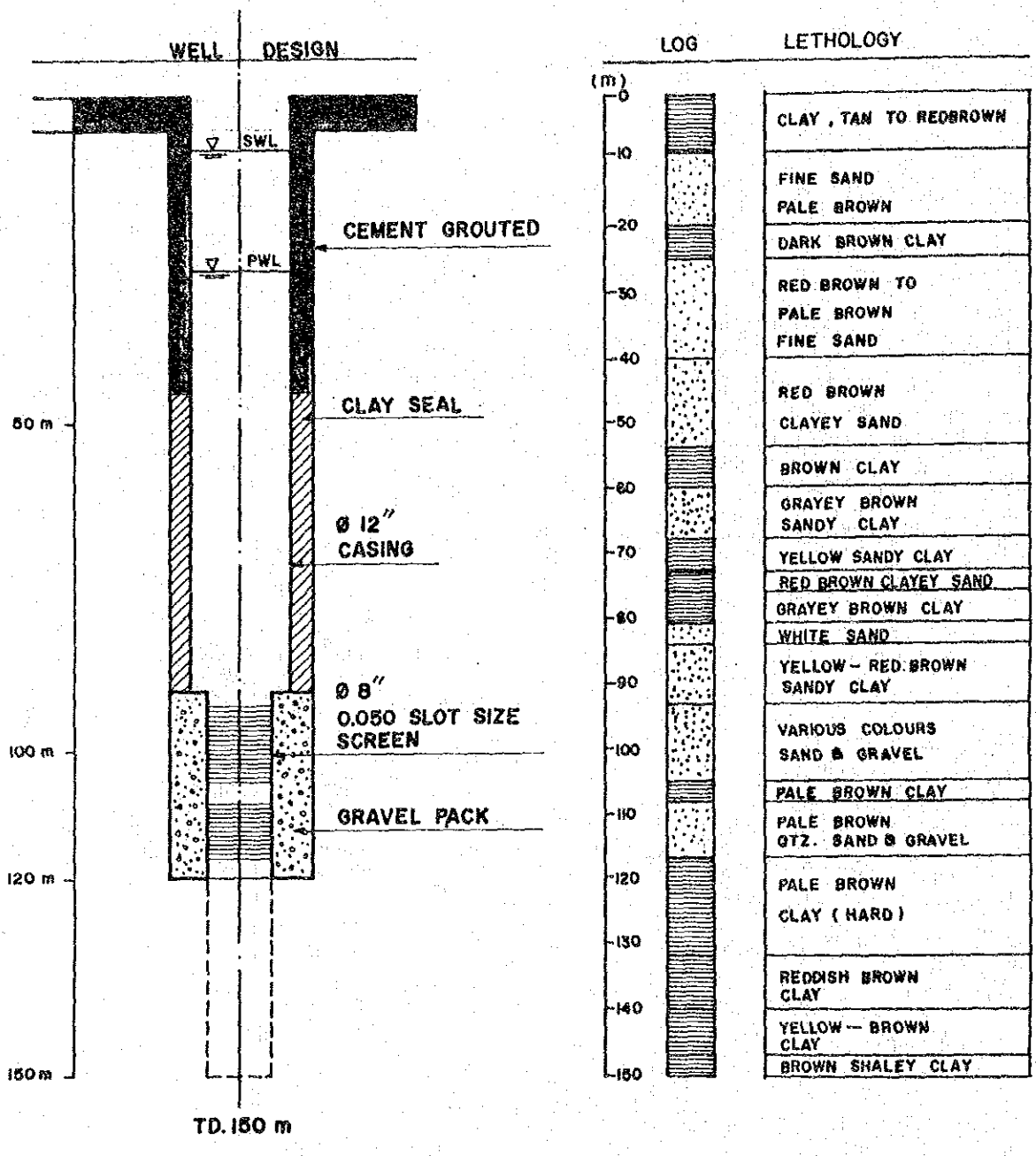

FIGURE	SUPHANBURI, PWA PRODUCTION WELL, 1985
3.8	

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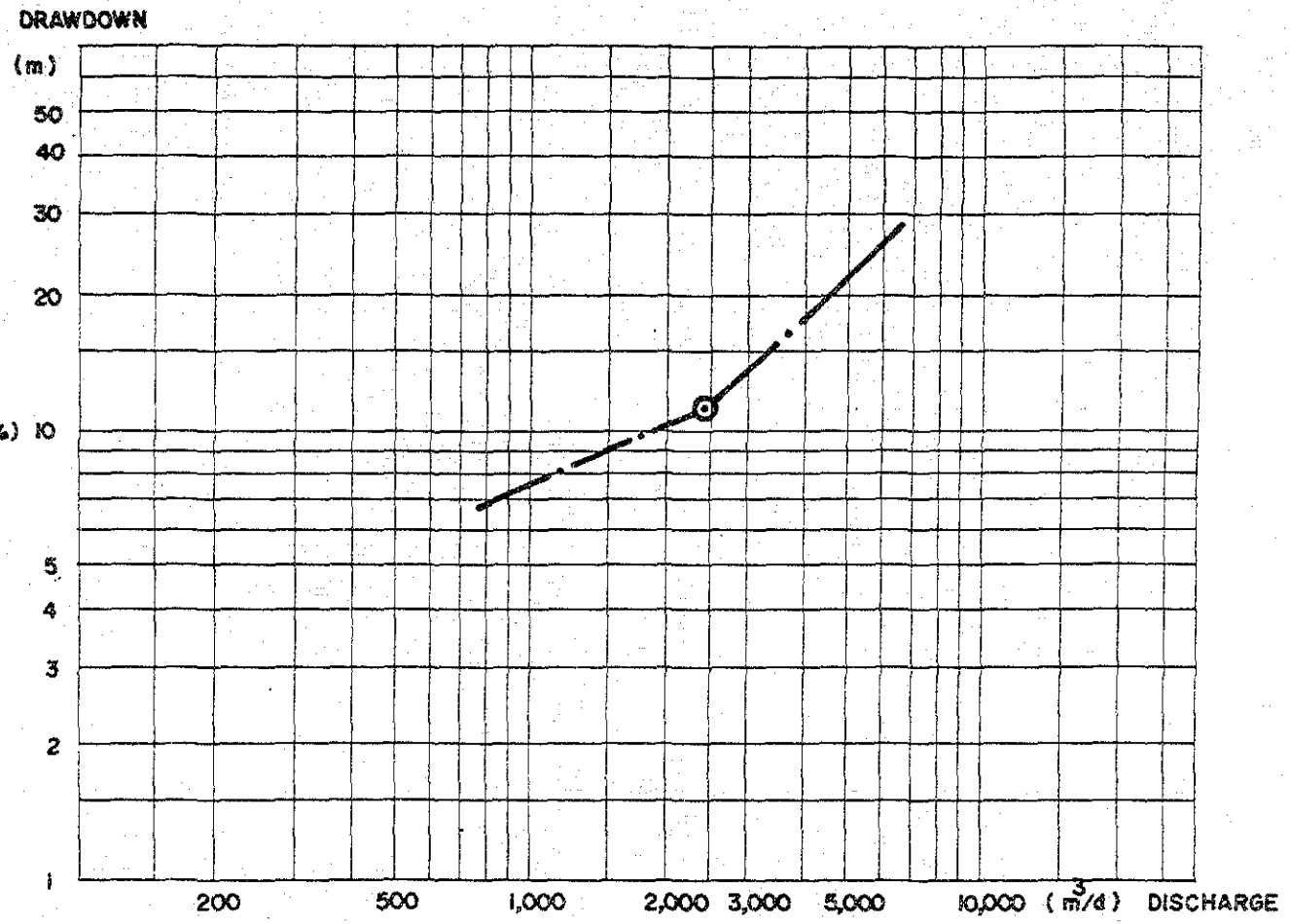
DRAWDOWN – DISCHARGE CURVE AT SUPHANBURI



CRITICAL POINT

DISCHARGE = 2400 m^3/d

DRAWDOWN = 11.5 m.

SUSTAINABLE YIELD

Q = 2400 m^3/d x(80~90%)

ΔS = 10 m.

AQUIFER LOSS 0.375

WELL LOSS 7.66×10^{-6}

WELL EFFICIENCY 90.7 %

DATA , PWA , 1985

FIGURE	DRAWDOWN DISCHARGE CURVE AT SUPHANBURI
3.9	
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table-3.4 PROSPECTIVE AQUIFER SYSTEM IN SUPHANBURI

Aquifer System	Aquifer Depth (m)	Mean Piezometric Level (m)	Mean Specific Capacity ($m^3/d/m$)	Expected Drawdown (m)	Potential Production (m^3/d)	Water Quality				
						pH	Iron (ppm)	Chloride (ppm)	T-Solid* (ppm)	T-Hardness** (ppm)
Bangkok Lower (50m)	30 - 43	4.0	5.3	10	53	7.3 - 8.1	0.7 - 13	55 - 146	960 - 1,262	150 - 170
Phra Pradaeng (100m)	76 - 105	5.9	330	10	3,300	7.8 - 8.3	0.1 - 0.2	5 - 63	210 - 326	60 - 118
NaKhon Luang (150m)	108 - 174	4.8	80.9	10	809	8.5	0.1 - 0.3	5.5 - 16	210	37
Sam Khok (250m)	253 - 268	5.2	83	10	830	8.6	0.2 - 0.5	11 - 13	579 - 628	28 - 32
					WHO Water Standard	6.5 - 9.2	0.5 - 1.0	200 - 600	500 - 1,500	0 - 300

** Total Hardness as $CaCO_3$
* Total Dis-Solved Solid

DATA : PWA,PWD,DMR

The top lying Bangkok Lower (50 m) Aquifer indicates high iron contents, ranging from 0.7 to 13 ppm, and comparatively high concentration of chloride, total dissolved solid and total hardness.

The other three aquifers show good quality in general, suitable for public supply, domestic and other uses.

The most productive aquifer, the Phra Pradaeng (100 m) Aquifer, indicates 3,300 cu m/d potential productivity with 10 m drawdown. The depth is expected to range from 76 to 105 m and the mean piezometric level is 5.9 m below the ground surface. The Nakhon Luang (150 m) and Sam Khok (250 m) Aquifers also indicate relatively high potential productivity of 809 to 830 cu m/d, respectively. However, only a few existing wells tap the Sam Khok Aquifer as it is very deep, ranging from 253 to 268 m.

Consequently, the most promising aquifers to be aimed at in groundwater development of the area will be both of the Phra Pradaeng and Nakhon Luang.

Fig-3.10 illustrates the hydrogeological fence diagram of Suphanburi area, especially groundwater development field, and Fig-3.11 concludes the prospective well locations in the Suphanburi area. They are located along the Suphanburi River and the left bank of the river.

Along the terraces on the west bank of the Suphanburi River, wells yielding small output are located, but where thick clay sediments underlies, no water is found in some wells.

Conclusively, the recommendable area for groundwater development in future is located in the east side and along the Suphanburi River, and almost all of the future service area shown in Fig-3.11 including the Phophraya Treatment Plant site are covered with the aforenamed area.

HYDROGEOLOGICAL FENCE DIAGRAM OF SUPHANBURI

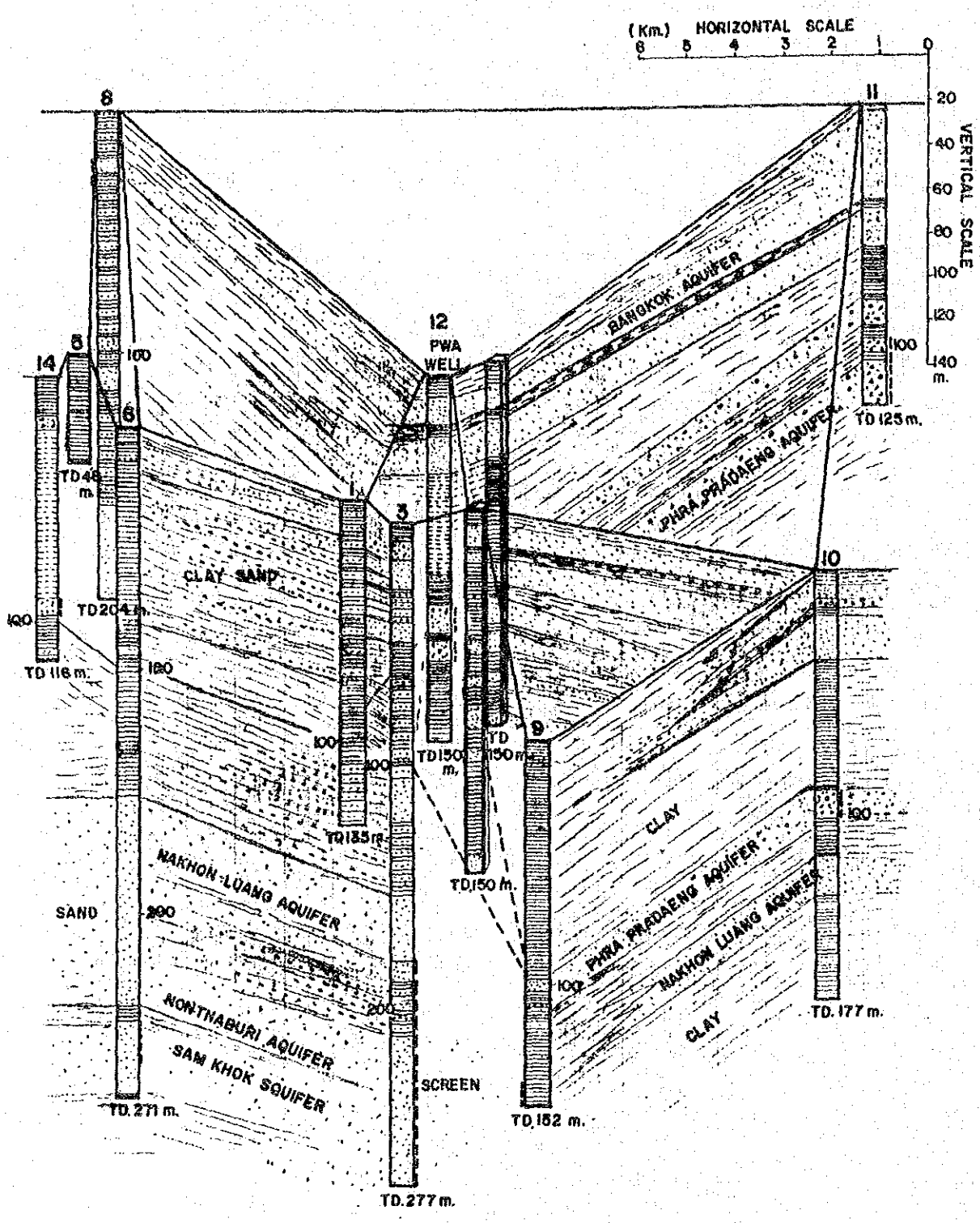


FIGURE	HYDROGEOLOGICAL FENCE DIAGRAM OF SUPHANBURI
3.10	

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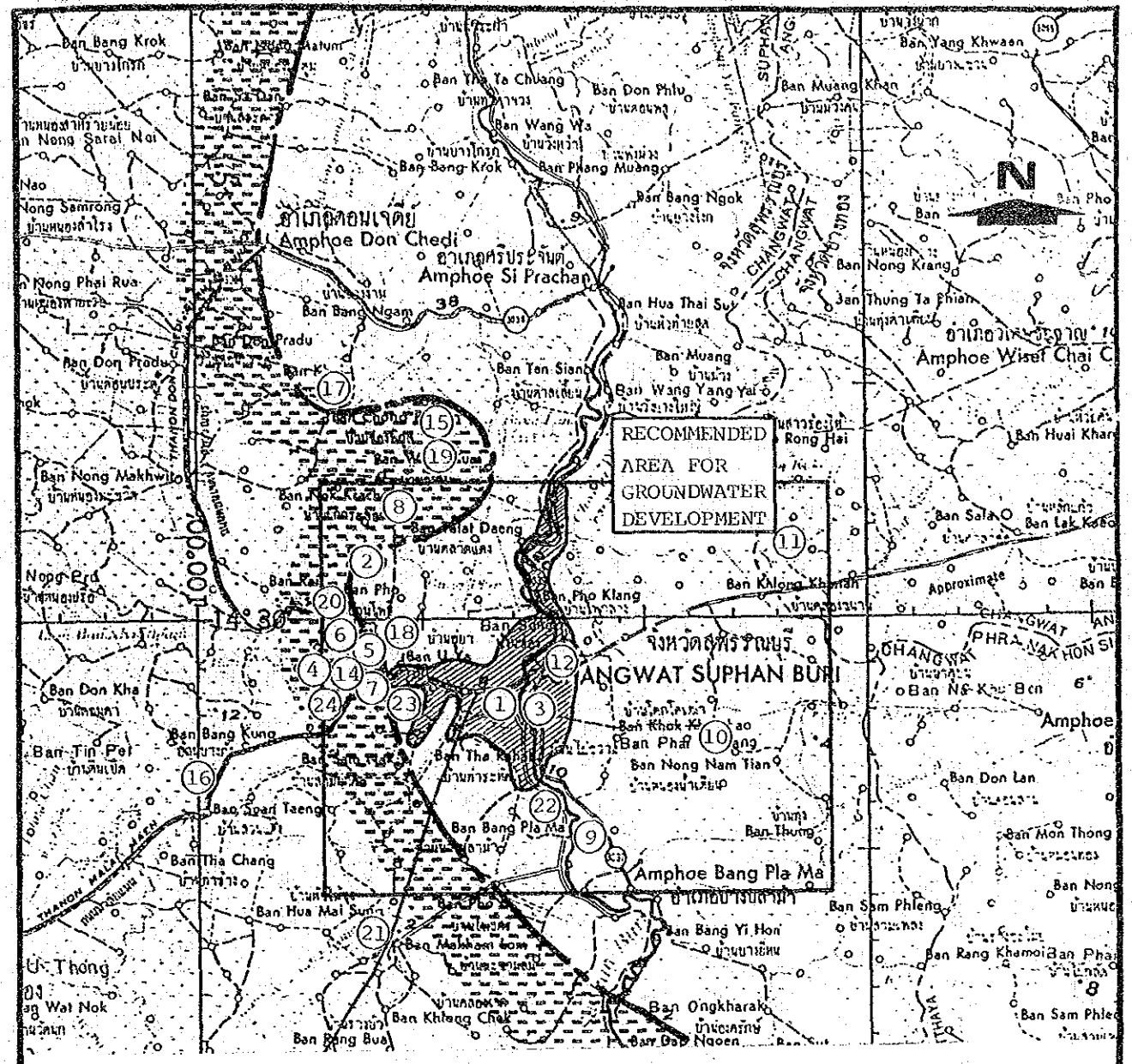

LEGEND

: Groundwater High Potential Area (2,000 to 3,000 m3/d)

: Groundwater Less Potential Area (0 to 500 m3/d)

: Future Service Area

: Location of Deep Well

FIGURE	GROUNDWATER POTENTIAL IN SUPHANBURI
3.11	

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3.7 Water Resources Development plan

Fig-3.12 concludes the existing water source and water resources development plan up to the year of 2010.

I. Present Water Source (1986)

1) Suphanburi River (Phophraya Treatment Plant) = 4,800 cu m/day
2) Groundwater (Deep well, Dab Fafhun) = 2,000 cu m/day

II. Water Source Development (up to 2010)

To meet the 2010 demand, 7,900 cu m/d shall be produced, additionally to the existing 6,800 cu m/d production of the two sources, as mentioned above.

As both of the surface and groundwater sources are available, a comparative study has to be made on the below:

1) expanding the Phophraya Plant's capacity, or
2) constructing new wells

The well construction alternative was found to be far economical than the plant expansion, in both of the investment and operation/maintenance cost. Therefore, deep well construction is planned for the future water source development.

The conditions of the wells planned for construction will be as follows:

a) Well Diameter : ϕ10"
b) Drilling Depth : 150 m
c) Target Aquifer : Phra Pradaeng (100 m) and Nakhon Luang (150 m)
d) Well Yield : Around 2,000 cu m/day
e) Piezometric leve : About 5 m
f) Drawdown : About 10 m

WATER RESOURCES DEVELOPMENT PLAN OF SUPHANBURI

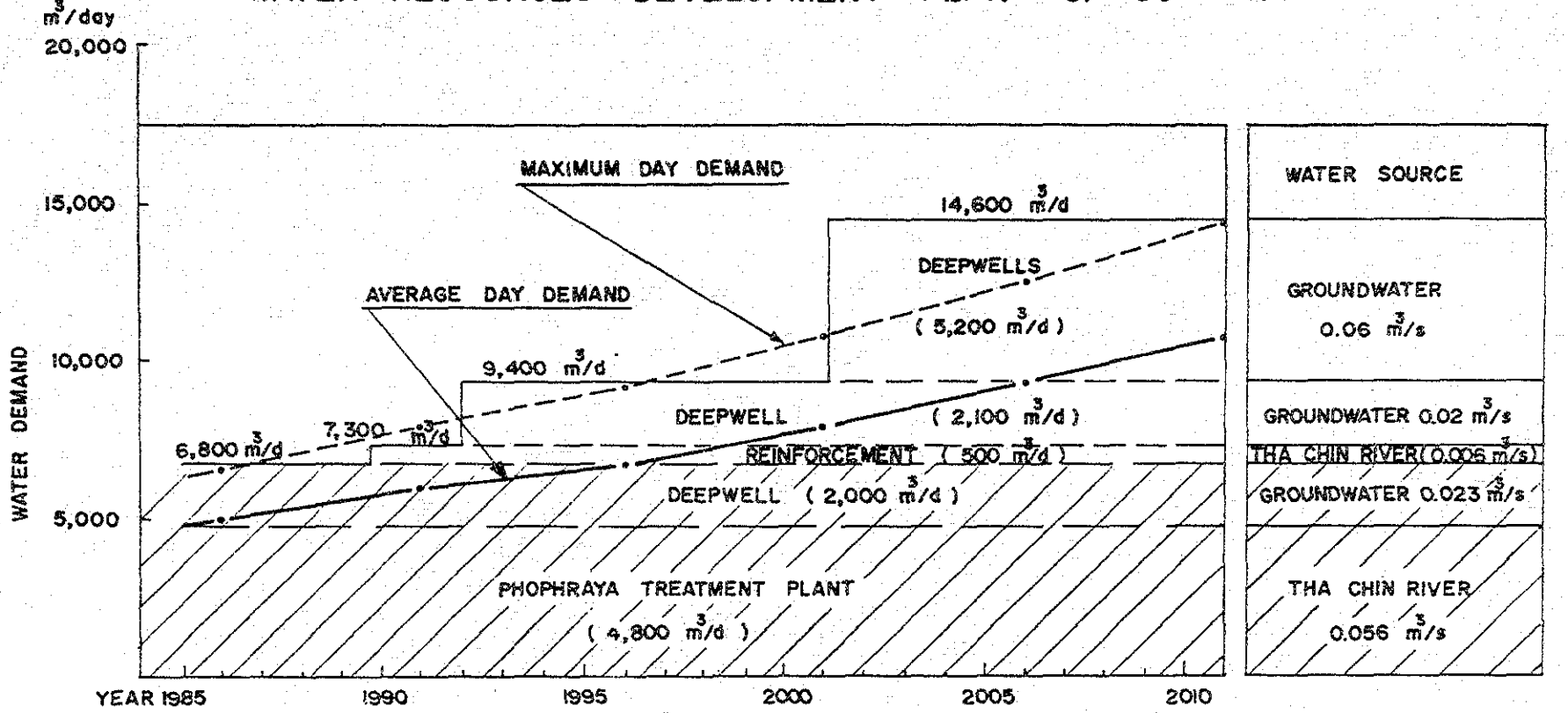

FIGURE	WATER RESOURCES DEVELOPMENT PLAN
3.12	OF SUPHANBURI

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The recommendable groundwater development program is as follows. The deepwells are to be located in the Suphanburi area where high density water demand, as shown in Fig-3.13, is foreseen.

1) The Year of 2000

Groundwater (Deep well)	=	@ 2,100 cu m/d x 2 wells
	=	4,200 cu m/d

2) The Year of 2006

Groundwater (Deep well)	=	@ 1,800 cu m/d x 2 wells
	=	3,600 cu m/d

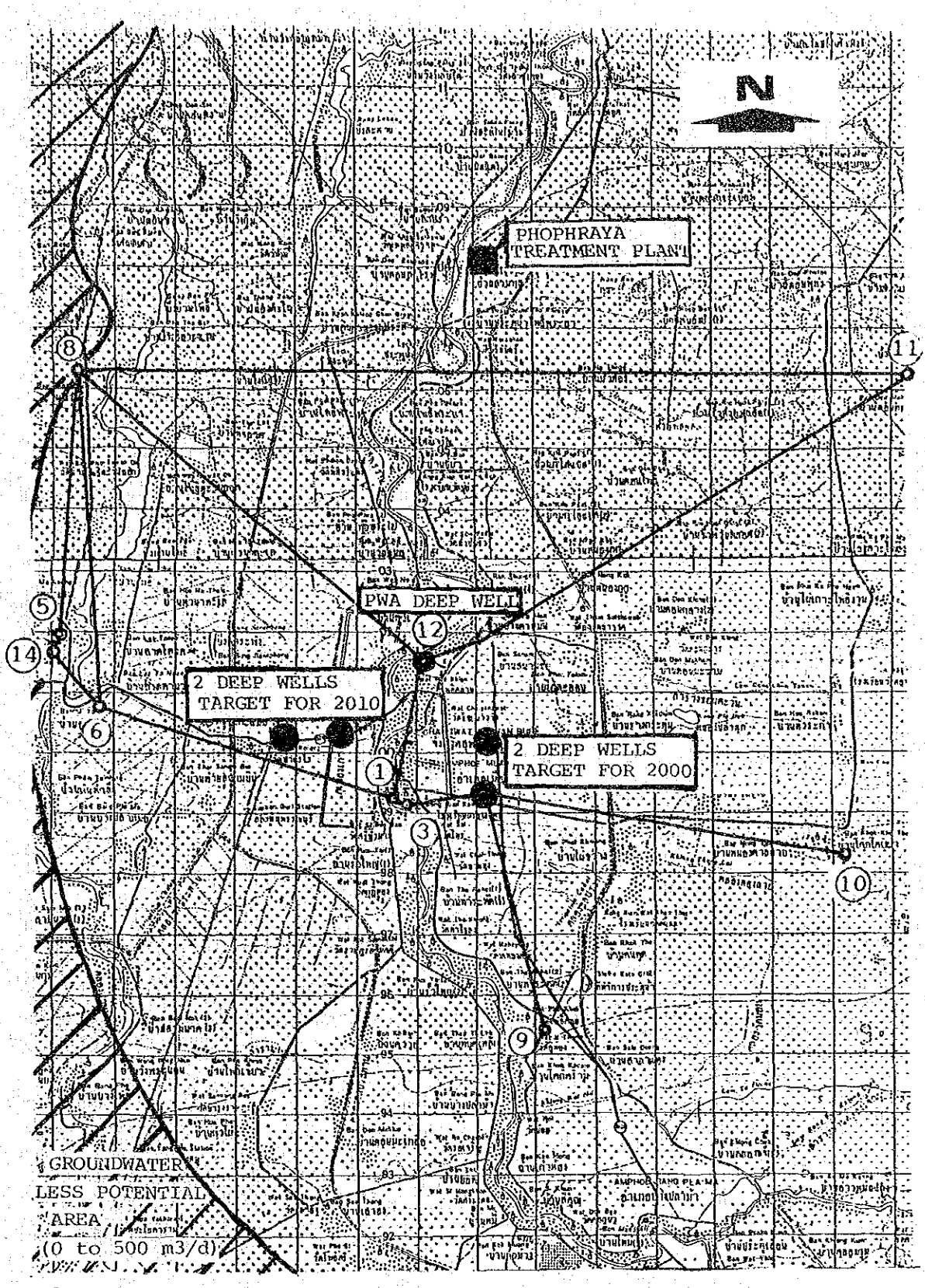

FIGURE	GROUNDWATER DEVELOPMENT IN SUPHANBURI
3.13	

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3.8 List of References

1) PWA, Wellcon, 1985
Summary Data Of Production Well, Suphanburi

2) SEATCE, March 1978
Water Balance Study for Chao Phraya and Mae Klong River Basin
Main Report, NESDB, EGAT, RID

3) PWD, 1985
Records of Wells in Suphanburi

4) MWA, NSC, July 1982
Review of 1970 Master Plan and Present System and Preparation of
Detailed Design of Stage II Water Improvement Program,
Working Paper No. 2, Groundwater Study

5) Lutfor Rahman Khan, AIT, 1976
Safe Yield of Bangkok Aquifers

6) Asian Institute of Technology, Department of Mineral Resources
"Groundwater Resource in Bangkok Area - Development and Management Study"
Report prepared for the Office of National Environment Boad
1978 - 1981

7) Sopit Sodsri, AIT, April 1978
Geohydrology of the Chao Phraya Basin with Respect to Subsidence

8) Ch. Piancharoen, Ch. Chuamthaisong, 1978
Groundwater of Bangkok Metropolis, Thailand
International Association Hydrogeologist XI, pp.510 to 528

9) National Statistical Office, 1983
Statistical Report of Changwata, Suphan Buri

10) NEA (National Energy Adominstration, Ministry of Science), 1983
1981 Hydrologic Data Vol-I (River Discharge)
1981 Hydrologic Data vol-II (Meteologic Data)

11) RID Nov. 1983
Thailand Hydrological Yearbook, Water Year Vol-24

12) EGAT, July 1985
Guide Book for Accessing Hydrologic Data

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

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

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

16) Royal Thai Survey Department, 1974
Hydrography (Atlas of Thailand)
Mean Monthly Discharge (1951-1970)

17) Royal Thai Survey Department, 1974
Daily Discharge of the Major Rivers, 1965/66-1969/70
-Ping River at Ban Tha Sala, Chiang Mai
-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 Water Sources for Suphanburi Waterworks

Tha Chin River

The results of water quality analysis of the Tha Chin River, are shown in Table-4.1. The water is treated by the Phophraya Treatment Plant.

1) Characteristics of water

a) Color

The value, usually ranging from zero to 30 Pt-Co units, is low to moderate, though an exceptionally high 88 Pt-Co units was recorded in December 1984.

b) Turbidity

The values range from 4 to 58 SiO2 units by PWA and 11 NTU by the study team. It tends to fall in the dry season.

c) pH

The value ranges from 7.0 to 8.3 and satisfies DWS.

d) Alkalinity

The value ranges from 66 to 96 mg/l as CaCO3, showing a small fluctuation through the year.

e) Hardness

The value, ranging from 66 to 122 mg/l as CaCO3, is moderate.

f) Iron and Manganese

The value ranges from 0.21 to 2.59 mg/l for iron and from nil to 0.1 mg/l for manganese. Iron tends to increase in the rainy season and exceeds DWS sometimes. However,iron can be controlled to fall within DWS, through the conventional treatment process such as coagulation, sedimentation, filtration and disinfection.

Table-4.1 WATER QUALITY OF THE THA CHIN RIVER

Item	Year 1984/85 Month Unit	10	11	12	1	2	4	5	6	9	10	PWA STANDARD
Color	Pt·Co units	none	none	88	4	6	6	6	4	20	16	5
Turbidity	SiO2 units	38	46	9	4	11	14	58	54	50	20	5
pH		7.8	8.2	7.8	8.3	7.6	7.8	7.4	7.7	7	7.3	6.5-8.5
Conductivity	micromhos/cm	150	165	196	198	168	185	150	165	185	151	-
Total solids	mg/l	122	245	98	119	112	145	144	177	150	137	500
Alkalinity	mg/l as CaCO3	68	82	84	86	74	78	68	68	70	66	-
Hardness	mg/l as CaCO3	66	92	100	86	78	76	78	86	122	66	-
A B S	mg/l	0.06	-	-	-	-	-	-	-	-	-	0.5
Calcium	mg/l	21	29	26	24	26	19	19	19	24	16	75
Magnesium	mg/l	3.4	4.8	8.6	6.2	2.9	6.7	2.4	9.1	15	6.2	50
Iron	mg/l	2.1	1.78	0.31	0.21	0.45	2.59	1.44	1.98	1	2.5	0.5
Manganese	mg/l	nil	0.08	nil	0.01	nil	nil	nil	nil	0.1	0.1	0.3
Chloride	mg/l	8	6	9	11	9	7	8	9	12	8	250
Sulfate	mg/l	2	3.5	0.8	2.5	1.5	1.7	1.5	4	6	2	200
Copper	mg/l	0.041	0.025	nil	0.009	0.019	0.025	0.044	0.055	-	0.035	1
Zinc	mg/l	0.15	nil	0.12	0.02	nil	nil	nil	0.22	0.9	0.03	5
Fluoride	mg/l	0.39	0.47	nil	0.22	0.29	0.25	0.46	0.11	-	nil	0.7

DATA SOURCE : PWA

Item	Unit		PWA STANDARD
Date		11/1/'86	-
Temperature	°C	24.8	-
Color	Pt·Co units	30	5
Turbidity	N T U	11	5
pH		7.62	6.5-8.5
Conductivity	micromhos/cm	215	-
Alkalinity	mg/l as CaCO3	96	-
Hardness	mg/l as CaCO3	80	-
Calcium	mg/l	24.8	75
Magnesium	mg/l	4.4	50
Iron	mg/l	0.26	0.5
Manganese	mg/l	<0.1	0.3
Chloride	mg/l	5	250
Sulfate	mg/l	<2	200
Ammonia-N	mg/l	<0.2	-
Coliform group	N/100ml	3500	<2.2
Total colonies	N/ml	>300	500

DATA SOURCE : STUDY TEAM

g) Organic pollution

3,500 N/100 ml coliform group was counted in a sample studied by the team in November 1985. Ammonia and Chloride of the sample were low, however. Pollution has not reached a serious level yet, conclusively. The water can be treated to pass DWS through a conventional treatment process.

2) Evaluation

The Tha Chin River water, the raw water of the Phophraya Treatment Plant, presents no qualitative problem for drinking, after having been treated appropriately by the conventional treatment system of the plant.

Dab Fafhun Deep Well

A deep well was recently constructed in the Dab Fafhun Treatment Plant site which had been put out of operation.

The result of water quality analysis of groundwater in the Dab Fafhun Deep Well is shown in Table-4.2.

From the results it can be derived that the groundwater is of good quality, i.e.,has 1) low turbidity and no color, 2) satisfactory pH, 3) moderate hardness, 4) low iron and manganese contents and 5) low chloride and sulfate contents.

No treatment is needed for processing the well water for drinking, chlorination for disinfection and maintenance of residual chlorine in the distribution system.

4.1.2 Other Sources

Groundwater drawn from deep wells, mostly more than 100 m deep, is used especially by large consumers, like hotels and hospitals, in the service area. In the unserved area also, deep well water is utilized by people for drinking.

บริษัท วิศวการรมเคมี จำกัด
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243 3rd. Fl. Sub Road, Siphya, Bangkok 10500
☎ 2359286-9

Date May 27, 1985

No. 978-28

Table-4.2 **WATER ANALYSIS REPORT**

Messrs: เวลล์คอน (การประปาสุพรรณบุรี) Sampling Date May 24, 1985

Reference Number		WP/KM 523	Standard	
Item \ Sample		น้ำบาดาล	Drinking Water	
Turbidity	(NTU)	0.08	5-20	
Color	(UNIT)	nil	5-15	
pH		7.78	6.5-9.2	
Specific Conductivity	(μ℧/cm)	349.5	700-2200	
Total Dissolved Solid	(ppm as NaCl)	209.7	500-1500	
P-Alkalinity	(ppm as $CaCO_3$)	nil	nil	
M-Alkalinity	(ppm as $CaCO_3$)	200	30-500	
Total Hardness	(ppm as $CaCO_3$)	84	0-300	
Total Iron	(ppm as Fe)	0.03	0.5-1.0	
Chloride	(ppm as Cl)	10	200-600	
Sulfate	(ppm as SO_4-)	trace	200-250	
Silica	(ppm as SiO_2-)	37.05	-	
Phosphate	(ppm as PO_4-)	-	-	
Ca-Hardness	(ppm as $CaCO_3$)	54	0-200	
Manganess	(ppm as Mn^{2+})	trace	0.1-0.5	

Remark: ตัวอย่างน้ำนี้ใช้อุปโภคและบริโภคได้

DATA SOURCE : PWA

The sampling points of groundwater which were surveyed are shown in Fig-4.1 with the result of analysis in Table-4.3.

All deep wells water sampled by the study team is very good in quality. Especially, the 100 to 140 m depth water is better than the deeper well's of 264 m depth i.e., moderate pH, lower conductivity. When deep well water is used for potable water, however, disinfection by chemicals or boiling should be provided to protect from possible contamination.

4.2 Treated Water

4.2.1 Existing Conditions

Phophraya Treatment Plant

Table-4.4 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.

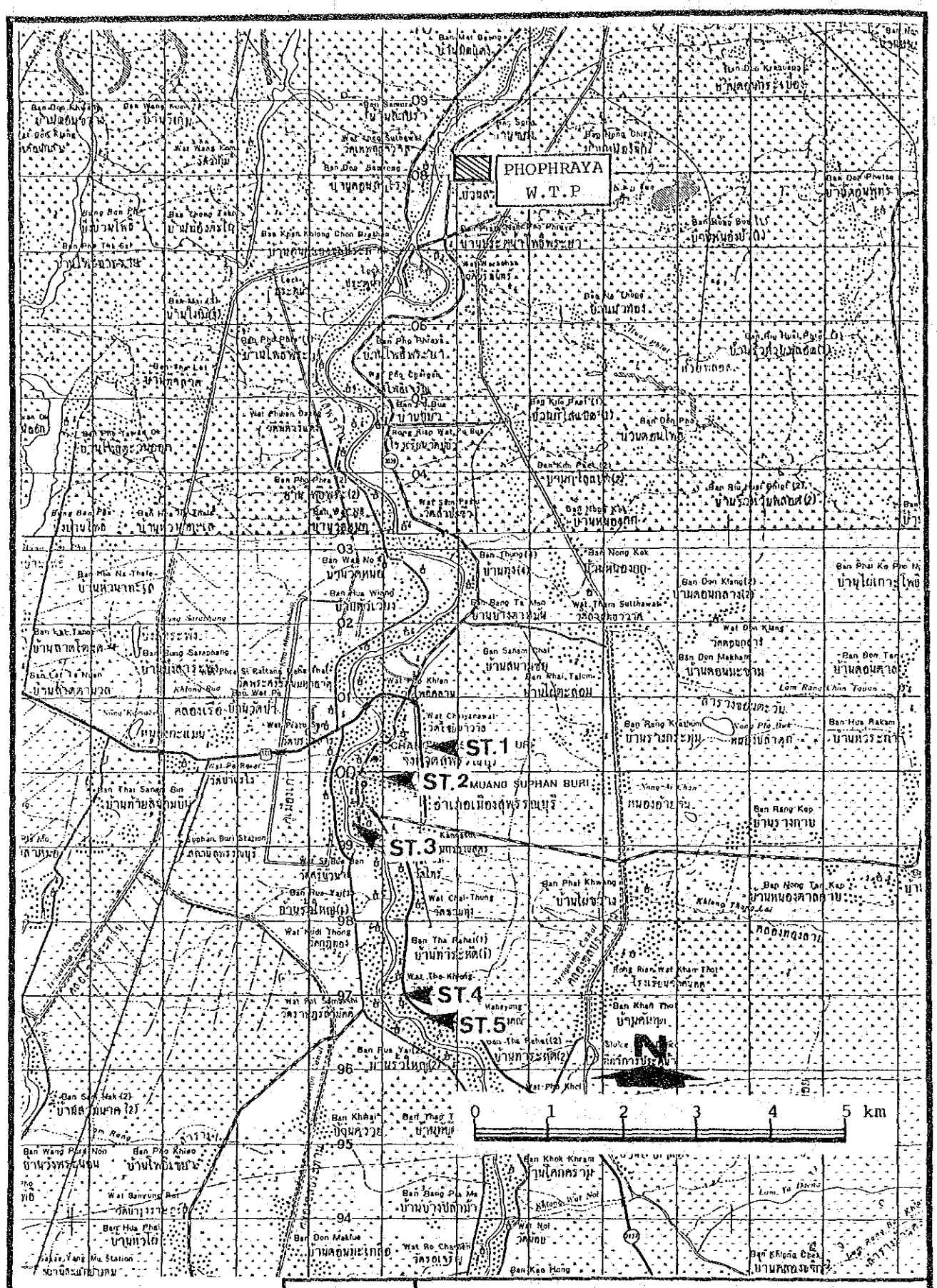
Present conditions of the treated water quality are described below based on the data.

a) Of the tested 10 samples, the cases exceeding DWS are numbered as follows:

Turbidity	: 7
Color	: 1
Iron	: 4

These conditions are possibly due to improper alum dosage and filters operation. Judging from the present raw water quality, removal of the above mentioned matters is not difficult, if the alum dosage is controlled and the filters are operated, properly.

b) In the dry season, as turbidity of the raw water decreases, the alum dosage tends to be decreased intentionally. Although less alum can manage lower turbidity and color, unreasonable decrease of alum dosage



ST.No : SAMPLING POINT

FIGURE 4.1 SAMPLING POINTS (SUPHANBURI)

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Table-4.3 WATER QUALITY OF GROUNDWATER IN THE SUPHANBURI AREA

Item	Unit	ST. 1	ST. 2	ST. 3	ST. 4	ST. 5
Date		12/1/'86	12/1/'86	12/1/'86	12/1/'86	12/1/'86
Well depth	m	140	120	264	108	120
Temperature	°C	25	28	24	25.1	25.9
Color	Pt·Co units	<1	<1	<1	<1	<1
Turbidity	N T U	<1	<1	<1	<1	<1
pH		8.11	8.45	8.66	7.9	7.91
Conductivity	micromhos/cm	400	415	880	420	460
Alkalinity	mg/l as CaCO3	193	240	456	236	240
Hardness	mg/l as CaCO3	76	92	38	104	104
Calcium	mg/l	22	17.6	5.6	24	15.6
Magnesium	mg/l	5.1	11.7	5.8	10.7	15.8
Iron	mg/l	0.03	0.03	0.03	0.1	0.06
Manganese	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1
Chloride	mg/l	2	2	7	2	12
Sulfate	mg/l	<2	<2	62	<2	15
Ammonia-N	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2
Coliform group	N/100ml	0	0	0	200	0
Total colonies	N/ml	25	190	10	74	0

DATA SOURCE : STUDY TEAM

Table-4.4 WATER QUALITY OF THE PHOPHRAYA TREATMENT PLANT

Item	Year 1984/85 Month	10		11		12		1		2		4		5		6		9		10		PWA STANDARD
	Unit	RAW	TREATED	RAW	TREATED	RAW	TREATED	RAW	TREATED	RAW	TREATED	RAW	TREATED	RAW	TREATED	RAW	TREATED	RAW	TREATED	RAW	TREATED	
Color	Pt-Co units	none	none	none	none	88	none	4	none	6	none	6	2	6	none	4	none	20	10	16	4	5
Turbidity	SiO2 units	38	6.1	46	3.7	9	7.2	4	8.9	11	5	14	5.8	56	4.7	54	22	50	12	20	8.2	5
pH		7.8	7.6	8.2	7.5	7.8	7.5	8.3	7.7	7.6	7.4	7.8	7.8	7.4	7.4	7.7	7.6	7	7	7.3	7.3	6.5-8.5
Conductivity	micromhos/cm	150	163	165	173	196	206	198	204	168	176	185	181	150	162	165	175	185	190	151	164	-
Total solids	mg/l	122	84	245	160	98	96	119	127	112	112	145	136	144	110	177	123	150	126	137	133	500
Alkalinity	mg/l as CaCO3	68	36	82	54	84	76	86	76	74	64	78	64	68	44	68	54	70	48	66	56	-
Hardness	mg/l as CaCO3	66	64	92	106	100	124	86	84	78	76	76	78	78	86	86	84	122	94	66	62	-
A B S	mg/l	0.08	0.03	-	0.02	-	nil	-	0.07	-	0.11	-	-	-	-	-	-	-	-	-	-	0.5
Calcium	mg/l	21	18	29	34	26	38	24	23	26	25	19	18	19	21	19	19	24	22	16	22	75
Magnesium	mg/l	3.4	4.3	4.8	5.3	8.6	6.7	6.2	6.2	2.9	3.4	6.7	8.2	2.4	10	9.1	8.6	15	9.6	5.2	1.9	50
Iron	mg/l	2.1	0.22	1.78	0.65	0.31	0.3	0.21	0.2	0.45	0.16	2.59	0.6	1.44	1.62	1.98	0.88	1	0.46	2.5	0.48	0.5
Manganese	mg/l	nil	nil	0.08	nil	nil	nil	0.01	0.01	nil	nil	nil	nil	nil	nil	nil	nil	0.1	0.1	0.1	0.1	0.3
Chloride	mg/l	8	12	6	18	9	10	11	14	9	10	7	9	8	9	9	11	12	16	8	8	250
Sulfate	mg/l	2	22	3.5	10	0.8	7.3	2.5	8	1.5	5.5	1.7	6	1.5	6	4	12	6	21	2	12	200
Copper	mg/l	0.041	nil	0.025	0.012	nil	nil	0.009	nil	0.019	0.004	0.025	0.002	0.044	0.032	0.055	0.075	-	0.009	0.035	nil	1
Zinc	mg/l	0.15	0.28	nil	0.15	0.12	0.29	0.02	nil	nil	<0.01	nil	nil	nil	0.03	0.22	<0.01	0.9	0.9	0.03	0.03	5
Fluoride	mg/l	0.39	0.16	0.47	0.38	nil	nil	0.22	0.26	0.29	0.1	0.25	0.22	0.46	0.17	0.11	0.53	-	0.53	nil	0.18	0.7
Residual chlorine	mg/l		1		0.5		0.8		0.7		0.8		0.8		0.6		0.8		1		0.5	-

DATA SOURCE : PWA

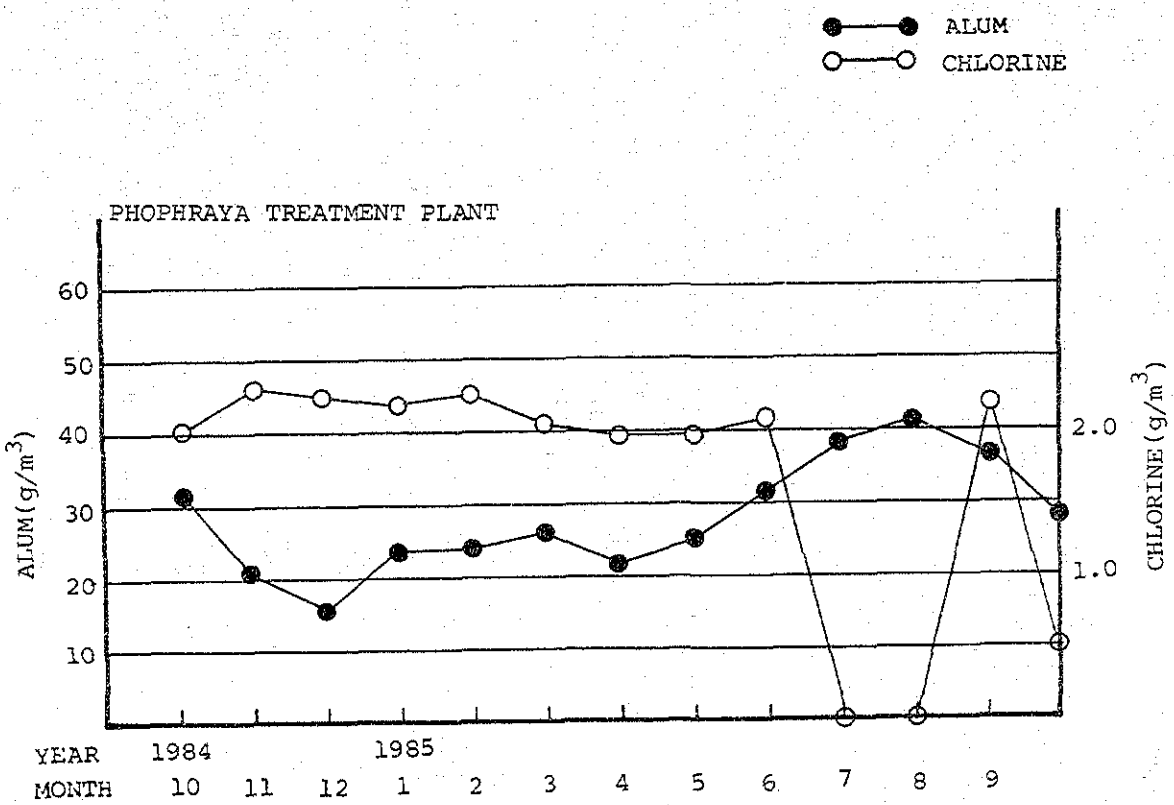

FIGURE	MONTHLY AVERAGE OF CHEMICAL DOSAGE
4.2	

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may result in poor coagulation and flocculation, and breakthrough of turbidity in the treated water. It may be the case mentioned in a). Alum dosage control leaves much room for improvement.

c) Although a small amount of ABS, indicative of domestic sewage intrusion, was detected, this was not anticipated to be a significant problem because of its low value.

d) The average chlorine dosage was 1.78 mg/l through the period recorded in Fig-4.2. Residual chlorine was detected in all samples shown in Table-4.4. However, suspension of chlorination as seen in Fig-4.2 should be avoided. In Table-4.4, two months' data, when chlorination was suspended, were not recorded.

When the plant was surveyed on January 11th 1986, chlorine gas was not being fed by reason of the feeder's breakdown. In the water sampled at a tap of the treatment plant, coliform group of 100 N/100 ml and total colonies of more than 300 N/ml were counted. To cope with such accidents, other disinfectants such as bleaching powder shall be introduced.

Chlorine dosage should be carried out without interruption and controlled to maintain a certain level of residue, by surveying the consumers taps.

Periodic investigation of residual chlorine has not been practiced by the waterworks. It is necessary to measure the residual chlorine in tap water at the pipe end and to maintain adequate residual chlorine throughout the entire system, to safeguard the hygienic quality of potable supply.

Dab Fafhun Deep Well Plant

Chlorine or any disinfectant has not been dosed, since the raw water, as seen in Table-4.2, has not significant problems both physically and chemically. Deep well water is usually believed to be safe bacteriologically, but disinfection is an indispensable practice to ensure the safety of drinking water.

4.2.2 Improvement of Treatment Method

Phophraya Treatment Plant

In general, the Phophraya's present treatment system, consisting of alum-using coagulation, sedimentation, filtration and disinfection, is suitable for treating the raw water.

To improve the treated water quality, rectifying the alum dosage and filter-backwashing is needed. In order to decide the optimum alum dosage, jar test should be made cautiously and regularly. Furthermore, backwashing should be carried out by reading the head loss of each filter and/or checking residual turbidity of filtered water. Head loss is an index of the filter conditions.

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

Dab Fafhun Deep Well Plant

Disinfection shall be practiced.

APPENDIX 5

QUESTIONNAIRE SURVEY

APPENDIX 5

APPENDIX 5 QUESTIONNAIRE SURVEY

5.1 Objective ..... A5 - 1

5.2 Survey Areas and Interviewees ..... A5 - 1

5.3 Survey Items ..... A5 - 3

5.4 Survey Method ..... A5 - 3

5.5 Survey Results ..... A5 - 5

APPENDIX 5 QUESTIONNAIRE SURVEY

5.1 Objective

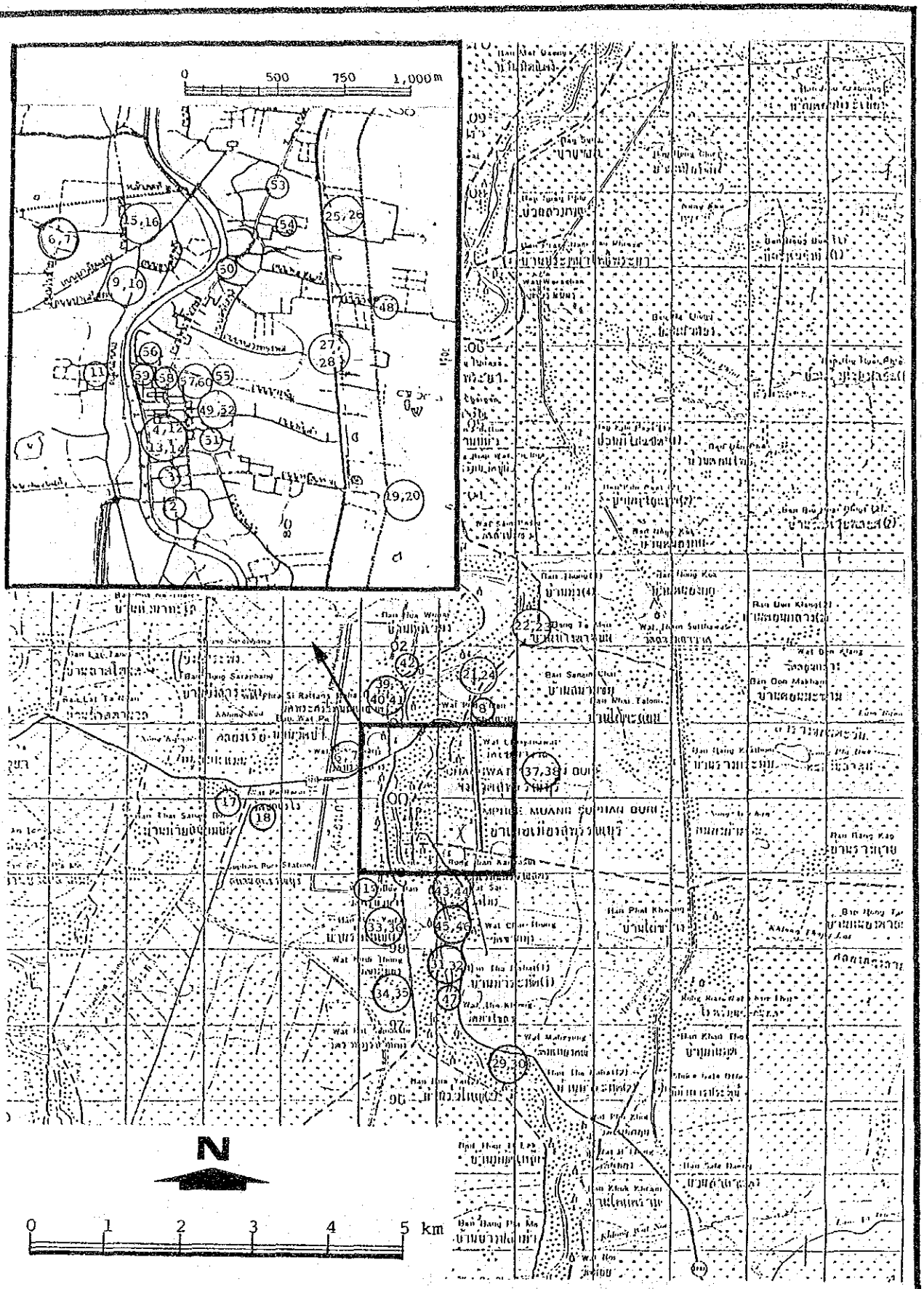
The JICA Study Team conducted a door-to-door questionnaire survey as a part of the Development Plan and Feasibility Study on the Provincial Water Supply Projects in the Kingdom of Thailand, in cooperation with the counterparts of the Provincial Waterworks Authority.

This survey was intended to obtain the basic and direct information on the present water use pattern of the inhabitants in the project areas 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 to all districts in the project areas, inclusive of both the served and unserved area. The points where the questionnaire survey was conducted are shown in Fig-5.1.

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	SUPHANBURI

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5.3 Survey Items

As seen in Table 5-1, the questionnaire form used for the survey consists of the following ten items:

- 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

5.4 Survey Method

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

The total of 44 local people, employed interviewers, were engaged in the survey and the interviewees, numbering 1193 in total, were selected randomly.

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

The survey was conducted on 4th, 11th and 12th of January, 1986.

Table-5.1 QUESTIONNAIRE FORM

QESTIONNAIRE

FOR

PROVINCIAL WATER SUPPLY PROJECT

Ward No. :

Interviewer :

Date : / / 19

				Registration 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
Sanaoi Reference No.																													
Name of Street																													
House/Building No.																													
Q-1. Type of Building Surveyed (Check appropriate one)	Pure Residencial																												
	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 - 500																												
	over 500																												
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																												
	1,000 - 3,000																												
	3,000 - 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 - 3,500																												
	3,500 - 4,500																												
	4,500 - 6,000																												
	6,000 - 7,500																												
	7,500 - 10,000																												
	10,000 - 15,000																												
	15,000 - 30,000																												
	over 30,000																												

5.5 Survey Results

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 1193 households answering the captioned question, 65.6 % lived in residential-only (purely residential) buildings while 26.8 % in residential -commercial buildings. Altogether 92.4 %, most of the 1193, 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 1192 households answering the captioned question, 75.5 % used the municipal system only, 0.3 % the municipal system and other sources and 24.2 % 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 rain/river water's share is the largest, 246 of the total 292, or 84.2 %, followed by the groundwater's 14.0 %.

In this area, the percentage of those using groundwater was as low as 14.0 %. This could be due to the reason that groundwater of good quality cannot be obtained at a depth of less than 100 m. For economic reasons, the percentage of those using groundwater was relatively low.

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

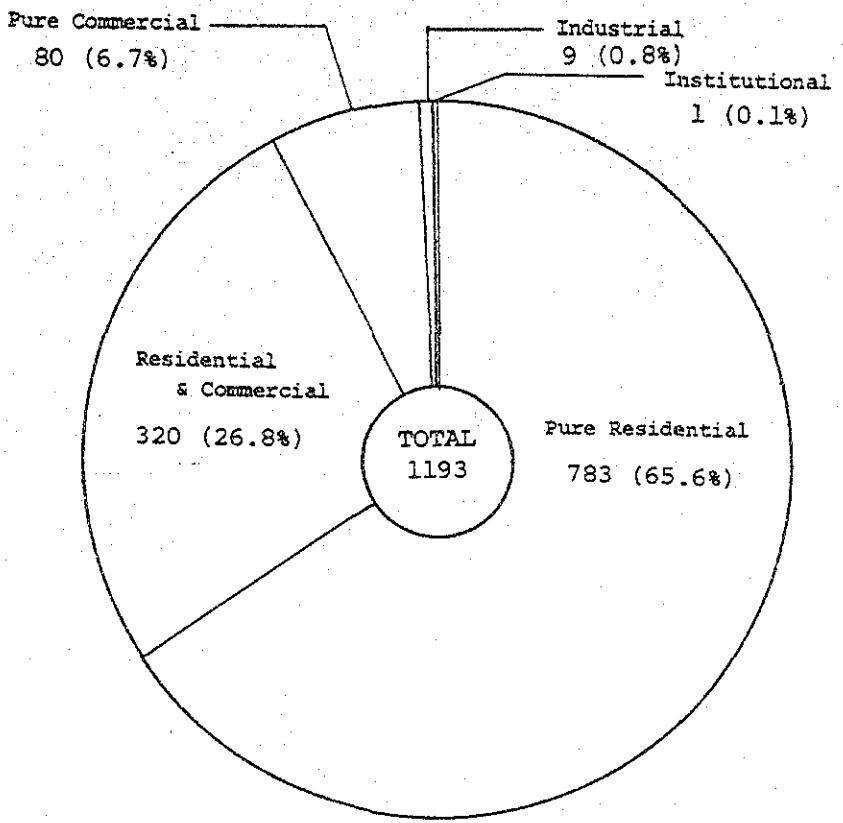
Of the 895 households using the PWA system wholly or partly, 60.7 % were found to be dissatisfied with the service. Of the reasons, 46.4 % of the 543, pointed out instability, 26.3 % costliness, 18.4 % combined reasons, 4.8 % poor quality and 4.1 % low pressure.

Table-5.2 SURVEY RESULTS

SUPHANBURI

QUESTIONNAIRE	TOTAL
Q-1 :Type of Building Surveyed	
Pure Residential	783
Residential & Commercial	320
Pure Commercial	80
Institutional	1
Industrial	9
No Answer	0
TOTAL Q-1	1193
Q-2 :Type of System Supply Sources	
A :Municipal System Only	900
B :Municipal System Plus Other Sources	
B-1 : Rain/River Water	1
B-2 : Pond / Reservoir Water	0
B-3 : Water Vender	0
B-4 : Groundwater	3
B-5 : Combined Sources	0
C :Sources Other Than Municipal System	
C-1 : Rain/River Water	245
C-2 : Pond / Reservoir Water	0
C-3 : Water Vender	1
C-4 : Groundwater	38
C-5 : Combined Sources	4
D :No Answer	1
Sub total (A + B)	904
Sub total (C)	288
TOTAL Q-2	1193
Q-5 :Current Status of Water Supply (Municipal System)	
A :Satisfactory	352
B :Unsatisfactory	
B-1 : Poor Quality	26
B-2 : Low Pressure	22
B-3 : Unstable	252
B-4 : Expensive	143
B-5 : Combined Reasons	100
C :No Answer	9
TOAL Q-5	904
Q-6 :Average Monthly Water Consumption	
1 :Less than 15 m3	200
2 :15 - 30	460
3 :30 - 50	192
4 :50 - 75	32
5 :75 - 100	11
6 :100 - 150	1
7 :150 - 200	2
8 :200 - 300	1
9 :Over 300	0
10 :No Answer	5
TOTAL Q-6	904
Q-7 :Average Cost of Water Per Month	
1 :Less than 50 Baht	159
2 :50 - 100	259
3 :100 - 150	217
4 :150 - 200	127
5 :200 - 300	94
6 :300 - 500	29
7 :500 -1,000	10
8 :1,000 - 5,000	4
9 :5,000 - 10,000	0
10 :Over 10,000	0
11 :No Answer	5
TOTAL Q-7	904
Q-8 :Willingness to be Connected	
1 :Yes	247
2 :No	40
3 :No Answer	2
TOTAL Q-8	289
Q-9 :Willingness to Pay for Water per Month	
1 :Upto 50 Baht	132
2 : 100	92
3 : 200	18
4 : 500	2
5 : 1,000	1
6 : 2,000	0
7 : 5,000	0
8 : 10,000	0
9 :No Answer	2
TOTAL Q-9	247
Q-10:Average Monthly Income per Household	
A :Sources Other Than Municipl System	
1 :Less than 2,000 Baht	196
2 : 2,000 - 3,000	55
3 : 3,000 - 4,500	18
4 : 4,500 - 6,000	6
5 : 6,000 - 7,500	7
6 : 7,500 -10,000	1
7 : 10,000 -15,000	1
8 : 15,000 -50,000	0
9 :Over 50,000	1
10 :No Answer	4
Sub total Q-10-A	289
B :Municipal System Plus Sources	
1 :Less than 2,000 Baht	315
2 : 2,000 - 3,000	259
3 : 3,000 - 4,500	93
4 : 4,500 - 6,000	65
5 : 6,000 - 7,500	51
6 : 7,500 -10,000	48
7 : 10,000 -15,000	23
8 : 15,000 -50,000	4
9 :Over 50,000	0
10 :No Answer	46
Sub total Q-10-B	904
TOTAL Q-10	1193

TYPE OF BUILDING SURVEYED



TYPE OF WATER SUPPLY SOURCE

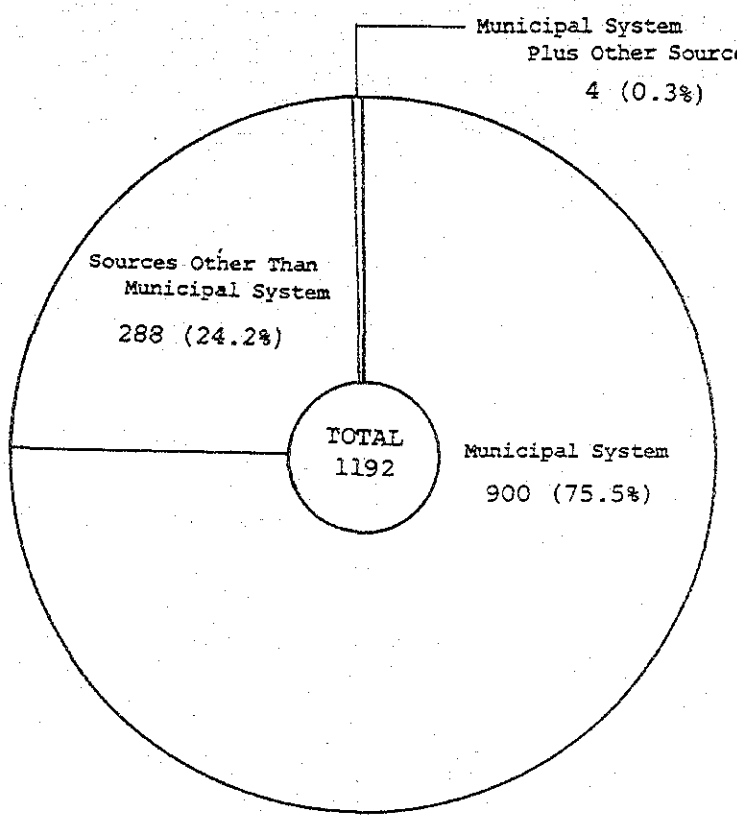
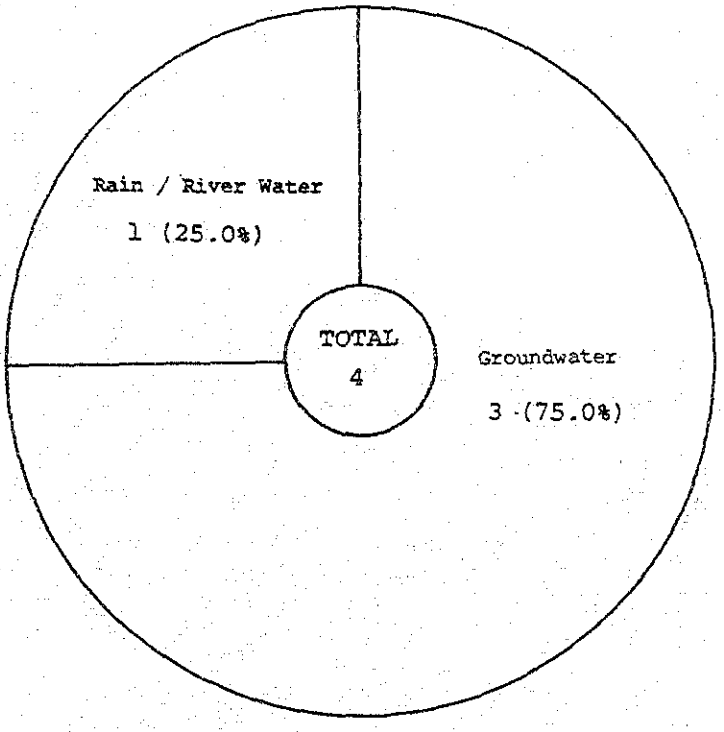


FIGURE	QUESTIONNAIRE SURVEY RESULTS (1)
5.2(1)	(SUPHANBURI)

JAPAN INTERNATIONAL COOPERATION AGENCY

MUNICIPAL SYSTEM PLUS OTHER SOURCES



SOURCES OTHER THAN MUNICIPAL SYSTEM

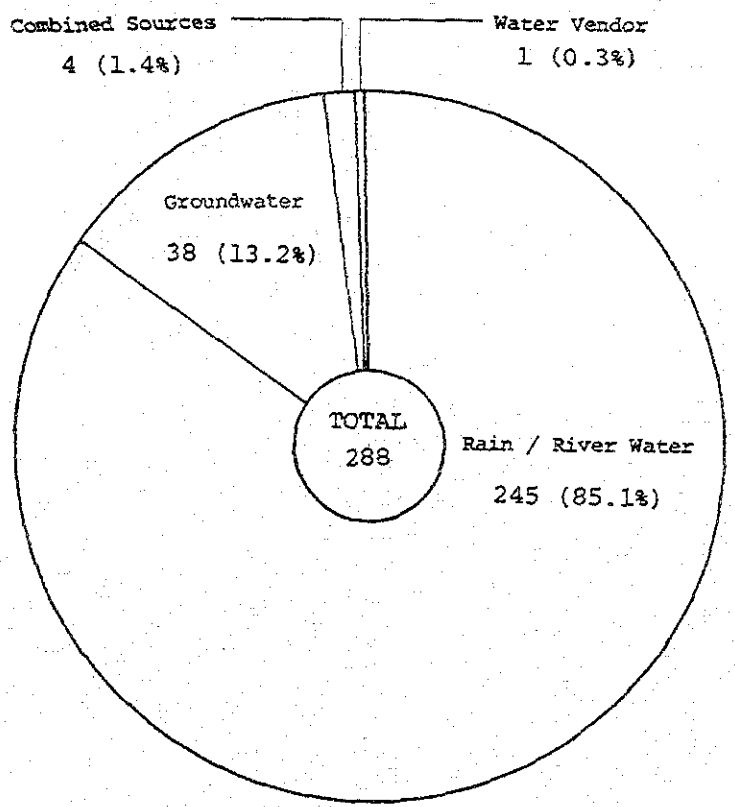
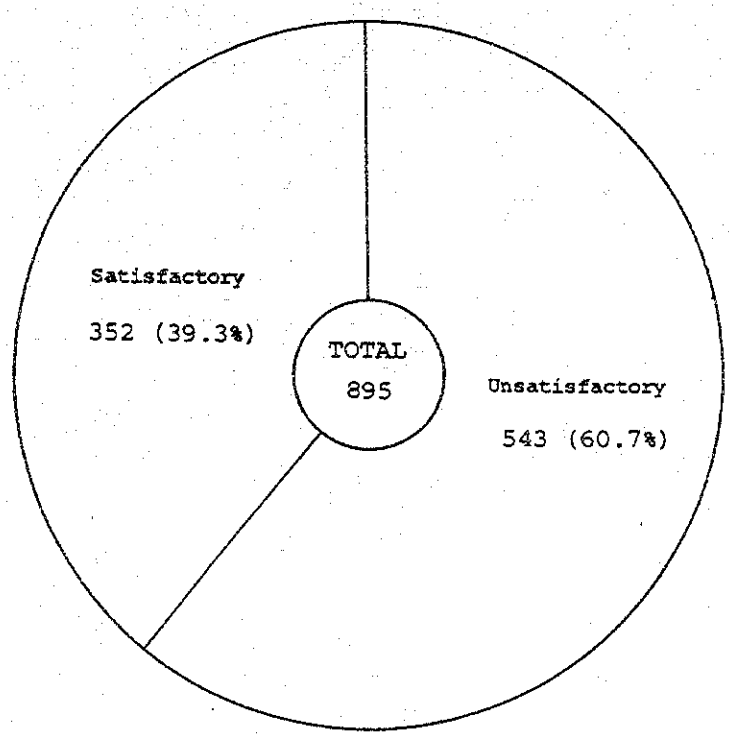


FIGURE	QUESTIONNAIRE SURVEY RESULTS (2)
5.2(2)	(SUPHANBURI)

JAPAN INTERNATIONAL COOPERATION AGENCY

CURRENT STATUS OF WATER SUPPLY

MUNICIPAL SYSTEM



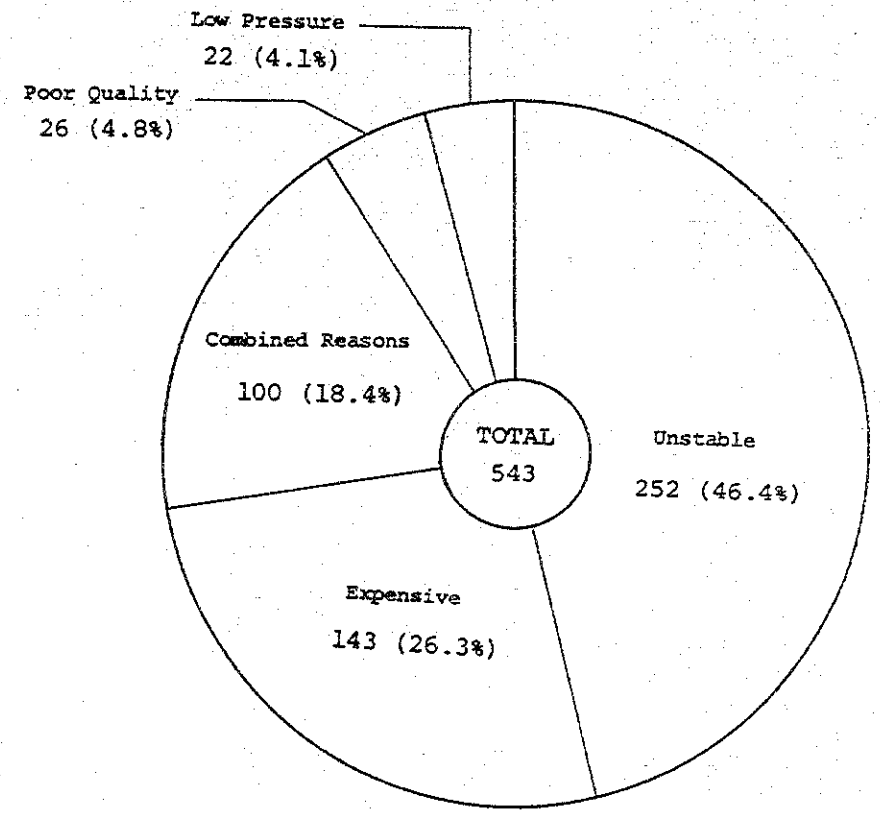


FIGURE	QUESTIONNAIRE SURVEY RESULTS (3)
5.2(3)	(SUPHANBURI)

JAPAN INTERNATIONAL COOPERATION AGENCY

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

Consumption and payment are closely related. Of the 899 households surveyed, the less-than-15 cu m/month consumer, numbering 200 and comprising 22.2 %, corresponds to the less-than 50 Baht payer, numbering 159 and comprising 17.7 %. Likewise, 15-30 cu m/month consumer correspond 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 86 %, or 247 of 287 of the answer, was positive.

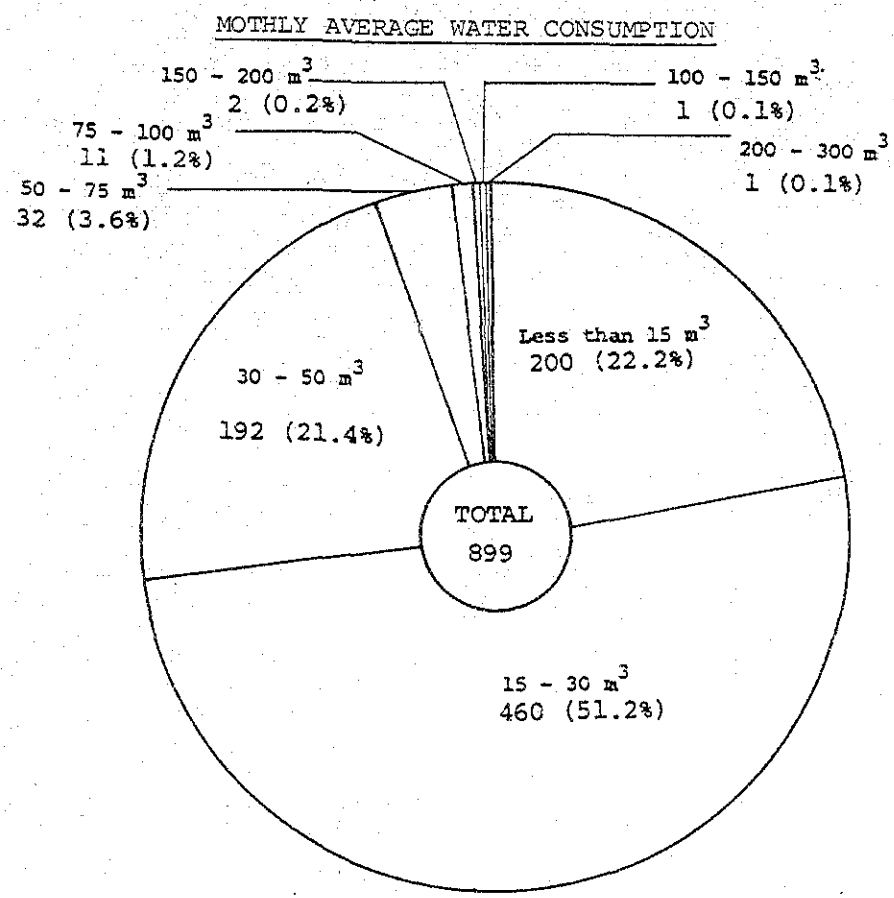
The others were not willing to be connected, which might be due to use of rain/river water and/or high percentage of water tariff of household income.

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., 132 out of 245, answered 50 Baht or less as a willing-to-pay amount. This percentage contrasts with that presently the less-than-50 Baht paying is only 17.7 %. The portion willing 50 Baht or less payment is 53.9 %, contrasting with the present percentage of users which is only 46.5 %.

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

285 other sources-than-Municipal system users and 858 wholly-or-partly-Municipal-System users were questioned and the result is shown for each separately.



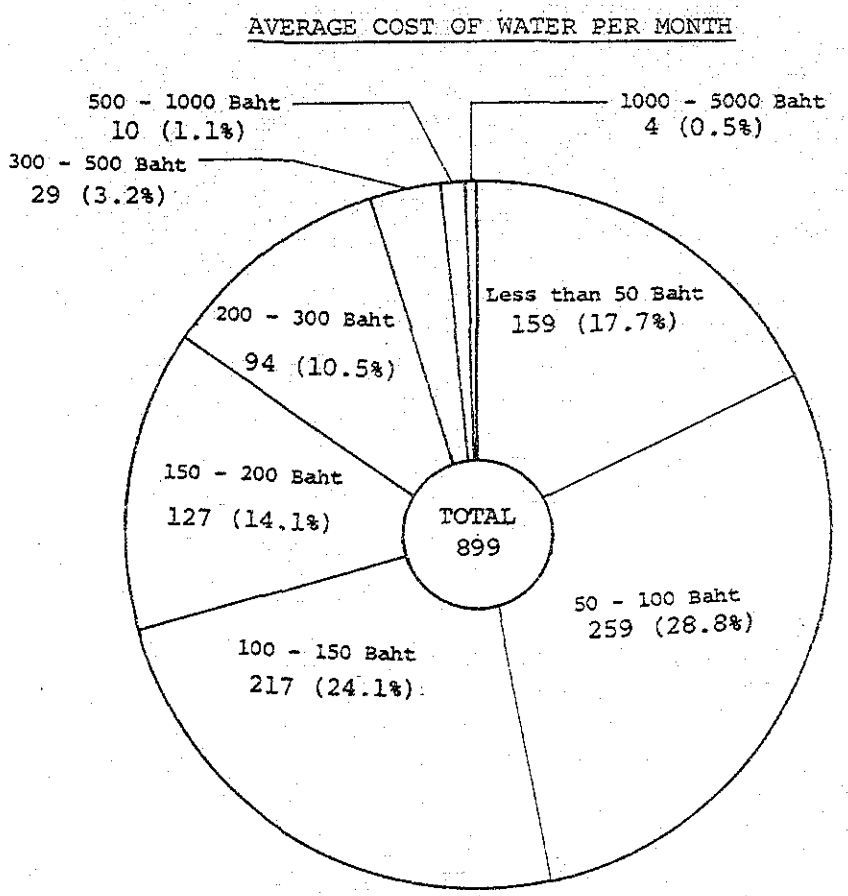
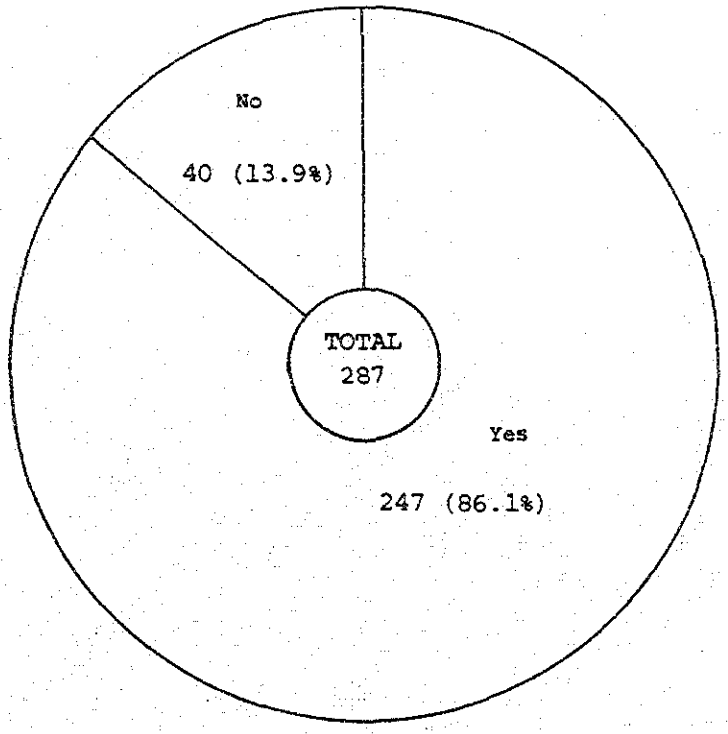


FIGURE	QUESTIONNAIRE SURVEY RESULTS (4)
5.2(4)	(SUPHANBURI)

JAPAN INTERNATIONAL COOPERATION AGENCY

WILLINGNESS TO BE CONNECTED



WILLINGNESS TO PAY FOR WATER PER MONTH

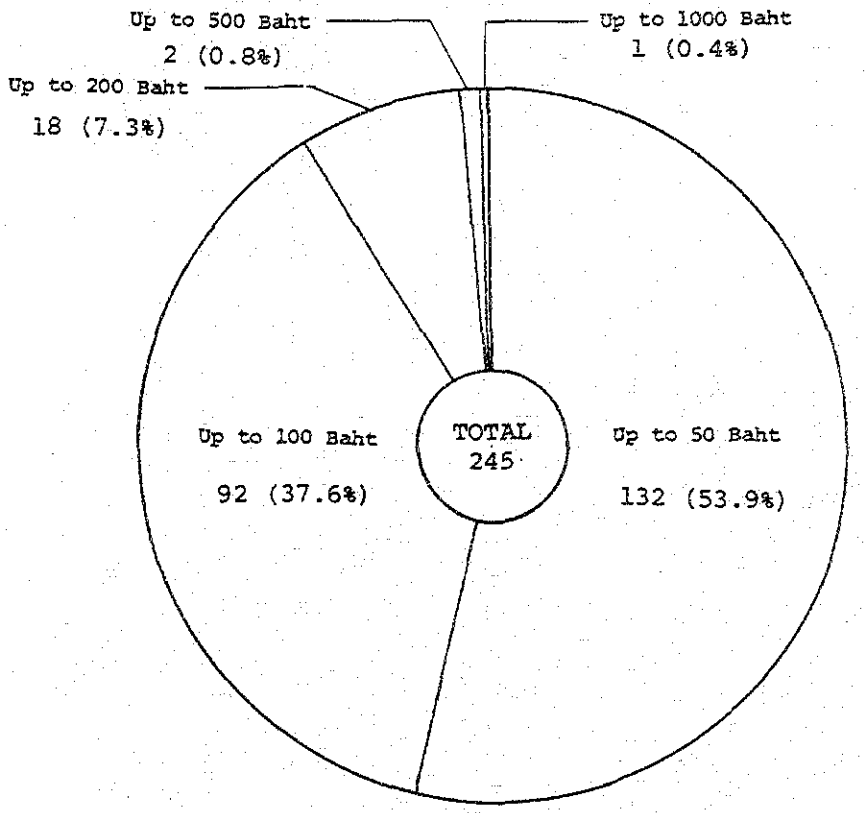
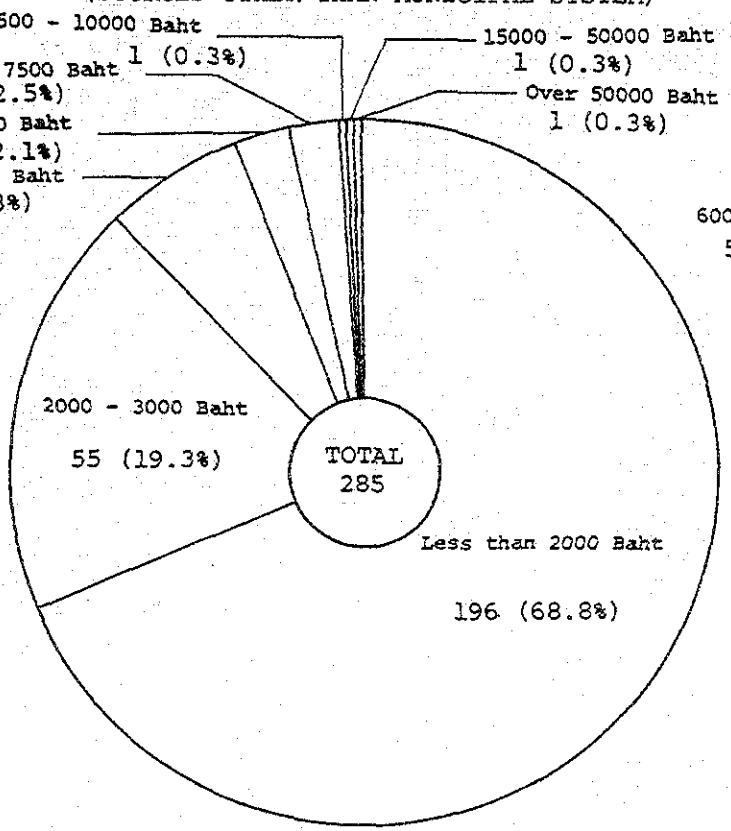


FIGURE	QUESTIONNAIRE SURVEY RESULTS (5)
5.2(5)	(SUPHANBURI)

JAPAN INTERNATIONAL COOPERATION AGENCY

AVERAGE MONTHLY HOUSEHOLD INCOME
(SOURCES OTHER THAN MUNICIPAL SYSTEM)



AVERAGE MONTHLY HOUSEHOLD INCOME
(MUNICIPAL SYSTEM PLUS OTHER SOURCES)

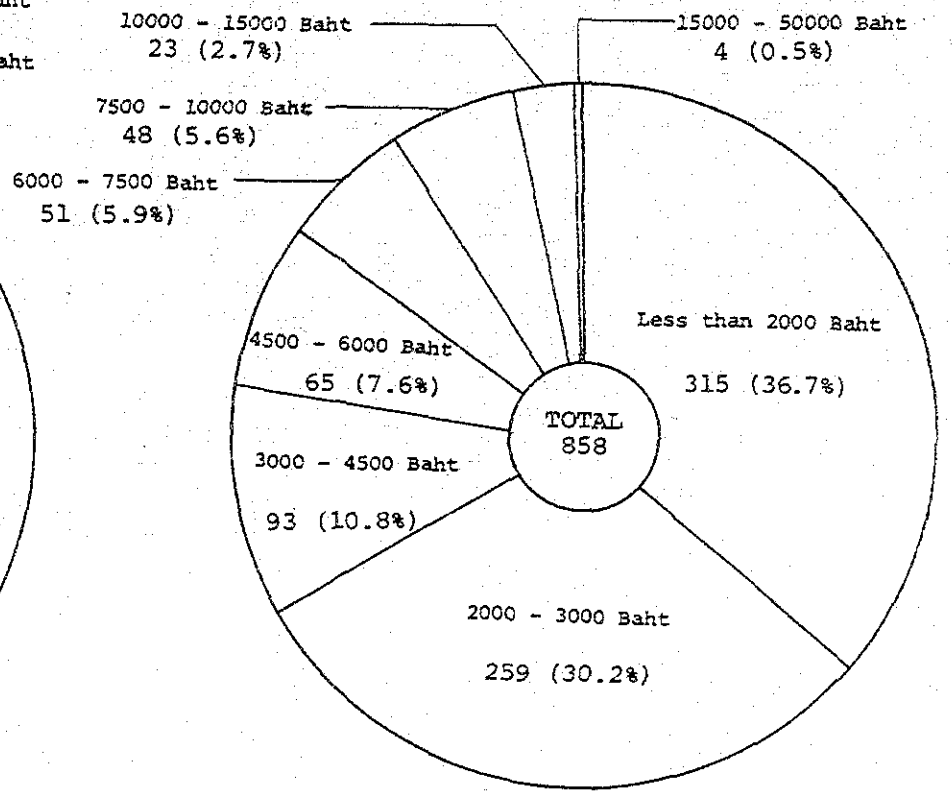


FIGURE	QUESTIONNAIRE SURVEY RESULTS (6)
5.2(6)	(SUPHANBURI)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Obviously, the income levels differ between the two. The less-than-2,000 Baht income group comprises 68.8 % of the non-users and 36.7 % of the wholly-or partly-users. The 94.4 % of those not receiving PWA service belong to a bracket of 4,500 Baht or less, while 77.7 % of PWA system users belonged to that bracket.

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) Picking up all families having less than 20 family members,

b) Picking up 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 per capita income and individual house connection services. It is also observed that more than 79 % of families whose incomes are higher than 500 Baht have PWA services through individual house connections.

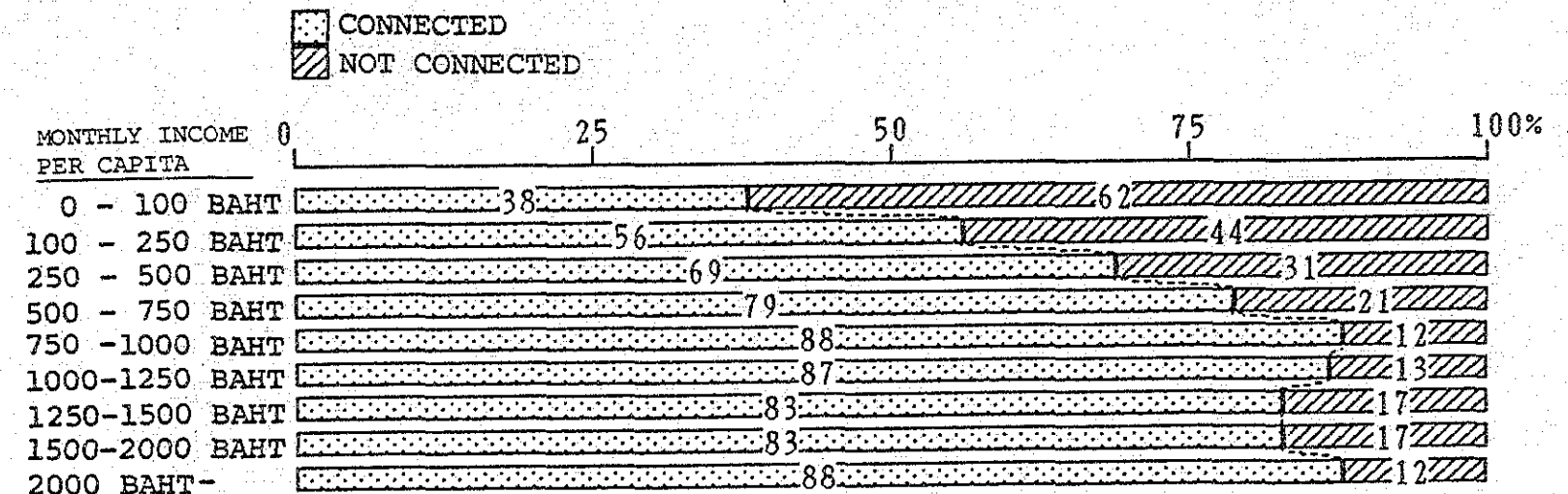


FIGURE	SYSTEM CONNECTION BY INCOME BRACKETS (SUPHANBURI)
5.3	

JAPAN INTERNATIONAL COOPERATION AGENCY

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 Concrete Structure

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

6.3 Pipeline

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

6.4 Groundwater Facilities

Groundwater is pumped up, disinfected with dosed chlorine, stored in a reservoir and distributed through pipeline by pumps.

The groundwater facilities are required to be of such structure as afford a long-period and stabilized supply of water.

6.5 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, importance of the pipeline, 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 reason. For cases requiring pipe strength such as roasd crossing works and the like, ductile cast iron pipes are to be employed.

2) 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.

6.6 Drinking Water Standard

Tables-6.1 shows the PWA Drinking Water Standard of Groundwater.

The facilities are required to produce treated water conforming to the standard.

Table-6.1 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 7-1 COMPARISON OF ALTERNATIVES FOR SURFACE WATER TREATMENT AND FOR DEEP WELL

7-1.1 Introduction

This study deals with comparison between two alternatives on water sources for Suphanburi Waterworks: whether the existing treatment plant should be used as it is or to be replaced with deep wells.

Development of groundwater, which is abundant in the study area, for the main source of supply is one of the basic concepts of the long-term development plan of the Suphanburi Waterworks. Within this context, PWA with its comments No. MI57401/2619 dated 17 October 1986, showed its interest in economy of replacement of the present surface water source by groundwater and the time justifying such replacement.

Thus the present study aims at finding benefit of groundwater development over the existing treatment plant and determining the time of replacement.

7-1.2 Description of Alternatives

Alternative-1

The source will be surface water of the Tha Chin River. The existing water treatment plant of Phophraya will be used to the present full capacity of 4,800 m3/day. No upgrading work will be undertaken, while the present unit processes operations will be maintained. Treated water will be distributed through Dab Fafhun Distribution Pump Station.

Alternative-2

This alternative is to develop groundwater with two deep wells with yield of 2,400 m3/day each, totaling to 4,800 m3/day for replacement of the existing Phophraya Plant. Of the two wells, one will be developed on the premises of the Phophraya Plant. The another well will be located about 1 km apart from the former well.

The yield of two wells will be combined and conveyed to the clear water reservoir at the Dab Fafhun Distribution Pump Station through an existing 300 mm diameter transmission pipeline.

7-1.3 Cost Comparison

Item	Alternative-1 Phophraya Plant	Alternative-2 Groundwater
1) Source	Tha Chin River	groundwater
2) Production Capacity	4,800 m3/d	4,800 m3/d
3) Water Production	3,556 m3/d (1,297,940 m3/year)	3,556 m3/d (1,297,940 m3/year)
4) Capital Cost		
Land Acquisition	-	฿ 200,000
Two Wells	-	฿ 5,000,000
Transmission Pipeline	-	฿ 1,000,000
Rehabilitation Works	฿ 2,350,000	-
Total	฿ 2,350,000	฿ 6,200,000
5) O/M Cost		
Electricity	฿ 0.960/m3	฿ 1.150/m3
Chemicals	฿ 0.174/m3	฿ 0.032/m3
Total Unit Cost	฿ 1.134/m3	฿ 1.182/m3
Personnel Cost	฿ 536,000/year	฿ 268,000/year
Annual O/M Cost	฿ 2,008,000/year	฿ 1,802,000/year

Assumptions:

1) The average day production of each alternative is 3,556 m3/d, while the rated capacity of the facilities is 4,800 m3/d each. Such production and capacity remain same until 2020.

2) All facilities are operable without any further capital investment until the year 2020. The life of the facilities terminates in the same year.

3) Personnel costs other than production staff remain same and are excluded from the computation. Number of production staff of Alternative-2 is half of Alternative-1 in view of the simplicity of operating wells.

4) The two deep wells to be completed in 1989 will start their operation in the same year to replace the treatment plant production.

5) In case of Alternative-2, the costs to be incurred with demolishment of the existing plant are ignored.

7-1.4 Present Value of Total Cost

The below table shows the present value of the combined total of capital and O & M costs mentioned in 7-1.3 above.

Terminate Year : 2020

Unit : x 1,000 Baht

Discount Rate (%)	Present Value Alternative-1	Present Value Alternative-2	Benefit of Alternative-2
3.0	38,903	38,656	+ 1,570
3.52	35,945	35,945	0
4.0	33,486	33,688	- 202
5.4	27,545	28,213	- 668

7-1.5 Conclusion

As revealed in the table above, the present values of the total cost (both capital and O & M) of both alternatives equal at the discount rate of 3.52 % per annum with the terminate year of 2020 and if the discount rate increases, the present value of Alternative-2 cost supersede that of Alternative-1 accordingly. In view of the prevailing opportunity cost of capital, therefore, immediate replacement of Phophraya plant by deep wells is considered uneconomical, and the existing Phophraya Treatment Plant is recommended to be used for supply to the Suphanburi Municipality as far as the present facilities of the plant and the pump station is serviceable without substantive capital investment.

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 500 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, 120 meter depth

b. Location of Well : in Suphanburi Municipality

c. Raw Water Quality : Iron - 0.1 mg/l or less
Manganese - less than Drinking Water Standard
pH - approximate 8.0
(medium values of varying data collected from existing wells)

d. Treatment Process : No treatment except for disinfection by chlorine, of the dosed bleaching powder

e. Treatment Capacity : 50, 100, 300, 500 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 1.0 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.
- 1.5 mg/l dosage of bleaching powder containing 30 % effective

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	500 cu m/d capacity Description
1) Deep Well dia. x depth	1	125 mm x 120 m	125 mm x 120 m	150 mm x 120 m	150 mm x 120 m
2) Submersible Pump dia. x capacity x head x motor rating	1	40 mm x 0.04 cu m/min 40 m x 1.1 KW	40 mm x 0.07 cu m/min 40 m x 1.1 KW	50 mm x 0.21 cu m/min 40 m x 2.2 KW	65 mm x 0.28 cu m/min 40 m x 3.7 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) Feeder of Bleaching Powder	1	with fittings	with fittings	with fittings	with fittings
5) Elevated Tank Capacity	1	5 cu m	10 cu m	30 cu m	50 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

chlorine is assumed to be dosed constantly.

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	500
1. Construction Cost				
- Amount of Investment (x 1,000 Baht)	1,010	1,040	1,230	1,390
- Monthly Depreciation (20 years, Baht/month)	4,200	4,300	5,100	5,800
2. O/M Cost (Baht/month)	2,500	3,100	4,800	6,300
3. Monthly Cost (Baht/month)	6,700	7,400	9,900	12,100
4. Unit Cost of Water (Baht/m3)	4.47	2.47	1.10	0.81

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.

Table-7.3 UNIT PRICE OF WATER, PWA

Item	Water Consumption (m3/d) 50	100	300	500
1. Size of connection Pipe (inches)	2	3	4	6
2. Water Price				
- Service Charge (Baht/month)	100	160	200	200
- Connection Fees in terms of monthly lot (20 years)*	80	130	250	250
- Monthly Price (Baht/month)	12,750	25,500	76,500	127,500
- Total Monthly Price (Baht/month)	12,930	25,790	76,950	127,900
3. Unit Price of Water (Baht/m3)	8.62	8.60	8.55	8.52

Note: * Based upon the assumption that connection is set at 30 m from the main pipe, i.e., 2 x Basic Fee.

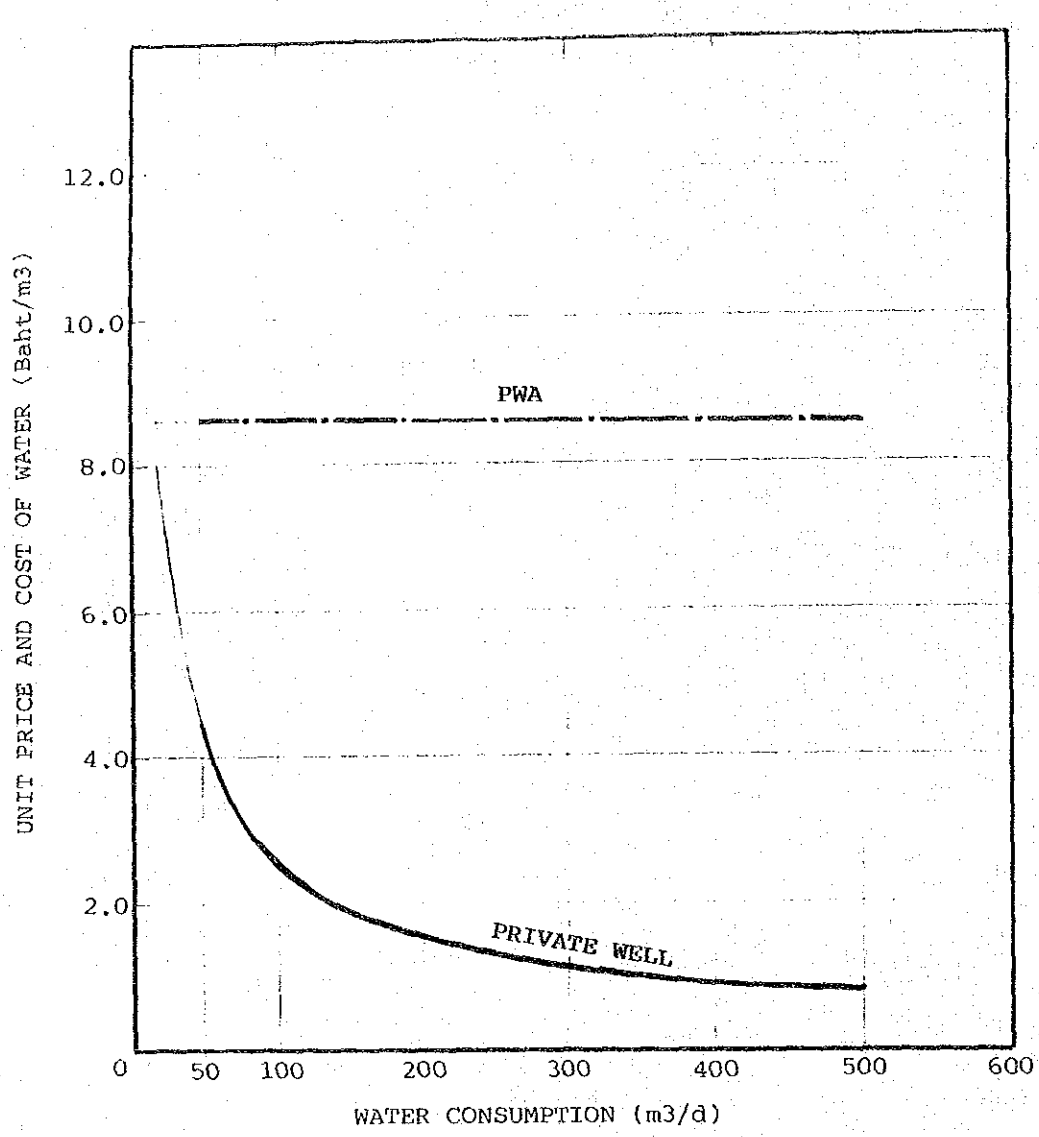
7-2.4 Remarks

The following can be induced from the study results as revealed in Fig-7.1.

1. The unit cost of water produced by private facilities whose capacity is larger than 50 cu m per day is found nearly half of the PWA price of water for the same volume of consumption.

2. The unit cost of water by private facilities decreases as the consumption volume increases, i.e., so low as 0.81 Baht/m3 at 500 cu m per day.

3. Because of no exact data available on the ratio of successful drilling in Suphanburi, no consideration is given to such ratio. If the ratio is assumed to be 50 %, the unit cost of water per cu m in case of 50



COMPARISON OF UNIT PRICE AND COST

WATER CONSUMPTION (m3/d)	PWA (Baht/m3)	PRIVATE WELL (Baht/m3)
50	8.62	4.47
100	8.60	2.47
300	8.55	1.10
500	8.52	0.81

FIGURE 7.1	COMPARISON OF UNIT PRICE AND COST
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m3/day consumption will be 7.27 Baht*, very near to PWA's unit price of water.

Note: [monthly depreciation allowances (4,200 Baht x 2) + monthly O/M cost (2,500 Baht)]/consumption volume (50 m3 x 30 days) = 7.27 Baht/m3

APPENDIX 8

PRELIMINARY DESIGN

APPENDIX 8

APPENDIX 8 PRELIMINARY DESIGN

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APPENDIX 8 PRELIMINARY DESIGN

8.1 Rehabilitation and Modification Works

The objective of the rehabilitation and modification works id to supplement insufficient supply before the completion of the expansion works, by 1) updating the present deteriorated equipments and obsolete pipelines and 2) constructing a new deep well at Kannasut in the southeastern part of the service area, as detailed as follows:

8.1.1 Phophraya Treatment Plant

(1) Replacement/Installation of flow meters and indicators

A flow meter and indicator should be installed on the 250 mm diameter raw water transmission main, for recording daily intake and determination of the chemical feeding rate and consumption. The malfunctioning flow meter and indicator on the 300 mm diameter clear water transmission main will be replaced for recording the daily production. The differential pressure type is proposed because of simpler mechanism and less costliness than other types.

(2) Replacement of level gauge

The defective float type water level gauges (direct reading type) will be replaced, for measuring the level of the clear water reservoir and elevated tank.

(3) Provision of chlorine gas container scale

A set of chlorine gas container scale will be provided for precise timing of replacement of the gas container, to secure continuous disinfection as well as reading consumption.

(4) Purchase of filter sand washer

A movable filter sand washer is proposed for purchase, and washing of filter sand should be practiced to provide clean sand for make-up.

8.1.2 Clear Water Transmission Pipeline

For repair and replacement of the leaking or weakened parts on the dia. 300 mm pipeline, necessary length is estimated at approximately 500 mm by the information of the Waterworks.

8.1.3 Dab Fafhun Deep Well and Distribution Pump Station

(1) Installation of flow meter and indicator

A flow meter and indicator will be installed on the 300 mm diameter clear water transmission pipeline, to measure the inflow rate from the Phophraya Plant.

Also, a flow meter and indicator will be installed the outlet pipe of the deep well, to record the yield of the well.

(2) Replacement of level gauge

Float type water level gauges for the distribution reservoir and elevated tank will be replaced.

(3) Provision of chlorination facilities

As no disinfection facility has been provided at the deep well, provision of chlorination facilities such as the container scale, chlorinator and appurtenances will be required .

8.1.4 Proposed Deep Well (Kannasut) No.1

The capacity, dimensions and features of the proposed facilities are described below:

(1) Deep well and well house

- Well diameter : 10 inches (250 mm)
- Drilling depth : 150 m
- Well yield : 2,100 cu m/day
- Drawdown : about 10 m
- Well house : brick masonry

(2) Well pump equipment

- Pump : Q 1.5 cu m/min. x H 35 m
- Pressure and level gauges, valves and piping

(3) Distribution reservoir

- two reservoirs 500 cu m capacity

The reservoirs have a total volume of 1,000 cu m including the 500 cu m necessary for the expansion works of the Stage I.

(4) Distribution pumps and pump house

- Large pump : 1 pump Q 4.1 cu m/min x H 35 m
- Small pump : 1 pump Q 2.1 cu m/min x H 35 m

Corresponding to the demand's fluctuation, the larger or smaller pump will be used to match it.

(5) Chlorination facilities and storage house

- Container scale, chlorinator and appurtenances

Chlorine gas is supplied by the regular transportation from PWA Headquarters Bangkok through the Regional Office and