MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

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

# FINAL REPORT FOR PATUM THANI & PRACHATIPAT

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

21597

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PREFACE

In response to a request from the Government of Thailand, the Japanese Government decided to conduct a Feasibility Study on the Improvement of the Sewerage System in the Southern Part of Lima and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a survey team headed by Mr. Ikuo Miwa, Nippon Jogesuido Sekkei Co., Ltd., from July to October, 1988, from January to March, 1989, and from October to November, 1989.

The team held discussions with concerned officials of the Government of Thailand, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Thailand for their close cooperation extended to the team.

March, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

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# EXECUTIVE SUMMARY

## Part 1 -GENERAL

### THE STUDY AREA

Patum Thani is the capital of Patum Thani province and is located 28 km. north of Bangkok while Prachatipat is 11 km. east of Patum Thani along Phaholyotin Road near Bangkok.

These two areas are rapidly expanding because of the good terrain and accessibility to Bangkok. Now, a portion of the working population in Bangkok is beginning to settle in the fringe areas of Patum Thani and Prachatipat. Housing and factories are being constructed thus generating a lot of employment opportunities.

Both areas occupy a total of 1,153 sq. km. and are bounded on the south by Bangkok Metropolis. The Chao Phraya River lies on the western side of the study area where its average width of 300 m is at Patum Thani discharging 2,200 cu. m/s into the Gulf of Thailand.

Patum Thani and Prachatipat lie in a flat low lying delta plain with average elevations of 1-3 m above mean sea level. The entire study area is covered by thick clay, called Bangkok Clay, to about 30 m thick. This contributes to the presence of a large artesian groundwater basin contained in a series of vast confined aquifers up to a depth of 600 m. This, also, is the cause of land subsidence in the area.

Annual rainfall in the areas average 1,300 mm with highly seasonal distribution. More than 50 percent of this occurs during the rainy season. The average annual pan evaporation level is about 1,780 mm. Humidity is as high as 80 percent in September. Mean temperature show a range of 4.4 °C from 29.9 °C in April to 25.5 °C in December.

Patum Thani Province is economically strong on the manufacturing sector, followed by agriculture and trade. Although the agricultural sector is dominated by rice crops, the live stock subsector showed high growth rates.

Education is an important contribution of the province as many educational institutions are located in the area. Another is its ability to absorb overconcentration of the population in Bangkok. Although the province has its rural characteristics as lack of infrastructure development, an industrial development plan to increase vocational training, agri-production and improve water supply will soon boost the economy of the province.

Urbanization is observed along major transportation routes especially along Phaholyothin Road where even an industrial estate is present. Housing projects are located along this road in Amphoe Muang and neighboring tambons.

Since land prices depend on accessibility, land prices of areas along Phaholyothin Road and of major side roads in Amphoe Muang, Lam Luka and Thanyaburi are high.

Two town planning areas, Patum Thani and Prachatipat have high commercial and population densities. These areas have also planned as industrial centers where factories are being put up. But to avoid inefficient investment and possible traffic congestion along a "linear urbanization" trend, measures for contracted development within planned areas should be made.

WATER SOURCE

With the remarkable industrial and residential development in the two areas ground water supply withdrawal needs government approval.

The aquifers in the area is divided into eight layers from top to bottom as follows:

1. Bangkok Aquifer - (500 m zone)
2. Phra Prading Aquifer - (100 m zone)
3. Nakhon Luang Aquifer - (150 m zone)
4. Nonthaburi Aquifer - (200 m zone)
5. Sam Khok Aquifer - (250 m zone)
6. Phaya Thai Aquifer - (300 m zone)
7. Thon Buri Aquifer - (450 m zone)
8. Pak Nam Aquifer - (550 m zone)

In the Prachatipit area, eight deepwells are owned by the PWA while other privately owned deepwells also exist. In the Patum Thani area, the PWA owns three deepwells although only two are in operation. Presently, however, some 65 deepwells are in the areas withdrawing groundwater from four different aquifers.

According to statistics, the present withdrawal or water production in the Bangkok Metropolis and adjacent provinces is 1.4 million cu.m/d. where 94 percent of the water is withdrawn from the Lower Chao Phraya Basin. This has caused serious land subsidence and saline intrusion into the groundwater so that land subsidence in Bangkok has averaged 5-10 cm in recent years. Saline intrusion is serious in the Southern part of Bangkok where high pumping continues.

As a result, a limit for groundwater withdrawal should be set 800,000 cu. m/d. in the whole Lower Chao Phraya Basin.

For the proposed water supply system, no other water source can be considered except the Chao Phraya River itself.

After the Mae Khlong Diversion Project is completed, RID's increased allocation for water supply will be 145 cu. m/s against which water demand in the service area at the intake level is:

| | |
|---|---|
| 1996 | 1.30 cu. m/s |
| 2001 | 2.60 |
| 2006 | 3.38 |
| 2011 | 4.16 |

EXISTING WATER SUPPLY SYSTEM

(1) Patum Thani

The waterworks system of Patum Thani, founded in 1962, is under the jurisdiction of PWA Regional Office 3 in Bangkok.

Water for the system comes from two deepwells with the combined capacity of 100 cu. m/h. A third deepwell is still under construction. Treatment is by chlorination after which the water distributed by clear water pumps either directly or through the elevated tank by gravity to some 1,445 concessionaires (as of 1987).

Water production and sales of the waterworks in the past are tabulated as follows:

| Year | Water Production (cu.m/y) | Water Sales (cu.m/y) | No. of Connection | Consumption per Conn. (cu.m/d) |
|---|---|---|---|---|
| 1980 | 343,110 | 309,498 | 822 | 1.029 |
| 1981 | 652,770 | 613,437 | 842 | 1.996 |
| 1982 | 765,459 | 416,541 | 954 | 1.196 |
| 1983 | 1,015,835 | 460,700 | 999 | 1.263 |
| 1984 | 982,852 | 472,424 | 1,060 | 1.218 |
| 1985 | 811,318 | 516,575 | 1,180 | 1.199 |
| 1986 | 1,071,769 | 530,103 | 1,255 | 1.157 |
| 1987 | 1,031,440 | 570,319 | 1,445 | 1,081 |

Actual water intake exceeds proper intake capacity by an average of 50 percent. Although the number of connections has increased to 1,713 in 1988, the increase in water sales remains unclear with the system having a rate of unaccounted water at a high 45.1 percent. This could have been caused in part by a big crack found at the pump foundation due to ground subsidence.

Expansion plans are underway especially for distribution pipelines the most recent of which was towards the north and southwest along the major roads.

(2) Prachatipat

The waterworks system of Prachatipat, founded in 1982, is under the jurisdiction of the PWA Regional Office 3 in Bangkok.

Water for the system comes from two deepwells with a combined capacity of 290 cu. m/d. Two new deepwells with the intake capacities of 120 cu. m/h and 240 cu. m/h are still under construction as of September 1988.

Water is treated by chlorination and is distributed to the 1,735 connection (as of 1987) by clear water pumps along the Rangsit Highway and its adjacent areas.

Water production and sales of the waterworks in the past are tabulated as follows:

| Year | Water Production (cu.m/y) | Water Sales (cu.m/y) | No. of Connection | Consumption per Conn. (cu.m/d) |
|---|---|---|---|---|
| 1983 | 84,068 | 63,033 | 230 | 0.751 |
| 1984 | 614,620 | 396,624 | 1,121 | 0.967 |
| 1985 | 1,255,873 | 585,518 | 1,295 | 1.239 |
| 1986 | 1,168,847 | 621,016 | 1,516 | 1.122 |
| 1987 | 1,204,972 | 707,649 | 1,735 | 1.117 |

Because of the boom in the industrial development and housing estates, the distribution pipelines have been expanded every year. This, however, resulted in operational inconsistencies because of the existence of many elevated tanks and deepwells for the housing estates. This caused pressure and flow control difficulties especially when all the pipelines are connected and in use.

Operation of the Prachatipat waterworks system improved when the water supply systems of two housing estates were put under its control. The number of connection has increased by 41.2 percent since 1987 reflective of the development in the area. But the average rate of unaccounted for water is as high as 42.1 percent.like in Patum Thani.

Constraints exist for both the Patum Thani and Prachatipat water works systems. These are land subsidence, saline intrusion and declining groundwater levels. As for constraints in the existing facilities, these are on the unevenness of intake and clear water pumps capacities, the ineffective use of the elevated tanks and the high unaccounted for water ratio.

Both systems are directly supervised by the regional office of PWA and are assisted technically by the same. The organization of the two waterworks systems consists of the water production, services and administration sections.

## POPULATION AND WATER DEMAND

Future service ratios forecasting is made by tambon since each of them has varying levels of development, population densities and characteristics.

Thus high density areas are Tambon 12 in Amphoe Muang and Tambon 1 in Thanyaburi; low density areas are Tambons 1, 2, 3, 5, 6 and 7 in Amphoe Sam Khok and Tambons 1, 3 and 6 in Lad Sum Kaeo. The rest of the 34 tambons are medium density areas.

Future served population is summarized as follows:

| Year | Population Density of Service Area | | | | Average Service Ratio (%) |
|---|---|---|---|---|---|
| | High | Medium | Low | Total | |
| 1991 | 28,183 | 12,478 | 0 | 40,661 | 34.4 |
| | (62.412) | (52,385) | (3,434) | (118,231) | |
| 1996 | 45,492 | 41,280 | 0 | 86,772 | 36.9 |
| | (80,554) | (151,128) | (3,635) | (235,317) | |
| 2001 | 69,986 | 86,340 | 976 | 156,302 | 45.5 |
| | (104,34) | (234,664) | (4,878) | (343,885) | |
| 2006 | 97,452 | 160,358 | 7,882 | 265,592 | 53.5 |
| | (123,384) | (351,091) | (22,522) | (496,997) | |
| 2011 | 128,182 | 236,073 | 12,016 | 376,271 | 67.2 |
| | (142,424) | (393,458) | (24,027) | (559,909) | |

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

For future water consumption, forecasts are made on five categories:

a) domestic water consumption

b) governmental/institutional consumption

c) commercial water consumption

d) university/colleges consumption

e) industrial water consumption

The future water demand was calculated and summarized as the table below:

Water Demand Prediction Summary

| Category | 1991 | 1996 | 2001 | 2006 | 2011 |
|---|---|---|---|---|---|
| Domestic | 6,319 | 14,205 | 26,529 | 47,595 | 73,657 |
| Gov'l/Inst'l | 1,578 | 3,141 | 4,590 | 6,634 | 7,474 |
| Commercial | 1,182 | 2,353 | 3,439 | 4,970 | 5,599 |
| University/College | 0 | 3,547 | 4,289 | 8,627 | 10,000 |
| Industrial | 0 | 28,100 | 39,851 | 69,753 | 74,130 |
| Others | 363 | 798 | 1,431 | 2,495 | 3,732 |
| Sub-Total | 9,443 | 52,144 | 80,129 | 140,073 | 174,592 |
| Unaccounted for Water | 3,227 | 14,584 | 21,848 | 35,896 | 43,648 |
| Daily Average | 12,670 | 66,728 | 101,977 | 175,969 | 218,240 |
| Daily Maximum | 15,204 | 80,074 | 122,372 | 211,163 | 261,888 |

Daily maximum demand = (Daily average demand) x 1.20

DESIGN CRITERIA

The design criteria for the treatment system and pipeline was established on the various design standards employed in Thailand and other countries, taking into consideration the project site and the raw water quality of Chao Phraya River.

The design criteria is summarized as follows:

1. Water loss - intake loss is 10%; treatment loss is 8% of production

2. Pipeline - velocity is a maximum of 3.0 m/s and a minimum of 0.3 m/s. Pipe material is steel for 400 mm diameter pipes or larger and A/C for 300 mm or smaller.

3. Treatment Plant - a) receiving well: treatment time is 1.5 min.; b) mixing tank: mechanical flush mixer; c) filter: rapid sand filtration; d) clear water reservoir: 3.0 hour retention time.

4. Distribution facilities - Minimum service pressure is planned at 1.0 kg/cm2 for hourly maximum flow.

5. Foundation Structure for Treatment Plant and Distribution Reservoir - Use of centrifugal prestressed concrete pile with a 500 mm diameter to a strength of 60 ton each is proposed

BASIS OF COST ESTIMATE

The construction of the facilities to be built is calculated based on 1989 prices.

a) Pipelines - by linear meter for transmission and distribution pipes

b) Water treatment plant and distribution reservoirs - by quantities for civil/architectural, mechanical, and electrical works. This method was adopted since there was no reference of the cost estimates for the system with this large capacity.

c) Land acquisition - land cost was calculated on the basis of the unit land costs which are Baht 2 million per rai (1,600 sq m) for the intake and water treatment plant, and Baht 5 million per rai for the distribution reservoirs.

The cost estimates are separated into foreign and local cost portions as shown here:

| Item | Foreign Currency | Local Currency |
|---|---|---|
| Pipeline | (%) | (%) |
| A/C pipes | 30 | 70 |
| Steel pipes | 80 | 20 |
| Structural/Architectural | 30 | 70 |
| Mechanical Works | 80 | 20 |
| Electrical Works | 80 | 20 |
| Land Acquisition | 0 | 100 |

Operation and maintenance costs, based on 1989 prices, consist of energy, chemical, manning, replacement and repair costs. Costs of the PWA's head office and the regional office allocated for this waterworks are also calculated and added in the financial study.

## PART 2 DEVELOPMENT PLAN

### DEFINITION AND EVALUATION OF ALTERNATIVES

The future service area is divided into eight zones as shown in Figure S-1 to facilitate the efficient and economical water transmission and distribution. The alternative study was made to determine the most reasonable scheme in the comparison of the six alternatives. The recommended scheme consist of the following features:

a. Water treatment plant with the maximum capacity of 283,000 cu m/day will be constructed at the upstream of the existing MWA's raw water intake.

b. A total of six distribution reservoirs will be constructed. The characteristics of the proposed reservoirs are summarized as follows:

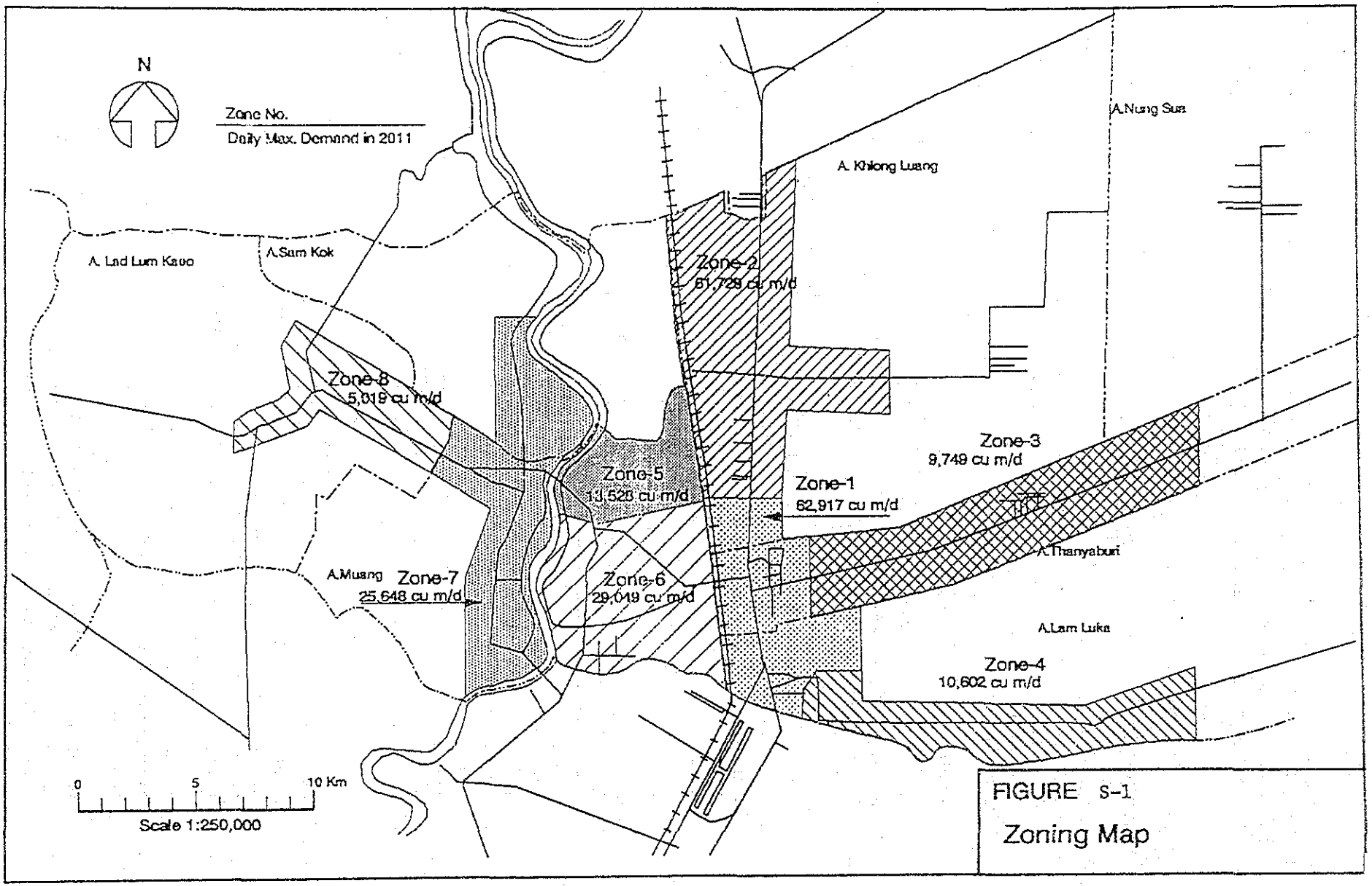
Proposed Distribution Reservoirs

| Reservoir No. | Zone No. | Location | Volume (cu m) | Structure | Land Requirement |
|---|---|---|---|---|---|
| D-1-1 | 1 | Exis.(New) | 5,000 | PC | - |
| D-1-2 | | Exis.(Old) | 13,000 | PC | - |
| D-2 | 2 | New | 19,100 | PC | 6,500 sq m |
| D-3 | 3 | Exis. | 2,000 | RC | - |
| D-4 | 4 | Exis. | 2,200 | RC | - |
| D-6 | 6 | New | 13,000 | PC | 6,000 sq m |
| D-7 | 7 | Exis.(New) | 9,000 | RC | - |

In the table above, Prestressed Concrete (PC) is proposed for some reservoirs. This is derived from the prospective constraints for the land acquisition. However, Reinforced Concrete (RC) structure is preferred if the enough size of the land is purchased with inexpensive cost and in time not to delay the the implementing schedule. The comparison of two structures are shown in Appendix A-8-6.

c. Water distribution to consumers will not be made directly from the treatment plant, but made from the distribution reservoirs provided in the zones.

d. Water transmission to the distribution reservoirs will be separated from the operation of water distribution to consumers. Figure S-2 shows a schematic diagram of the proposed system.


N
Zone No.
Daily Max. Demand in 2011
A. Lad Lum Kaeo
A.Sam Kok
A. Khlong Luang
A.Nung Sua
Zone-2
61,729 cu m/d
Zone-8
5,019 cu m/d
Zone-5
13,528 cu m/d
Zone-1
62,917 cu m/d
Zone-3
9,749 cu m/d
A.Thanyaburi
A.Muang
Zone-7
25,648 cu m/d
Zone-6
29,019 cu m/d
A.Lam Luka
Zone-4
10,602 cu m/d
0
5
10 Km
Scale 1:250,000
FIGURE S-1
Zoning Map

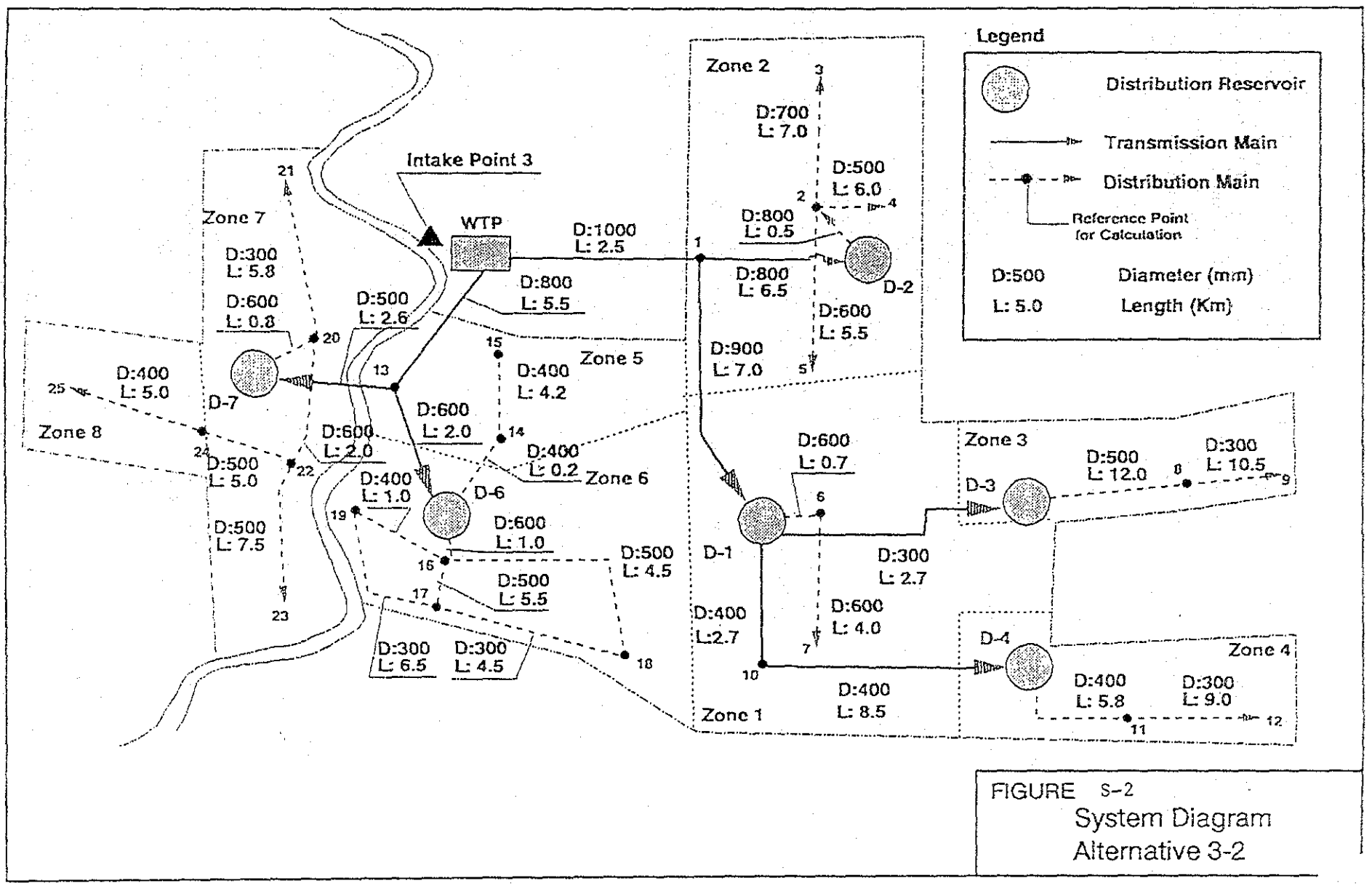



FIGURE S-2
System Diagram
Alternative 3-2

IMPLEMENTATION PLAN

The implementation plan of the total project will follow projections on water demand. The construction of the treatment plant is proposed to be carried out in two phases: (1) the first phase in 1993-1995, and (2) the second phase in 1998-1999. The construction of the distribution reservoirs, and the transmission and distribution pipelines will be constructed in two years in each phase. Figure S-3 shows the water demand, the treatment capacity and the construction schedule of the facilities.

ORGANIZATION OF WATERWORKS

The organization of the waterworks system will have to be expanded to include sections on administration, water production, operation of the distribution reservoirs and the number of staff needed to run the system depend on water demand. Figure S-4 shows a proposed organization for the new system.

PROJECT COST ESTIMATES

(1) Construction Cost

Construction cost summary was based on the 1989 prices and was calculated for each facility component as shown in the Table below.

Summary of Construction Cost

(unit : Baht 1000)

| Item | Total Value | Foreign Currency Portion | Local Currency Portion |
|---|---|---|---|
| 1.Raw Water Intake | 72,195 | 50,549 | 21,646 |
| 2.Treatment Plant | 656,017 | 305,705 | 350,312 |
| 3.Distribution Reservoirs | 367,487 | 147,426 | 220,061 |
| 4.Transmission Pipeline | 287,027 | 227,610 | 59,417 |
| 5.Distribution Pipeline | 600,223 | 424,969 | 175,254 |
| Sub Total | 1,982,949 | 1,156,259 | 826,690 |
| 6.Land Cost | 177,000 | 0 | 177,000 |
| Total | 2,159,949 | 1,156,259 | 1,003,690 |

(2) Operation and Maintenance Cost

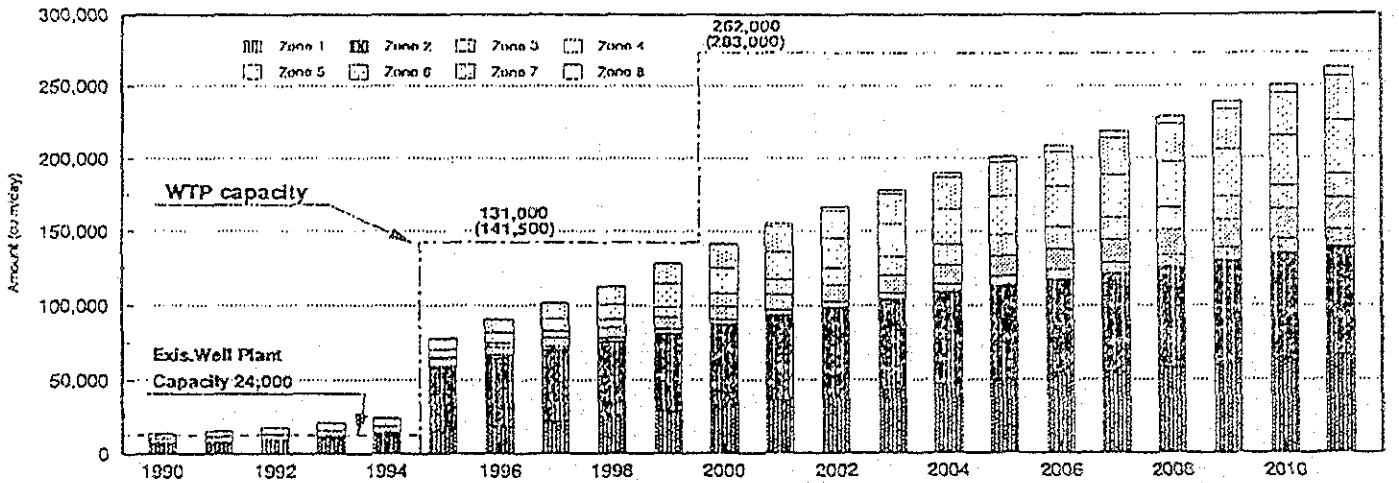
Operation and maintenance cost is calculated from the water demand in each year, and consists of energy, chemical, manning, repair, and replacement

costs.

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

| Year | Energy Cost | Chemical Cost | Manning Cost | Repair Cost | Total |
|---|---|---|---|---|---|
| 1990 : | 0 | 132 | 4,566 | | 4,698 |
| 1991 : | 0 | 145 | 5,178 | | 5,324 |
| 1992 : | 0 | 169 | 5,840 | | 6,009 |
| 1993 : | 0 | 196 | 6,555 | | 6,751 |
| 1994 : | 0 | 228 | 7,327 | | 7,555 |
| 1995 : | 21,740 | 3,204 | 8,793 | | 33,737 |
| 1996 : | 24,015 | 3,725 | 11,718 | 921 | 40,379 |
| 1997 : | 27,170 | 4,166 | 13,433 | 921 | 45,689 |
| 1998 : | 29,289 | 4,625 | 15,290 | 921 | 50,124 |
| 1999 : | 33,954 | 5,275 | 17,298 | 921 | 57,449 |
| 2000 : | 36,457 | 5,833 | 20,279 | 921 | 63,490 |
| 2001 : | 40,169 | 6,369 | 22,665 | 921 | 70,124 |
| 2002 : | 42,667 | 6,832 | 25,668 | 921 | 76,088 |
| 2003 : | 46,364 | 7,304 | 28,603 | 1,365 | 83,636 |
| 2004 : | 49,584 | 7,785 | 31,767 | 1,365 | 90,502 |
| 2005 : | 52,511 | 8,249 | 36,381 | 1,365 | 98,506 |
| 2006 : | 54,731 | 8,561 | 40,112 | 1,769 | 105,172 |
| 2007 : | 56,689 | 8,956 | 45,232 | 1,769 | 112,646 |
| 2008 : | 58,752 | 9,372 | 50,167 | 1,769 | 120,061 |
| 2009 : | 60,925 | 9,810 | 55,482 | 1,769 | 127,986 |
| 2010 : | 63,211 | 10,269 | 61,204 | 1,769 | 136,452 |
| 2011 : | 65,612 | 10,750 | 67,359 | 1,769 | 145,490 |



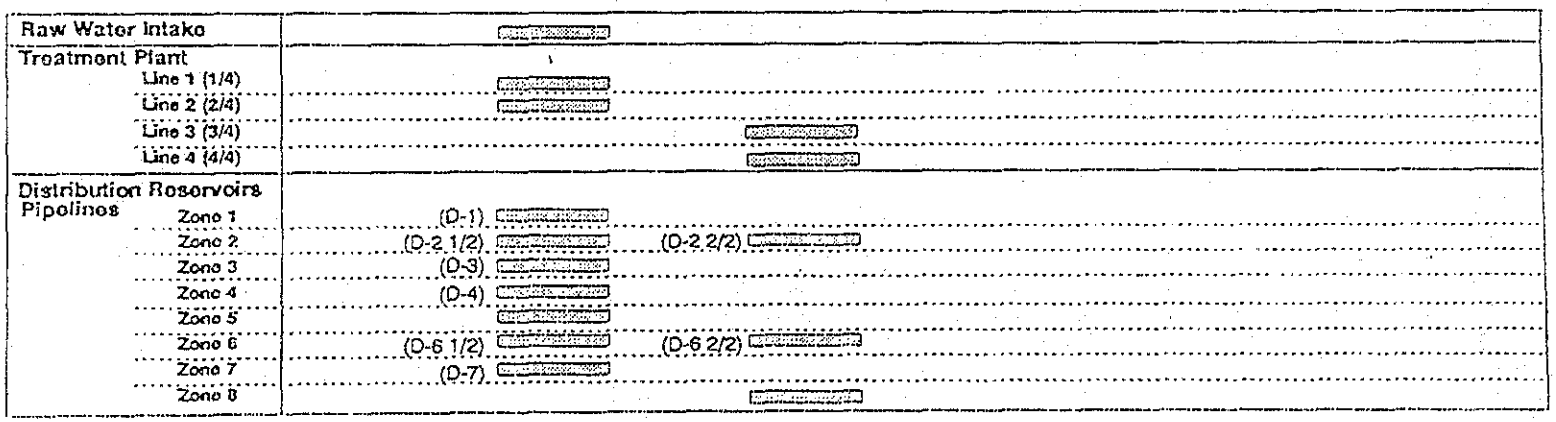




FIGURE S-3

Implementation Plan

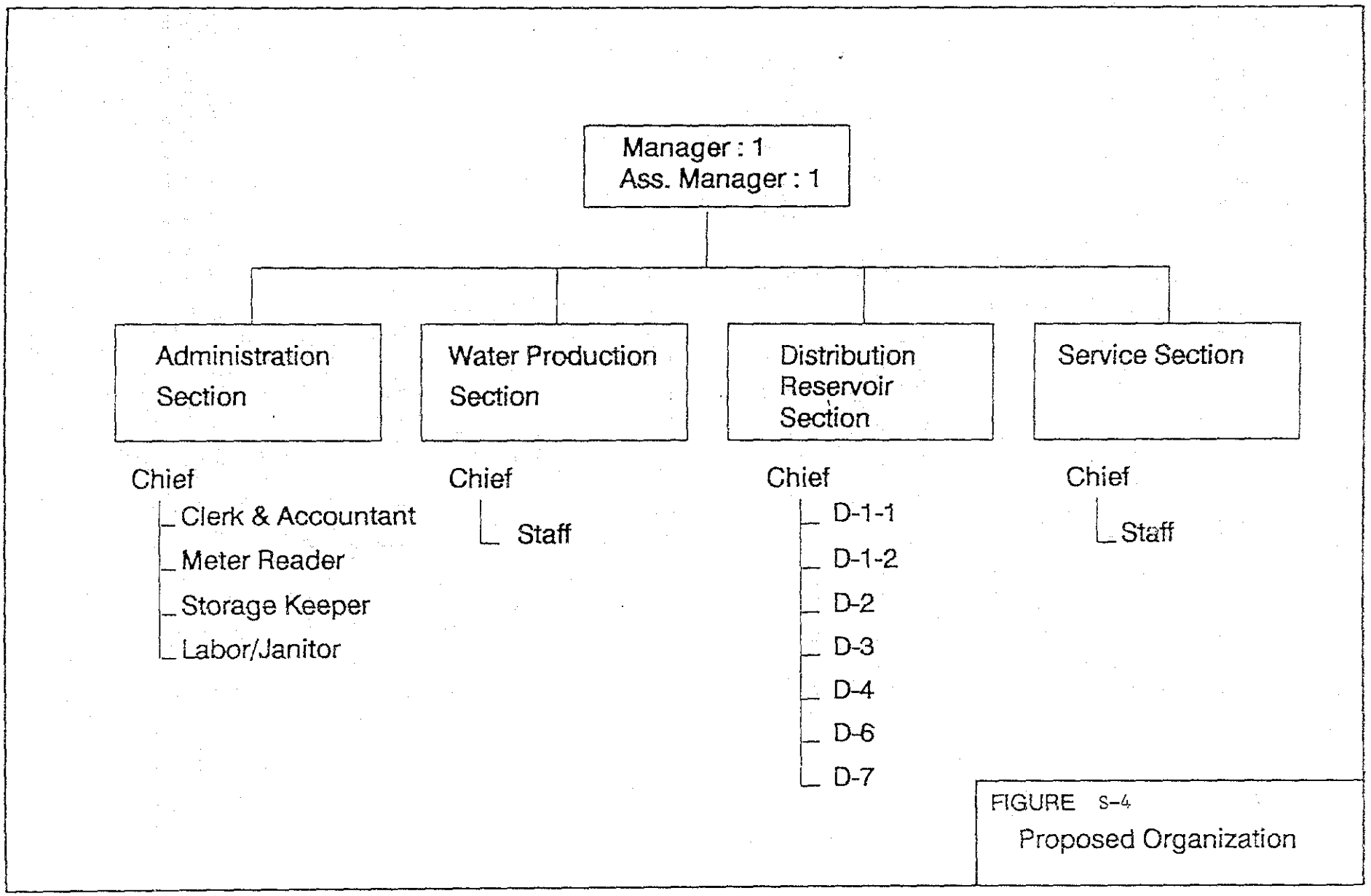



FIGURE S-4
Proposed Organization

PART 3 FEASIBILITY STUDY

Preliminary Design

The preliminary design was prepared for the proposed facilities. The characteristics of the major facilities of the treatment plant are summarized as follows:

a. Receiving Well
   Type : Circular
   Dimension : Dia. 9.0 m x D 5.0 m
   No. : 1

b. Mixing Basin
   Type : Square
   Dimension : L 4.0 m x W 4.0 m x D 3.0 m
   No. : 4

c. Flocculator
   Type : Mechanical flocculation
   Dimension : L 3.6 m x W 10.0 m x D 3.6 m x 3 stages
   No. : 16

d. Sedimentation Basin
   Type : Rectangular with Inclining Plate
   Dimension : L 18.0 m x W 18.0 m x D 4.5 m
   No. : 8

e. Sand Filter
   Type : Rapid Sand Filter, Inter-filter backwashing type
   Dimension : L 15.0 m x W 10.0 m
   No. : 16

f. Clear Water Reservoir
   Type : Rectangular
   Dimension : L 60.0 m x W 60.0 m x D 5.0 m
   No. : 2

g. Sludge Lagoon
   Type : Open Cut, Rectangular
   Dimension : L 68.0 m x W 33.0 m x D 3.0 m
   No. : 2

h. Sludge Drying Bed
   Type : Concrete Bed, Rectangular
   Dimension : L 30.0 m x W 20.0 m x D 1.0 m
   No. : 4

As shown in Figure S-3, the construction will be divided in two phases. The seven zones (Zones 1-7) will be covered in the first phase project while Zone 8 will be covered by the second phase. The project component is accordingly divided in two phases as shown below:

Project Component in Two Phases

| Facility | Phase 1 | Phase 2 |
|---|---|---|
| Raw Water Intake | | |
| | Intake Channel | |
| | Pumping Station | |
| | Pump : 3 units | Pump : 1 unit |
| | Raw water pipe | |
| Treatment Plant | | |
| | Capacity : 141,500 cu m/day | Capacity : 141,500 cu m/day |
| | Receiving well | |
| | Mixing tank : 2 units | Mixing tank : 2 units |
| | Flocculator : 2 lines | Flocculator : 2 lines |
| | Sedimentation basin: 8 basins | Sedimentation basins: 8 basins |
| | Sand filter : 8 units | Sand filter : 8 units |
| | Cleat water reservoir: 1 unit | Clear water reservoir: 1 unit |
| | Sludge lagoon : 2 units | |
| | Sludge drying bed : 2 units | Sludge drying bed : 2 units |
| | Clear water pump: 6 units | Clear water pump : 2 units |
| Distribution Reservoir | | |
| | D-1-1 : V = 5,000 cu m | |
| | D-1-2 : V = 13,000 cu m | |
| | D-2 : V = 9,550 cu m | D-2 : V = 9,550 cu m |
| | D-3 : V = 2,000 cu m | |
| | D-4 : V = 2,200 cu m | |
| | D-6 : V = 6,500 cu m | D-6 : V = 6,500 cu m |
| | D-7 : V = 9,000 cu m | |
| Transmission Pipelines | | |
| | Steel pipes | |
| | 1,000 mm, L = 2,500 m | |
| | 900 mm, L = 7,000 m | |
| | 800 mm, L = 12,000 m | |
| | 600 mm, L = 3,800 m | |
| | 400 mm, L = 11,200 m | |
| | AC Pipe | |
| | 300 mm, L = 2,700 m | |
| Distribution Pipelines | | |
| | (for Zones 1 to 7) | (for Zone 8) |
| | Steel Pipes | Steel Pipes |
| | 1,000 mm, L = 200 m | 400 mm, L = 3,900 m |
| | 900 mm, L = 3,190 m | |
| | 800 mm, L = 4,540 m | A/C Pipes |
| | 700 mm, L = 1,200 m | 300 mm, L = 1,750 m |
| | 600 mm, L = 14,720 m | 250 mm, L = 1,000 m |
| | 500 mm, L = 30,710 m | 200 mm, L = 2,300 m |
| | 400 mm, L = 30,170 m | 150 mm, L = 500 m |
| | A/C Pipes | |
| | 300 mm, L = 39,480 m | |
| | 250 mm, L = 19,255 m | |
| | 200 mm, L = 13,300 m | |
| | 150 mm, L = 3,270 m | |
| | 100 mm, L = 8,050 m | |

## Financial Study

### Project Cost Estimates

Total Project cost is estimated at 2,291,633 Baht, with a foreign exchange requirement of 1,385,231 Baht and local cost component of 906,402 Baht. The breakdown of cost estimates by phase is as follows:

| | Foreign Portion | Local Portion | TOTAL |
|---|---|---|---|
| a. Construction Cost | 1,300,752 | 682,200 | 1,982,952 |
| Phase 1 | 1,032,226 | 512,664 | 1,544,890 |
| Phase 2 | 268,526 | 169,536 | 438,062 |
| b. Engineering Cost | | | |
| Design, 4% of (a) | 55,974 | 31,276 | 87,250 |
| Phase 1 | 50,377 | 28,148 | 78,525 |
| Phase 2 | 5,597 | 3,128 | 8,725 |
| Supervision, 2% of (a) | 28,505 | 15,926 | 44,431 |
| Phase 1 | 17,310 | 9,671 | 26,981 |
| Phase 2 | 11,195 | 6,255 | 17,450 |
| c. Land Cost (Phase 1) | 0 | 177,000 | 177,000 |
| TOTAL | 1,385,231 | 906,402 | 2,291,633 |
| Phase 1 | 1,099,913 | 727,483 | 1,827,396 |
| Phase 2 | 285,318 | 178,919 | 464,237 |

### Financing Plan

The following financing schemes were considered:

Alternative 1: Total project cost financed from multilateral loan

Alternative 2: Foreign cost portion financed from bilateral loan; local cost from multilateral loan

Alternative 3: Foreign cost portion financed from bilateral loan; local cost equally financed from domestic loan and from PWA equity

Alternative 4: 86% of total project cost consisting of all foreign cost and 593,670 million Baht of local cost financed from bilateral loan; the remaining 312,732 million Baht of local cost equally financed from domestic loan and from PWA equity

Alternative 5: 86% of total project cost, consisting of all foreign cost and 593,670 million Baht financed from bilateral loan; 312,732 million Baht of local cost from domestic loan

Alternatives 3 and 4 are more desirable in view of lower funding burden for PWA. However, Alternative 4 is recommended over Alternative 3 due to lower fund requirements during construction stage.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on Alternative 4 financing scheme, water sales, connection fees, service charges, and other income including revenues from sales of materials, collected fines and about 2% of water sales. Water sales were projected using the current tariff structure until year 2020. Outflows consist of project expenditure, amortization based on Alternative 4 financing scheme, O&M, and connection expenses (50% of connection fees).

Results of cash flow analysis show deficits ranging from -24.626 million Baht to -411.268 million Baht for the period 1990 to 1994. These are expected to be covered with PWA equity. However, large surpluses during the subsequent years (1995-2020) are forecasted. For year 2020, cumulative cash surpuls is estimated at 2,339.3 Million Baht.

Financial Internal Rate of Return (FIRR)

The project's internal rate of return on equity (IRROE), based on Alternative 4 financing scheme, was assumed to represent the FIRR. The IRROE, unlike the internal rate of return on investment (IRROI), takes into account the debt payments that have to be made each year. Also considered in the analysis was the salvage value of capital assets which was added to the benefit flows. Results indicate that the project is financially viable, with an FIRR of 11.5%, which is greater than the 9% opportunity cost of capital.

ECONOMIC STUDY

The benefits were represented by the following: a) economic value of water, assumed to be 20% higher than the average rate per volume of water used in the financial analysis; b) health benefits, expressed as the reduction in cost of time lost and reduction in medical expenses (assuming 50% of waterborne diseases are caused by poor water supply system); c) increase in land values, assuming an increase of 50% up to year 2011 (7 years after construction of the project) and assuming that 5% of the increase in land values is attributed to the availability of water supply system. Other expected benefits such as increased employment opportunities, intensified land use, increaed government tax revenues were not quantified.

The econoimc costs were calculated based on financial costs adjusted for the following: a) import duties and domestic tax assumed to be 10% and 5%, respectively; b) shadow prices for foreign and local currency of 1.00 and 0.95 respectively, and for unskilled labor of 0.5.

The project was found to be economically viable, with an economic internal rate of return (EIRR) of 9.5%, which is greater than the 9% opportunity cost of capital.

# Part 1
# GENERAL

# Part 1 GENERAL

## 1 DESCRIPTION OF THE STUDY AREA

### 1.1 Natural Conditions

#### 1.1.1 General

The Municipality of Patum Thani is a capital of Patum Thani Province located 28 km north of Bangkok. Prachatipat is located 11 km east of Patum Thani along the Phaholyotin Road (Route 1) close to Bangkok. The advantage of terrain has brought a rapid development and expansion in these areas. A growing number of population working in Bangkok are beginning to settle in these fringe areas where a number of factories are also located. This has created an extensive employment opportunities. The construction of housings and factories are still actively going on especially in Prachatipat because of its accessibility to Bangkok.

Two of the PWA waterworks system are currently supplying water in these areas separately. In the area not covered by the PWA waterworks, two rural water supply systems are operating by the sanitary districts of Thanyaburi and Lam Luka. The private water sources such as ground water and canal/river water are also being used.

#### 1.1.2 Topography

Patum Thani is located at the right bank of the Chao Phraya River while Prachatipat is located at the left bank extending to both the north and east. Both areas occupy a total area of 1,153 sq.km bounded on the south by the Bangkok Metropolis. Both areas are situated on the flat plain with average elevations ranging from 1 to 3 m above the mean sea level, where rice is mainly planted and the withdrawal by ground water can be often seen.

The Chao Phraya River, the biggest river in Thailand has a length of 1,100 km and has a total catchment area of about 180,000 sq.km. It lies in the western side of the study area and is flowing into the Gulf of Thailand. The width of the river at Patum Thani is about 200 to 300 m on average while its discharge amount reaches 2,200 cu.m/s.

#### 1.1.3 Geology

Patum Thani and Prachatipat, the vicinity of the Bangkok Metropolitan area, is located in the Lower Central Chao Phraya Plain along the Chao Phraya River. It forms a flat low-lying delta plain.

The Lower Central Chao Phraya Plain is covered by thick alluvial and tertiary sediments. The topmost thick clay, called "Bangkok Clay" is about 20 to 30 m thick and covers the whole of the study area. The Bangkok Clay is divided into three kinds: weathered clay, soft clay and stiff clay. Bangkok Clay is considered to be one of the more important factors in considering land subsidence.

In the geological structure of the Lower Central Chao Phraya Plain, there is a large artesian ground water basin which formulates a north-south trending block fault. Ground water is contained in a series of vast confined aquifers consisting of sand gravel which extends to a maximum depth of 500 to 600 m of Pleistocene underlaying Bangkok Clay.

### 1.1.4 Meteorology

The annual rainfall in Patum Thani and Prachatipat averages about 1,300 mm with highly seasonal distribution. More than 50% of the total rainfall occurs during the wet season from May to October. During this period, there is a series of flooding in the low-lying area. Rainfall during the rest of a year is scarce.

The average annual pan evaporation level is about 1,780 mm with little monthly variation. Relative humidity is rather high ranging from 79.9% in September to 69.7% in January. The mean monthly temperature varies from 29.9°C in April to 25.5°C in December which shows a range of 4.4°C only. The extreme range is from 40.8°C to 10.0°C.

Details of the meteorology are given in Tables 1-1-1 and Appendix A-1-1.

Table 1-1-1 Meteorological Data at Phachathipat

| Items | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature (C.degree) | | | | | | | | | | | | | |
| Mean | 26.0 | 27.5 | 29.0 | 29.9 | 29.4 | 28.9 | 28.5 | 28.3 | 28.0 | 28.0 | 27.2 | 25.5 | 28.0 |
| Mean Max. | 31.7 | 32.9 | 34.2 | 35.1 | 34.3 | 33.2 | 32.7 | 32.4 | 31.9 | 31.5 | 31.0 | 30.7 | 32.6 |
| Mean Min. | 20.2 | 22.3 | 24.0 | 25.2 | 25.5 | 25.3 | 25.0 | 25.0 | 24.8 | 24.8 | 23.5 | 20.9 | 23.9 |
| Ext. Max. | 36.6 | 37.4 | 40.0 | 39.9 | 40.8 | 38.1 | 36.8 | 36.4 | 36.5 | 35.3 | 35.6 | 34.8 | 40.8 |
| Ext. Min. | 11.6 | 16.0 | 16.8 | 19.6 | 20.0 | 21.2 | 21.9 | 20.3 | 21.2 | 20.6 | 15.0 | 10.0 | 10.0 |
| Relative Humidity (%) | | | | | | | | | | | | | |
| Mean | 69.7 | 73.4 | 73.8 | 74.3 | 76.7 | 76.2 | 77.2 | 78.2 | 79.9 | 78.2 | 75.1 | 71.3 | 75.3 |
| Mean Max. | 89.6 | 92.3 | 91.9 | 91.4 | 91.3 | 90.0 | 90.5 | 91.2 | 91.9 | 91.3 | 89.2 | 88.6 | 90.8 |
| Mean Min. | 47.0 | 50.1 | 49.8 | 52.2 | 56.7 | 58.2 | 59.7 | 61.3 | 63.4 | 63.2 | 58.0 | 51.4 | 55.9 |
| Ext. Min. | 20.0 | 20.0 | 25.0 | 25.0 | 30.0 | 30.0 | 38.0 | 40.0 | 40.0 | 28.0 | 25.0 | 26.0 | 20.0 |
| Evaporation (mm.) | | | | | | | | | | | | | |
| Mean - Pan | 136.0 | 141.0 | 182.0 | 188.0 | 171.0 | 150.0 | 148.0 | 147.0 | 130.0 | 128.0 | 126.0 | 133.0 | 1780.0 |
| Rainfall (mm.) | | | | | | | | | | | | | |
| Mean | 7.7 | 19.7 | 26.7 | 63.5 | 155.3 | 140.3 | 149.2 | 208.4 | 284.8 | 197.6 | 36.1 | 14.8 | 1304.1 |
| Mean Rainy Days | 1.1 | 2.0 | 2.5 | 6.2 | 14.1 | 14.3 | 16.5 | 19.0 | 20.5 | 14.9 | 5.5 | 1.4 | 118.0 |
| Greatest in 24 hr. | 34.3 | 48.4 | 58.1 | 106.2 | 78.6 | 67.0 | 81.8 | 117.5 | 148.4 | 132.9 | 53.8 | 48.8 | 148.4 |
| Day / Year | 26/85 | 18/61 | 21/84 | 26/61 | 4/64 | 2/70 | 3/60 | 23/62 | 6/72 | 1/57 | 9/83 | 13/70 | 6/72 |

Source : Meteorological Department

## 1.2 Socioeconomic Conditions

### 1.2.1 Economic Conditions

(1) The gross provincial product (GPP) of Patum Thani Province at 1972 prices are shown in Table 1-2-1. The largest share is accounted for by manufacturing, followed by agriculture and trade. The agriculture sector is dominated by crops of rice.

In terms of growth rate between 1980 and 1986, banking shows the highest growth rate, followed by transportation and communications and manufacturing. The growth of agriculture is low but the live stock sub-sector shows very high growth.

(2) The annual industrial development plan for the province for the year 1989 includes the following projects.

Extension service for vocational training
Vocational training of family industry and handicrafts
Project to increase production
Occupational training group leaders
Boring for ground water
Water supply to villages
Installation of water filtration plants

(3) The province is an important education center in the Bangkok Metropolitan Region and its vicinity. A number of educational institutions are located in the province. The major ones are The Asian Institute of Technology (AIT), Thammasat University Rangsit Campus, Bangkok University, Phretburi-Vithayalongkorn Teachers College, Rangsit University and Bangpoon Agriculture College.

(4) The province is absorbing population expansion of Bangkok and is expected to alleviate over-concentration of Bangkok.

(5) Though the province is in vicinity of Bangkok, it still has rural characteristics with the most share of employment by the agriculture sector. Infrastructure is not yet well developed. However, it is expected that development of industries together with infrastructure will further boost the economy of the province.

Table 1-2-1 Gross Provincial Product (GRP) at Constant 1972 Prices

Unit : Million Baht

| INDUSTRIAL ORIGIN | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986E |
|---|---|---|---|---|---|---|---|
| Agriculture | 488.6 | 559.6 | 740.8 | 655.8 | 676.2 | 635.6 | 696.4 |
| Crops | 439.2 | 504.2 | 661.6 | 576.6 | 600.3 | 577.9 | 593.0 |
| Livestock | 22.4 | 37.3 | 41.9 | 47.3 | 48.7 | 44.4 | 69.5 |
| Fisheries | 27.0 | 18.1 | 37.3 | 31.9 | 27.2 | 33.2 | 33.8 |
| Forestry | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| Mining & Quarrying | 48.3 | 47.5 | 38.4 | 43.3 | 48.1 | 48.4 | 48.7 |
| Manufacturing | 2,291.5 | 2,579.6 | 3,434.8 | 4,104.4 | 4,560.2 | 4,195.0 | 4,525.6 |
| Construction | 39.2 | 35.5 | 39.9 | 45.8 | 72.3 | 64.0 | 65.3 |
| Elect. & Water Supply | 240.7 | 272.9 | 301.9 | 278.5 | 379.3 | 446.3 | 452.8 |
| Trans. & Comm. | 45.2 | 54.6 | 57.7 | 72.7 | 90.8 | 107.5 | 116.3 |
| Trade | 294.6 | 321.1 | 368.0 | 414.6 | 439.6 | 475.7 | 504.8 |
| Banking | 68.7 | 83.6 | 104.5 | 134.5 | 160.2 | 176.1 | 201.1 |
| Ownership of Dwelling | 32.3 | 33.5 | 34.9 | 36.6 | 37.4 | 40.6 | 42.9 |
| Public Ad. & Defence | 67.2 | 73.1 | 78.8 | 86.7 | 80.5 | 91.7 | 97.6 |
| Services | 200.4 | 223.7 | 235.8 | 270.6 | 280.3 | 301.3 | 329.6 |
| GPP | 3,816.7 | 4,284.7 | 5,434.5 | 6,143.5 | 6,824.9 | 6,582.2 | 7,081.1 |
| Per Capita GPP (Baht) | 12,002 | 13,143 | 16,271 | 17,807 | 19,064 | 18,033 | 18,536 |

### 1.2.2 Transportation

The transportation network in the province consists of roads, railways and river transportation.

The major road network is as shown in Figure 1-3-1. The primary road is Route 1 (Phaholyothin Road), which connects the province with Bangkok and Ayutthaya Province. Paved roads connect amphoe centers with the Phaholyotin Road, of which Route 305 leads to Nakhon Nayok. Numbers of canals have local roads along them but the local road network is yet to be developed

The northern line of the Thai National Railways passes through the province along the Phaholyotin Road.

The Chao Phraya River and other canals serve water transportation of cargoes and people.

In the southern vicinity of the province is the Don Muang International Airport.

### 1.2.3 Education

The educational system in Thailand is divided into three levels: primary, secondary and tertiary.

In recent years, pre-primary education, including kindergarten, has become available to children whose ages range from three to five. Children enter primary school when they are anywhere between six to eight years old, depending largely on the locality. Secondary education is divided into lower and upper divisions each consisting of three years such that, typically, those 12-14 years of age attend lower secondary while those 15-17 attend upper secondary.

The government plays a major role in all aspect of Thailand's education system. Government expenditure on education as a percentage of total government expenditure varied from 19% to 21% in recent eight years. The percentage of government expenditure on education in Thailand is among highest compared to other developing countries.

In Patum Thani Province, there are 147 schools. However, this figure does not include Amphoes Sam Khok, Thanyaburi and Nong Sua. A detailed breakdown of schools, including the number of students is shown in Tables 1-2-2 to 1-2-7.

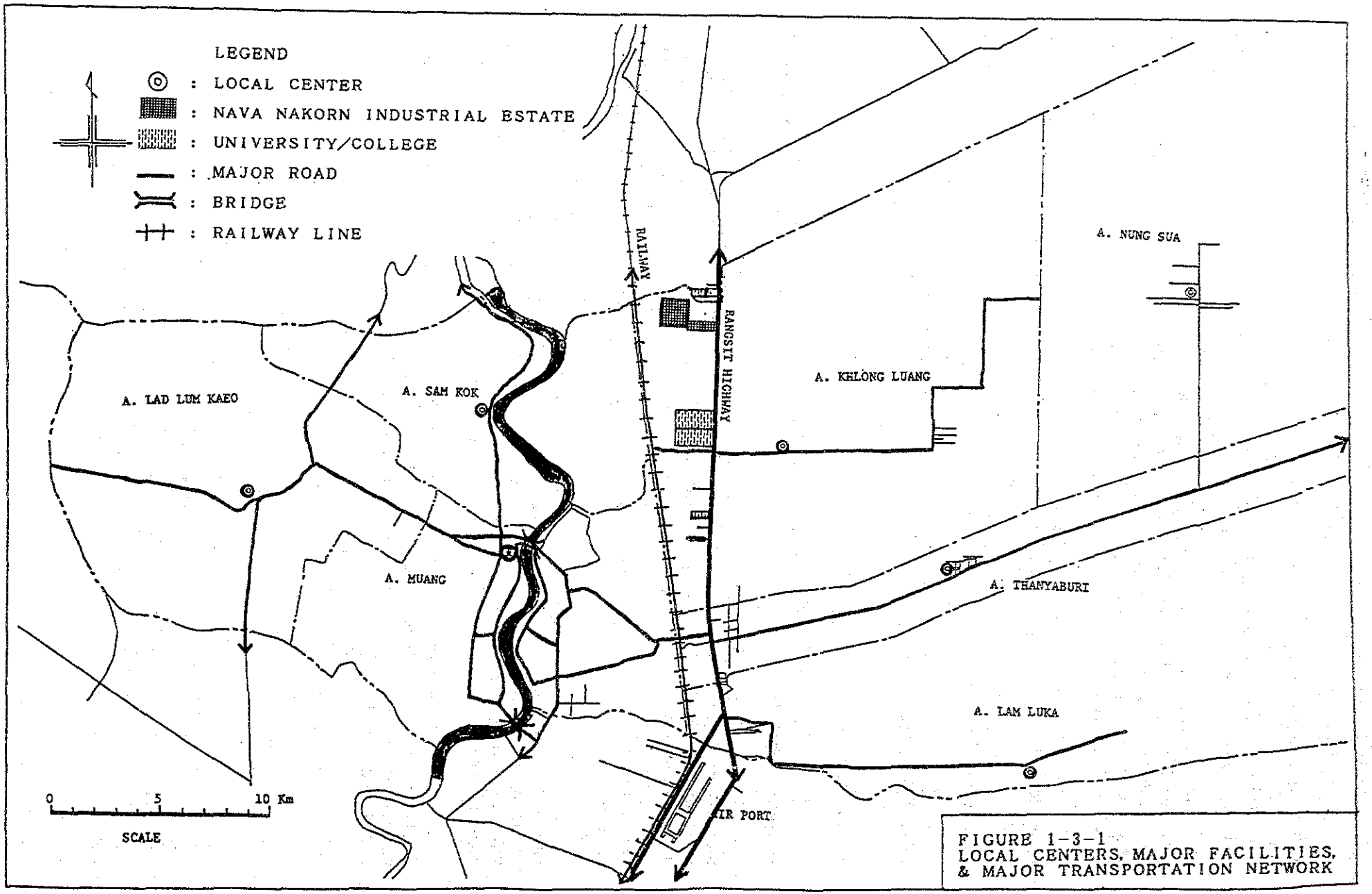



FIGURE 1-3-1
LOCAL CENTERS, MAJOR FACILITIES,
& MAJOR TRANSPORTATION NETWORK

Table 1-2-2 School in Patum Thani Municipality

| Grade of School | No. of Schools | No. of Students | No. of Teachers |
|---|---|---|---|
| Primary School | - | 8,889 | 373 |
| Grade School of Education | - | 6,167 | 342 |
| Private School | - | 3,761 | 178 |
| Total | - | 18,817 | 893 |

Table 1-2-3 School in Amphoe Muang Patum Thani

| Grade of School | No. of Schools | No. of Students | No. of Teachers |
|---|---|---|---|
| Education of School | 27 | 11,890 | 536 |
| Grade School of Education | 3 | 5,154 | 275 |
| Vocational Education | 12 | 5,507 | 313 |
| Private School | 1 | 1,524 | 99 |
| Total | 43 | 24,075 | 1,223 |

Table 1-2-4 School in Amphoe Khlong Luang

| Grade of School | No. of Schools | No. of Students | No. of Teachers |
|---|---|---|---|
| Kindergarten | - | - | - |
| Primary School | 33 | - | - |
| Secondary School | 2 | - | - |
| College/University | - | - | - |
| Total | 35 | - | - |

Table 1-2-5 School in Amphoe Sam Khok

| Grade of School | No. of Schools | No. of Students | No. of Teachers |
|---|---|---|---|
| Kindergarten | - | 477 | - |
| Primary School | - | 3,661 | - |
| Secondary School | - | 744 | - |
| College/University | - | - | - |
| Total | - | 4,882 | - |

Table 1-2-6 School in Amphoe Lam LuKa

| Grade of School | No. of Schools | No. of Students | No. of Teachers |
|---|---|---|---|
| Education of Primary | 2 | 1,308 | 74 |
| Grade School of Education | 32 | 7,379 | 356 |
| Private School | 11 | 6,321 | 264 |
| Total | 45 | 15,008 | 694 |

Table 1-2-7 School in Amphoe Lad Lum Kaeo

| Grade of school | No. of Schools | No. of Students | No. of Teachers |
|---|---|---|---|
| Kindergarten | - | - | - |
| Primary school | 23 | 4,403 | 245 |
| Secondary School | 1 | 1,126 | 60 |
| College/University | - | - | - |
| Total | 24 | 5,529 | 305 |

### 1.2.4 Sanitation (Water-borne diseases)

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

To decrease the incidence of water-borne diseases and the number of patients are one of the significant purposes of water supply project. The status of water-borne diseases in relation to the number of patients is shown in Tables 1-2-8 to 1-2-14.

Table 1-2-8 Water-Borne Diseases in Amphoe Muang Patum Thani

| Year | Diarrhea | Dysentery | Food Poisoning | Cholera | Total |
|---|---|---|---|---|---|
| 1983 | 525 | 143 | 22 | 10 | 700 |
| 1984 | 536 | 158 | 18 | 8 | 720 |
| 1985 | 628 | 147 | 15 | 7 | 797 |
| 1986 | 635 | 132 | 10 | 12 | 789 |
| 1987 | 725 | 196 | 14 | 13 | 948 |

Table 1-2-9 Water-Borne Diseases in Amphoe Nong Sua

| Year | Diarrhea | Dysentery | Cholera | Total |
|---|---|---|---|---|
| 1983 | 286 | 31 | 1 | 318 |
| 1984 | 324 | 20 | - | 344 |
| 1985 | 367 | 13 | - | 380 |
| 1986 | 511 | 33 | - | 544 |
| 1987 | - | 70 | - | (70) |

Table 1-2-10 Water-Borne Diseases in Amphoe Sam Khok

| Year | Diarrhea | Dysentery | Cholera | Total |
|---|---|---|---|---|
| 1983 | 481 | 64 | 3 | 548 |
| 1984 | 432 | 46 | 0 | 478 |
| 1985 | 419 | 59 | 0 | 478 |
| 1986 | 504 | 53 | 2 | 557 |
| 1987 | - | 64 | 9 | (73) |

Table 1-2-11 Water-Borne Diseases in Amphoe Lad Lum Kaeo

| Year | Diarrhea | Dysentery | Cholera | Total |
|---|---|---|---|---|
| 1983 | 497 | 79 | 5 | 581 |
| 1984 | 613 | 64 | 0 | 677 |
| 1985 | 592 | 54 | 1 | 647 |
| 1986 | 504 | 48 | 0 | 552 |
| 1987 | - | 43 | 18 | (61) |

Table 1-2-12 Water-Borne Diseases in Amphoe Lam LuKa

| Year | Diarrhea | Dysentery | Cholera | Total |
|---|---|---|---|---|
| 1983 | 534 | 62 | 5 | 601 |
| 1984 | 631 | 37 | - | 668 |
| 1985 | 698 | 30 | - | 728 |
| 1986 | 640 | 46 | - | 686 |
| 1987 | - | 50 | 4 | (54) |

Table 1-2-13 Water-Borne Diseases in Amphoe Khlong Luang

| Year | Diarrhea | Dysentery | Cholera | Total |
|---|---|---|---|---|
| 1983 | 366 | 50 | 6 | 442 |
| 1984 | 540 | 41 | - | 581 |
| 1985 | 553 | 52 | 2 | 607 |
| 1986 | 478 | 77 | 4 | 559 |
| 1987 | - | 112 | 28 | (140) |

Table 1-2-14 Water-Borne Diseases in Amphoe Thanyaburi

| Year | Diarrhea | Dysentery | Cholera | Total |
|---|---|---|---|---|
| 1983 | 539 | 86 | 3 | 628 |
| 1984 | 570 | 73 | 1 | 644 |
| 1985 | 640 | 91 | 1 | 732 |
| 1986 | 659 | 178 | 5 | 842 |
| 1987 | - | 186 | 34 | (200) |

## 1.3 Land Use

### 1.3.1 Existing Land Use Pattern

Main features of the existing land use pattern are as follows.

(1) Urbanization in General

Local centers, major facilities and a major transportation network are shown in Figure 1-3-1.

Major urbanization is observed along major roads such as the Paholyothin Road, the roads through the new and old bridges over the Chao Phraya River, Route 305 and the road to Lam Luka, especially in Amphoe Muang and neighboring tambons to the Paholyothin Road.

In most cases, remote areas from the Phaholyothin Road are less urbanized. For example amphoe centers except of Amphoe Muang still show rural characteristics.

(2) Industrial Location

As shown in Figure 1-3-2, industrial development is remarkable in areas near the Paholyothin road, i.e. Amphoe Muang and neighboring tambons of Amphoes Khlong Luang, Thanyaburi and Lam Luka and also in the eastmost tambons of Lad Lum Kaeo.

The Nava Nakorn Industrial Estate is located along the Phaholyothin Road in Tambon Klong Nung of Amphoe Khlong Luang. According to the list of factory plans registered at the Industry Office Patum Thani, most factories are going to be located along or near the Phaholyothin Road, and others are mostly in the southern part of Amphoe Muang and along the road to Lam Luka.

(3) Housing Location

Existing housing projects are mostly located in Amphoe Muang, neighboring tambons along the Paholyothin Road, and also along Route 305 as shown in Figure 1-3-3. Along Route 305 Tambons up to Tambon Bun Nun Pak farthest from the Paholyothin Road have many units of housing projects.

Future housing projects registered at the Province Office are in neighboring tambons to the Paholyothin Road and in Amphoe Muang.

### 1.3.2 Land Value

Land prices depend on accessibility to roads. Market land prices of areas along the Phaholyotin Road and of major road side areas as in the Municipality, Amphoe Muang, Lam Luka, and Thanyaburi are over 625 ฿/sq.m (1,000,000 ฿/rai).

While those of areas far from roads such as agricultural areas in remote tambons from the Phaholyotin Road are less than 62.5 ฿/sq.m (100,000 ฿/rai).

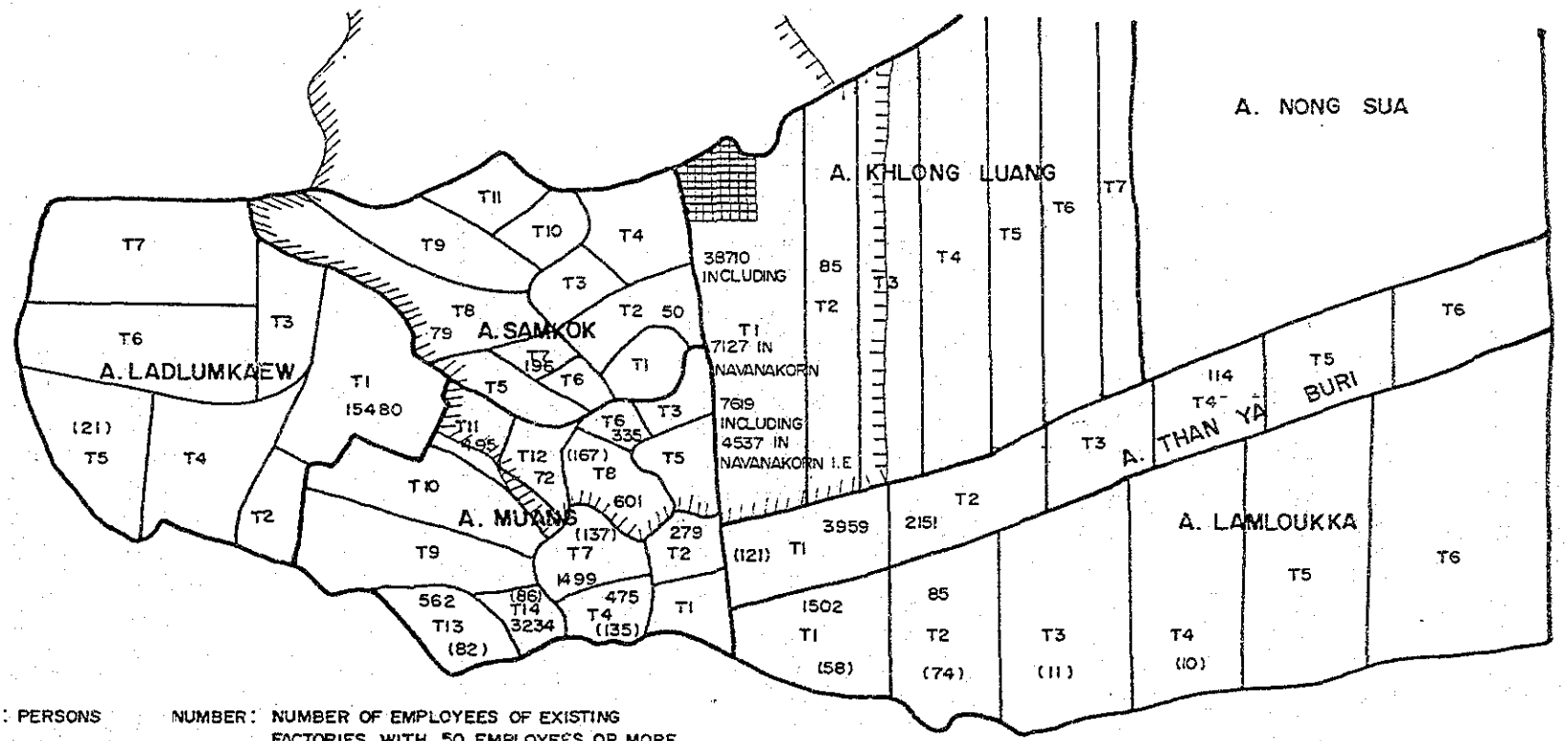
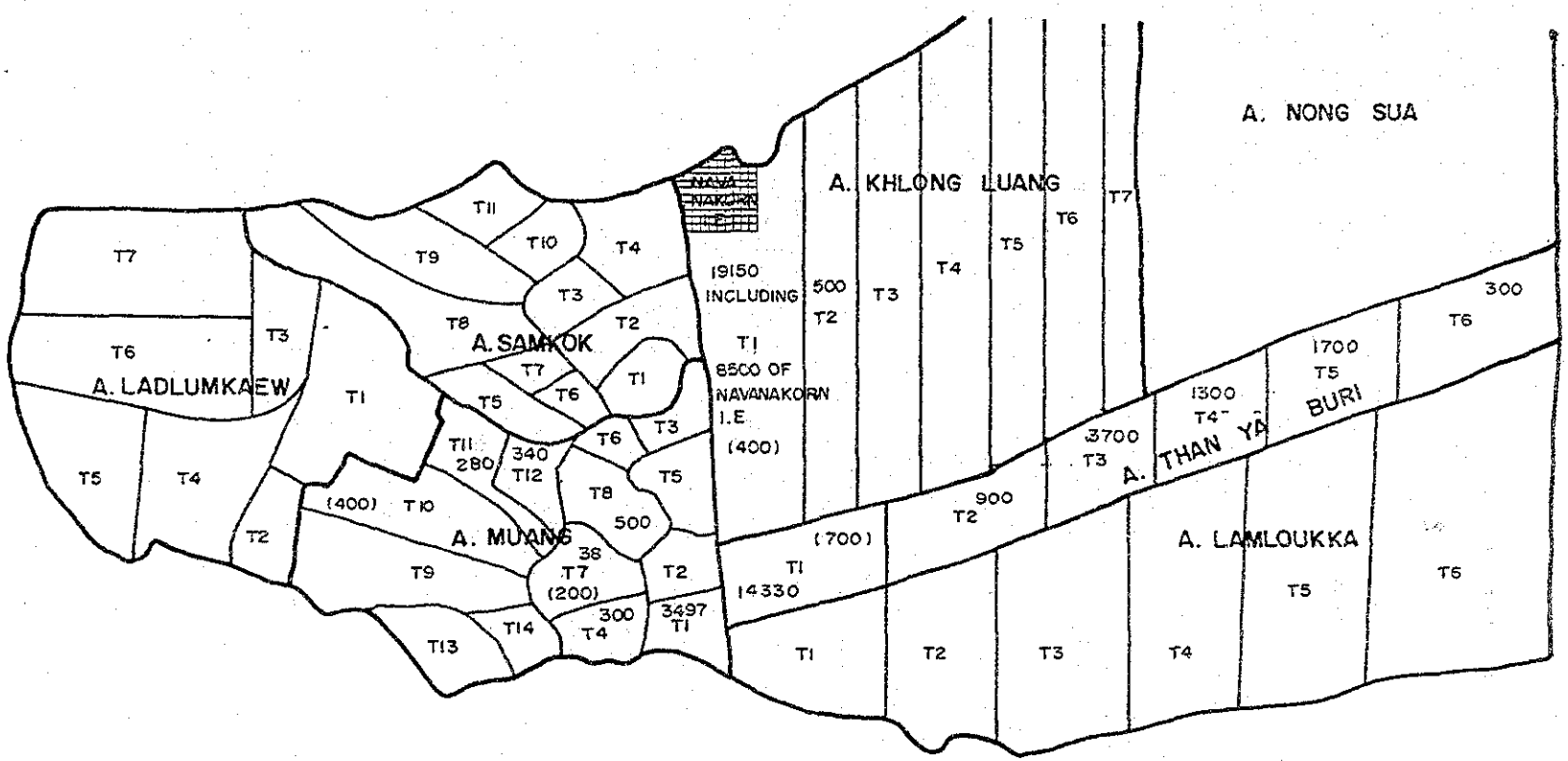



FIGURE 1-3-2
INDUSTRIAL LOCATION




NUMBER : NUMBER OF HOUSES OF EXISTING HOUSING PROJECTS REGISTERED AT PATUM THANI PROVINCE OFFICE

(NUMBER) : NUMBER OF HOUSES OF FUTURE HOUSING PROJECTS REGISTERED AT PATUM THANI PROVINCE OFFICE

FIGURE 1-3-3
HOUSING LOCATION

Official land prices are considerably lower than market prices. The Municipality is going to revise the official land prices in March 1989.

### 1.3.3 Future Land Use Pattern and Development PLan

(1) Town Planning Areas of DTCP

There are two town planning areas in the province, which are Patum Thani and Prachatipat as shown in Figure 1-3-4. The Patum Thani planning area covers the surrounding tambons of the Municipality considering future urban expansion beyond the municipal boundary. The latter covers the tambons neighboring the Paholyothin Road in Amphoe Khlong Luang and Thanyaburi to meet the urbanization trend.

In the town planning areas, commercial and high density residential areas are to have population density over 120 persons per ha, medium density residential areas between 60 and 120 persons per ha and low density residential areas less than 60 persons per ha.

These areas will be the commercial centers in the province as well as industrial centers, which are the Nava Nakorn Industrial Estate, large scale factories along the Phaholyotin Road, and Tambon Bang Kra Dee. In Tambon Bang Kra Dee, a large scale private industrial estate is being developed.

(2) Expansion of Municipality

The current urban development of these areas do not seem to be limited in these areas, due to active investment in the province.

The Patum Thani Municipality is considering expansion of its boundaries. The expanded boundary may cover the major part of Amphoe Muang on the west side of the Chao Phraya River where rapid urban, industrial and housing growth is observed especially along the main road to the old bridge.

The general locations for future industries are along the Phaholyotin Road, southern part of Amphoe Muang, east part of Amphoe Lat Lum Kaeo and along Route 305 and the Lam Luka Road. It is anticipated that the southern area of the MWA conservation area will attract more factories than inside the areas.

Considering the urbanization trend taking place linearly along the major roads, coordination on land use with agricultural areas is necessary. To avoid inefficient investment and possible traffic congestion on the major existing roads, measures for controlled development within delineated areas as well as development of subsidiary roads should be sought for.

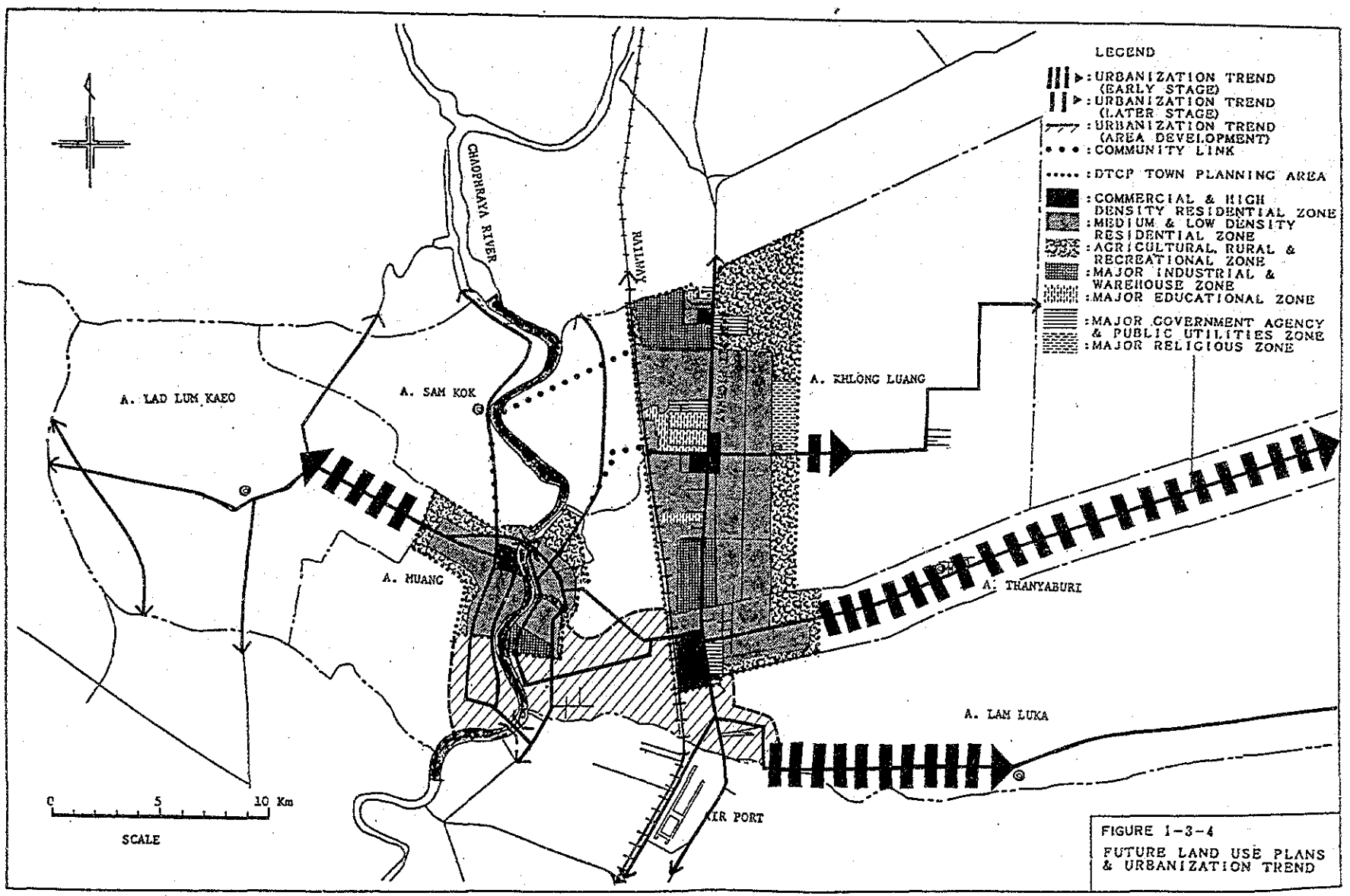



FIGURE 1-3-4
FUTURE LAND USE PLANS & URBANIZATION TREND

# 2 WATER SOURCE

## 2.1 Existing Water Use Pattern

### 2.1.1 General

In recent years, these two areas have been remarkably developed as an industrial and residential district in the suburbs of the Bangkok Metropolis. With a rapid development, ground water source has been fully utilized for industrial and domestic purpose all over the area.

In view of the land subsidence and sea water intrusion progressed in Bangkok, the Government takes precautions against the crisis in such a way that any ground water development newly proposed by private sectors needs the DMR's approval.

### 2.1.2 Aquifers in the Study Area

From the geological, hydrogeological and geophysical studies, DMR differentiates the aquifers of Bangkok area into eight aquifers from top to bottom as shown in Figure 2-1-1, namely:

| | | |
|---|---|---|
| (1) | Bangkok Aquifer | ( 50 m zone) |
| (2) | Phra Pradaeng Aquifer | (100 m zone) |
| (3) | Nakhon Luang Aquifer | (150 m zone) |
| (4) | Nonthaburi Aquifer | (200 m zone) |
| (5) | Sam Khok Aquifer | (250 m zone) |
| (6) | Phaya Thai Aquifer | (300 m zone) |
| (7) | Thon Buri Aquifer | (450 m zone) |
| (8) | Pak Nam Aquifer | (550 m zone) |

(1) Bangkok Aquifer (50 m Zone)

The Bangkok Aquifer is the topmost aquifer which is overlaid by the Bangkok clay. It consists of a sequence of thin to thick layers of sand and gravel with clay lenses. Depth to the aquifer is about 15 to 30 m from the ground surface. The thickness of the aquifer ranges from 20 to 60 m. Ground water from the Bangkok Aquifer is unused due to brackish to salty water.

(2) Phra Pradaeng Aquifer (100 m Zone)

The aquifer is separated from the Bangkok Aquifer by a clay bed of about 10 to 15 m in thickness. The top of the aquifer ranges from 60 to 80 m from the ground surface and the thickness varies from 20 to 50 m. The aquifer consists of white sand and gravel with clay lenses. The carbonized woods or logs have been found in many places. Ground water is heavily developed from this aquifer in the south and southwest of Bangkok.

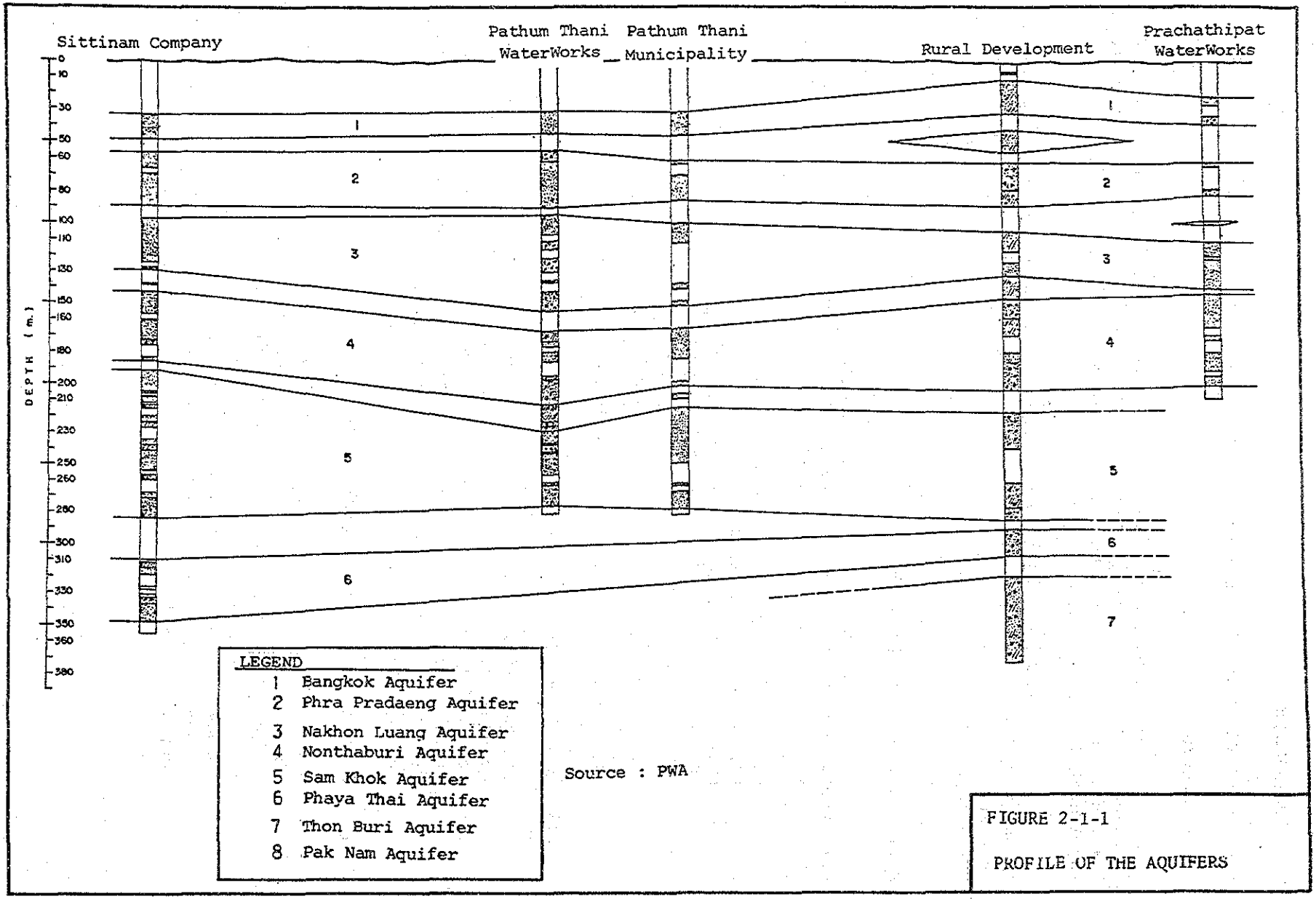



FIGURE 2-1-1

PROFILE OF THE AQUIFERS

(3) Nakhon Luang Aquifer (150 m Zone)

The aquifer also consists of sand and gravel with some clay lenses and leaky clay beds. The depth to the top of the aquifer is about 100 to 140 m below the ground surface and the thickness is about 50 to 70 m. The aquifer is hydraulically separated from the above aquifer by hard and compact clay with a thickness of 3 to 10 m. It is very heavily developed since ground water has been utilized for water supply in Bangkok.

(4) Nonthaburi Aquifer (200 m Zone)

The aquifer is similar and conform to the Nakhon Luang Aquifer. It consists of sand and gravel with minor clay lenses, and can be divided into at least 3 sub-aquifers being separated by leaky clay beds. The depth to the aquifer is about 170 to 200 m below the ground surface and the thickness is 30 to 70 m. The Nonthaburi Aquifer has been utilized since 1975 after the Nakhon Luang Aquifer was highly suffered from the over-pumping. The aquifer is now popular to drillers who require larger productive wells for industrial uses.

(5) Sam Khok Aquifer (250 m Zone)

The deepest aquifer ever penetrated by normal drilled wells is the Sam Khok Aquifer. The depth to the aquifer is about 240 to 250 m below the ground surface and the thickness is 40 to 80 m. The aquifer consists of alternating layers of sand or gravel and clay. Clay is generally brown to yellow and moderately to highly compacted. The production wells penetrated this aquifer are located at the north of Nonthaburi and Patum Thani.

(6) Phaya Thai (300 m Zone), Thon Buri (450 m Zone) and Pak Nam (550 m Zone) Aquifers

The aquifers at a depth exceeding 350 m, Phaya Thai, Thon Buri and Pak Nam are too deep to reach by normal production wells. They consist of thin to rather thick sand-gravel layers with the water bearing properties similar to those of the Sam Khok Aquifer. The Pak Nam Aquifer has been considered necessarily for some government authorities and companies which is in the south and southwest of Bangkok. The aquifer is now being exploited for industrial uses.

### 2.1.3 Ground Water Use

The location of deep wells in Patum Thani and Prachatipat areas is shown in Figure 2-1-2.

(1) Deep Wells Owned by PWA

(a) Prachatipat Area

At present PWA owns eight deep wells including deep wells taken over from private sectors as shown in Table 2-1-1. The log data at the PWA Waterworks are shown in Figures A2-1-1 and A2-1-2 and their water quality is shown in Table A2-1-1 in Appendix A-2-1.

Figure 2-1-1 Location Map of Water Sources

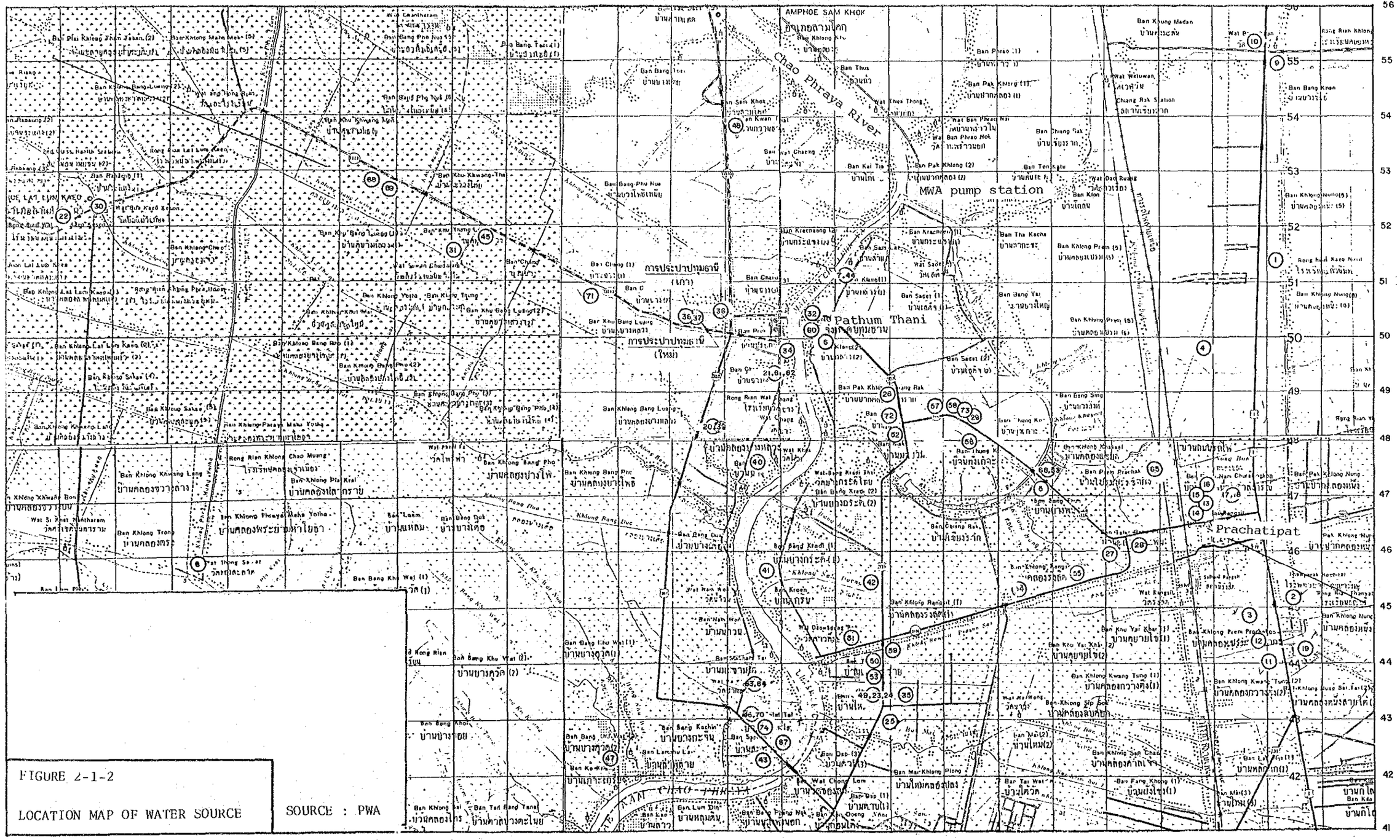


Table 2-1-1 List of Deep Wells

| Location | Capacity | Remarks |
|---|---|---|
| PWA Waterworks | 150 cu.m/h x 1 | Another is abandoned. |
| Sivali Village | 50 cu.m/h x 1 | w/ chlorination and aeration w/ an elevated tank. |
| Sanitary Dist. | 50 cu.m/h x 1 | under rehabilitation w/ a 200 cu.m elevated tank |
| (Rattna Kosin) | 50 cu.m/h x 3 | w/o chlorination and aeration |
| Factory | 50 cu.m/h x 1 | w/o chlorination and aeration |
| (Planning) | (150 cu.m/h x 3) | |
| Total | 460 cu.m/h (360 cu.m/h) | |

(b) Patum Thani Area

Out of the PWA owned three deep well plants, one is abandoned while the other two are operating. Their total capacity is 2 x 60 cu.m/h. Another well with a capacity of 80 cu.m/h is under planning.

The water quality tested by PWA is given in Table A2-1-1 and their log data in Figure A2-1-2 in Appendix A-2-1.

(2) Deep Wells Owned by Private and Public Sectors

At present, more than 65 deep wells exist in the Patum Thani and Prachatipat area as shown in Figure 2-1-2 and Tables A2-1-2 to A2-1-5 in Appendix A-2-1. These tables show the deep wells withdrawing ground water from four different aquifers.

## 2.2 Evaluation of Existing Water Source

### 2.2.1 Ground Water Problem in the Bangkok Metropolis

(1) General

According to the DMR's and MWA's statistics, the present total ground water production in Bangkok Metropolis and adjacent provinces including Samut Prakarn, Samut Sakorn, Nonthaburi, Patum Thani and Ayutthaya was reported to be over 1.4 million cu.m/d in April 1982; about 32% of which is from the public wells and remaining 68% from the private wells (Refer to Figure 2-2-1).

The ground water has mostly been withdrawn in the MWA's Central System Service area and the vicinity, estimated at approximately 1,318,000 cu.m/d, or about 94% of the total ground water withdrawn in the Lower Chao Phraya Basin. The above total pumpage in the area is made from a total 8,602 deep wells of which about 447,000 cu.m/d is from 110 public wells and 871,000 cu.m/d from 8,492 private wells.

The existing high rate of pumpage has seriously caused land subsidence and salinity intrusion into the well water.

(2) Land Subsidence, Saline Water Intrusion and Piezometric Level

According to the study conducted by AIT-DMR (1978-1981), the Bangkok area, in the past 40 to 50 years, has subsided about 30 to 80 cm from the original elevation. During the recent period between 1975 and 1980, the average rate of subsidence was about 5 to 10 cm per year in the urban area of Bangkok, and the maximum rate was more than 12 cm per year in the eastern part of Bangkok.

The piezometric level analysis and the declining rate of the MWA wells (1960-1982) are shown in Figures 2-2-1 and 2-2-2, for each of the Phra Pradaeng 100m, Nakhon Luang 150 m and Nonthaburi 200 m aquifers.

In early stages (1951-1960), the piezometric level was only 8 to 9 m below the ground surface, while it is presently about 35-53 below the ground surface in three aquifers.

The land subsidence depends on many factors, particularly the compression characteristics of the subsoil. The Bangkok Clay is soft and highly compressible due to high natural water content, with very low total unit weight, which are all related to the cause of possible settlement.

The problem of saline water intrusion has mostly taken place in the southwestern and southern parts of Bangkok. Saline water front (200 mg/l chloride content) crosses the Chao Phraya River moving to the northeastern part of the Central Bangkok where the high rate of ground water pumping continues.

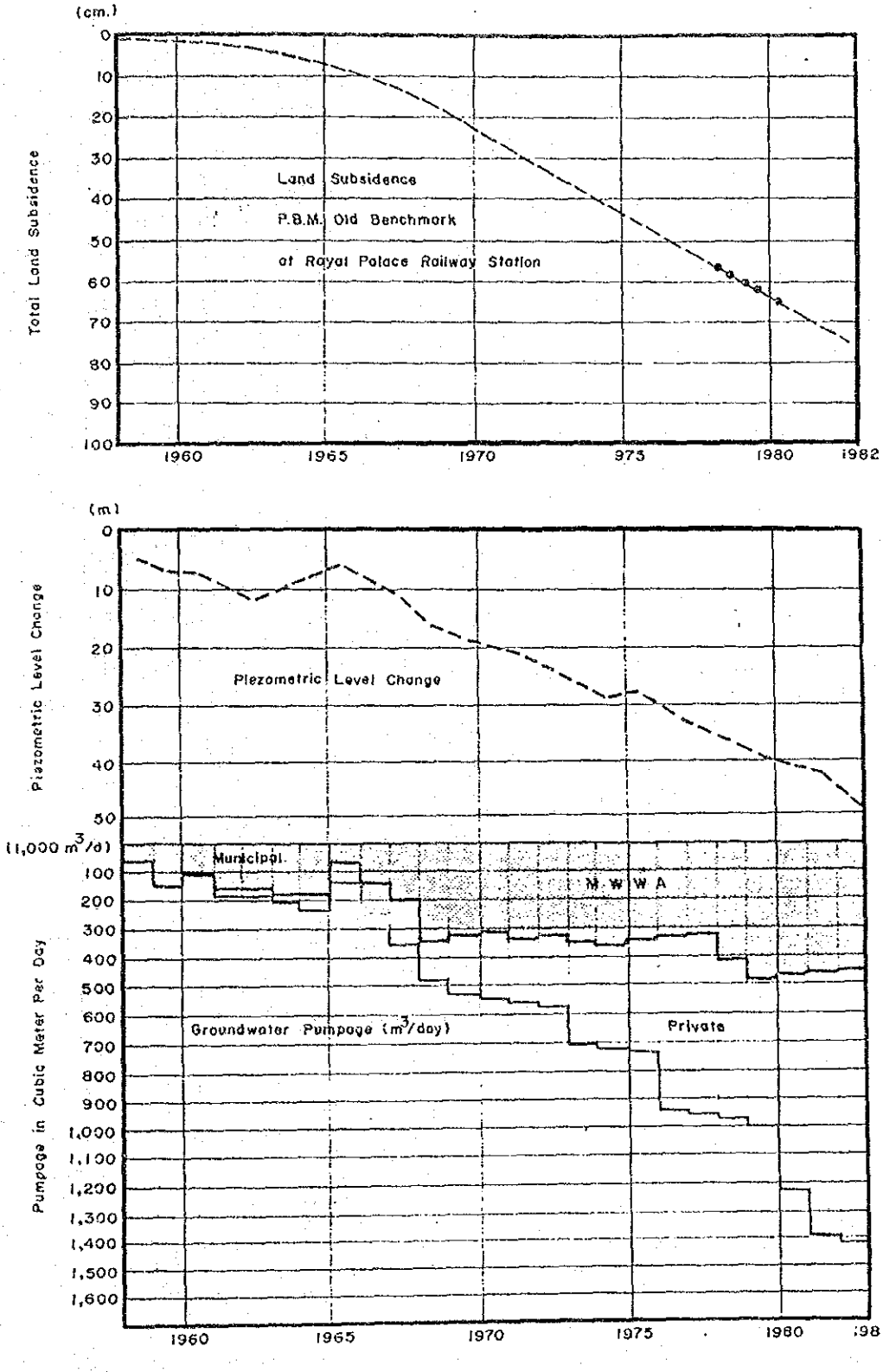
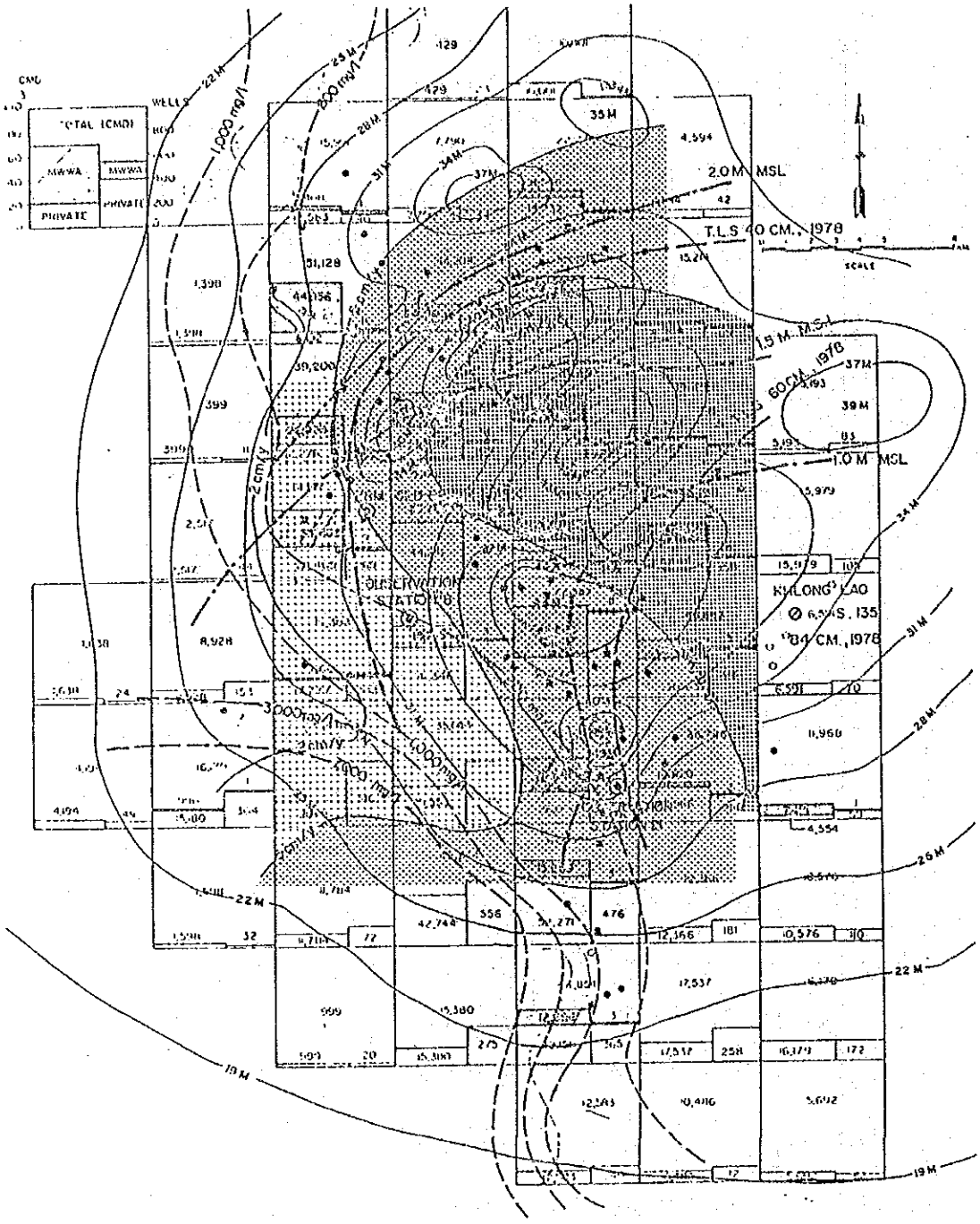



**FIGURE** 2-2-1
Land Subsidence, Piezometric Level Decline and Saline Water Encroachment in Bangkok



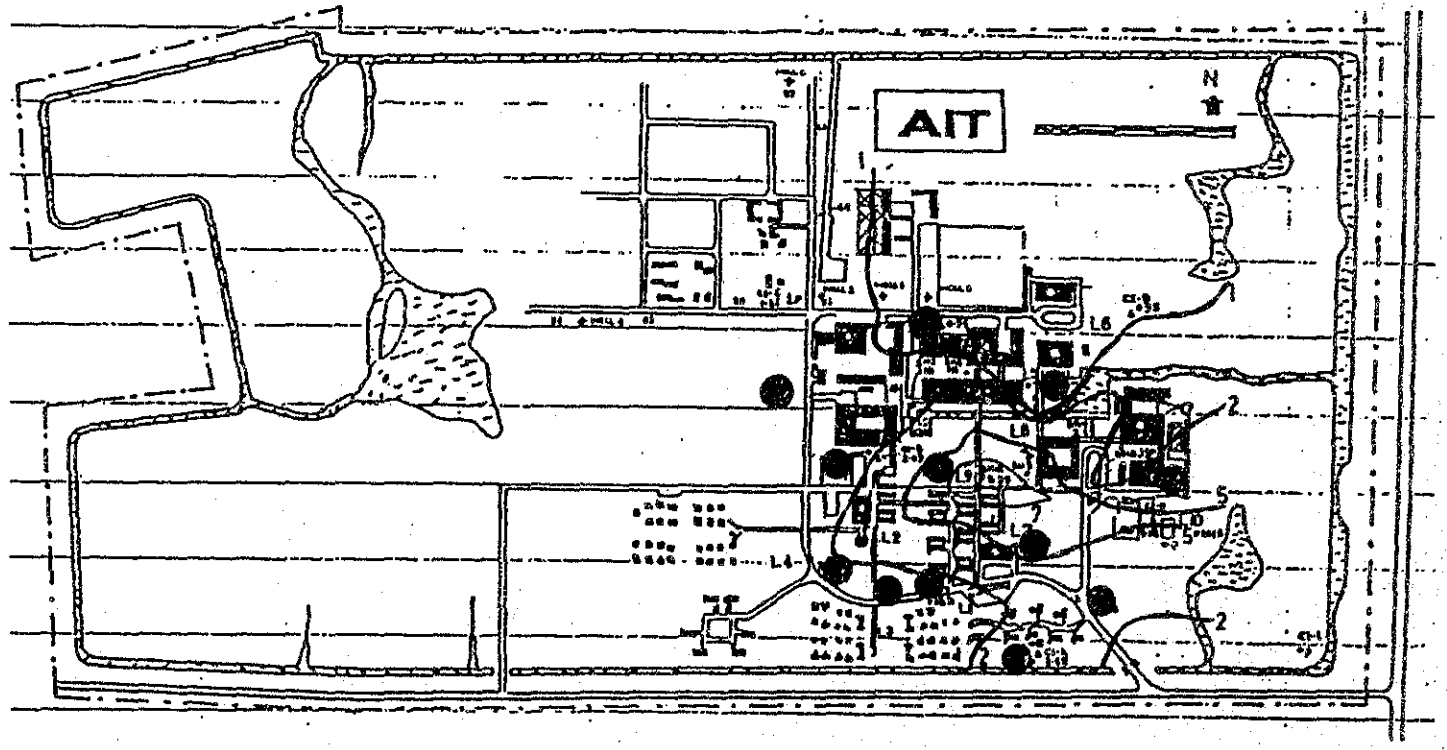

SOURCE : Review of the 1970 Master Plan and Present System, MWA

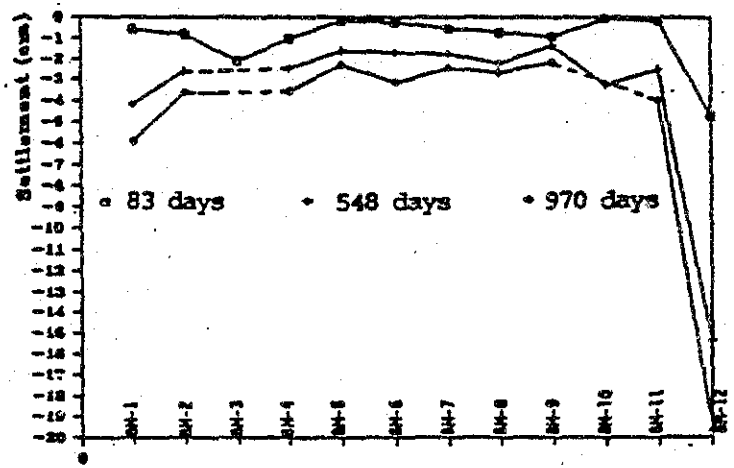
**FIGURE** 2-2-2
LAND SUBSIDENCE, PIEZOMETRIC LEVEL DECLINE AND SALINE WATER ENCROACHMENT IN BANGKOK

### 2.2.2 Ground Water Problem in the Study Area

The AIT study indicates that the campus of the AIT, which is located in the center of the Study Area, is subsiding due to the ground water pumping for water supply. It was found that the AIT campus subsided at an average rate of 2 to 4 cm/year with a maximum of 8 cm/year as shown in Figure 2-2-3. The subsidence rate in the dry season is twice the amount during the rainy season.

The subsidence of the AIT campus can be attributed to the excessive ground water pumping for water supply both inside and around the vicinity of the campus. During the past years, the rate of ground water extraction has increased and presently it stabilizes to 1,500 cu.m/d. The water supply for the AIT campus is pumped out from the 200 m depth in the Nonthaburi Aquifer. The deep wells are located as shown in Figure 2-2-3.




Location:

| | | | |
|---|---|---|---|
| BH - 1 | NZ Housing | BH - 7 | Energey Park |
| BH - 2 | Dormetry A | BH - 8 | Basket Ball Court |
| BH - 3 | Korea House | BH - 9 | RCC |
| BH - 4 | Village III | BH - 10 | AIT Center |
| BH - 5 | Library | BH - 11 | Administration Building |
| BH - 6 | Cricket Field | BH - 12 | Walkway at Foot Ball |

**FIGURE** 2-2-3
Subsidence contours and location of boreholes, pumping wells

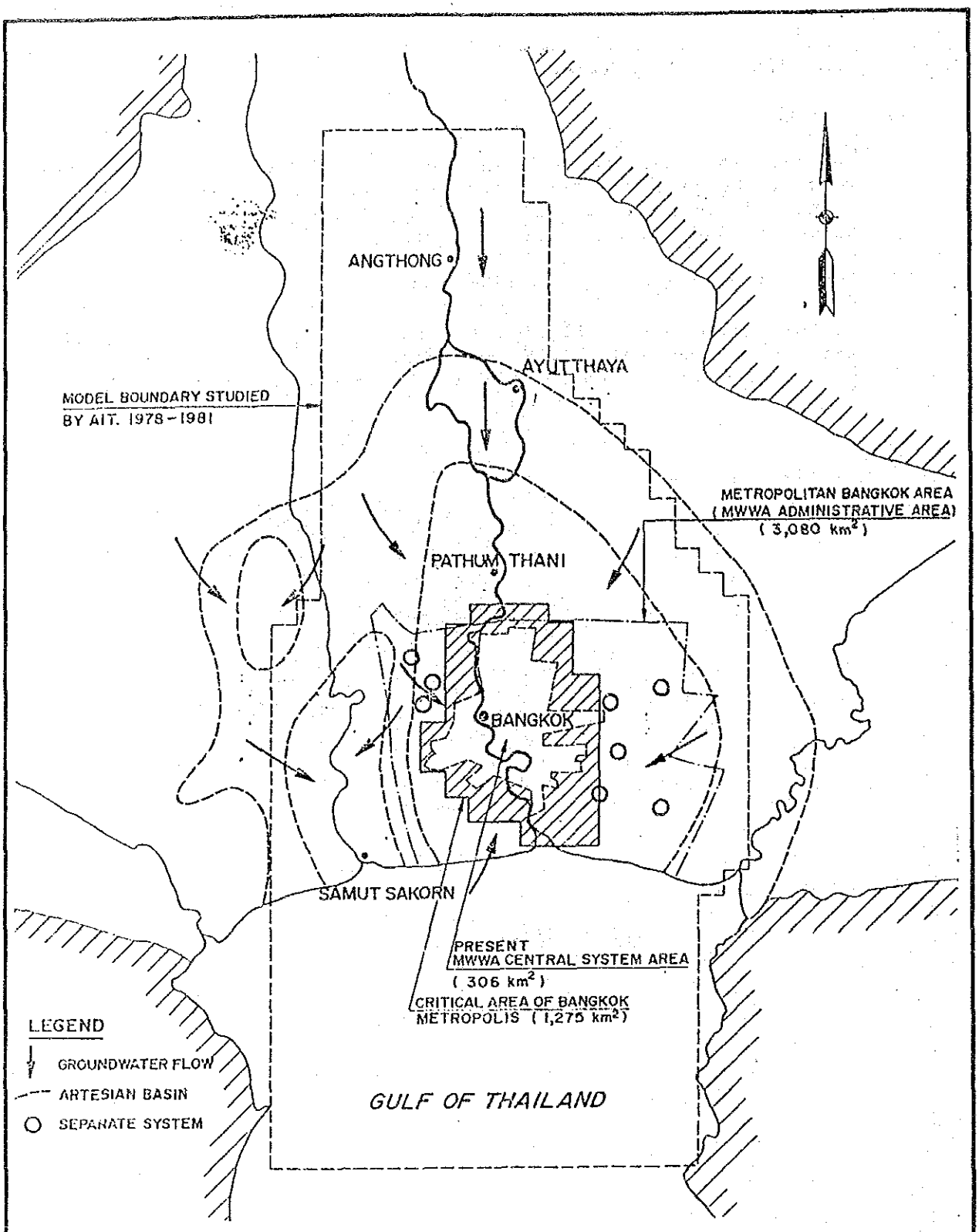
### 2.2.3 Availability of Groundwater

(1) General

For the Lower Chao Phraya Basin, the various studies regarding ground water recharge in the basin have been conducted by several institutions and government agencies to analyze water balance on the basis of rechargeable rainfall into the basin (see Figure 2-2-4).

The summary of these studies is shown in Table 2-2-1.

As the result of overall review of these ground water recharge studies, it is concluded that a limit for ground water withdrawal in the whole Lower Chao Phraya Basin should not exceed 800,000 cu.m/d.




SOURCE : Review of the 1970 Master Plan and Present System,MWA

**FIGURE** 2-2-4
HYDROGEOLOGICAL SUB-BASIN BOUNDARY,AND METROPOLITAN BANGKOK AREA AND ITS VICINITY

Table 2-2-1 Summary of Ground Water Recharge Studies

| Description | Plancharoen 1976 | SEATEL 1978 | | NEB-AIT, DMR 1980 | AIT, Thesis No. 861, 1976 |
|---|---|---|---|---|---|
| Cover Area | Lower Central Plain | Lower Central Chao Phraya Basin | | Lower Chao Phraya Plain | Lower Central Plain |
| | | Sub-Basin No.9 | Sub-Basin No.10 | | |
| Drainage Area (sq.km) | 54,000 | 37,262 | 15,197 | 53,400 | 53,417 |
| Ave. Annual Basin Rainfall | 1,300 | 1,121 | 1,140 | 1,190.8 | 1,075 |
| Ground Water Recharge (mm) | 78 | 235 | 0 | 37.9 | 25.22 |
| % of Annual Basin Rainfall | 6 | 21.0 | 0 | 3.2 | 2.4 |
| Unit Ave. Ground Water Recharge (cu.m/y) | 4,212 x10 | 8,756 x10 | 0 | 2,024 x10 | 1,375 x10 |
| Unit Ave. Ground Water Recharge (cu.m/d/sq.km) | 214 | 457 | | 104 | 69 |
| Sustainable Yield from the Lower Chao Phraya Basin (cu.m/d) | 700,000 to 900,000 | -- | | 600,000 | -- |
| Note | ESCAP MTG Study 1976 | Water Balance Study 1967-1973 | | Water Balance Study 1956-1974 | Water Balance Study 1965-1973 |

Source : Review of the 1970 Master Plan and Present System, MWA

(2) Sustainable Yield in the Study Area

According to the study conducted by MWA, the sustainable amount of ground water usage in the Lower Chao Phraya Basin is allocated to various users as shown below:

Table 2-2-2 Sustainable Yield of Ground Water

(Unit : 1/1,000 cu.m/d)

| Year | Sustainable Yield | MWA | | Outlying Area* | |
|---|---|---|---|---|---|
| | | Bangkok Metropolis | Separate System | Patum Thani | Ayuttaya |
| 1982** | | 1,318 | 8 | 86 | - |
| 1988 | 600 - 800 | 465 - 665 | 20 | 110 | 9 |
| 1990 | 600 - 800 | 448 - 648 | 25 | 116 | 11 |
| 1995 | 600 - 800 | 402 - 602 | 36 | 138 | 24 |
| 2000 | 600 - 800 | 344 - 544 | 49 | 153 | 54 |

* The future demand in the outlying area in Ayuttaya and Patum Thani is estimated with an annual increase rate of 5%.

** Identification Report for Mineral and Industrial Project

Source : Review of the 1990 Master Plan and Present System, MWA

The various studies indicate that the sustainable yield in the Lower Chao Phraya Basin is approximately 70 - 100 cu.m/d/sq.km. Patum Thani Province have an area of 1,500 sq.km in the whole and 1,130 sq.km in the study area. Therefore, the total sustainable yield in the study area is estimated at 80,000 - 120,000 cu.m/d on the condition that ground water is withdrawn evenly all over the study area, namely the amount of 3 - 4.3 cu.m/h per sq.km is withdrawn.

## 2.3 Developability of Alternative Water Source

### 2.3.1 General

For the proposed water supply system, no alternative water source is considered except the Chao Phraya River.

The Chao Phraya River has an abundant flow in the wet season from July to October. In the dry season from November to June, however, the amount of water released from the Bhumiphol and Sirikit Dams is controlled in response to the water demand downstream.

### 2.3.2 Availability of the Chao Phraya River

In 1987, severe drought brought serious water shortage in the Lower Chao Phraya Basin where water demand is extremely high (refer to Figure 2-3-1). In view of the serious shortage, RID, the government agency responsible for managing the Chao Phraya Diversion Dam, set the water allocation for various water users as shown in Figure 2-3-2. The amount of water allocated to water supply and salinity control is approximately 2,000 MCM in the drought year, 1987.

Water demand for this category is described below.

(1) MWA Water Demand

Raw water demand estimated by MWA is given in Table 2-3-1.

Table 2-3-1 Raw Water Demand in Bangkok Metropolis

(Unit : cu.m/s)

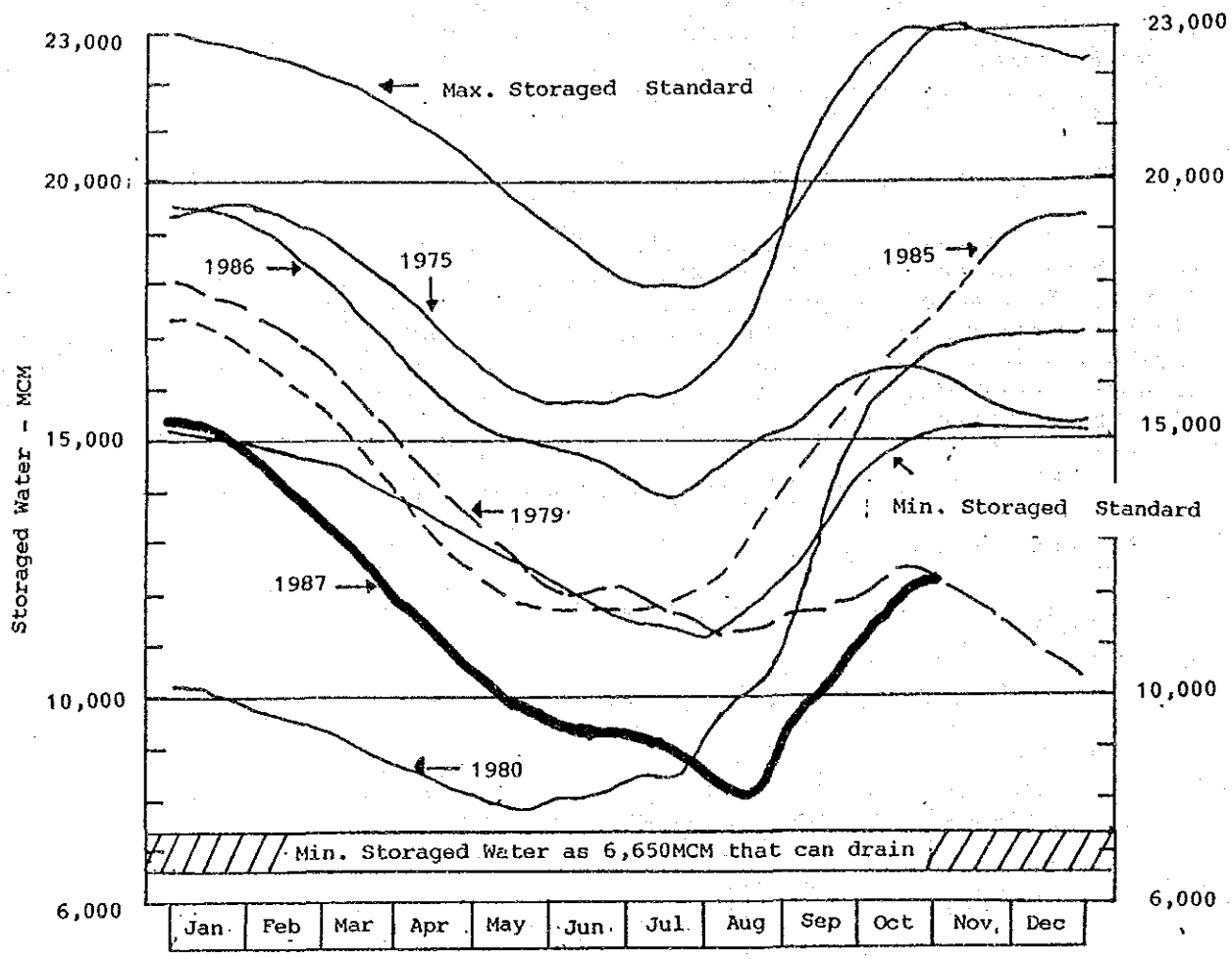
| Year | East Zone | West Zone | Total |
|---|---|---|---|
| 1987 | 30 | -- | 30 |
| 1992 | 33 | 12 | 45 |
| 1997 | 40 | 15 | 55 |
| 2000 | 44 | 16 | 60 |
| 2002 | 45 | 17 | 62 |
| 2007 | 51 | 19 | 70 |
| 2012 | 55 | 20 | 75 |
| 2017 | 60 | 25 | 85 |

Note: Raw water demand includes 5% transmission loss.

MWA plans to supply raw water to the east zone from the Chao Phraya and to the west zone from the Mae Khlong River using the Tha Sarn-Bang irrigation canal (refer to Figure 2-3-3).

(2) Salinity Control

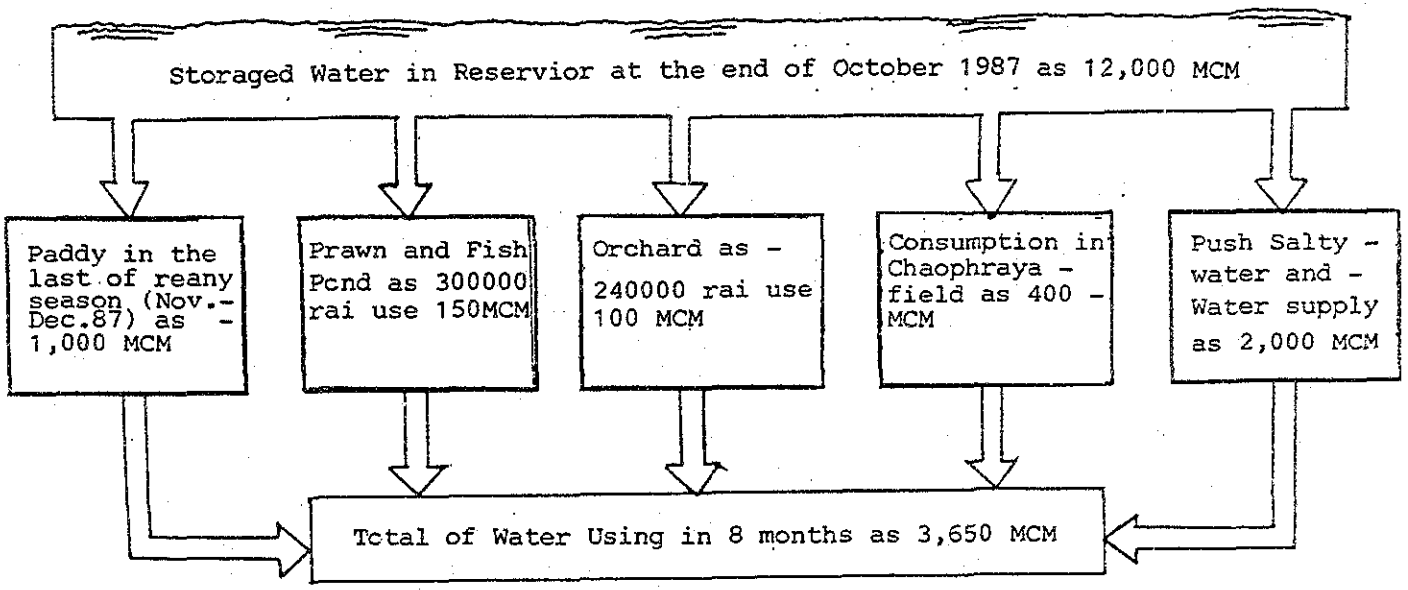
An amount of water for salinity control is set at 70 cu.m/s both at present and in future as shown in Figure 2-3-4.




SOURCE : RID

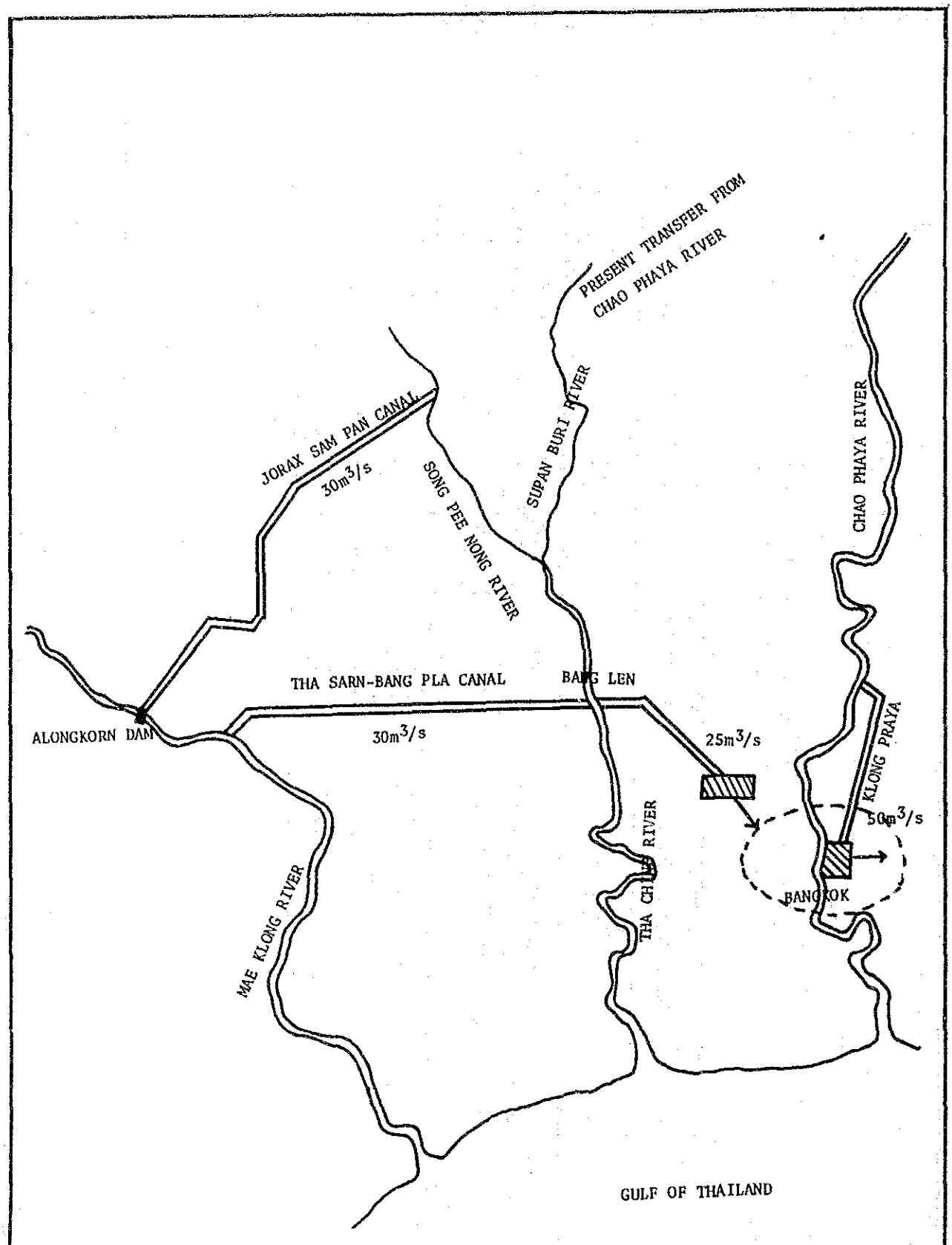
**FIGURE** 2-3-1
Storyed Water in Reservoir of Bhumiphol and Sirikit Dam

In dry season , year 1988 (Nov.87-Jun.88,8months)




SOURCE : RID

**FIGURE** 2-3-2
Water utilization plan from Bhumiphol Dam and Sirikit Dam Reservoir




SOURCE : MWA

FIGURE 2-3-3
PLANNED INTER BASIN
WATER TRANSFERS

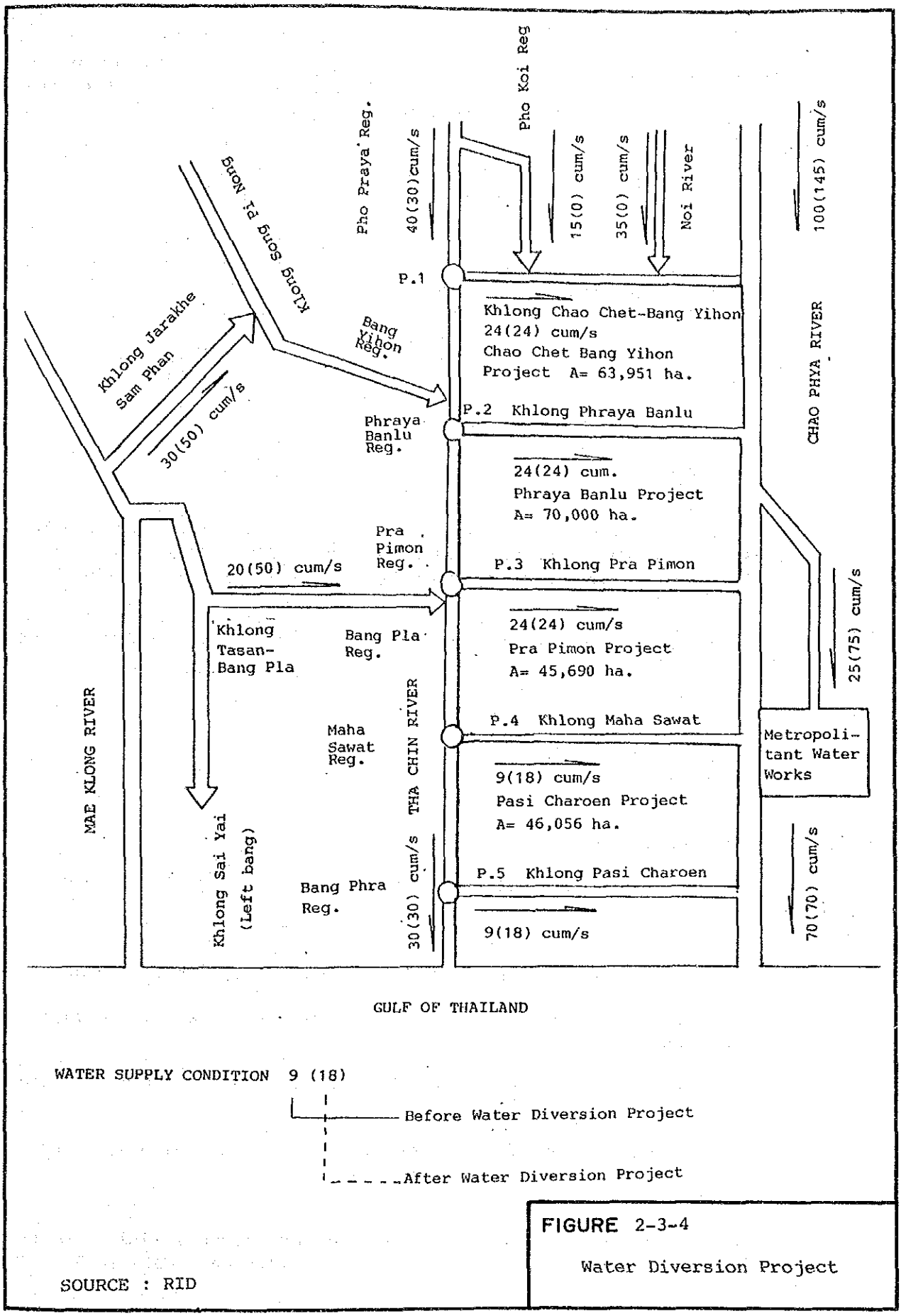



**FIGURE** 2-3-4

Water Diversion Project

SOURCE : RID

(3) Availability for PWA Water Supply

RID has a plan to increase the amount of water allocated for water supply to 145 cu.m/s in future from 100 cu.m/s at present, after the Mae Khlong Diversion Project is completed (see Figure 2-3-4).

Table 2-3-2 Water Allocation for Water Supply and Salinity Control

(Unit : cu.m/s)

| Water Allocation | 1987 | 2011 |
|---|---|---|
| Total | 100 (2,000 MCM) | 145 (3,000 MCM) |
| MWA | 28 | 55 |
| Salinity Control | 70 | 70 |
| Balance | 2 | 20 |

This table shows that there are some allowance for water supply after 1996. But the amount of water available for water supply is so limited in the dry season that coordination with the authorities concerned as RID is needed.

Water demand for water supply to the service area is as follows at the intake level:

| | |
|---|---|
| 1996 | 1.30 cu.m/s |
| 2001 | 2.60 |
| 2006 | 3.38 |
| 2011 | 4.16 |

## 2.3.3 Selection of Intake Point

On selection of the intake point for water supply, the following matters should be considered:

- The main stream should be stable and closer to the intake point.
- The foundation should be durable and closer to prevent differenyial subsidence.
- No industry or institution discharging wastewater upstream of the intake point.
- The intake point should be closer to the proposed treatment plant.
- Easy access

Data concerning the Chao Phraya River are given in Table A2-3-1 and Figure A2-3-1 for water level at the MWA pump station and Table A2-3-2 for water quality in Appendix A-2-2.

The intake point suitable for the pump station can be selected in between the Patum Thani Bridge and the MWA pump station.

between the Patum Thani Bridge and the MWA pump station.

# 3. EXISTING WATER SUPPLY SYSTEM

## 3.1 Existing Water Supply System

### 3.1.1 General

(1) Patum Thani

The waterworks system for the Municipality of Patum Thani was founded in 1962. It had a water production capacity of 40 cu.m/h by taking raw water from the deep well. In 1977, the production capacity was expanded to 100 cu.m/h with the construction of a 60 cu.m/h deep well near the existing one. The new deep well was still under construction as of September 1988 at the premises of the new plant.

The waterworks system was placed under the control of PWA and put under the jurisdiction of the PWA Regional Office 3 in Bangkok.

The PWA Patum Thani Waterworks Office is located at the new deep well plant.

(2) Prachatipat

The waterworks system for Prachatipat was founded in 1982. It was also during this year that a deep well which had an intake capacity of 240 cu.m/h was constructed. In 1984, the intake capacity was expanded to 290 cu.m/d with the construction of a 50 cu.m/h deep well. The two new deep wells with intake capacities of 120 cu.m/h and 240 cu.m/h were still under construction as of September 1988.

The waterworks system was placed under the control of PWA in 1984 and put under the jurisdiction of the PWA Regional Office 3 in Bangkok.

The PWA Prachatipat Waterworks Office is located at the old treatment plant.

### 3.1.2 Treatment

(1) Patum Thani

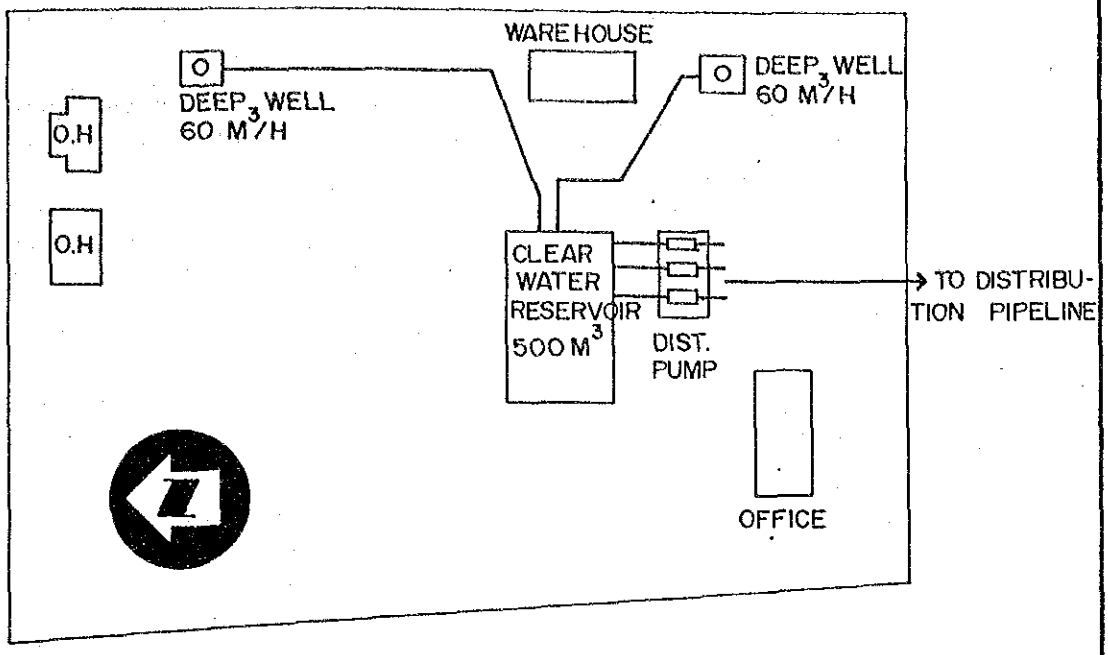
In the old deep well plant (Patum Thani 1), raw water is taken from the deep wells by the raw water pumps, and is immediately stored in a 200 cu.m clear water reservoir. It is then chlorinated and distributed directly by clear water pumps during high water demand and by gravity from the 50 cu.m elevated water tank from the old plant during low water demand.

The raw water stored in the 500 cu.m clear water reservoir after chlorination is distributed directly by clear water pumps from the new deep well plant (Patum Thani 2).

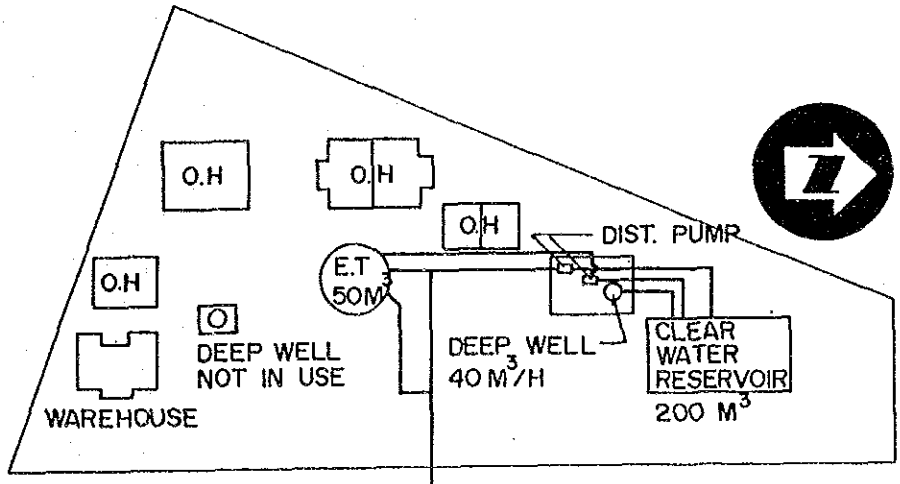
The elements that compose the deep well plant are summarized in Table 3-1-1. Figure 3-1-1 provides the layout of the two deep well plants.

Table 3-1-1 Outline of Water Treatment Facilities
(Patum Thani)

| Name of Plant | Patum Thani 1 | Patum Thani 2 |
|---|---|---|
| Water Source | Ground Water | Ground Water |
| Treatment Capacity | 40 cu.m/h | 60 cu.m/h |
| Treatment Facilities | | |
| Deep Well | | |
| No. of Units | 1 unit | 2 units |
| Intake Capacity | 40 cu.m/h | 60 cu.m/h |
| Raw Water Pump | 40 cu.m/h x 40 m x 11 kw x 1 unit motor-driven | 60 cu.m/h x 60 m x 30 hp x 1 unit motor-driven<br>60 cu.m/h x 60 m x 30 hp x 1 unit motor- and engine-driven |
| Clear Water Reservoir | | |
| No. of Units | 1 unit | 1 unit |
| Capacity | 200 cu.m | 500 cu.m |
| Detention Time | 4.0 h | 8.3 h |
| Clear Water Pump | 120 cu.m/h x 40 m x 30 kw x 1 unit motor-driven | 130 cu.m/h x 28 m x 17.4kw x 2 units motor-driven<br>120 cu.m/h x 40 m x 30 hp x 1 unit engine-driven |
| Elevated Water Tank | | |
| No. of Units | 1 unit | None |
| Capacity | 50 cu.m | |
| Detention Time | 1 h | |
| Height Above G.L. | approx. 18 m | |




LAYOUT OF NEW PLANT




LAYOUT OF OLD PLANT

FIGURE 3-1-1
PATUM THANI
WATER TREATMENT PLANT

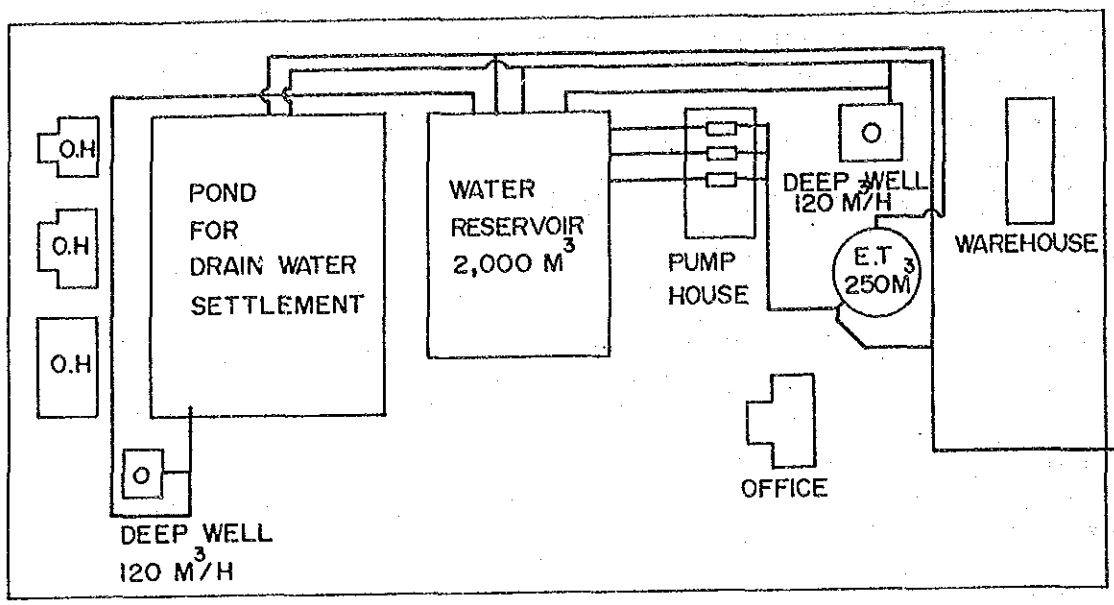
(2) Prachatipat

The old is no longer used. The manner of water treatment is the same as described.

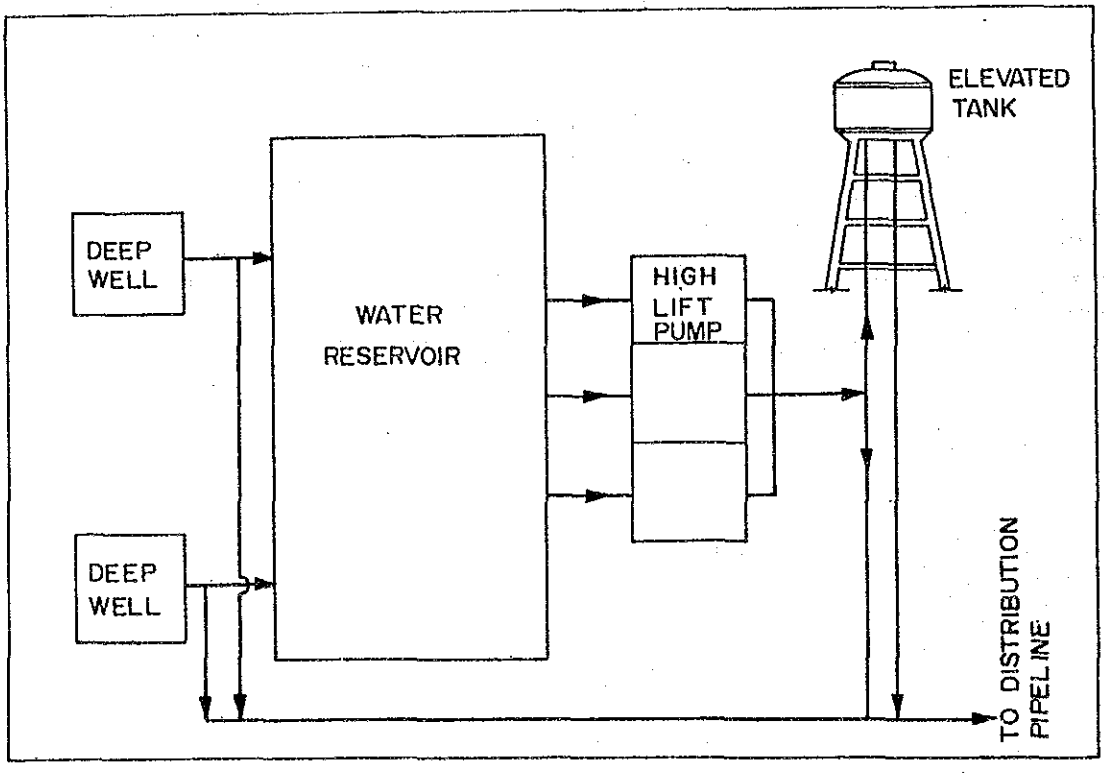
The outline of the deep well plant facilities is summarized in Table 3-1-2. Figure 3-1-2 provides the schematic representation and layout of the treatment plant.

Table 3-1-2 Outline of Water Treatment Facilities

| Name of Plant | Lam Luka (Under Const'n) | Prachatipat 1 | Prachatipat 2 | Thanyaburi (Under Const'n) |
|---|---|---|---|---|
| Water Source | Ground Water | Ground Water | Ground Water | Ground Water |
| Treatment Capacity | | 240 cu.m/h | 120 cu.m/h | 240 cu.m/h |
| Treatment Facilities | | | | |
| Deep Well | | | | |
| No. of Units | 1 unit | 2 unit | 1 units | 2 units |
| Intake Capacity | 50 cu.m/h | 120 cu.m/h | 120 cu.m/h | 120 cu.m/h |
| Raw Water Pump | | 100 cu.m/h x 90 m x 2 units motor-driven | 120 cu.m/h x 70 m x 1 unit motor-driven | 120 cu.m/h x 70 m x 2 units motor-driven |
| Treatment Unit | | | | |
| No. of Units | 1 unit | none | none | none |
| Capacity | 70 cu.m/h | | | |
| Clear Water Res'r | | | | |
| No. of Units | 1 unit | 1 unit | 1 unit | 1 unit |
| Capacity | 500 cu.m | 2,000 cu.m | 1,000 cu.m | 1,000 cu.m |
| Detention Time | 10.0 h | 8.3 h | 8.3 h | 4.2 h |
| Clear Water Pump | | 150 cu.m/h x 34 m x 33 hp x 2 units motor-driven<br>150 cu.m/h x 35 m x 33 hp x 1 unit engine-driven | 120 cu.m/h x 35 m x 2 units motor-driven | 120 cu.m/h x 35 m x 3 units motor-driven |
| Elevated Water Tank | | | | |
| No. of Units | 1 unit | 1 unit | 1 unit | 1 unit |
| Capacity | 120 cu.m | 250 cu.m | 120 cu.m | 120 cu.m |
| Detention Time | 2.4 h | 1.0 h | 1.0 h | 0.5 h |




LAYOUT OF PRACHATIPAT WATERWORS




FLOW DIAGRAM

FIGURE 3-1-2
PRACHATIPAT
WATER TREATMENT PLANT