No. 39

FINAL REPORT
FOR THE STUDY ON
THE EFFECTIVE USE OF INDUSTRIAL WATER
IN
THE KINGDOM OF THAILAND

PREPARED FOR
INDUSTRIAL WORKS DEPARTMENT
MINISTRY OF INDUSTRY
THE KINGDOM OF THAILAND

MARCH 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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Preface

In response to a request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the Effective Use of Industrial Water and entrusted the survey to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand totally four times the study teams headed by Mr. Naoto Hashimoto, Water Re-Use Promotion Center, from August 25 to September 8, from October 12 to December 10, 1987, from July 14 to July 28 and from December 7 to December 15, 1988.

The team held discussions with the concerned officials of the Government of the Kingdom 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 development of the project and to the promotion of friendly relations between our two countries.

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

March, 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Summary

Summary

1. Background

Faced with the aggravating problems of subsidence of land in the Bangkok Metropolitan Area, the Industrial Works Department (IWD) of the Ministry of Industry in Thailand has launched on the program for reducing the pumping up of groundwater.

For this purpose, IWD requested the Japanese Government to provide technical cooperation in conducting a study on the effective use of industrial water.

Upon the acceptance of this request, the Japanese Government entrusted the Japan International Cooperation Agency (JICA) to carry out the study in Thailand. JICA commenced the study in August 1987 and completed it in March 1989.

2. Purposes of the Study

For the field study, IWD chose Samut Prakarn in the Bangkok Metropolitan Area. The purposes of the study were to grasp the actual situation of industrial water uses, estimate the potential amount of water saving, and prepare technical guidelines for more effective industrial water use.

The relationship between this study and other measures against land subsidence is as summed up in Fig. 1.

3. Contents of the Study

The study comprised of eight steps. For the outline of each step, refer to Fig. 2.

4. Results of the Study

The survey in Samut Prakarn covered 59 factories in five different industries. The gist of the survey is as shown in Table 1.

Although the number of surveyed factories accounted for only 2.2% of all factories in Samut Prakarn Province, their consumption of groundwater amounted to 17.6% of the total.

5. Programs for Effective Use of Industrial Water

On the basis of the results of the study, specific problems in implementing water saving measures were examined. Next, programs were established for both the public and private sectors regarding the measures taken for effective use of industrial water. Programs outlines are as shown in Table 2.

6. Feasible Programs for Effective Use of Industrial Water

The following five programs were selected from those above as being relatively easy to implement.

a. To promote the technical guidelines for effective use of industrial water to all persons concerned (by holding seminars, for example)

b. To conduct the survey on an enlarged number of factories

c. To operate a model plant to demonstrate effective use of industrial water

d. To visit industrial factories in order to help them implement the technical guidelines for effective use of industrial water

e. To send experts to industrial factories in order to implement the technical guidelines for effective use of industrial water

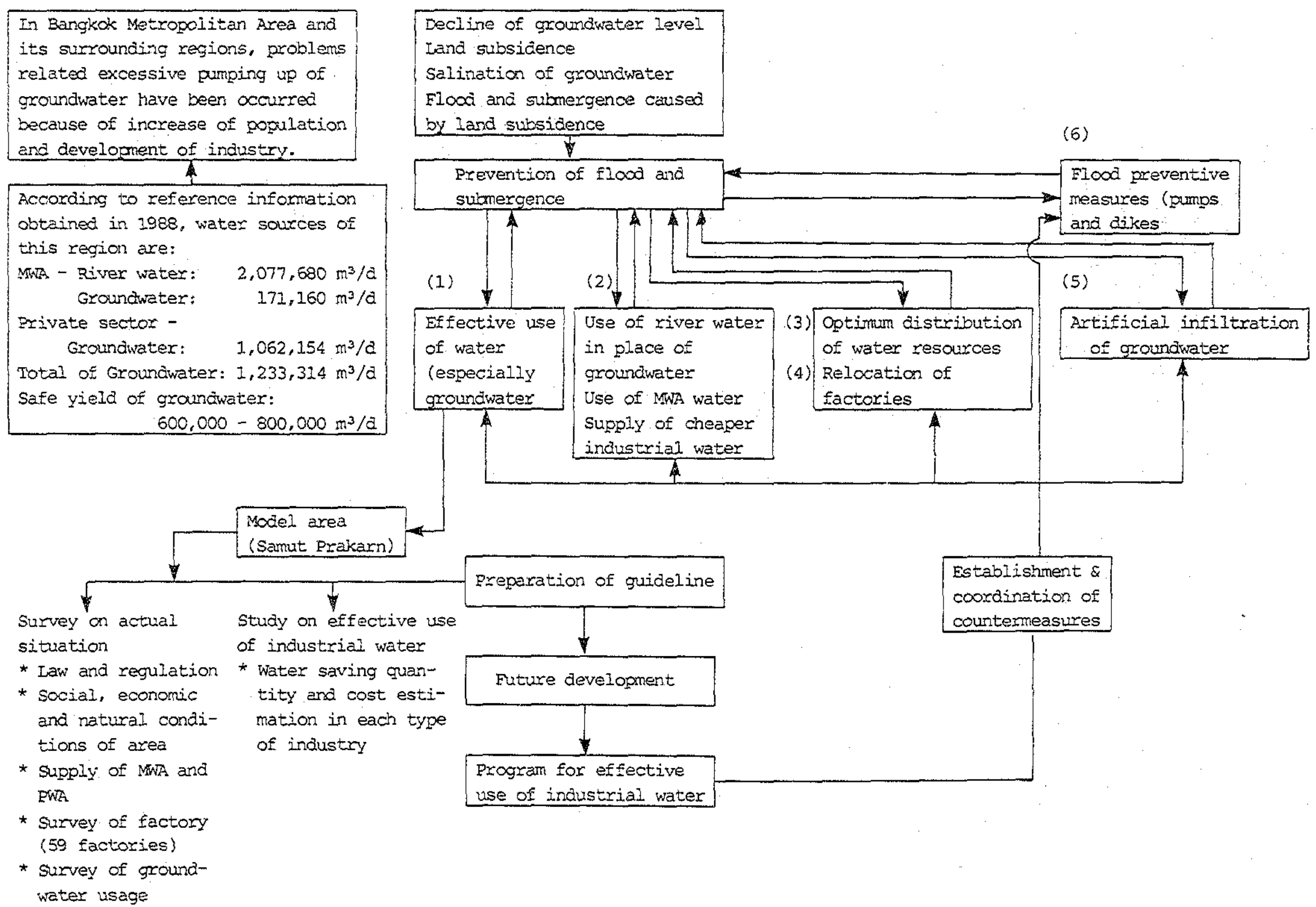


Fig. 1: Study Results and Relations to Plan for Effective Use of Industrial Water

Step 1	Preparatory Office Work	Preparation of questionnaire Preparation of Inception Report
Step 2	Preparation of the Field Work	Selection of factories to be studied Distribution of questionnaire
Step 3	Preparatory Office Work for the Field Work	Collection of answer to questionnaire Analysis of answer
Step 4	Field Work	Visiting survey of 59 factories Technical seminar Preparation of the Progressive Report
Step 5	1st Home Office Work	Clarification of present situation of the use of industrial water Study of effective use of industrial water Estimation of the potential quantity of water saving and reclamation Cost estimation Preparation of the Interim Report
Step 6	Supplementary Field Work	
Step 7	2nd Home Office Work	Preparation of technical guideline for effective use of industrial water classified by water usage Preparation of technical guideline for effective use of industrial water classified by type of industry Preparation of the Draft Final Report
Step 8	Presentation of the Draft Final Report in Thailand Technical seminar Preparation of the Final Report	

Fig. 2: Flow Diagram of Study Implementation

Table 1: Summary of Study Results

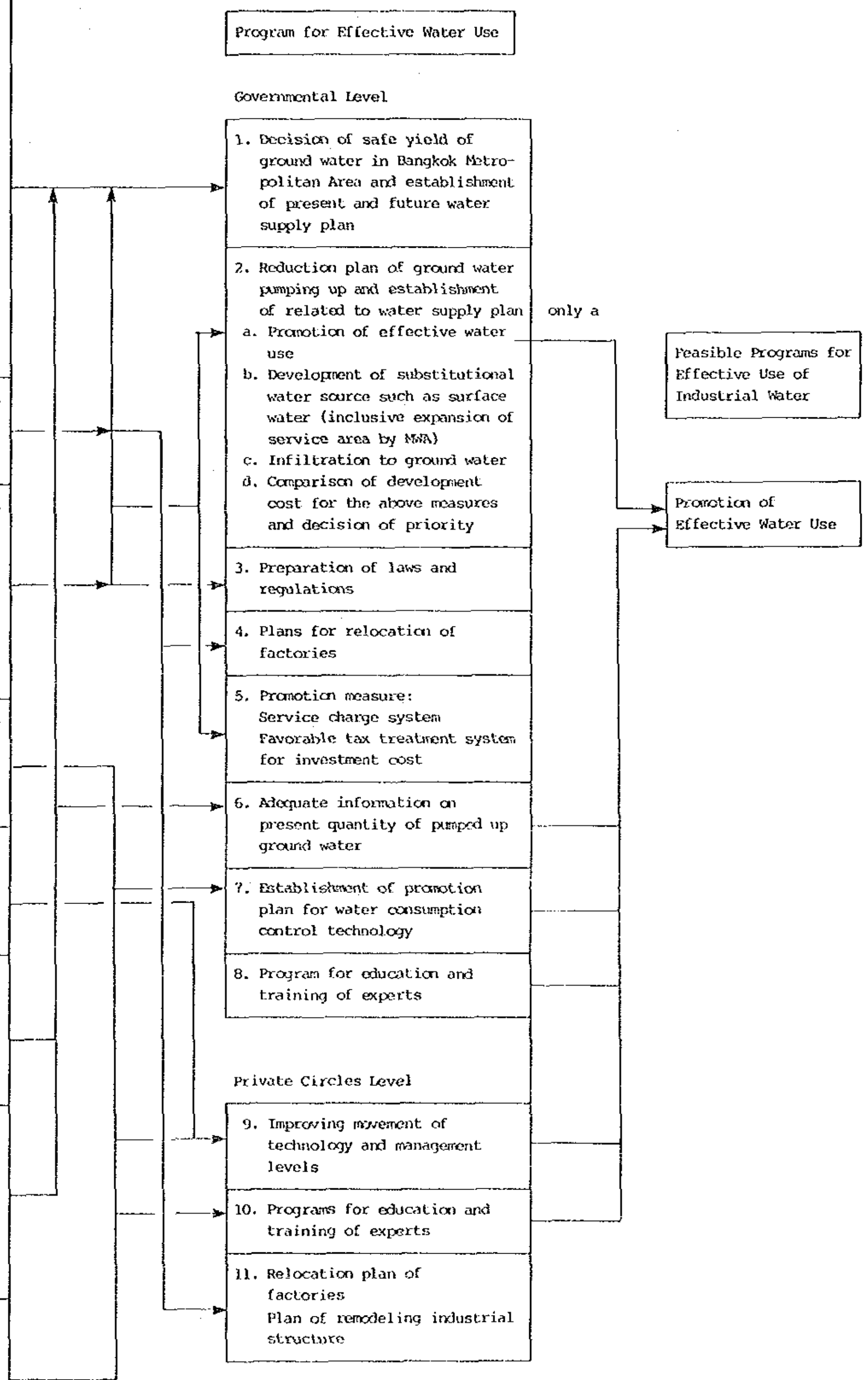
Item / Industry	No. of Fact.	Industrial Water Consumption (m^3/d)				Recovery Rate 1) (%)	Potential Quantity of Water Saving 2) (m^3/d)	Saving Rate of Well 3) Water (%)	Unit Cost of Improvement 4) (฿/m^3)
		Make-up Water	Well Water for Make-up	Recovered Water	Total				
Food	14	7,025	6,521	39,301	46,326	84.8	969	14.9	3.4
Paper	5	18,845	16,945	11,009	29,854	36.9	5,260 Ex Rec* 1,560	31.0 9.2	3.3 0.8
Textile	7	13,632	13,578	53,535	67,167	79.7	2,636 Ex Rec* 636	19.4 4.7	10.1 0.8
Metal	20	8,594	8,547	26,563	35,157	75.5	1,603	18.8	1.4
Chemical	13	4,799	4,704	43,693	48,492	90.1	694	14.8	0.3
Total	59	52,895	50,295	174,101	226,996	76.7	11,162 Ex Rec* 5,462	22.2 10.8	4.7 1.4

Note: Ex Rec* = Excluding Reclamation

1) Recovery Rate = (Amount of Recovered Water)/(Total Quantity of Water Consumption) x 100
2) Refer to 4.4
3) Saving Rate = (Potential Quantity)/(Well Water) x 100
4) Refer to 4.3

Table 2: Problems and Measures related to Effective Use of Industrial Water

Present Situation/Problems	Measures	Promoter
A. System and Policy		
1. Water act, especially adjustment of plan for water utilization, preparation of laws and regulations, and intensification of enforcement regulations are necessary.	Quantity of pumped up groundwater in Bangkok Metropolitan Area is over 1,200,000 m³/day, and allowable quantity for prevention of land subsidence is said to be 600,000 to 800,000 m³/d. Therefore, pumping up of 400,000 to 600,000 m³/d groundwater must be reduced. In order to promote this reduction program in each industrial area, safe yield in each area must be estimated and reduction plan must be prepared to attain the object. MWA is reducing quantity of pumped up groundwater, but quantity of pumped up groundwater by industries is rather increasing. Thus, quantity of pumped up groundwater is not reduced as a whole. Reducible quantity of industrial water by adoption of water saving and effective water use is not sufficient, and developments of substitutional water source (surface water and others) are necessary. Use of surface water requires quantity adjustment with agricultural water and public water works. Plan for independent public industrial water works would necessitate adjustment with MWA Act and consideration of service charge. (Some factories would not like to pay high service charge.)	Government
2. Review of plans for factory location and factory relocation	By relocation of factories in industrial zone for modernization and expansion of factories, effective water use and waste water treatment shall be promoted. In this modernization plan of factory, change to new production process that does not use much water shall be included.	Government Private Sector
3. Measure for effective use of industrial water is not fully established.	As an incentive of effective water use, introduction of service charge system, especially gradual increase system by which user of much quantity of water has to pay higher service charge, is most effective. But, for those factories which depend on groundwater, service charge of public industrial water works would be operating burden. To solve the problems, laws and regulations should be enacted to enforce the promotion of effective use of industrial water, and public industrial water works should be constructed to supply substituted water of reasonable price by developing river water and other water sources.	Government
4. Personnel engaged in industrial water supply and discharge is shorthanded and system for authorizing process is not established.	Education and training system shall be expanded. At the same time, authorizing system such as "water control engineer" and "environmental preservation engineer" shall be newly established, so that control capabilities shall be intensified.	Government
5. Test and inspection institutions, evaluation body of test process and services related to industrial water supply and discharge are not established.	Confirmation of water quantity and quality data by establishment of flow meter repair center and authorizing system for material standardizing, for example. Establishment and operation of technology development center for promotion of water treatment technology.	Government
B. Technology		
6. Designation of safe yield of pumped up groundwater in area of land subsidence is not clear.	This figure is basis for restriction of pumping up quantity of groundwater. It is necessary to clarify target quantity of reduction of pumping up groundwater. The data are also used for future plans of factory relocation in various areas.	Government
7. Factory staff does not grasp exact quantity and quality of consumed water.	These data must be fundamentally grasped for effective use of industrial water. Quantity of process water and water for living including leakage must be clearly grasped. Recycled quantity from cooling tower for recycling use of water, quantity of flow, quantity of discharged water and quality of discharge water must be firmly grasped. Overall situation must be grasped by further investigation of those on these items.	Government Private Sector
8. Intermediate managing staff and engineers specializing in water treatment are shorthanded, and training institute of engineers is lacked.	Promotion for establishing guidance organization initiated by central government. Promotion of improvement activities of managing and technological levels by private circles. Establishment of engineering firms capable of acting as coordinator of these matters.	Government Private Sector



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Chapter 1

Introduction

Chapter 1 Introduction

1.1 Background

Bangkok, the capital of the Kingdom of Thailand, is situated at the southern edge of the Thai central plain, approximately 25 km north of the Gulf of Thailand.

The Bangkok Metropolitan area lies in the delta of the Chao Phraya River, rising only 0.5 to 1.5 meters above the sea level.

In recent years, as the area's population and industrial activities have rapidly expanded, the demand for water (domestic water and industrial water alike) has greatly intensified.

Recently, the Chao Phraya River, the largest water source in the region, does not provide water of good quality, as considerable sea water flows upstream. To obtain fresh water containing little salt, one must go up river as far as the vicinity of the Bangkok International Airport. (about 50 km from the mouth of the Chao Phraya River)

The greater portion of the water used in the Bangkok Metropolitan area, therefore, comes from underground table which contain excessive and increasing quantity of salt.

The subsidence of land, in particular, is so serious at present that it often triggers floods during the rainy season. As such, effective methods are urgently required.

An extreme solution to the land subsidence problem would be to stop the use of groundwater entirely, relying on river water only. The drawback of this solution, however, is the huge amount of time and money involved, notwithstanding the technical difficulties required in developing new water sources and constructing water supply systems (water purifying facilities and piping).

Japan is not unfamiliar with the problems arising from excessive pumping up of groundwater, which results in the subsidence of land and the increase of salt in the water. To cope with these problems, a variety of methods have been devised to realize more effective use of industrial water.

Specifically, in Japan, efforts have been made to economize the use of groundwater in various industries on the basis of detailed studies of the actual situations. These efforts have brought favorable results in preventing or reducing the subsidence of land in such areas, where river water is not easily available.

In Thailand, the use of industrial water is supervised by the Industrial Works Department (IWD) of the Ministry of Industry (MOI). Cognizant of the results of water saving efforts in Japan, IWD has initiated a program to prevent land subsidence and other adverse effects of excessive pumping up of groundwater in the Bangkok Metropolitan area through more effective use of industrial water.

To obtain the required know-how, in August 1985, IWD requested the Japanese Government to provide technical cooperation in order to establish the "study on the effective use of industrial water".

In response to this request, in March 1986 the Japanese Government dispatched personnel from the Japan International Cooperation Agency (JICA) to Bangkok for consultations with IWD. Upon studying the contact mission's report, the Japanese Government compiled with the IWD request.

In March 1987, JICA sent a preliminary survey team to Bangkok and concluded an agreement with IWD regarding the scope of work. Based on the scope of work and minutes of meeting between both parties, Samut Prakarn Province, located south of the Bangkok Metropolitan area, was selected for the survey. About 60 factories covering five different industries were selected for individual case studies.

1.2 Purposes of the Study

As mentioned previously, IWD is fully aware of the importance of effective use of industrial water, realizing that a reduced consumption of industrial water will lead to the reduction in groundwater pumping up, and hence, to the prevention of land subsidence.

The problem, however, is that, in Thailand, no clear guidelines exist for implementing concrete methods. Owing to this, IWD is unable to provide specific instructions, while factories find it difficult to initiate methods on their own.

The main purpose of this study, therefore, is to provide both IWD and the factories with appropriate guidelines aimed at more effective use of industrial water. Also important is the transfer of know-how and techniques. At the end of the study, IWD and each factory concerned will no doubt be able to implement effective methods for reduction in the consumption of industrial water without any help from outside.

More precisely, the purposes of the study are as follows.

(1) For each of the surveyed factories, to determine possible methods for reducing consumption of well water, and to calculate the potential quantity of water saving

(2) On the basis of (1) above, to establish technical guidelines for each industry and each usage of water

(3) To make suggestions to IWD with regard to implementing water saving methods for more effective use of industrial water in Thailand

(4) To hold two seminars in order to transfer know-how and techniques. (In addition, for the purpose of technical transfer to IWD staff, on-the-job training (OJT) is carried out in the process of the study.)

1.3 Content of the Study

1.3.1 Work Flow

The study comprised of the following eight steps.

Step 1: Preparatory office work in Japan

Step 2: Preparation of field work in Thailand

Step 3: Preparatory office work in Japan (for the field work)

Step 4: Field work in Thailand

Step 5: Home office work (The first analysis in Japan)

Step 6: Supplementary field work in Thailand

Step 7: Home office work (The second analysis in Japan)

Step 8: Presentation of and discussion on the Draft Final Report in Thailand
Preparation of the Final Report

Technical seminars took place at Step 4 and Step 8.

The work flow is as illustrated in Fig. 1.1. The following describes content of work at each step.

1.3.2 Preparation for the Study

To conduct the study, a team of experts was formed as shown in Table 1.1. Members of IWD who participated in the study are as shown in Table 1.2.

Step	Details of Work
Preparatory Office Work	Preparation of Questionnaire ↓ Preparation of Questions to Counterpart ↓ Preparation of Requests to Counterpart ↓ Preparation of the Inception Report (Consultation with JICA)
Preparation of the Field Work in Thailand	Courtesy Calls on Concerned Organizations ↓ Discussions with Counterpart (Explanation of the Inception Report) ↓ Selection of Factories to be Surveyed ↓ Preparation of Explanation Meeting (Announcement to Factory, Translation of Questionnaire and Preparation of Meeting Hall) ↓ Explanation Meeting and Distribution of Questionnaire
Preparatory Office Work for the Field Work	Collection of Site Information and Data ↓ Collection of Answer to Questionnaire (Cooperation of Counterpart) ↓ Analysis of Answer to Questionnaire ↓ Decision of Main Points of Field Work

(Continued on next page)

Fig. 1.1: Flow of Implementation Procedure

Step	Details of Work
Field Work in Thailand	Discussions with Counterpart (Schedule of Visiting Survey, Formation of Survey Team, Transportation and Implementation Procedure) ↓ Visiting Survey (2 Teams x 30 Factories = 60 Factories) ↓ Technical Seminar ↓ Result Summary of Visiting Survey Related Study (Law, Regulation & Information on Cost Estimation) ↓ Preparation of the Progress Report ↓ Discussion with Counterpart regarding the Progress Report ↓ Approval of Contents of the Progress Report and Preparation of Minutes of Meetings
Home Office Work (1st Analysis)	Presentation and Explanation of the Progress Report to JICA ↓ Clarification of Present Situation of Water Use in Surveyed Factories ↓ Study on Effective Use of Industrial Water ↓ Estimation of Potential Amount of Water Saving and Water Reclamation ↓ Cost Estimation (Unit Cost of the Improvement for Effective Use of Industrial Water and Others) ↓ Decision of Details of Supplementary Field Work (Consultation with JICA and Counterpart) ↓ Preparation of the Interim Report ↓ Preparation for Supplementary Field Work

(Continued on next page)

Fig. 1.1: Flow of Implementation Procedure (Continued, 2/3)

Step	Details of Work
Supplementary Field Work	Discussion with Counterpart (Explanation of Interim Report and Details of Supplementary Field Work) ↓ Implementation of Supplementary Factory Survey
Home Office Work (2nd Analysis)	Supplement to the Results of the 1st Analysis ↓ Preparation of Guideline for Effective Use of Industrial Water Classified by Water Use ↓ Preparation of Guideline for Effective Use of Industrial Water Classified by Industry ↓ Preparation of the Draft Final Report ↓ Explanation of Draft Final Report to JICA
Presentation of the Draft Final Report	Presentation of the Draft Final Report to Counterpart ↓ Technical Seminar ↓ Approval of Contents of Draft Final Report and Preparation of Minutes of Meeting
Final Report	Preparation of Final Report

Fig. 1.1: Flow of Implementation Procedure (Continued, 3/3)

Table 1.1: List of Study Team Members and Their Assignments

Name	Function	Assignment	Org.
Naoto Hashimoto	Team Leader Engineer	Overall management and coordination Field work and home office work	WRPC
Shun-ichiro Uchida	Deputy leader Engineer	Control of technical works Field work and home office work	WRPC
Hozumi Eto	Deputy Leader for General Planning Engineer	Control of technical works Field work and home office work	TEC
Keiichi Ohta	Engineer	Study on washing water use Field work and home office work	WRPC
Sueo Nagasawa	Engineer	Study on washing water use Field work and home office work	WRPC
Takao Tamura	Engineer	Study on water use for cooling and air conditioning Field work and home office work	WRPC
Hideaki Fukui	Engineer	Study on water use for cooling and air conditioning Field work and home office work	WRPC
Shoji Kubota	Engineer	Study on water re-use Home office work	WRPC
Haruo Honda	Engineer	Study on water saving apparatus Home office work	WRPC
Toshio Tsuda	Engineer	Cost estimation Home Office work	TEC
Mitsuyoshi Hirai	Engineer	Cost estimation Home office work	WRPC
Junzo Hori	Engineer	Study on governmental policy, law and regulation Field work and home office work	WRPC

Note: Org. = Organization

WRPC = Water Re-Use Promotion Center

TEC = Toyo Engineering Corporation

Table 1.2: List of IWD Staff

Name	Title/Division
Yingyong Strithong	Director-General
Pisal Khongsamran	Ex-Director-General
Chane Boonsong	Deputy Director-General
Sompoch Strimarut	Deputy Director-General
Boonyong Lohwongwatana	Director Office of Industrial Services and Waste Treatment
Adisorn Naphavaranonth	Chief Industrial Water Supply Service Sub-Division
Kasemsri Homchean (Mrs.)	Industrial Water Supply Service Sub-Division
Suphot Somthawiltrakul	Industrial Water Supply Service Sub-Division
Peeraphan Buranasomphob (Mrs.)	Industrial Water Supply Service Sub-Division
Sugunaya Bunpaesat (Mrs.)	Industrial Technical Development Sub-Division
Somchai Kraikichrach	Industrial Water Supply Service Sub-Division
Phalsan Lertsolauch	Industrial Water Supply Service Sub-Division
Thavorn Leelatrakul	Ex-Industrial Water Supply Service Sub-Division

1.3.3 Work schedule

The work schedule is as shown in Fig. 1.2.

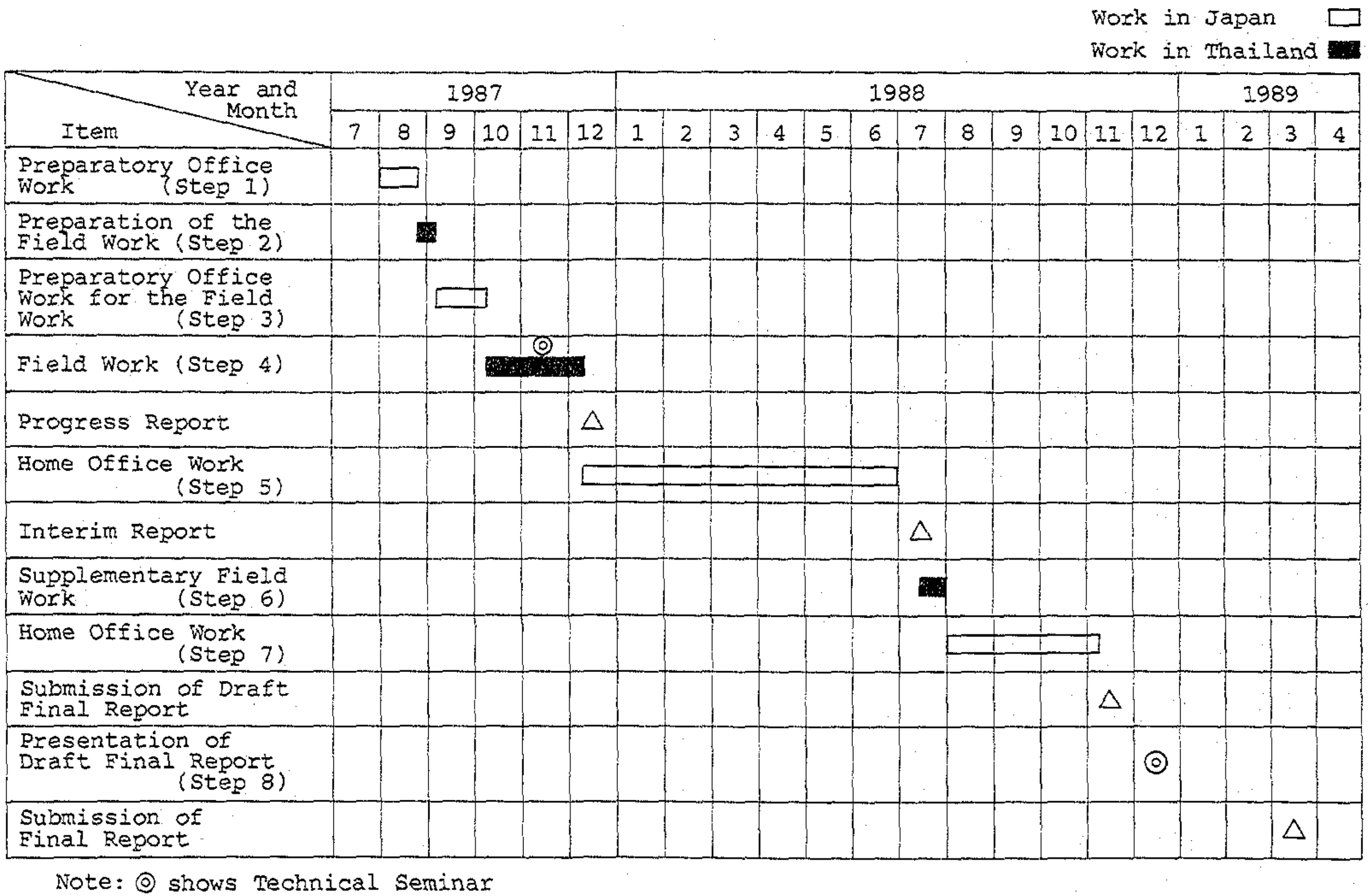


Fig. 1.2: Schedule of the Study

1.4 Implementation of the Study

1.4.1 Preparatory Office Work in Japan

On August 15, 1987, the questionnaire (in English) and the Inception Report were submitted to IWD via the Bangkok office of JICA. (The questionnaire is included in Appendix Part 2 of this report.)

1.4.2 Preparation of Field Work in Thailand

From August 25 to September 8, 1987, the study team consisting of four members (the leader: N. Hashimoto) visited Bangkok to make the following preparations.

(1) Presentation of the Inception Report to IWD

(2) Selection of the factories to be surveyed

(3) Preparation for questionnaire survey

(4) Preparatory factory survey (four factories)

(5) Determination of contents of field surveys and the technical seminars

1.4.3 Preparatory Office Work in Japan (for Field Work)

Before conducting the field work, the following preparations were made in Japan.

(1) Examination of collected data

(2) Preparation of materials for technical seminar

(3) Analysis of questionnaire results which have collected and sent back by IWD

(4) Practice and training for operation of measuring equipment used in field work

1.4.4 Field Work in Thailand

From October 12 to December 10, 1987, the study team of eight members, headed by N. Hashimoto, visited Bangkok to carry out field work. Details of field work were as follows.

(1) Survey of 59 factories (through visit)

(2) Technical seminar on November 11 (for contents of the seminar, refer to Appendix Part 2 of this report.)

(3) Gathering of data (laws and regulations, data for cost estimation, data related to industrial water and water resources in general, and other necessary materials)

(4) Preparation of Progress Report and explanation to IWD

1.4.5 Home Office Work (First Analysis in Japan)

On the basis of the field work, the analysis was made in Japan and covered the following matters.

(1) Clarification of present situation of use of industrial water

(2) Study of effective use of industrial water

(3) Preparation of cost estimation data

(4) Determination of items to be covered in supplementary field work

(5) Estimation of potential quantity of water saving and water reclamation (Estimation of these quantity were made taking the required costs into consideration)

(6) Estimation of required costs

(7) Preparation of Interim Report

After being reviewed by JICA on July 6, 1988, the Interim Report was submitted to IWD via Bangkok office of JICA.

1.4.6 Supplementary Field Work in Thailand

(1) Explanation and discussion on Interim Report

(2) Supplementary factory survey by visits (5 factories)

(3) Discussion on contents of Final Report

(4) Discussion on contents of second technical seminar

1.4.7 Home Office Work (Second Analysis in Japan)

The data obtained from the main and supplementary field work was sorted out and analyzed to compilation of the following items.

(1) Supplement to the results of the first analysis

(2) Preparation of technical guidelines for effective use of industrial water (classified by use of water)

(3) Preparation of technical guidelines for effective use of industrial water (classified by industry)

(4) Analysis of problems encountered in implementing effective use in Thailand

(5) Preparation of suggestions to be made to IWD

(6) Preparation of Draft Final Report

After being reviewed by JICA on November 16, 1988, the Draft Final Report was submitted to IWD via Bangkok office of JICA.

1.4.8 Presentation of and Discussion on the Draft Final Report

From December 7 to 15, 1988, the four-member study team, headed by N. Hashimoto, visited Bangkok to explain contents of the Draft Final Report to IWD.

Also, the second technical seminar was held on December 12, 1988. (For the contents of the seminars, refer to Appendix Part 2 of this report.)

1.4.9 Completion of the Final Report

On the basis of the comments from IWD, deletions, additions and corrections were made to the Draft Final Report.

Chapter 2

General Conditions in Thailand--from the Viewpoint of Effective Use of Industrial Water

Chapter 2 General Conditions in Thailand--From the Viewpoint of Effective Use of Industrial Water

2.1 General Conditions

The population of Thailand, at present 62.65 million, has shown a rapid increase in recent years (refer to Fig. 2.1). Among the nation's total population, about 10 million people are concentrated in Bangkok and its surrounding areas.

(Sources of tables, figures and data in this Chapter are shown in the last page of this Chapter with reference number.)

Thailand has an area of 513,103 km², which is approximately 1.4 times larger than Japan.

The annual rainfall in Thailand averages 1,550 mm. As shown in Fig. 2.2 and Table 2.1, the quantity of rainfall differs from region to region. Generally speaking, the south has greater rainfall precipitation than the north.

Comparatively, Japan has a slightly larger annual rainfall (1,750 mm in 1985) than Thailand. The total volume of rainfall, however, is larger in Thailand (8,000 x 108 m³/Y) than in Japan (6,600 x 108 m³/Y). Thus, both countries are blessed with abundant water.

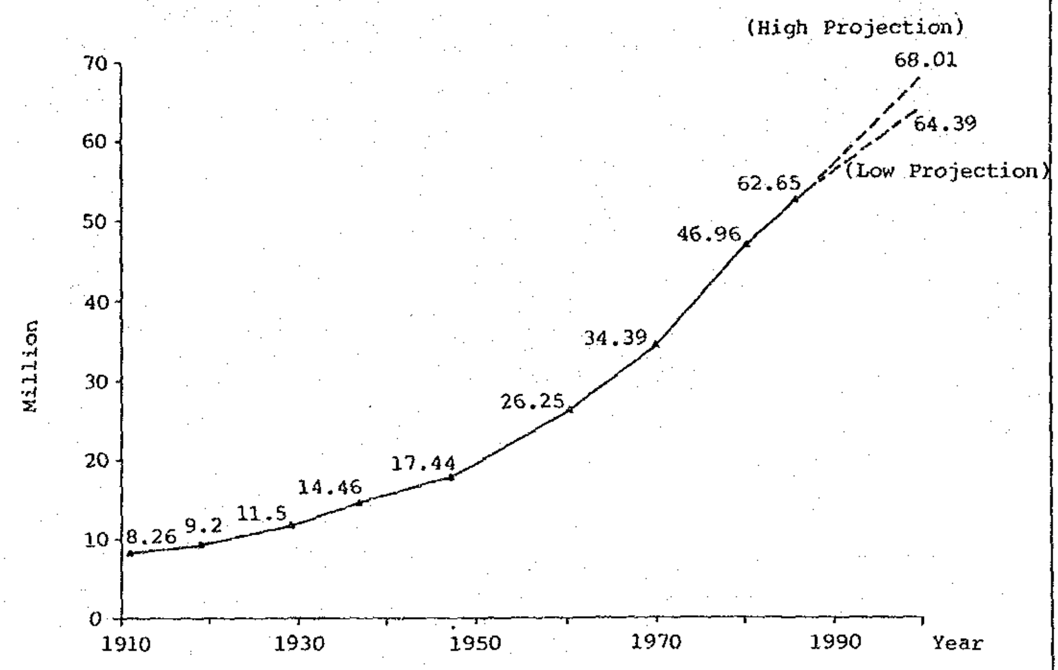


Fig. 2.1: Population of Thailand (1910 - 2000) 1)

Nonetheless, as Thailand and Japan differ in geographical features and climates, the conditions of water sources also differs. For example, the run-off ratio of the Chao Phraya, the largest river in Thailand, is much smaller than those of any Japanese rivers.

Considering the fact that the Chao Phraya River has a large catchment area and flows a considerable distance through hot and tropical regions, this small run-off ratio is understandable. In other words, different conditions produce different effects on the use of water in each country.

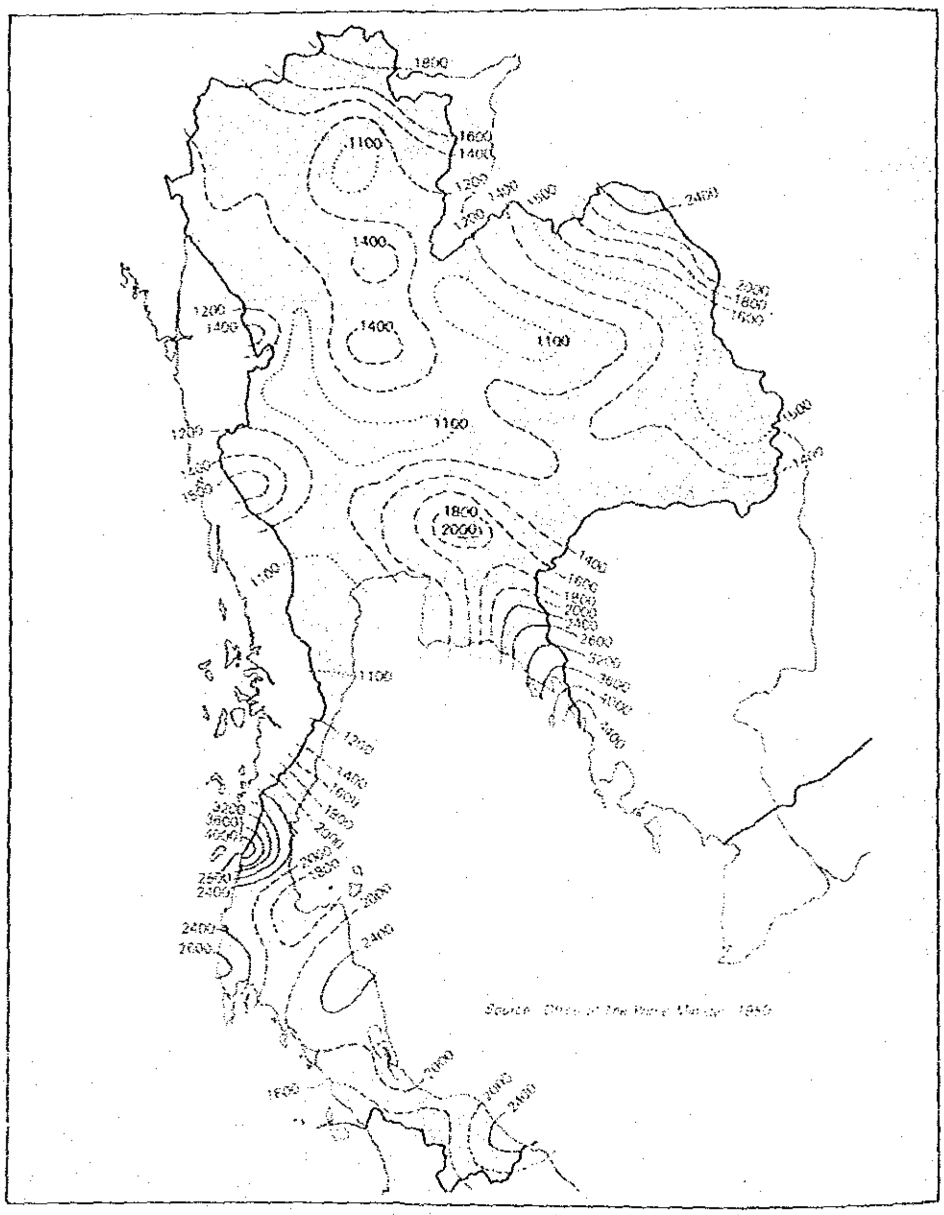


Fig. 2.2: Average Rainfall Distribution (1951 - 1975) 1)

Table 2.1: Annual Rainfall in Thailand by Region 1)

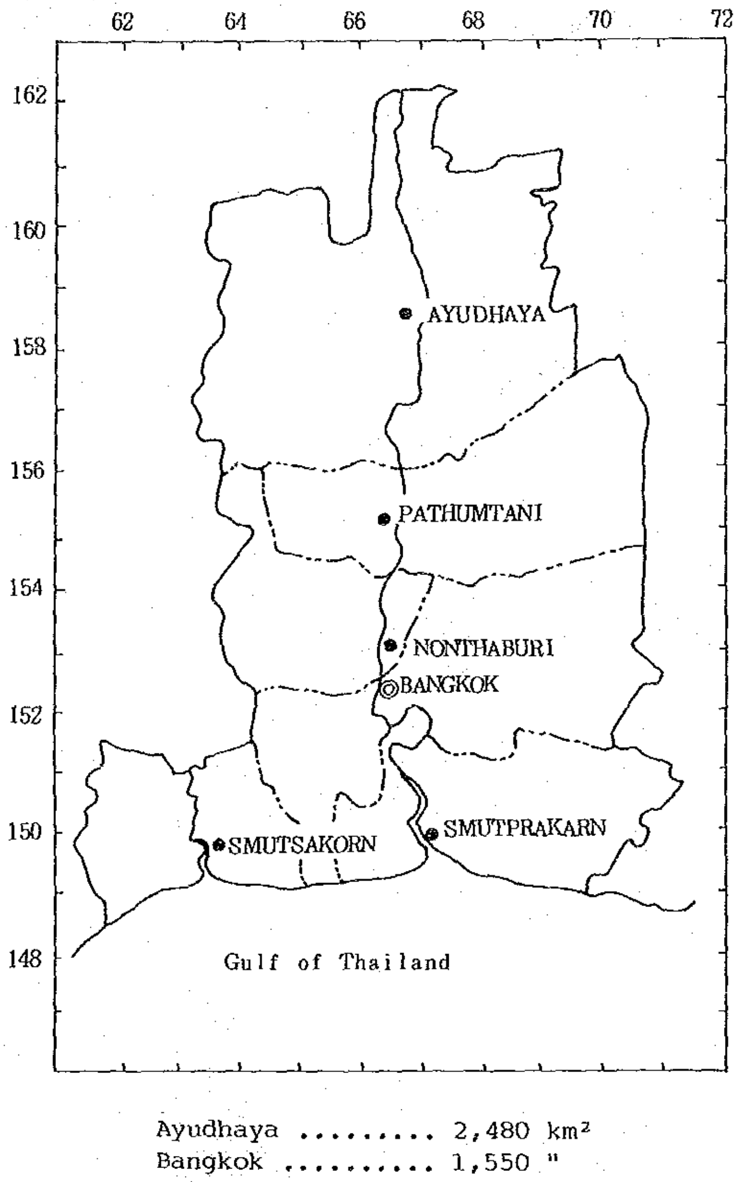
Region	Average Annual Precipitation (mm)	Area (km^2)	Rainfall Volumes (Mm^3)
Northeast	1,400	168,854	236,400
North	1,300	169,644	220,500
East	2,100	36,503	76,700
Central	1,350	67,399	91,000
South	2,400	70,715	169,700
Total		503,115	794,300

Note: The categorization of different regions is based on compiled statistics on water resources available in related governmental agencies.

2.2 Conditions in the Bangkok Metropolitan Area and Surrounding Area

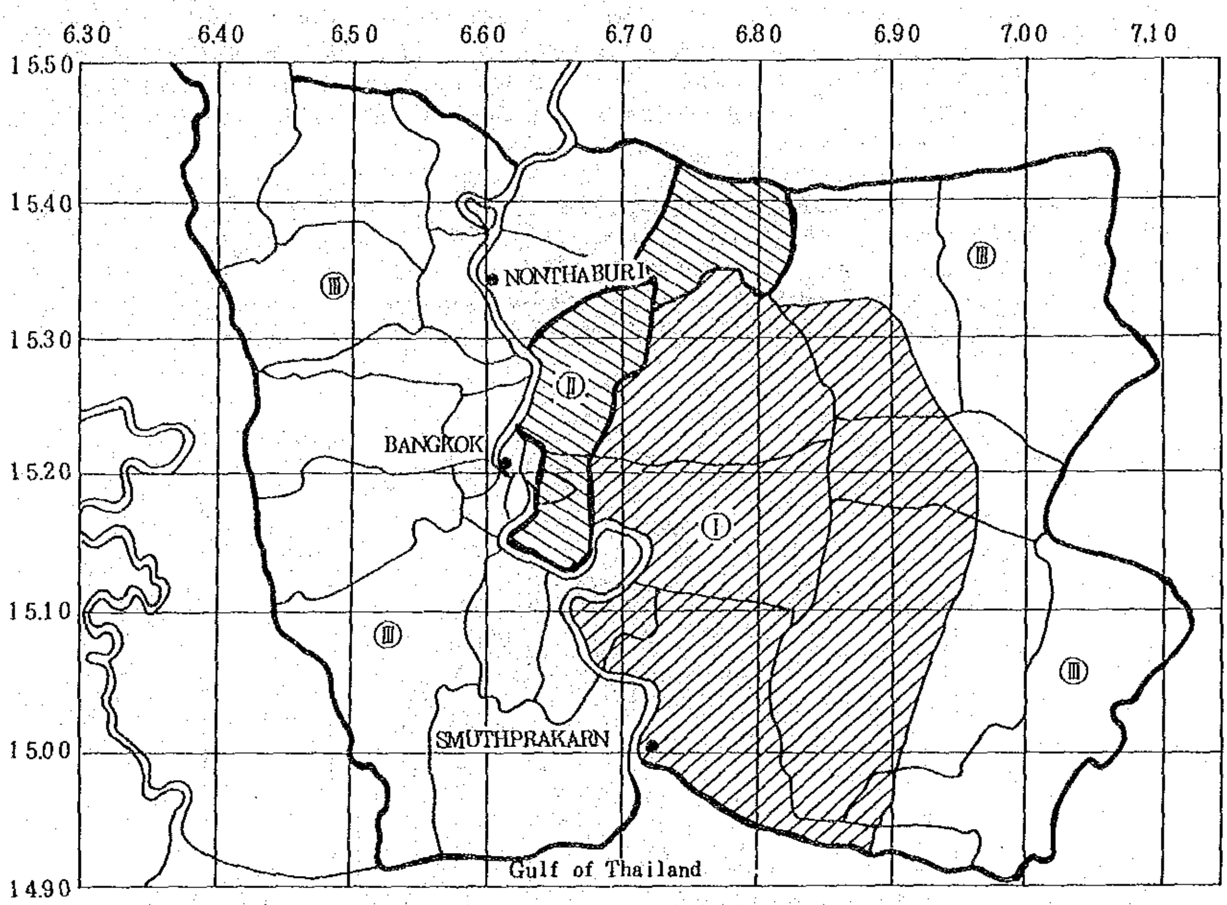
2.2.1 Pumping Up of Groundwater and Land Subsidence

According to the Groundwater Act of 1977, 7,923 km² of the Bangkok Metropolitan area (including its surrounding area) is designated as "the Bangkok Groundwater area". Inside this area, a certain portion (2,285 km² in total) is designated as " the Groundwater Critical Area". The former is shown in Fig. 2.3, and the latter in Fig. 2.4.



Ayudhaya	2,480 km²
Bangkok	1,550 "
Nonthaburi	622 "
Pathumtani	1,497 "
Smutprakarn	934 "
Smutsakorn	840 "
	7,923 "

Fig. 2.3: Map of Bangkok Groundwater Area 2)



Explanation: Critical Area I: Subsidence Rate > 10 cm/Y (763 km² Approx.)

Explanation: Critical Area II: Subsidence Rate 5 - 10 cm/Y (213 km² Approx.)

Explanation: Critical Area III: Subsidence Rate < 5 cm/Y (1,309 km² Approx.)

(Total: 2,285 km² Approx.)

Fig. 2.4: Map of Groundwater Critical Areas in Bangkok and Surrounding Areas 2)

The present situation of land subsidences in the Bangkok Metropolitan area is as shown in Fig. 2.5. In the worst affected area, the subsidence reaches some 12 cm per year. The Groundwater Critical Area corresponds to those areas which suffer more than 5 cm/Y of land subsidence.

Situated at the mouth of the Chao Phraya River, the Bangkok Metropolitan area is only 0.5 to 1.5 m above sea level. If land subsidence continues at the rate of 10 cm/Y, most of the Bangkok Metropolitan area would sink below the water in ten years' time. Hence, the graveness of the problem in this region is evident.

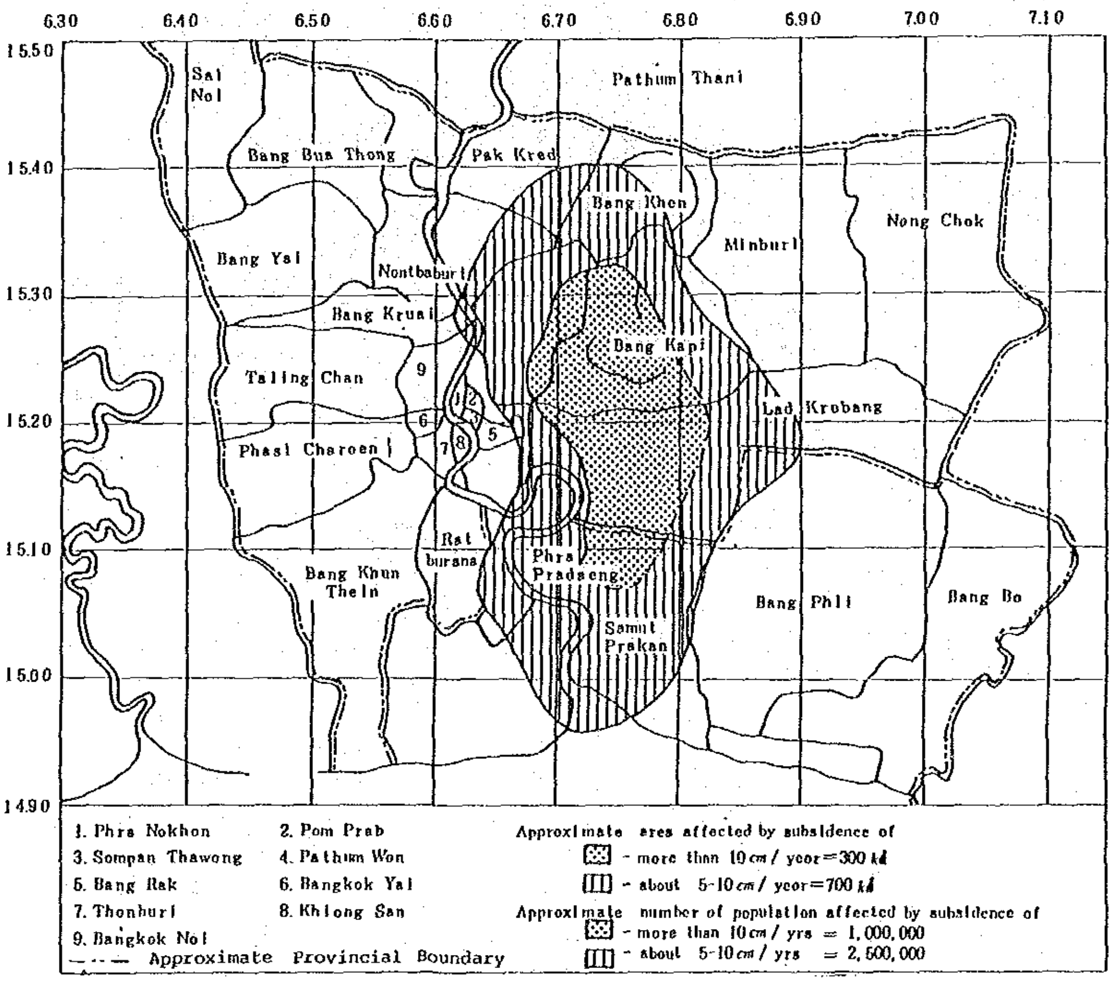


Fig. 2.5: Bangkok, Samut Prakarn and Nonthaburi Administrative Districts and Subsidence Area 3)

The seriousness of the problem shows itself in the extent of the affected areas, too. The areas designated by the Groundwater Act of 1977 would well cover the Tokyo 23 Wards (597.1 km^2) and the Osaka Prefecture (1,866.9 km^2) put together.

In Japan, the Industrial Water Act (which controls the pumping up of groundwater) affects altogether 1,925 km^2 of areas over the nationwide. Among them, Aichi (449 km^2), Osaka (421 km^2) and Tokyo (244 km^2) are the largest. Another law, the Water-for-Buildings Control Act, concerns 1,621 km^2 of areas in total (made up of 591 km^2 in Tokyo, 564 km^2 in Chiba, 254 km^2 in Saitama and 212 km^2 in Osaka).

Table 2.2 shows the number of wells and the pumping up amounts in various parts of the Bangkok Metropolitan area. As seen in this Table, altogether 1,100,000 cubic meters of water is daily pumped up through more than 10,000 wells.

However, considering the fact that "unlicensed abstraction of groundwater may be as high as 50 % of the legal licensed total of 1.3 million m^3/d" (Reference 1), Part II, page 62), and that the small quantity of pump up need not be notified (B.E. 2527, notification of the Ministry of Industry No.15 issue in accordance with the Factory Act B.E. 2512), these figures are likely to be underestimated.

Table 2.3 shows the pumping up quantity adjusted in accordance with Reference 1). "MWA" in the Table stands for the Metropolitan Waterworks Authority, a public organization supplying potable water through piping systems. MWA uses river water as well as groundwater. The Table includes only groundwater used by MWA.

As shown in Fig. 2.6, it is planned to stop the land subsidences by gradually replacing the use of groundwater in the private sector (i.e. excluding MWA) with the use of river water.

Table 2.2: Pumped Up Quantity of Groundwater by Private Sector

Upper: Number of Well
Lower: (m^3/d)
As of January 1986

Area \ Use	Domestic	Commercial	Agricultural	Total	%
Bangkok	3,263 (270,589)	1,639 (215,385)	220 (12,543)	5,122 (498,517)	52.5 (46.9)
Samut Prakarn	1,684 (60,402)	1,500 (286,070)	122 (4,284)	3,306 (350,756)	33.9 (33.0)
Samut Sakorn	368 (5,585)	246 (63,519)	91 (1,461)	705 (70,565)	7.2 (6.6)
Nothaburi	181 (3,260)	85 (19,539)	2 (40)	268 (22,839)	2.8 (2.2)
Pathumtai	113 (21,362)	139 (87,792)	22 (1,227)	274 (110,381)	2.8 (10.4)
Ayudhaya	32 (950)	31 (7,782)	9 (364)	72 (9,096)	0.7 (0.9)
Total	5,641 (362,148)	3,640 (680,087)	466 (19,919)	9,747 (1,062,154)	100.0 (100.0)
%	57.9 (34.1)	37.3 (64.0)	4.8 (1.9)	100.0 (100.0)	

Source, IWD, MOI, Thailand

Table 2.3: Pumped Up Quantity of Groundwater in Bangkok Metropolitan Area 1)

(m^3/d)

Year	MWA	Decrease (%)	Private	Change (%)	Total	Decrease (%)
1982	447,000		944,305		1,391,305	
1983	350,000	21.7	993,842	+5.2	1,343,842	4.3
1984	272,365	22.3	1,034,511	+4.1	1,306,876	2.7
1985	269,410	1.0	1,026,032	-0.8	1,295,442	0.9

Note: Record up to May

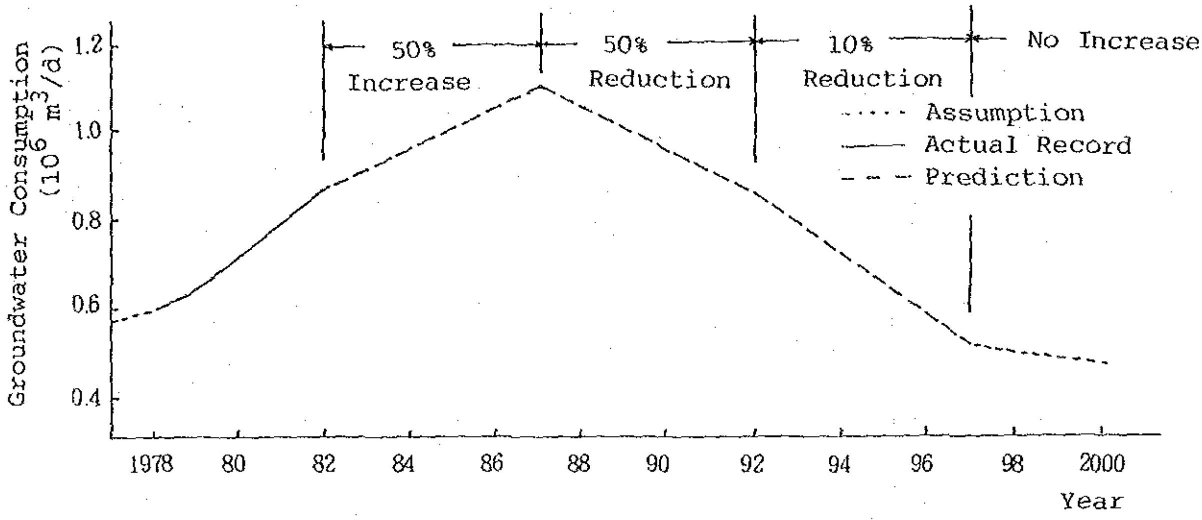


Fig. 2.6: Reduction Target of Pumped Up Groundwater by Private Sector 2)

2.2.2 Water Supply by MWA

Pursuant to the MWA Act 6-Item, MWA was established on July 25, 1967 with the aim of supplying potable water in the Bangkok Metropolis, Nonthaburi and Samut Prakarn. The Table 2.4 shows the volumes of water supplied by MWA in recent years. Figs. 2.7 and 2.8 illustrate MWA's service area and its water production capacity respectively.

MWA plans to extend the water supply areas up to 3,080 km², which is larger than the Groundwater Critical Area. Also, MWA intends to replace the use of groundwater with that of river water, setting the goal as in Fig. 2.9.

So far, this goal has been achieved well (refer to Fig. 2.8). The methods for the reduction of groundwater consumption in the private sector (except MWA) are described later in this report.

Table 2.4: Supply Record of MWA 4) 5)

Item \ Year	1984	1985	1986
Total Water Production (10^6 m^3/Y)	731.2	801.8	820.8
Water Sales (10^6 m^3/Y)	423.4	477.4	485.0
Leakage Ratio (%)	41.2	40.5	40.9
Customers (Number)	519,487	602,267	659,660
Total Water Production/-Customer (m^3/d/customer)	3.86	3.65	3.41
Water Sales/Customer (m^3/d/customer)	2.23	2.17	2.01

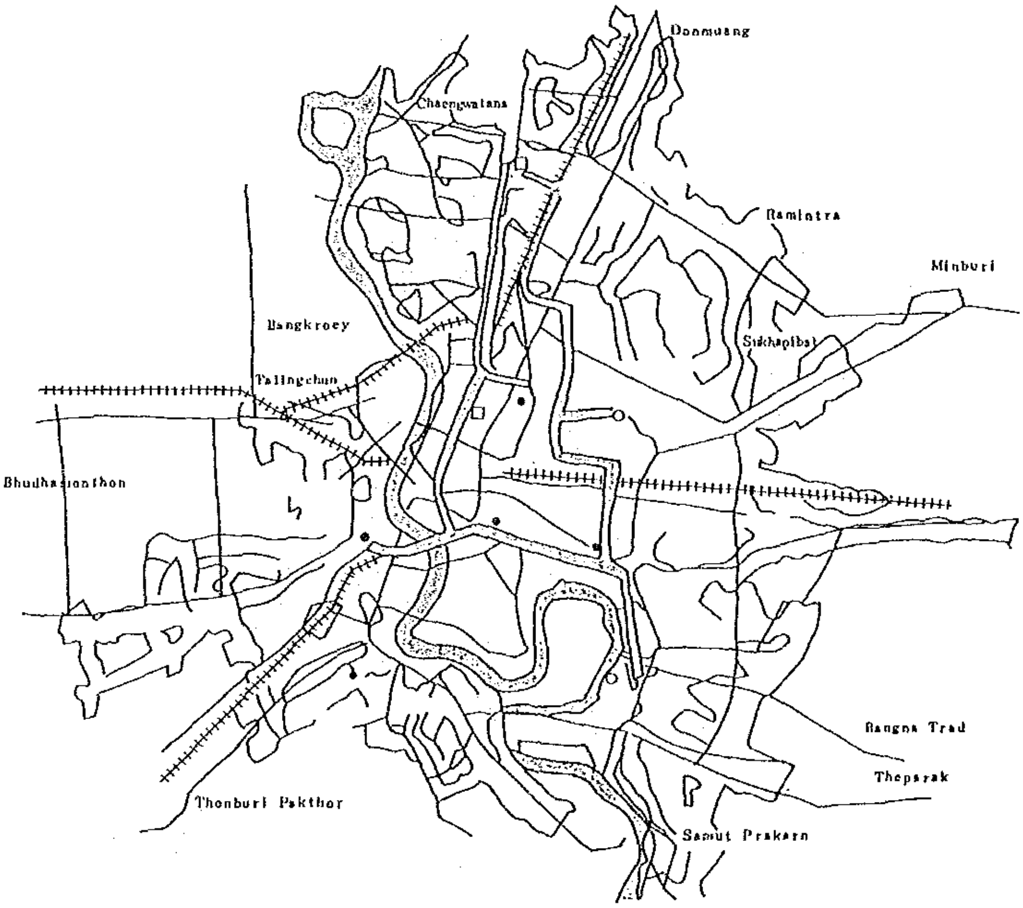


Fig. 2.7: Service Area of MWA 5)

Production Capacity in 1985 4)
(Unit : Average m³/day)

Production Capacity in 1986 5)
(Unit : Average m³/day)

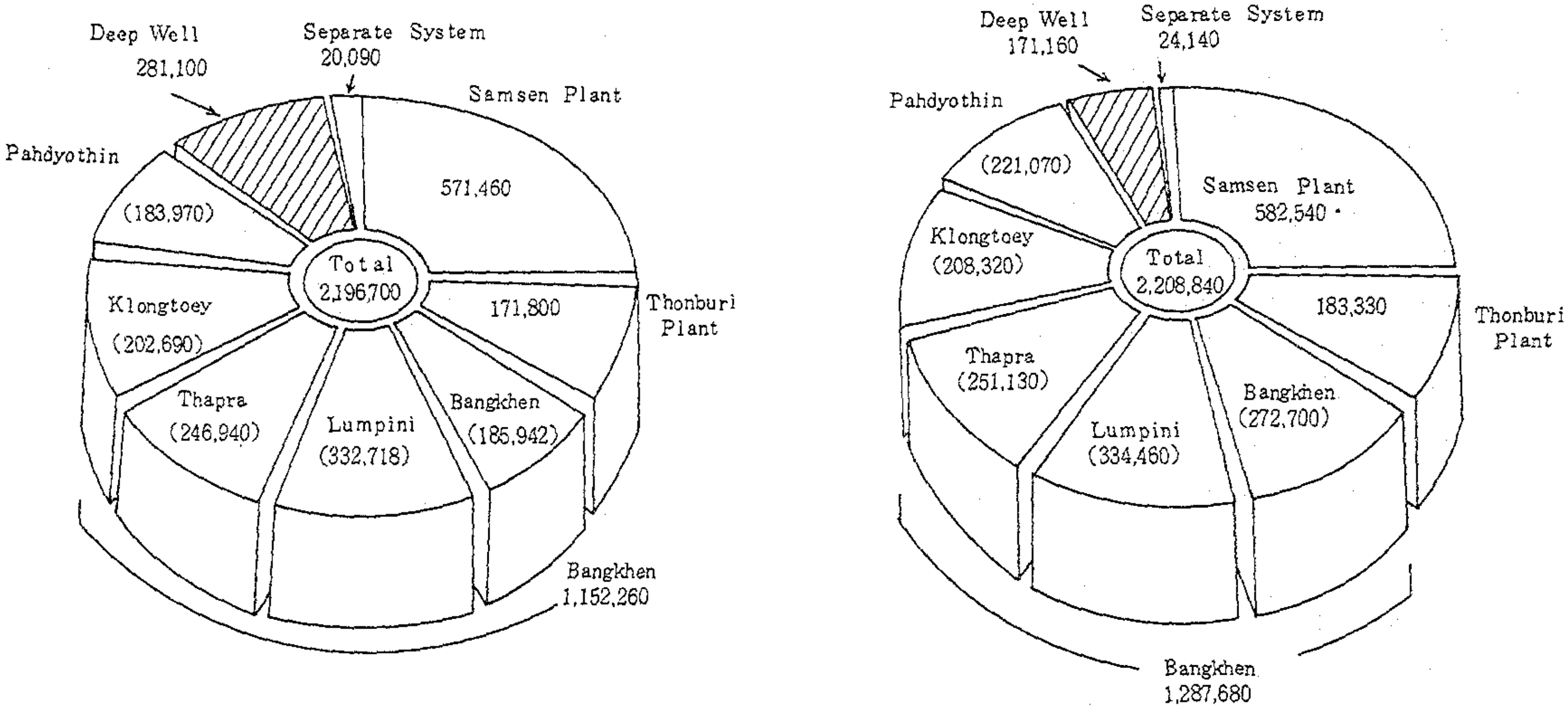


Fig. 2.8: Production Capacity of MWA 4) 5)

As shown in Table 2.4, MWA's water leakage ratio is as high as around 40%. Measures are now being taken to reduce the ratio by 10% at least. This high ratio of water leakage means that MWA's actual water supply is not so high as its water production capacity suggests.

In 1986, for example, only 1,328,770 m^3/d (485 x 106 m^3/Y) of water is actually used out of 2,248,840 m^3/d produced by MWA. For comparison, the water leakage ratio in recent years in the Tokyo Metropolitan area is as shown in Fig. 2.10.

According to the "Water Plan 2000" published by the National Land Agency of Japan, the leakage ratio of domestic water will be reduced from 18.8% at the 1983 level down to 16.8% by the year of 2000, while the leakage ratio of industrial water will remain unchanged with 6.3% at the 1983 level. (refer to Table 2.5.)

Needless to say, it is a quite waste to let once-produced water leak. The subsidence of land seems to be one of the factors accelerating water leakage.

(Unit: m^3/d)

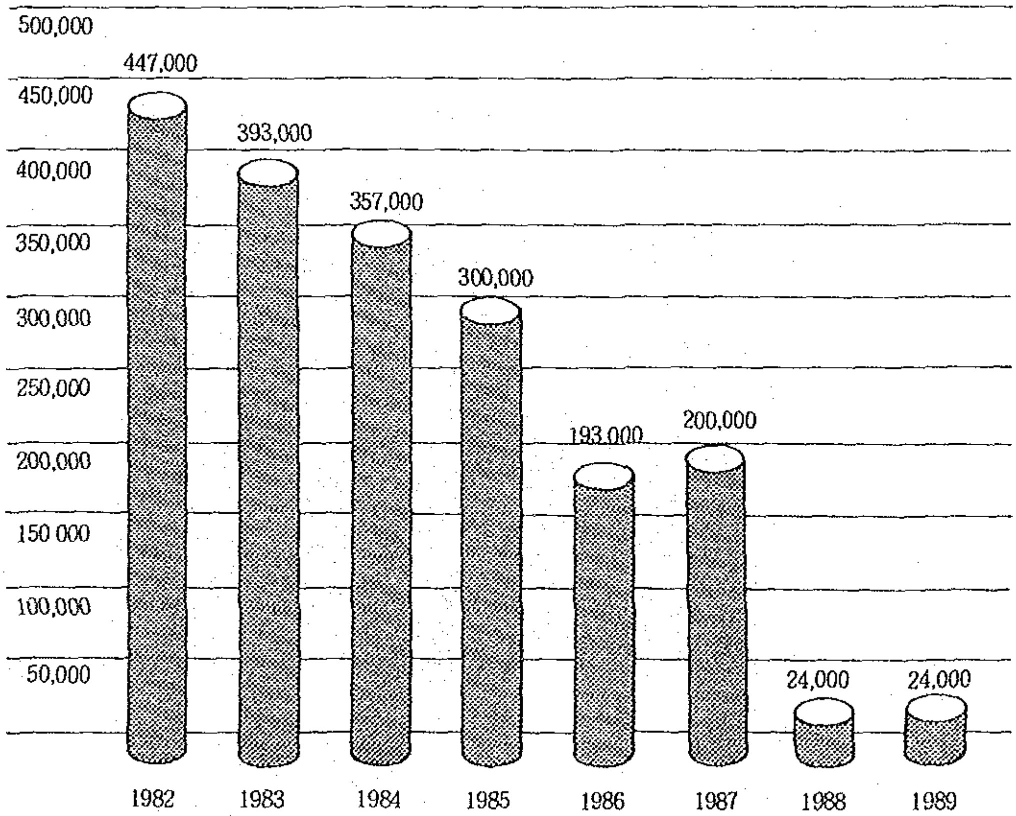
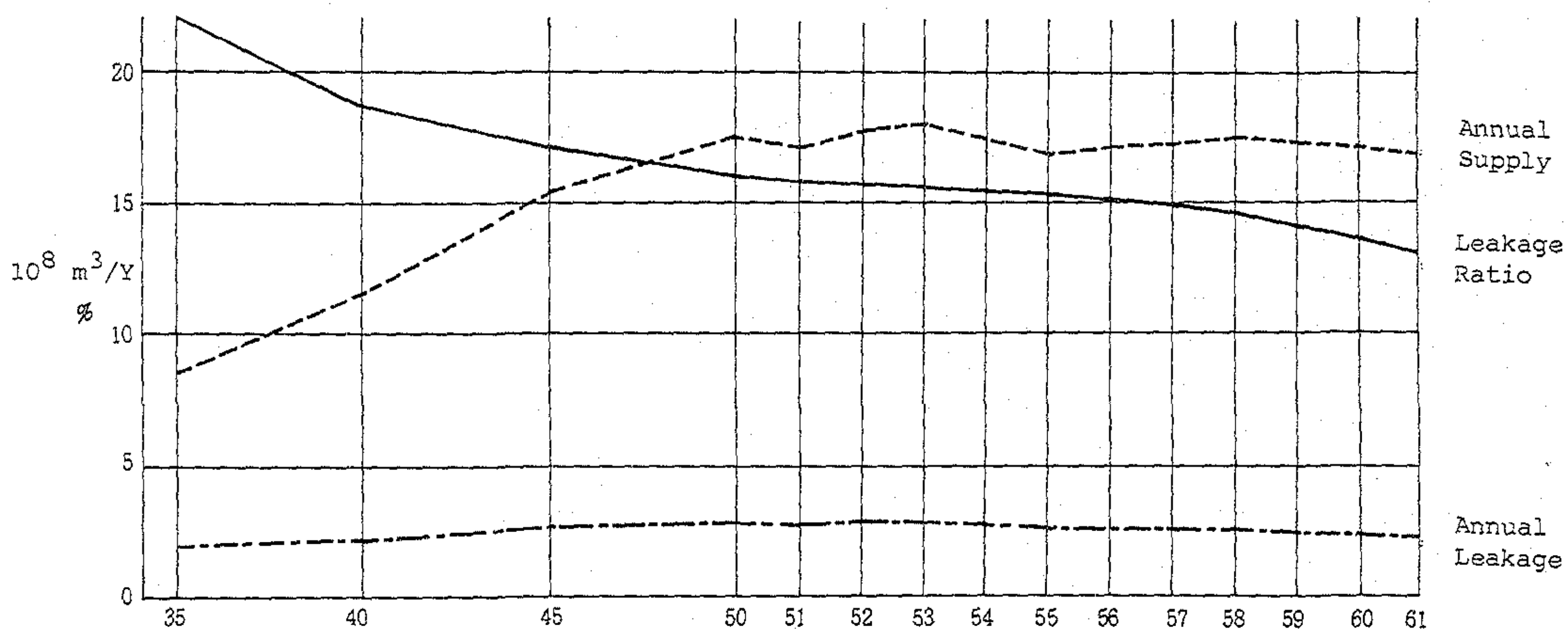


Fig. 2.9: Quantity of Groundwater to be Pumped Up by MWA 5)



Year	1960	1965	1970	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Ratio (%)	22.0	18.7	17.2	16.1	15.9	15.8	15.6	15.5	15.4	15.2	15.0	14.7	14.2	13.7	13.2

Source: Data of Tokyo Metropolitan Government (1983)

Fig. 2.10: Leakage Ratio, Leaked Quantity and Supply Quantity in Tokyo

Table 2.5: Water Plan 2000 of Japan

Item	Year	1983	2000	Unit
Domestic Water	Total Population	11,948	13,020	10^4
	Served Population	11,070	12,860	10^4
	Served Ratio	92.6	98.0	%
	Unit Usage	298	368	lit/capita/d
	Water Demand (Effective Paid Base)	121	173	10^8 m^3/Y
	Water Demand (Intake Amount)	149	208	10^8 m^3/Y
Industrial Water	Industrial Output	235	480	10^{12} Yen
	Fresh Water Use	554	893	10^8 m^3/Y
	Recovery Rate	73.3	76.7	%
	Fresh Make-up Water (Effective Paid Base)	148	208	10^8 m^3/Y
	Fresh Make-up Water (Intake Amount)	158	222	10^8 m^3/Y
Agricultural Water	Irrigation of Paddy Field	562	577	10^8 m^3/Y
	Irrigation of Farmland	18	43	10^8 m^3/Y
	Stock Breeding	5	6	10^8 m^3/Y
	Total	585	626	10^8 m^3/Y
Gross Total		892	1,056	10^8 m^3/Y

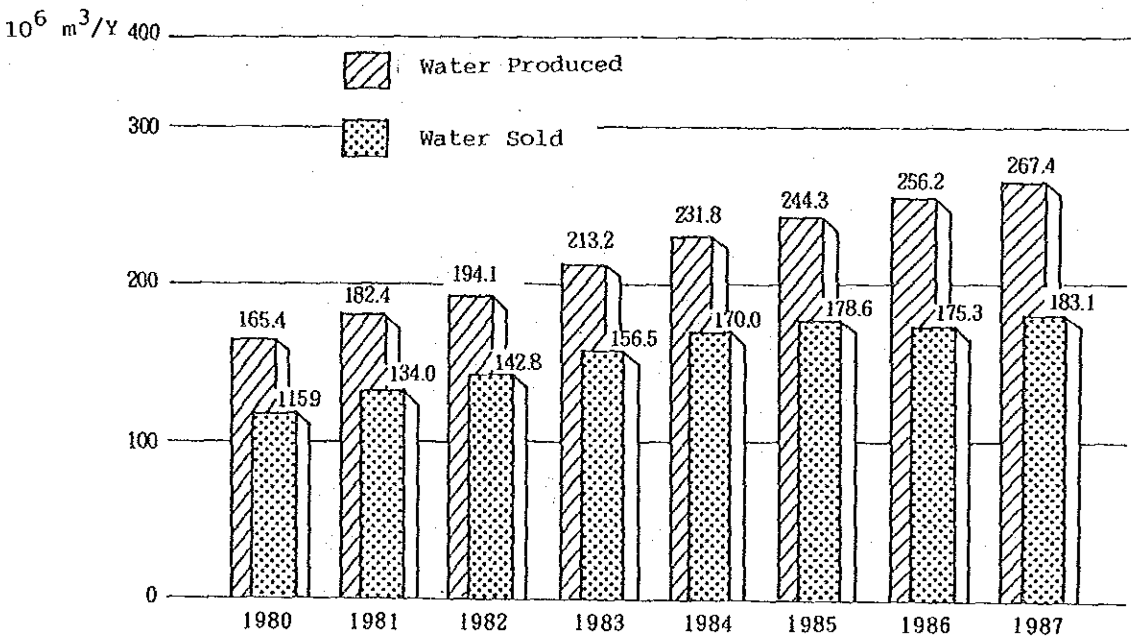
Source: National Land Agency, Japan

2.2.3 Water Supply by PWA

PWA (Provincial Waterworks Authority) .takes charge of water supply for the areas that are not covered by MWA. For instance, the Pathumtani and Ayudhaya Provinces, both of which lie in the north of Bangkok Metropolitan area, fall under the responsibility of PWA.

PWA uses 9,360 m^3/d of groundwater for Pathumtani, and 2,160 m^3/d of river water and 1,200 m^3/d of groundwater for Ayudhaya. Putting together with the pumping up volumes shown in Table 2.2, the groundwater used in Pathumtani and Ayudhaya reaches around 120,000 m^3/d and 10,300 m^3/d respectively. As the industrial activities grow, the demand for water is expected to increase in both Provinces.

Fig 2.11 illustrates the growth of PWA's water supply. The water leakage ratio averages 31.5%. It is to be noted that the leakage ratio grows as the total water supply grows.



	1980	1981	1982	1983	1984	1985	1986	1987
Water Loss (%)	26.11	26.48	26.44	26.60	26.72	26.90	31.57	31.51

Fig. 2.11: Water Produced and Sold by PWA 6)

2.3 Quality of Water

2.3.1 Quality of Potable Water in Thailand

Table 2.6 shows the quality standards for potable water in Thailand. For comparison, Japanese standards for potable water (domestic water) is shown in Table 2.7.

Table 2.6: Quality Standard of Potable Water in Thailand (1)

(1) Drinking Water Quality Standard

Properties	Parameters	Unit	Standard Value (Max. Allowance)
Physical	Color	Hazen	20
	Odor	-	none
	Turbidity	Silica Scale	5.0
	pH	-	6.5 - 8.5
Chemical	Total Solids	mg/lit	500
	Total Hardness as $CaCO_3$	"	100
	Arsenic (As)	"	0.05
	Barium (Ba)	"	1.0
	Cadmium (Cd)	"	0.01
	Chloride as Chlorine	"	250
	Chromium (Cr)	"	0.05
	Copper (Cu)	"	1.0
	Iron (Fe)	"	0.5
	Lead (Pb)	"	0.1
	Manganese (Mn)	"	0.05
	Mercury (Hg)	"	0.002
	Nitrate as Nitrogen (NO_3-N)	"	4.0
	Phenol	"	0.001
	Selenium (Se)	"	0.01
	Silver (Ag)	"	0.05
	Sulphate	"	250
	Zinc (Zn)	"	5.0
	Fluoride as Fluorine (F)	"	1.5
Bacterial	Coliform	MPN/100 mlit	2.2
	E. Coliform	"	none
	Disease Causing Bacterial	"	none

Source: Notificaation of the Ministry of Public Health, No. 61, B.E. 2524, printed in the Royal Government Gazette, Vol. 98, Part 157 (Special Issue), dated September 24, B.E. 2524 (1981)

(Continued on next page)

Table 2.6: Quality Standard of Potable Water in Thailand (2)

(2) Groundwater Quality Standard for Drinking Purpose

Properties	Parameters	Unit	Standard Values	
			Suitable Allowance	Max. Allowance
Physical	Color	Hazen	5	50
	Turbidity	JTU	5	20
	pH	-	7.0 - 8.5	6.5 - 9.2
Chemical	Fe	mg/lit	0.5	1.0
	Mn	"	0.3	0.5
	Cu	"	1.0	1.5
	Zn	"	5.0	15.0
	Sulphate	"	200	250
	Chloride	"	200	600
	Fluoride	"	1.0	1.5
	Nitrate	"	45	45
	Total Hardness as $CaCO_3$	"	300	500
	Non-Carbonate Hardness as $CaCO_3$	"	200	250
	Total Solids	"	750	1,500
Toxic	As	"	none	0.05
	Cyanide	"	none	0.2
	Pb	"	none	0.05
	Hg	"	none	0.001
	Cd	"	none	0.01
	Se	"	none	0.01
Bacterial	Standard Plate Count Coliform	Colonies/-mlit	500	-
	Bacterlial E. Coliform	MPN/100 mlit	2.2	-
	E. Coliform	"	none	

Penalty: A licensee who does not comply with this notification is punishable by fine not exceed twenty thousand bahts.

Source: Notification of the Ministry of Industry, No. 4, B.E. 2521, issued under Groundwater Act B.E. 2520, printed in the Royal Government Gazette, Vol. 95, Part 66, dated June 27, B.E. 2521 (1978)

Table 2.7: Quality Standard of Potable Water in Japan

Water supplied by water works shall meet the following requirement:
(Article 4, Water Works Law)

Not to be affected by a pathogenic organ or not to contain an organism or substance which gives ground for suspicion of being affected by a pathogenic organ:	Nitrite nitrogen and Nitrate nitrogen Chlorine ion Organic substances (Consumption of potassium permanganate) Standard plate count Coliform group bacteria count	Not more than 10 mg/lit Not more than 200 mg/lit Not more than 10 mg/lit Not more than 100/mlit Not to be detected
Not to contain cyanogen, mercury and other poisonous substances:	Cyanic ion Mercury Organic phosphorus	Not to be detected Not to be detected Not to be detected
Not to contain copper, iron, fluorine, phenol and other substances in excess of their allowable quantities:	Copper Iron Manganese Zinc Hexavalent chromium Cadmium Arsenic Fluorine Calcium, magnesium, etc. (Hardness) Evaporation residue Phenol Methylene blue active substance	Not more than 1.0 mg/lit Not more than 0.3 mg/lit Not more than 0.3 mg/lit Not more than 1.0 mg/lit Not more than 0.05 mg/lit Not more than 0.01 mg/lit Not more than 0.05 mg/lit Not more than 0.8 mg/lit Not more than 300 mg/lit Not more than 500 mg/lit Not more than 0.005 mg/lit as phenol Not more than 0.5 mg/lit
Not to assume abnormal acidity or alkalinity:	pH value	5.8 - 8.6
Not to give an abnormally offensive smell, except an offensive smell caused by sterilization:	Odor Taste	Not abnormal Not abnormal
To almost colorless and transparent in appearance:	Color Turbidity	Not more than 5 degree Not more than 2 degree

Table 2.8 shows the qualities of well water used in one of the surveyed factories (i.e. P-04 factory). Compared with the figures in Table 2.6, this factory's water is of fairly bad quality.

More alarmingly, some qualities in Table 2.8 show deterioration from 1985 to 1986. This deterioration may have been caused partly by the excess pumping up of groundwater. Thus, excess use of groundwater affects not only the area in general but also individual factories.

Table 2.8: Quality of Well Water in Factory No. P-04

Upper: February 1985
Lower: February 1986

(Unit except pH: mg/lit)

Item \ Well No.	1	2	3	5	6	7	8	9	10
pH	8.2 6.9	8.0 6.8	8.1 7.0	8.4 7.0	7.9 7.1	- 7.0	8.4 6.8	8.2 -	8.6 -
SS	1.4 2.9	3.3 4.1	3.8 2.6	0.5 1.4	5.2 7.6	- 0.8	1.3 2.4	3.7 -	3.7 -
Total Residue	491 1,004	1,903 2,404	1,654 1,853	501 1,201	2,105 1,608	- 701	651 1,402	1,504 -	493 -
Hardness	120 275	835 765	545 585	130 245	905 470	- 115	190 410	735 -	165 -
Cl^-	119 387	1,139 1,207	926 928	138 354	1,230 703	- 161	277 624	922 -	119 -
Fe	0.4 1.2	3.2 3.2	1.6 1.6	0.6 1.0	1.9 1.6	- 0.8	1.1 1.5	2.8 -	0.6 -

2.3.2 Quality of Supplied Water in Japan

Table 2.9 shows the qualities of water supplied from some typical sources in Japan. Thanks to many sources of clean water, the qualities of water in Japan is much better than those of well water in Samut Prakarn.

Table 2.10 shows Japanese target standards for public industrial water. (These are not so much "standards" as "yardsticks". There are no formal standards for public industrial water in Japan.) Water actually supplied to Japanese factories has often better qualities than specified in Table 2.10.

Besides public industrial water, many factories in Japan use water from various sources. Those factories often set up their own standards for industrial water. Some of such standards (those of a pulp/paper factory and an iron mill equipped with a blast furnace) are included in the Appendix Part 2 of this report.

Table 2.9: Water Quality Classified by Water Source in Japan

Item \ Water Source	Industrial Water (Tokyo) (Note A)	Potable Water (Osaka)	Surface Water (Note B)	Surface Water (Note C)	Ground Water (S/Well) (Note D)	Sea Water
Temperature (°C)	9.7 - 27.0	4.4 - 31.5	-	-	-	5 - 28
Turbidity (°)	1 - 15	0 - 1.5	-	-	-	-
Color (°)	10 - 38	1.5 - 6.0	-	-	-	-
pH	6.4 - 7.0	6.3 - 6.4	6.9 - 7.2	-	-	8.01 - 8.24
Electrical Conductivity (μS/cm)	-	140 - 160	-	-	-	4,800-66,000
Total Hardness (ppm)	131 - 344	30.0 - 40.5	-	-	-	-
Chloride Ion (ppm)	96 - 960	15.2 - 21.6	2.0 - 6.0	5.8	5 - 50	18,980
Sulfate (ppm)	-	18.0 - 21.0	3.0 - 10.0	10.6	5 - 10	2,649
Nitrate (ppm)	-	0.26 - 0.68	0.1 - 0.3	1.0	0.1 - 0.2	-
Silicate (ppm)	-	0	10 - 20	18.7	5 - 35	-
Ammonium (ppm)	-	0.024 - 0.040	0.02 - 0.05	-	0.2 - 0.3	0.005 - 0.05
Calcium (ppm)	-	-	5 - 10	8.8	5 - 20	400
Magnesium (ppm)	-	-	1.0 - 3.0	1.9	3 - 15	1,272
Iron (ppm)	0.13 - 0.67	0.01 - 0.06	0 - 0.05	0.3	0.1 - 2.0	0.01
Reference	Annual Report 1969 Tokyo Metro Gvnt.	Report 1967 Osaka	Journal of Ind. Water Dr. Kurata	Water in Japan	Journal of Ind. Water Dr. Kurata	

Note A: Municipal waste water effluent
Note B: Majority of 225 rivers in Japan
Note C: Average of 225 rivers in Japan
Note D: S/Well = Shallow Well

Table 2.10: Desirable Quality of Industrial Water
(Make-up Water)

Item	Desirable Quality of Industrial Water	Reference Value	
		Industrial Water (Tokyo Metro. Gvnt.)	Water Works (Min. of Health & Welfare)
Turbidity	20 ppm	15°	2°
pH	6.5 - 8.0	5.8 - 8.6	5.8 - 8.6
Alkalinity ($CaCO_3$) (ppm)	75	-	-
Hardness ($CaCO_3$) (ppm)	120	-	300
Total Residue (ppm)	250	-	500
Chloride Ion (ppm)	80	200	200
Fe (ppm)	0.3	0.3	0.3
Mn (ppm)	0.2	-	0.3

Source: Industrial Water Handbook, 1977, Japan

2.3.3 Quality of Effluent Water from Factories

In Thailand, standards are established both for factory effluent water and household waste water. The former is shown in Table 2.11, the latter in Table 2.12.

These standards are stricter than the waste water standards in Japan. (Some local governments in Japan, however, impose very strict regulations on effluent water.) Since the regulations on effluent water depend on particular conditions of each country, there is not much point in comparing Thai standards with Japanese ones.

Table 2.11: Quality Standard of Waste Water

#	Item	Standard Values
1	pH	Between 5.0 and 9.0
2	Permanganate Value	60 mg/lit
3	Dissolved Solids	
	3.1 Discharge into watercourses	2,000 mg/lit or more, but not exceeding 5,000 mg/lit, depending upon discharging point
	3.2 Discharge into sea or estuaries (Salinity higher than 2,000 mg/lit)	5,000 mg/lit higher than dissolved solids content in sea or estuary waters
4	Sulfide as H_2S	1.0 mg/lit
5	Cyanide as HCN	0.2 mg/lit
6	Heavy Metals	
	6.1 Zinc	5.0 mg/lit
	6.2 Chromium	0.5 "
	6.3 Arsenic	0.25 "
	6.4 Copper	1.0 "
	6.5 Mercury	0.005 "
	6.6 Cadmium	0.03 "
	6.7 Barium	1.0 "
	6.8 Selenium	0.02 "
	6.9 Lead	0.2 "
	6.10 Nickel	0.2 "
	6.11 Manganese	5.0 "
7	Tar	Nil
8	Oil and Grease	5.0 mg/lit (Except for crude oil refinery and lubricant blending plant: less than 15 mg/lit)
9	Formaldehyde	1.0 mg/lit
10	Phenol and Cresols	1.0 mg/lit
11	Free Chlorine	1.0 mg/lit
12	Insecticides and radioactive substance	Nil

(Continued on next page)

Table 2.11: Quality Standard of Waste Water (Continued, 2/2)

#	Item	Standard Values
13	Suspended Solids	30 mg/lit more depending on dilution ratio as shown below
	Dilution Ratio	Allowable Suspended Solids
	8 - 150	30 mg/lit
	151 - 300	60 "
	301 - 500	150 "
14	BOD, 5 days, 20 °C	20 mg/lit or more, but not exceeding 60 mg/lit depending upon discharging point, except for industries as shown below
	14.1 Fish Canning (Category 7 (1))	200 mg/lit Until 31 Dec 1982 100 mg/lit As of 1 Jan 1983
	14.2 Tapioca Starch, New Process (Category 9 (3))	100 mg/lit Until 31 Dec 1982 Thereafter as in #14
	Old Process	200 mg/lit Until 31 Dec 1982 100 mg/lit As of 1 Jan 1983
	14.3 Noodle Factory, using less than 500 kg of Rice per day (Category 10 (3))	150 mg/lit Until 31 Dec 1982 100 mg/lit As of 1 Jan 1983
	14.4 Tanneries (Category 29)	200 mg/lit Until 31 Dec 1982 100 mg/lit As of 1 Jan 1983
	14.5 Pulp Mills (Category 38 (1))	150 mg/lit Until 31 Dec 1982 100 mg/lit As of 1 Jan 1983
	14.6 Seafood Processing (Category 92)	200 mg/lit Until 31 Dec 1982 100 mg/lit As of 1 Jan 1983
15	Temperature	Less than 40 °C
16	Color and Odor	Not objectionable when mixed in receiving water

Source: Office of Industrial Services and Waste Treatment
IWD, MOI, Thailand
June 12, 1982

Table 2.12: Quality Standard of Household Waste Water

Parameters	Units	Domestic Effluent Standards for Community Group - (Persons)			
		A (<101)	B (101-500)	C (501-2500)	D (>2500)
BOD_5 20	mg/lit	30	60	30	20*
Solids					
Suspended Solids	"	60	50	40	30
Settable Solids	"	0.5	0.5	0.5	0.5
Total Dissolved Solids	"	+500	+500	+500	+500**
Sulfide	"	4.0	3.0	1.0	1.0
Free Residual Chlorine	"	-	-	0.3	0.3***
Nitrogen					
TKN	"	40	40	-	-
ORG-N	"	15	15	10	10
NH_3-N	"	25	25	-	-
NO_3-N	"	-	-	-	-
pH		5-9	5-9	5-9	5-9
Oil and Grease	mg/lit	20	20	20	20

Note: * Settled BOD (30 min)
** More than TDS of used water
*** Maximum allowance under epidermic condition only

Parameters	Methods of Analysis Ref.: Standard Methods of Examination of Water and Waste Water APHA - AWWA - WPCF
BOD_5 20	- Azide Modification: 20 °C, 5 days
Solids	
Suspended Solids (SS)	- Non filterable residue through glass fiber filter discs
Settable Solids	- 60 min settling in 1,000 cc imhof cone
Total Dissolved Solids	- Filtrate from SS and evaporate at 103-105 °C 1 hour
Sulfide	- Titration for total sulfide
Free Residual Chlorine	- Orthotolidine arzenide
Nitrogen	
TKN	- Kjeldahl
ORG-N	- Kjeldahl after NH_3-N separate
NH_3-N	- Nesslerization
NO_3-N	
pH	- Electrometric meter
Oil and Grease	- Soxhlet extraxtion

Source: Setting by Sub-Committee of Domestic Effluent Criteria under the Committee on Water (May 27, B.E. 2527 (1984))
Approved by the National Environment Board (Jan. 31, B.E. 2528 (1985))

2.4 Characteristics of Samut Prakarn

To establish the guidelines the effective use of industrial water in Thailand, Samut Prakarn area was chosen as a sample of our study.

Sandwiched between Bangkok Metropolis and the Gulf of Thailand, Samut Prakarn spreads on the both sides of the Chao Phraya River (Fig. 2.3, 2.4, 2.5 and 2.12). It has been rapidly urbanized in recent years, the north now being inseparably fused into Bangkok Metropolis.

Samut Prakarn area covers an area of 934 km^2 (refer to Fig. 2.3) with about 700,000 inhabitants, most of whom concentrate in the area neighboring Bangkok metropolis on the both sides of the river. As shown in Fig. 2.12, the population growth rate of this area is also very high, reaching about 8% per year.

Situated to the south of Bangkok, a great consuming city as well as a great port of industrial materials, Samut Prakarn area has recently seen a rapid growth in industrial activities. Fig. 2.13 shows the growth of production in various economic sectors in Samut Prakarn area. The increase in the manufacturing industries is particularly sharp.

Fig. 2.14 shows the growth of industrial activities in terms of the number of factories, the amount of annual investment and the number of factory employees. All three indicators confirm the rapidness of the growth in recent years.

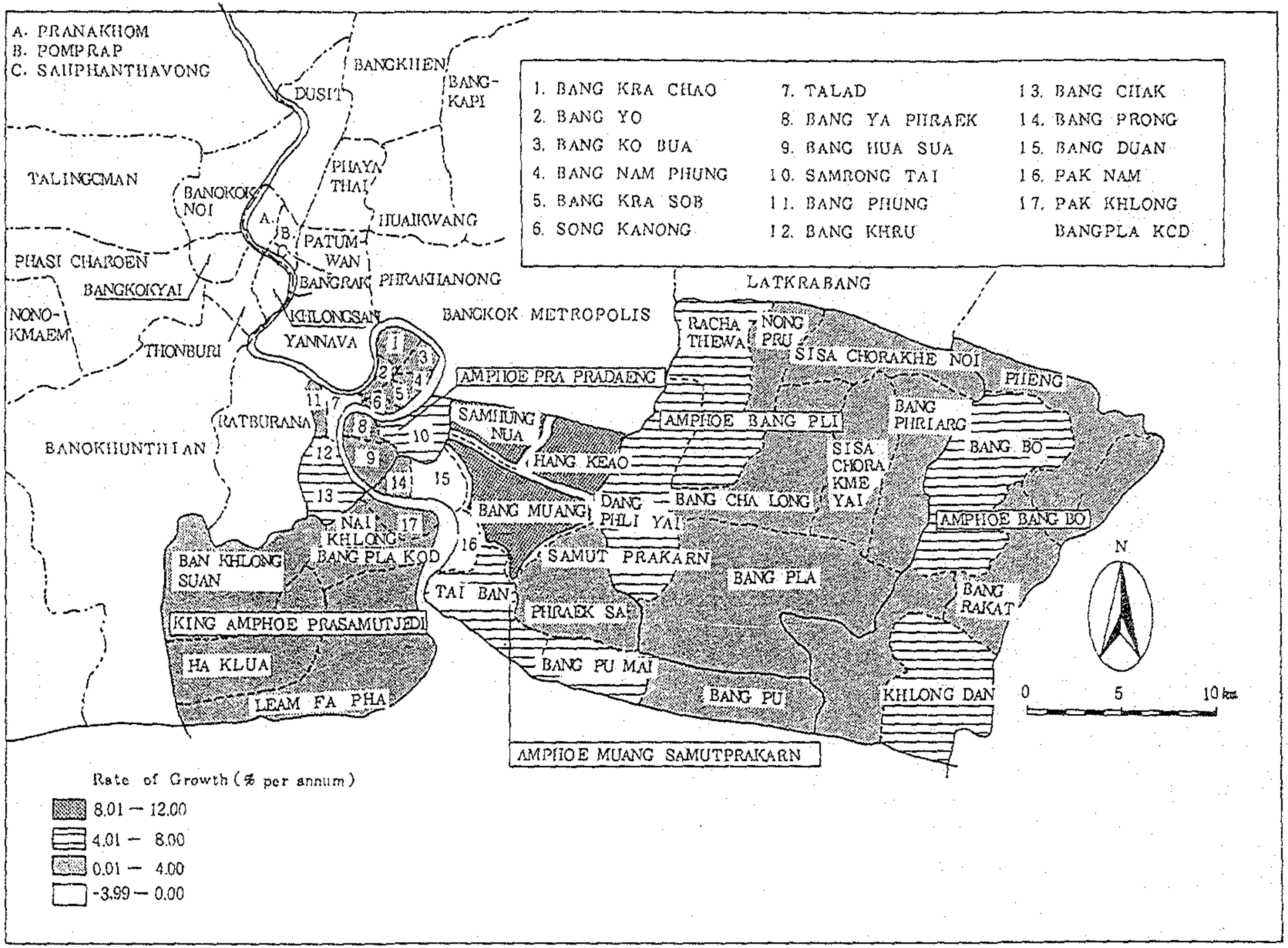
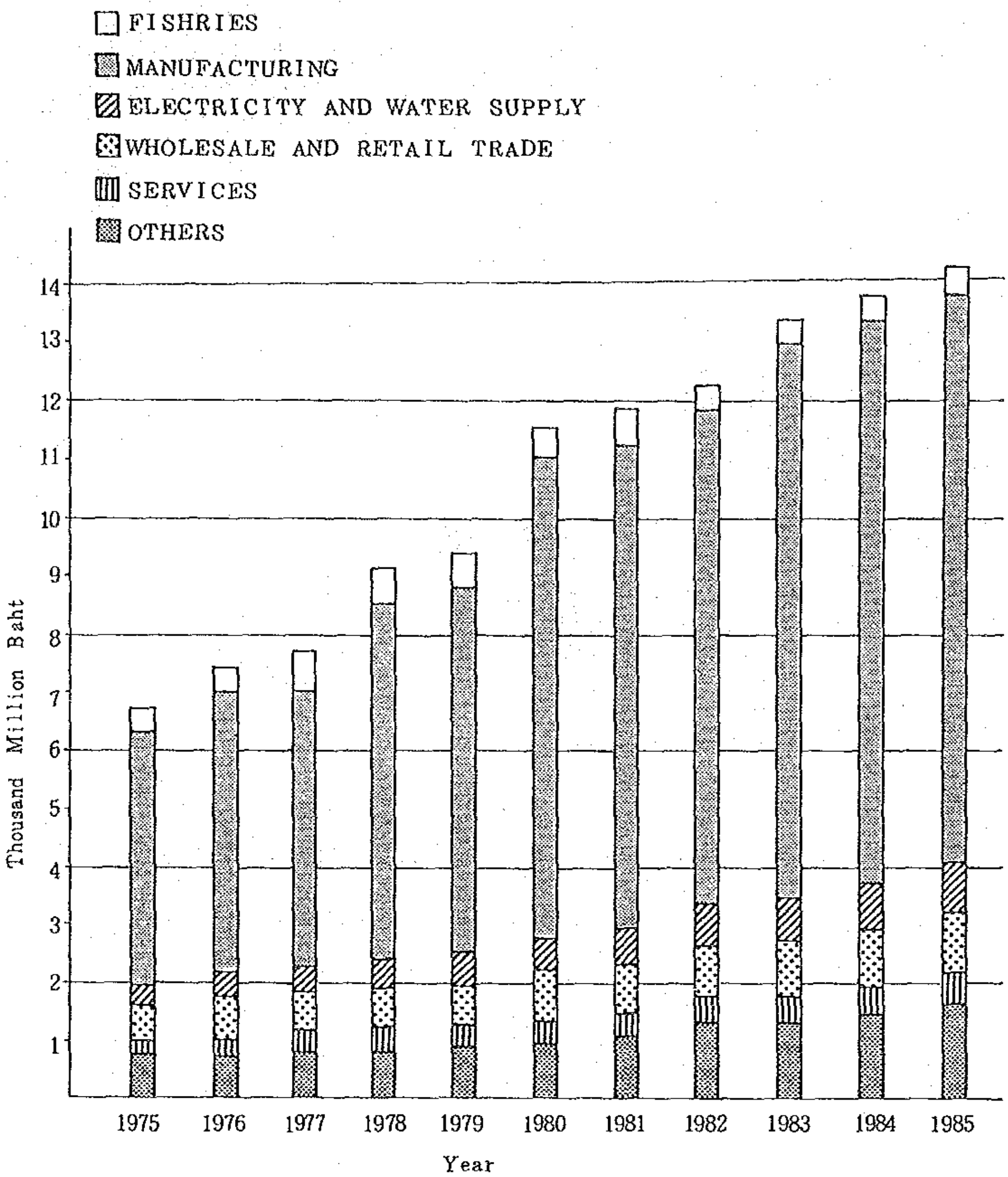


Fig. 2.12: Population Growth Rate of Samut Prakarn by Tambon, 1986 3)



Source : Office of the National Economic and Social Development Board

Fig. 2.13: Gross Provincial Product of Samut Prakarn, Distribution by Main Sector 1975 - 1985

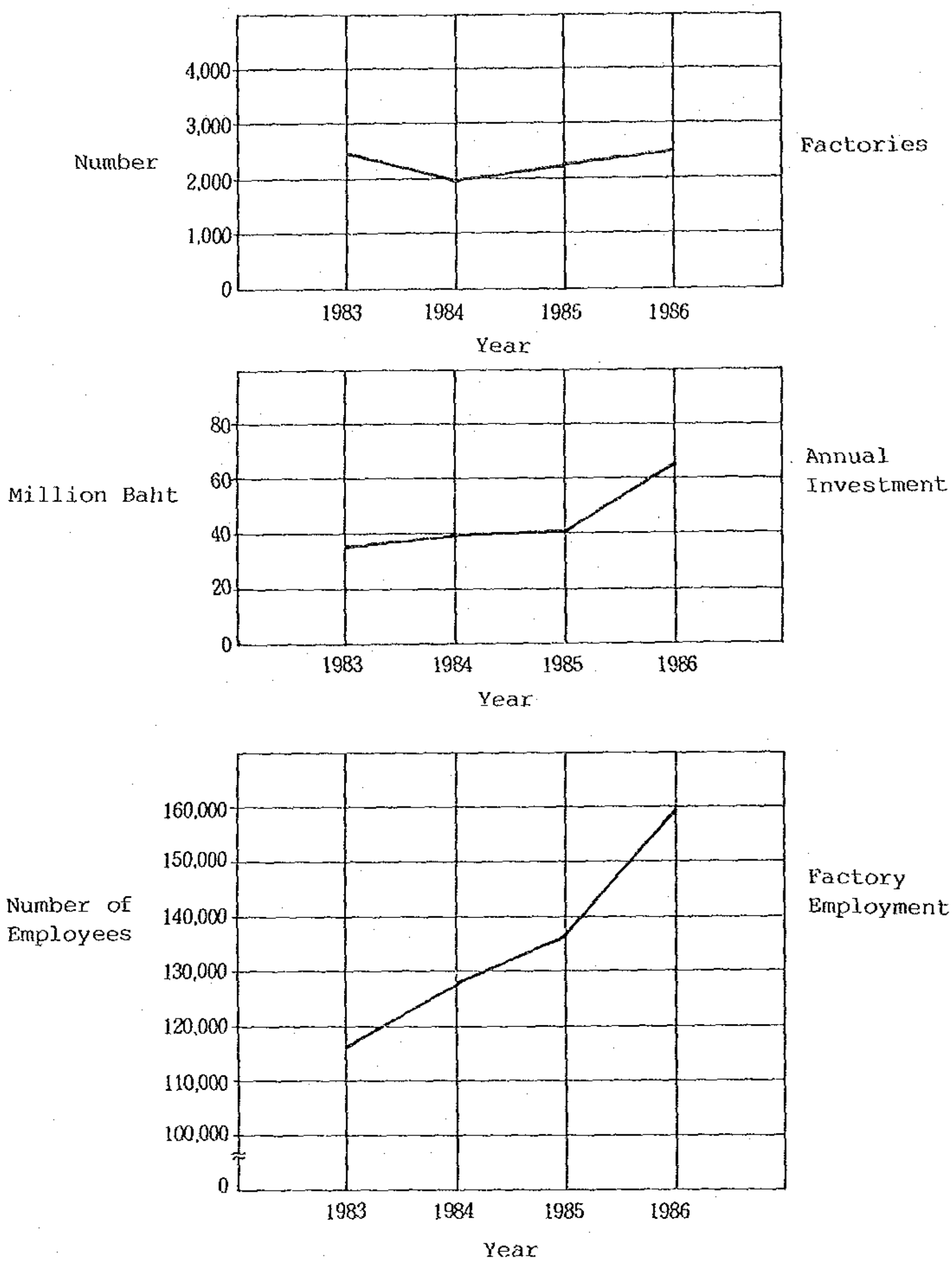


Fig. 2.14: Industrial Sector--Number of Factories,[3] Annual Investment and Factory Employment in Samut Prakarn 1983 - 1986

Along with the growth in the population and industrial activities, the consumption of water has also considerably increased. Since MWA covers only small part of Samut Prakarn area, most of water used in this area comes from wells, whose locations are shown in Fig. 2.15.

As seen in Table 2.13, both the number of wells and the pumping up quantity have grown in Samut Prakarn area, though the Groundwater Act seems to have curbed the growth rate a little lately.

Besides wells, rainfall is an important water source. As shown in Fig. 2.2, the rainfall precipitation in Samut Prakarn Area amounts to around 1,400 mm/Y. The average monthly rainfall precipitation and rainy days in the area are shown in Fig. 2.16.

The industrial development of Samut Prakarn is expected to be accelerated in the future. The supply of industrial water, therefore, will inevitably gain its importance. Also important is to harmonize the supply of industrial water with the improvements of other infrastructures (roads, harbor facilities, city water systems, etc.).

Table 2.13: Number of Wells and Pumped Up Quantity

Area / Year	Samut Prakarn		Bangkok	
	No. of Well	Quantity (m^3/d)	No. of Well	Quantity (m^3/d)
1978	2,329	228,115	4,229	339,496
1979	2,529	244,534	4,643	363,164
1980	2,731	264,347	4,999	418,354
1981	2,901	285,277	5,251	465,361
1982	3,028	316,153	5,430	498,837
1983	3,104	319,261	5,542	518,299
1986	3,306	350,756	5,122	498,517
1988	3,411		4,958	

Source: IWD, MOI, Thailand

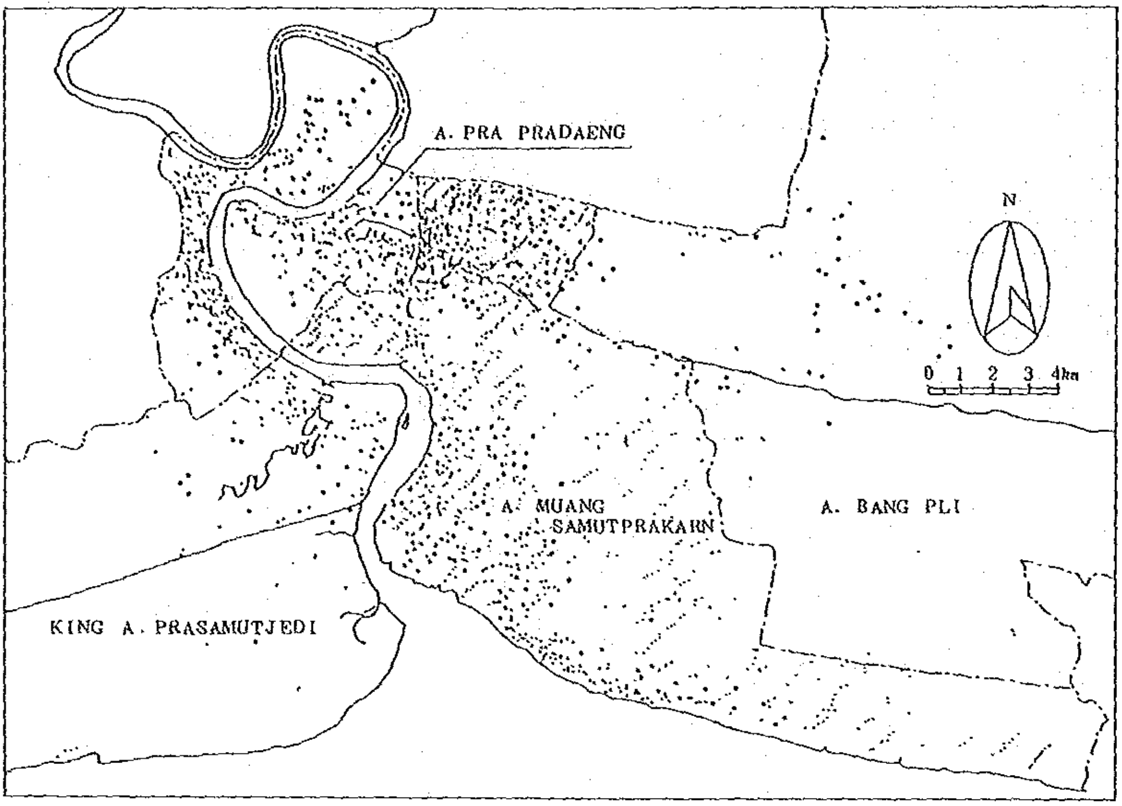


Fig. 2.15: Location of Groundwater Wells 3)

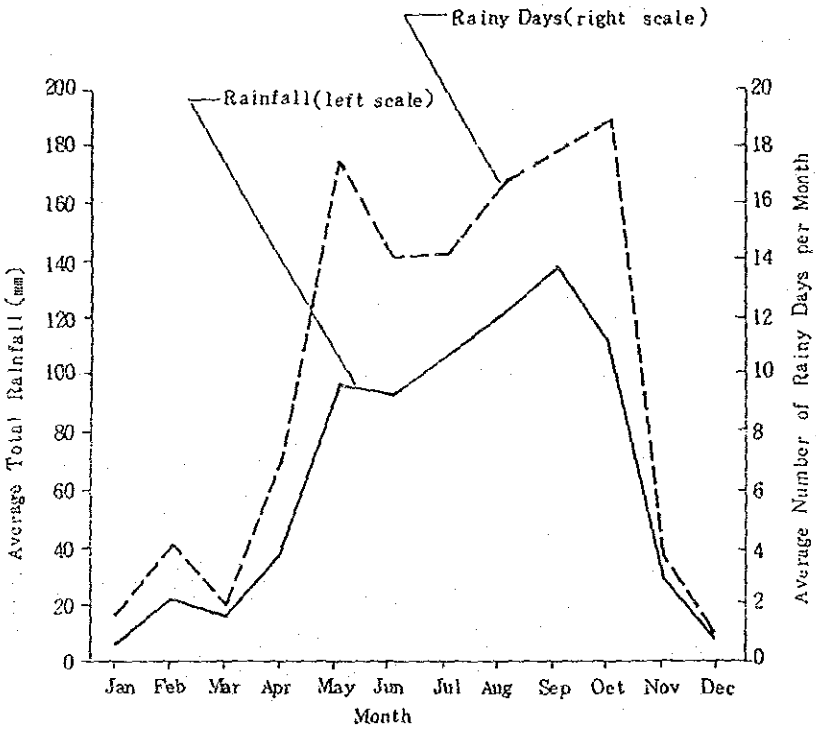


Fig. 2.16: Average Monthly Rainfall and 3) Rainy Days per Month in Samut Prakarn, 1952 - 1981

2.5 Safe Yield of Groundwater

2.5.1 Safe Yield in Samut Prakarn

It is without doubt that the subsidence of land results from the excessive pumping up of groundwater. To judge whether any pumping up quantity is excessive or not, a certain criterion has to be given. The safe yield provides this criterion. If pumping up quantity exceed the safe yield continuously, the land will gradually subside.

The safe yield of groundwater depends on the various conditions of the area concerned, so that long-term and large-scale measurements are required to determine it. The safe yield in the Bangkok Metropolitan Area, though some suggestions are made, has not been unambiguously established yet. The following is our estimation.

Tables 2.14 and 2.15 are respectively the records of actual pumping up quantity in the Bangkok Groundwater Area (BGA) and the Groundwater Critical Area (GCA) On the basis of these figures (plus the figures in the Table 2.2), the actual pumping up quantity per square kilometer are calculated for both Areas.

Item \ Area	Bangkok Groundwater Area (BGA)	Groundwater Critical Area (GCA)
Land Area (km^2)	7,923	2,285
Pumping Up (m^3/d)	Approx. 1,100,000	Approx. 935,000
Pumping Up ($m^3/d/km^2$) Ratio	139	409

* 1,100,000 x 0.85 = 935,000
(0.85 is the ratio of the pumping up in GCA to that in BGA)

On the other hand, it has been suggested (Reference 1), Part II, page 62) that the safe yield in the Bangkok Metropolitan area is approximately 800,000 m^3/d. Though it is not clear whether this figure is applicable to BGA or GCA, the quantity per km^2 for each Area is to be calculated as follows:

BGA: 101 $m^3/d/km^2$
GCA: 350 $m^3/d/km^2$

Table 2.14: Number of Well Owned by Private Sector 2) in BGA and Quantity of Pumped Up Groundwater

Item / Year	Use			Total	Increment of the Preceding Year (%)
	Domestic	Business	Agriculture		
1978	3,947 (218,312)	3,042 (454,033)	330 (11,675)	7,319 (684,020)	- -
1979	4,512 (245,738)	3,165 (471,530)	345 (11,982)	8,022 (729,250)	9.6 (6.6)
1980	4,976 (289,350)	3,349 (526,732)	396 (14,023)	8,721 (830,105)	8.7 (13.8)
1981	5,318 (324,048)	3,502 (571,411)	417 (16,307)	9,237 (911,766)	5.9 (9.8)
1982	5,558 (361,600)	3,601 (619,359)	433 (19,018)	9,592 (999,977)	3.8 (9.7)
1983 (Up to Oct)	5,733 (384,535)	3,625 (635,704)	441 (22,063)	9,799 (1,042,302)	2.2 (4.2)

Explanation: Figures without ( ) are the number of wells and their related values, whereas figures in ( ) are pumpage (in m^3/d) and their related values.

Table 2.15: Number of Well Owned by Private Sector 2) in GCA and Quantity of Pumped Up Groundwater

Year	No. of Well (Pumpage m^3/d)	Increment of the Preceding Year (%)	Percentage of the Bangkok Groundwater Area
1978	6,707 (594,083)	-	91.6 (86.9)
1979	7,350 (636,780)	9.6 (7.2)	91.6 (87.3)
1980	7,936 (717,069)	8.0 (12.6)	91.0 (84.4)
1981	8,380 (792,648)	5.6 (10.5)	90.7 (86.9)
1982	8,699 (860,200)	3.8 (8.5)	90.7 (86.0)
1983 (Up to Oct)	8,876 (884,743)	2.0 (2.9)	90.6 (84.9)

Explanation: Figures without ( ) are the number of wells and their related values, whereas figures in ( ) are pumpage (in m^3/d) and their related values.

According to another suggestion (Reference 7), IX. B), the safe yield for the Bangkok Metropolitan area is estimated at 600,000 m^3/d. As in the above case, the unit-quantity for each Area is to be calculated as follows:

BGA: 76 $m^3/d/km^2$
GCA: 263 $m^3/d/km^2$

Compared with the pumping up quantity in various parts of Japan, the above figures, if applied for BGA, seem to be fairly small. on the other hand, considering the fact that the land subsidence has already occurred, it is obvious that the actual pumping up quantity in GCA (409 $m^3/d/km^2$) exceed the safety limit.

Thus, the safe yield for the Bangkok Metropolitan area is estimated to be somewhere between 260 and 410 $m^3/d/km^2$.

Samut Prakarn is 934 km^2 in area (Fig. 2.3) and uses around 350,000 m^3/d of groundwater (Table 2.2). As seen in Fig. 2.15, the pumping up of groundwater is concentrated in certain parts (500 to 700 km^2 in total) of Samut Prakarn.

If these particularly active parts of the province is taken as a base, the pumping up quantity per square kilometer is calculated to be 500 to 700 $m^3/d/km^2$ (350,000 divided by 700 or 500).

Considering the fact that the land subsidence has already occurred, this quantity is above the safety limit. So, taking the safe yield for the Bangkok Metropolitan area (260 to 410 $m^3/d/km^2$) into account, the safe yield of groundwater in Samut Prakarn area is estimated at roughly 300 to 350 $m^3/d/km^2$. (Continuation of the study and establishment of more reliable figures by the Thai Government is highly expected.)

In order to see the extent of the excess in pumping up in the densely populated parts of Samut Prakarn area, calculation was made on the following assumptions.

(1) The area concerned is either 500 km^2 (case 1) or 700 km^2 (case 2).

(2) The safe yield is either 300 $m^3/d/km^2$ (case 1) or 350 $m^3/d/km^2$ (case 2).

(3) The pumping up quantity in the area concerned is 80 % (i.e., 280,000 m^3/d) of the total pumping up quantity (350,000 m^3/d) in the Samut Prakarn Province.

The result of calculation is shown in Table 2.16.

Table 2.16: Study on Safe Yield

Area (km²) \ Safe Yield (m³/d/km²)		Case 1 300	Case 2 350
Case 1 500	Safety Limit of Pumping Up Quantity (m³/d)	150,000	175,000
	Quantity Over Safety Limit (m³/d)	130,000 (46.4%)	105,000 (37.5%)
Case 2 700	Safety Limit of Pumping Up Quantity (m³/d)	210,000	245,000
	Quantity Over Safety Limit (m³/d)	70,000 (25.0%)	35,000 (12.5%)

Note: (%) shows ratio of quantity over safety limit to total pumping up quantity.

As shown in Table 2.16, the actual pumping up quantity exceeds the safety limit by 13 to 46%. Although based on the assumptions that are not wholly reliable, these figures may provide some criteria in deciding the necessary quantity of water saving/reclamation.

2.5.2 Examples in Japan

Table 2.17 shows the actual examples of groundwater consumption in Japan. Except for some cases (for instance, the Fuji-South area, where the water is exceptionally abundant in underground, records more than 2,000 $m^3/d/km^2$ of pumping up), the pumping up quantity is generally less than 1,000 $m^3/d/km^2$.

To be more specific, the examples of groundwater consumption in Chiba (a prefecture bordering the east of Tokyo) and Saitama (a prefecture bordering the north of Tokyo) are shown in Tables 2.18 and 2.19 respectively.

Table 2.17: Actual Example of Quantity of Pumped Up Groundwater in Japan

Area (Prefecture)		Pumping Up Quantity (m^3/d)	No. of Wells	Area (km^2)	Unit Pumping Up Rate ($m^3/d/km^2$)
Yatsushiro	(Kumamoto)	131,971	69	146.70	900.0
Saga	(Saga)	5,458	57	103.68	52.6
Ehime	(Ehime)	67,304	107	507.99	132.5
Kagawa	(Kagawa)	44,689	110	425.43	105.0
Yoshino - River	(Tokushima)	172,897	136	508.43	340.1
Kobe, Akashi	(Hyogo)	95,222	266	929.54	102.4
Shimamoto	(Osaka)	24,246	37	16.82	1,441.5
Nagaokakyo	(Kyoto)	21,849	70	19.24	1,135.6
Nobi	(Aichi)	313,198	533	275.11	1,138.4
Hamanako	(Shizuoka)	32,499	335	137.15	237.0
Enshu	(")	486,926	1,859	254.49	1,913.3
Enshu	(")	287,803	688	405.14	710.4
Oigawa	(")	1,403,505	2,368	535.23	2,622.2
Shimizu	(")	750,449	1,295	1,374.12	546.1
Fujigawa	(")	94,554	86	46.76	2,022.1
Fuji - South	(")	2,002,364	1,228	529.56	3,781.2
Kisegawa	(")	720,058	399	245.89	2,928.4
Shokawa	(Toyama)	221,514	462	213.55	1,037.3
Toyama	(")	186,873	298	1,712.70	109.1
Echigo	(Niigata)	130,417	250	1,165.75	111.9
Echigo	(")	396,487	28,462	572.10	693.0
Uonuma	(")	200,398	703	585.22	342.4
Yamagata	(Yamagata)	73,148	689	381.58	191.7
Okitama	(")	196,200	2,535	1,057.60	185.5
Murayama	(")	65,856	377	515.50	127.8
Shinjo	(")	43,979	271	882.68	49.8
Kesennuma	(Miyagi)	18,700	70	184.02	101.6
Hachinoe	(Aomori)	15,928	147	214.69	74.2
Aomori	(")	8,690	138	774.92	11.2

Source: Users Organization of Groundwater in Japan, 1987

Table 2.18: Pumping Up Rate of Groundwater in Chiba Prefecture, Japan

Name of City or Town	Pumping Up Rate ($m^3/d/km^2$)	Name of City or Town	Pumping Up Rate ($m^3/d/km^2$)
A Town	1,430	F City	629
B City	1,093	G City	596
C City	976	H City	513
D City	922	J City	508
E City	681	K Town	491

Source: Chiba Prefectural Government, 1987

Table 2.19: Pumping Up Rate of Groundwater in Saitama Prefecture, Japan

Name of City or Town	Pumping Up Rate ($m^3/d/km^2$)	Name of City or Town	Pumping Up Rate ($m^3/d/km^2$)
A City	4,214	G City	691
B Town	1,821	H City	617
C City	1,745	J City	429
D City	1,485	K City	311
E City	1,049	L City	144
F Town	872		

Source: MITI, Japan, 1977

Some exceptional cases excluded, the pumping up rate in Chiba and Saitama Prefectures range from 500 to 1,500 $m^3/d/km^2$. The fact is that those places whose pumping up rate are close to 1,500 $m^3/d/km^2$ are suffering the subsidence of land.

The above examples suggest that the groundwater safe yield in Japan is around 1,000 $m^3/d/km^2$. Since the safe yield much depends on soil, geographical and weather conditions, it is too hasty to apply this figure directly to Samut Prakarn. As mentioned above, the safe yield in Samut Prakarn seems to be fairly smaller than that in Japan.

The concept of safe yield, if cautiously applied, provide an effective criterion for checking pumping up quantity.

2.6 Related Laws and Regulations

2.6.1 Laws and Regulations in Thailand

The following two laws in Thailand have a direct relationship to the study.

(1) Factory Act, B.E. 2512 (1969)

(2) Groundwater Act, B.E. 2520 (1977)

Notifications attached to each of these Acts are as listed in Table 2.20.

Furthermore, the following laws also bear certain relationship to the study.

(1) Public Health Act, B.E. 2484 (1941)

(2) Act for the Cleanliness and Tidiness of the Country, B.E. 2503 (1960)

(3) Building Act, B.E. 2522 (1979)

(4) Act for Metropolitan Waterworks Authority, B.E. 2510 (1967), Revision B.E. 2522 (1979)

(5) Act for Provincial Waterworks Authority, B.E. 2522 (1979)

Among the above, the Act for MWA stipulates that MWA should take charge of the water supply in Samut Prakarn.

Some important clauses of these related laws are as given in Appendix 2.4 to 2.7 of this report.

2.6.2 Laws and Regulations in Japan

Japan has a considerable number of laws and regulations concerning the water sources (flood control, water resource development, groundwater and the like). The main water source in Japan being rivers, the River Act is the most important of them.

The Industrial Water Act and the Groundwater-for-Buildings Control Act regulates the exploitation of groundwater. Unlike Thai laws that control the use of groundwater by means of economic incentive, these Acts relates the use of groundwater with the availability of substitute water (public industrial water, city water, etc.).

The gist of the Industrial Water Act is shown in Table 2.21. As for the supply of substitute water, the Public Industrial Waterworks Act and the City Water Act provide regulations. Table 2.22 lists the Japanese laws and regulations concerning the water resources.

Table 2.20: Related Laws and Notification

No.	Law and Notification	Supervising Ministry	Items related to Water Supply and Discharge
1	Factory Act B.E. 2512	Ministry of Industry	1. License is necessary for location and operation of factory. 2. Treatments of solid waste, waste water and waste gas are requested for approval.
2	Industrial Effluent Standard Notification No. 10 and 12 B.E. 2525 (1982)	"	Industrial effluent standard (Refer to Table 2.11)
3	Supervisors for Prevention of Pollution Notification No. 13 B.E. 2525 (1982)	"	Scale and kind of factory that is obliged to employ supervisor and his (her) qualification
4	Environmental Impact Assessment Report Notification No. 15 B.E. 2527 (1984)	"	Scale and kind of factory that is obliged to submit the report and contents of the report
5	Ground Water Act B.E. 2520 (1977)	"	1. Permit is necessary to pump up groundwater 2. Price rate can be imposed on those who use groundwater. But, rate* is under 1 ฿/m³.
6	Technical Measures for Conservative Use of Deep Well Water Notification No. 7 B.E. 2528 (1985)	"	1. Flow meter must be installed to *deep well of more than 15 m deep.* 2. Technical standard of flow meter.

Note: Price rate* inside service area of MWA is 1 ฿/m³ and that outside area is 0.75 ฿/m³.

Table 2.21: Outlines of Public Industrial Water Works (PIWW) in Japan

[Objective]

Guarantee of effective supply of industrial water
Preservation of groundwater source

Sound development of industry
Prevention of land subsidence

[Restriction]

Designation of area
(Designation by national laws and regulations)

(17 areas in 10 prefectures)

Conditions for designation
(1) Abnormal drop of groundwater level, intrusion of saline water and contaminated water or occurrence of land subsidence
(2) Consumption of industrial water is high
(3) PIWW have been installed, or construction of PIWW would start within one year

New well for industry

Criteria for Governor's approval
(1) Location of strainer (depth)
(2) Section area of pump delivery outlet

Existing well for industry (Conformed with criteria for Governor's approval)

Assumed that Governor's approval is granted

Regulations related to Governor's approval

(1) Approval for change
(2) Terms for approval
(3) Emergency procedures and others

Existing well for industry (Not conformed with criteria for Governor's approval)

Assumed that Governor's approval is granted until the day when water supply by PIWW starts.

Instruction of changing water source

Change water source as water can be supplied by PIWW

Change to PIWW and others

Remarks: For the prevention of land subsidence, the followings are formulated:
(1) Law related to Groundwater used in Building
(2) Public Pollution Control Law
(3) Regulations enforced by local governments
(4) Voluntary adjustment agreement and regulation set up by parties including users of water

Table 2.22: Laws Related to Water in Japan

- Overall Development
  - Land Development
    - Land Overall Development Law (1950)
    - Land Utilizing Plan Law (1974)
    - Law to Promote the Development of Designated Industrial Areas (1964)
    - Law for Accelerating Regional Development based upon High-Technology Industrial Areas (1983)
    - Industrial Relocation Promotion Law (1972)
    - Urban Area Development Law (1968)
    - Urban Area Redevelopment Law (1969)
  - Water Survey
    - Land Survey Law (1951)
- River Management
  - Mountain and River Improvement
    - River Law (1964)
    - Forestory Law (1951)
    - Sea Coast Law (1956)
  - Prevention of
    - Basic Law for Anti-Measures for Disasters
    - Flood Control Law (1949)
    - Fire Fighting Law (1948)
  - Restoration of Disasters
- Water Utilization
  - Water Use
    - Civil Law (1896)
    - River Law (1964)
    - Water Resources Development Law (1961)
    - Water Resources Development Corporation Law (1961)
    - Electric Power Resources Development Law (1952)
    - Public Water Works Law (1957)
    - Industrial Water Works Law (1958)
    - Local Public Enterprise Law (1952)
    - Electric Power Supply Law (1964)
    - Land Improvement Law (1949)
    - Fire Fighting Law (1948)
- Utilizaion of Water Area
  - Water Utilization
  - Fishery
    - Fishing Law (1949)
    - Fishing Port Law (1950)
  - Transportaion by Ship
    - River Law (1964)
    - Harbor Law (1950)
    - Harbor Regulation Law (1948)
    - Canal Law (1913)
  - Picking of Soil and Sand
    - Picking of Soil and Sand Law (1968)
    - River Law (1964)
  - Reclamation of Water Area
    - Law for Reclamation of Public Water Area (1921)
  - Utilization of Natural Condition
    - Natural Environment Preservation Law (1972)
    - Natural Park Law (1957)

(Continued on next page)

Table 2.22: Laws Related to water in Japan (Continued, 2/2)

Preservation of Water Resources	Supervision of Water Source	Forestory Law (1951)
	Preservation of Groundwater	Industrial Water Law (1956)
		Law for Restriction of Pumping up of Groundwater by Building (1962)
		Hot Spring Law (1948)
	Preservation of Water Quality	Public Pollution Control Law (1967)
		Water Pollution Control Law (1970)
		Sewage Law (1958)
		Waste Treatment and Cleaning Law (1970)

2.7 Measures against Land Subsidence

2.7.1 Measures against Land Subsidence in Thailand

The measures taken in Thailand against land subsidence may be divided into the following two categories.

(1) Measures to prevent the disastrous consequences (i.e. floods) of land subsidences. These measures are applied where the land has been already significantly subsided (e.g. the Bangkok Metropolitan Area).

(2) To prevent land subsidences themselves by reducing the pumping up quantity of groundwater

The category (1) is a "symptomatic treatment". In the Bangkok Metropolitan Area, for instance, measures such as the construction of dikes, the improvement of waterways and the installation of flood gates and drainage apparatus are now being taken for this purpose. The category (2) is more fundamental.

To reduce the pumping up quantity of groundwater, the following measures are now being taken in the Bangkok Metropolitan area.

(1) Control of pumping up through the 1977 Groundwater Act. As mentioned above, this Act is intended to reduce the consumption of groundwater by charging rates on pumping up (refer to Table 2.20).

(2) Switching of MWA's water source from wells to rivers, and the enlargement of its supply areas (refer to 2.2.2)

(3) IWD's Program for the Effective Use of Industrial Water. The study is now under way with the help of the Japanese government.

(4) Industrial waterworks planned by IWD. This water works is to be installed in Samut Prakarn using river water. 9)

Among the above, the measures stated in (2) do not work well, since both MWA's supply capacity and its supply areas are limited. Moreover, the water tariff MWA imposes seem to be too high to encourage the use of its service (see 2.8.1 below). The measures stated in (3) and (4) have goals in the future, and hence are not expected to have immediate effects. So, at present, the Groundwater Act is the only means to cope with the subsidence of land.

However, the Groundwater Act alone is not sufficient. The rates imposed on pumping up appears to be too low to encourage the conversion of water source in the private sector.

2.7.2 Measures against Land Subsidence in Japan

As is the case in Thailand, the measures taken in Japan are divided into two categories (refer to 2.7.1). Table 2.23 shows not only the measures against land subsidences but also those against other problems (e.g. saline water intrusion and decreasing of water level in aquifer) resulting from excess pumping up. Among them, the Industrial Water Act is one of the most important (refer to 2.6.2)

To give concrete examples, Table 2.24 outlines the measures taken in Chiba, a prefecture bordering the east of Tokyo. Also, Fig. 2.17 shows the relation between the reduction in pumping up and the prevention of land subsidence in Saitama, a prefecture bordering the north of Tokyo. As seen in Fig. 2.17, the land subsidence at Kawaguchi in Saitama has virtually stopped since the beginning of 1970's.

As a concrete example of the measures listed in Table 2.23, the flow chart of the "Guidance for the Effective Use of Industrial Water" is given in the Fig. 2.18. This Guidance is to be implemented jointly by the MITI each local government concerned.

The "study" in the Fig. 2.18 is equivalent to the study in Samut Prakarn Area, and the "guidance" indicates the specific measures for further water saving.

In a certain area of Japan, around 30% of groundwater consumption was saved by implementing this Guidance.

A study on implementation of this guidance in Thailand is described in Chapter 9.

Table 2.23: Countermeasures against Groundwater Troubles

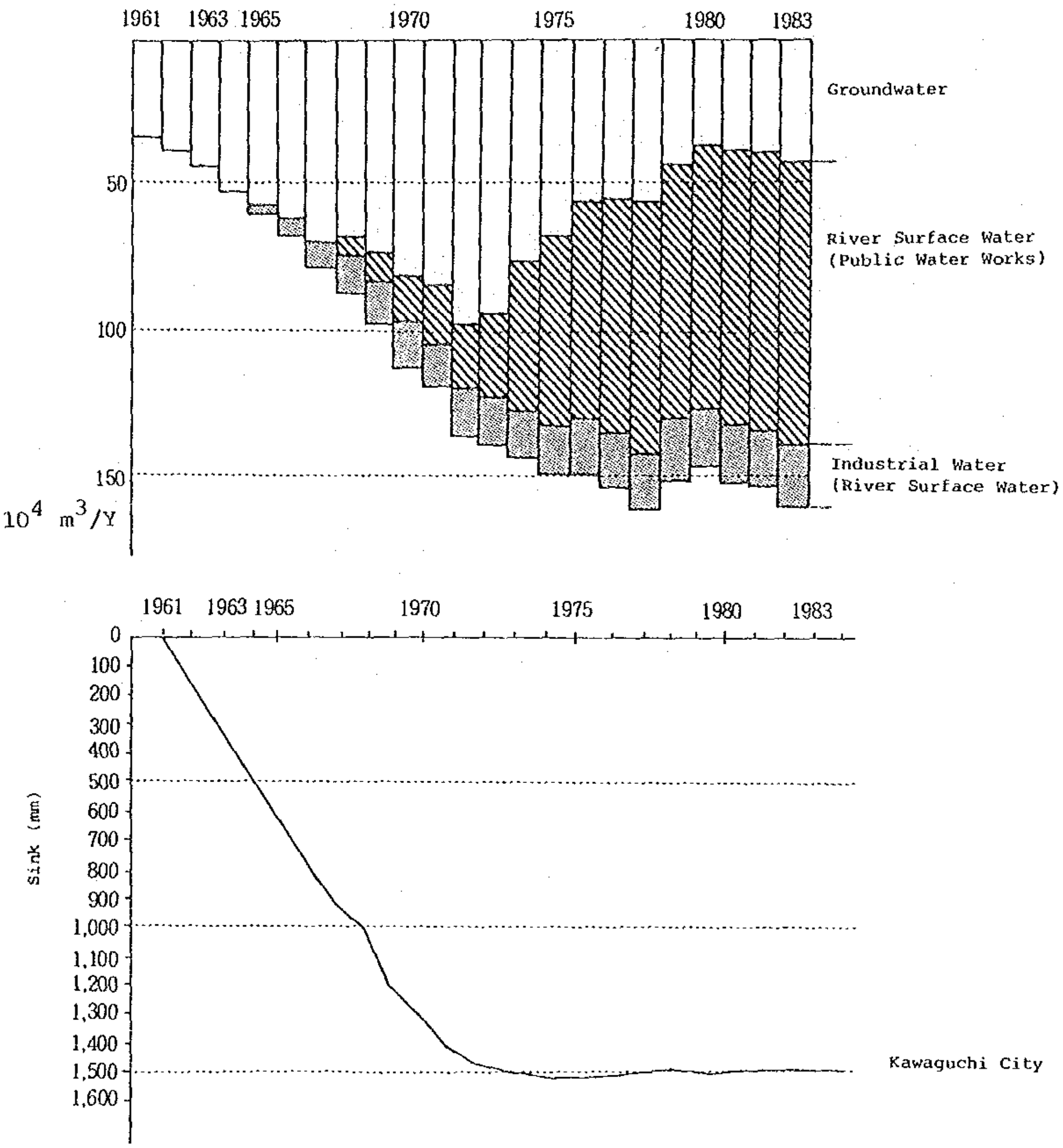
- Countermeasures for Groundwater Troubles
  - Measures for Prevention of Troubles
    - Restriction of pumping up of groundwater
      - Restriction by Law (Industrial Water Law, Law for Restriction of Pumping Up of Groundwater by Building)
      - Restriction by Regulation
      - Voluntary Restraint by Council set up by Private Sector
    - Regulation on Pumping Up of Groundwater (Substitute of Groundwater)
      - Supply of Substitute Water by Development of Water Resources
        - Water Works (Public Water Works Law)
        - Industrial Water Works (Industrial Water Works Law)
      - Water Saving
      - Effective Water Use (including Recycle Use of Water)
      - Re-Use of Reclaimed Waste Water
      - (Sea Water Desalination)
    - Artificial Infiltration of Groundwater
    - Recycle Use by Restoration
  - Measures for Troubles
    - Countermeasures against Land Subsidence
      - Countermeasures against Direct Troubles
        - Repair of Building
        - Repair of Underground Structure
        - Repair of Bank and Shore Protection
        - Repair of Road
        - Repair of Farmland of Agricultural Facility
      - Countermeasures against Indirect Troubles
        - Countermeasures against High Tide and Tidal Wave
        - Countermeasures against Flood
        - Inland Drainage
    - Countermeasures against Salination and Drop of Groundwater Level
      - Installation of Public Water Works

Table 2.24: Measures for Prevention of Land Subsidence by Chiba Prefecture, Japan

* Industrial Water Law
* Law for Restriction of Pumping Up of Groundwater by Building (Bldg. Water Law)
* Pollution Control Regulation of Chiba Prefecture
* Agreement for Pollution Control
* Agreement for Prevention of Land Subsidence

↓

- Countermeasures
  - Measures for Prevention of Ground Subsidence
    - Regulation
      - Industrial Water (Industrial Water Law and Prefectural Regulation)
      - Building Water (Bldg. Water Act and Prefectural Regulation)
      - Agricultural Water
    - Guidance
      - Agreement for Pollution Control (Conclude with Factories)
      - Agreement for Prevention of Land Subsidence (for the Pumping Up Salt Water of Natural Gas)
    - Observation
      - Precise Level Survey (Measurement of Ground Level Change) (Arrange 1363 Stations in Prefecture)
      - Measurement of Land Subsidence and Groundwater Level by Observation Well (Lay down 50 Wells)
    - Survey
      - Survey on Actual Situation of Groundwater Use (Pumping Up of Groundwater and Salt Water of Natural Gas)
      - Basic Survey of Balance Sheet of Groundwater
      - Survey on Geological Features and so on
    - Establishment of Observation Setup
      - Preparation of Check Point of Land Subsidence and Well for Measuring Groundwater Level
      - Increase and Maintenance of Bench Mark
  - Related Measures
    - Development of Water Source Substituting Groundwater
      - Preparation of Public Water Works
      - Preparation of Industrial Water Works
    - Countermeasures against Accompanied Troubles
      - Countermeasures against High Tide in Harbor
      - Countermeasures against High Tide in Sea Coast
      - River Reconstruction Works against Land Subsidence



Source: National Land Agency, Japan

Fig 2.17: Change of Water Usage Classified by Water Source and Change of Land Subsidence in Saitama Prefecture

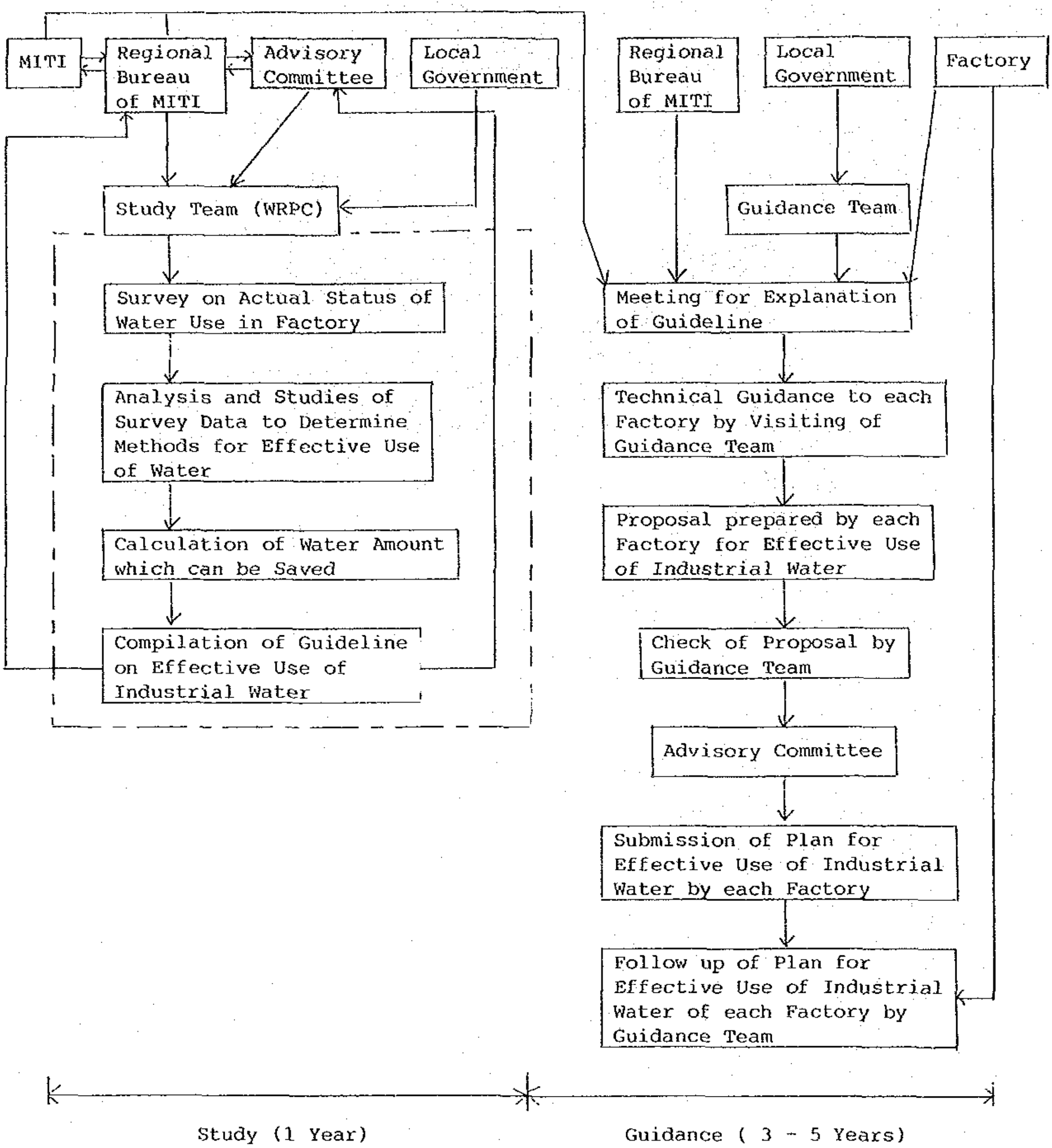


Fig. 2.18: Flow Chart for Guidance

2.8 Water Rates

2.8.1 Water Rates in Thailand

Water rates (i.e. the costs of water) are an important factor in establishing methods for effective use of industrial water.

Table 2.25 shows water rates imposed by MWA. As seen in the Table, MWA employs a two-tier rate system, one for household and the other for commercial use. The rates for household are lower than those for progressively. With the MWA's rate system, the unit cost of water increases as the consumed volume grows.

Table 2.25: Water Tariffs in MWA, 1988

Category I: Residence		Category II: Industry	
Quantity (m^3/mon)	Rates (฿/m^3)	Quantity (m^3/mon)	Rates (฿/m^3)
0 - 30	4.05, but no less than ฿20	0 - 10	Package rate 50.00
31 - 40	4.30	11 - 20	6.20
41 - 50	4.55	21 - 30	6.45
51 - 60	4.80	31 - 40	6.70
61 - 70	5.05	41 - 50	6.95
71 - 80	5.30	51 - 60	7.20
81 - 90	6.20	61 - 80	7.45
91 - 100	6.45	81 - 100	7.70
101 - 120	6.70	101 - 120	7.95
121 - 160	6.95	121 - 160	8.20
161 - 200	7.20	161 - 200	8.45
201 & up	7.70	201 - 2,000	8.60
		2,001 - 4,000	8.40
		4,001 - 6,000	8.00
		6,001 - 10,000	7.50
		10,001 - 20,000	7.00
		20,001 - 30,000	6.50
		30,001 - 40,000	6.00
		40,001 - 50,000	5.50
		50,001 and up	5.00

Table 2.26 shows water rates imposed by PWA. Unlike MWA, the PWA's tariff system make no distinction between household and industrial use. The PWA's tariff is higher than MWA's rates for the commercial use.

Meanwhile, the cost of well water in Samut Prakarn Area can be calculated by adding up the well water rates (refer to Table 2.20), the boring cost, the maintenance cost and the pumping cost. It amounts to 2 - 2.5 ฿/m³. This being much cheaper than the MWA's water rates, the economic incentive does not work well enough to encourage the conversion of water source.

Table 2.26: Water Tariffs in PWA

Quantity (m^3/mon)	Rates (฿/m^3)
0 - 10	Unit charged ฿3.75 (but not less than ฿15)
11 - 20	Unit charged ฿4.50
21 - 30	" ฿6.50
31 - 50	" ฿7.50
51 - 80	" ฿8.00
81 - 100	" ฿8.50
101 - 300	" ฿9.00
301 - 1,000	" ฿9.25
1,001 - 2,000	" ฿9.50
2,001 - 3,000	" ฿9.75
3,001 & above	" ฿10.00

Note: Water charge was calculated from group of water used and is subjected to use for water bill from October 1987 and on ward.

2.8.2 Water Rates in Japan

For the purpose of comparison, the rates of Japanese city water are shown in the Table 2.27. Prepared by converting the water rates in various places of Japan into ฿, this Table corresponds to the household section of Table 2.25. (To identify the places listed in this Table, refer to Fig. 2.19.)

Table 2.27: Service Charge for Family Use of Public Water Works in Japan (Fiscal 1985)

Area \ Item	Basic Charge (฿/m^3)		
	Maximum	Minimum	Average
Hokkaido	68.0	13.8	31.2
Tohoku	90.0	6.0	26.6
Kanto, Inland	54.0	4.8	19.4
" , Coastal	36.0	5.0	17.6
Tokai	46.0	5.8	18.0
Hokuriku	43.2	5.6	19.6
Kinki, Inland	48.0	10.0	20.8
" , Coastal	60.0	6.0	20.8
San-in	38.4	10.2	17.8
San-yo	46.6	6.2	22.0
Northern Kyushu	50.0	10.0	23.4
Southern Kyushu	50.0	9.6	20.8
Okinawa	41.8	13.0	22.8
Nationwide	90.0	4.8	21.8

Source: Public Water Works Census, Ministry of Health and Welfare

Currency Conversion Rate: ฿ 1 = ¥ 5

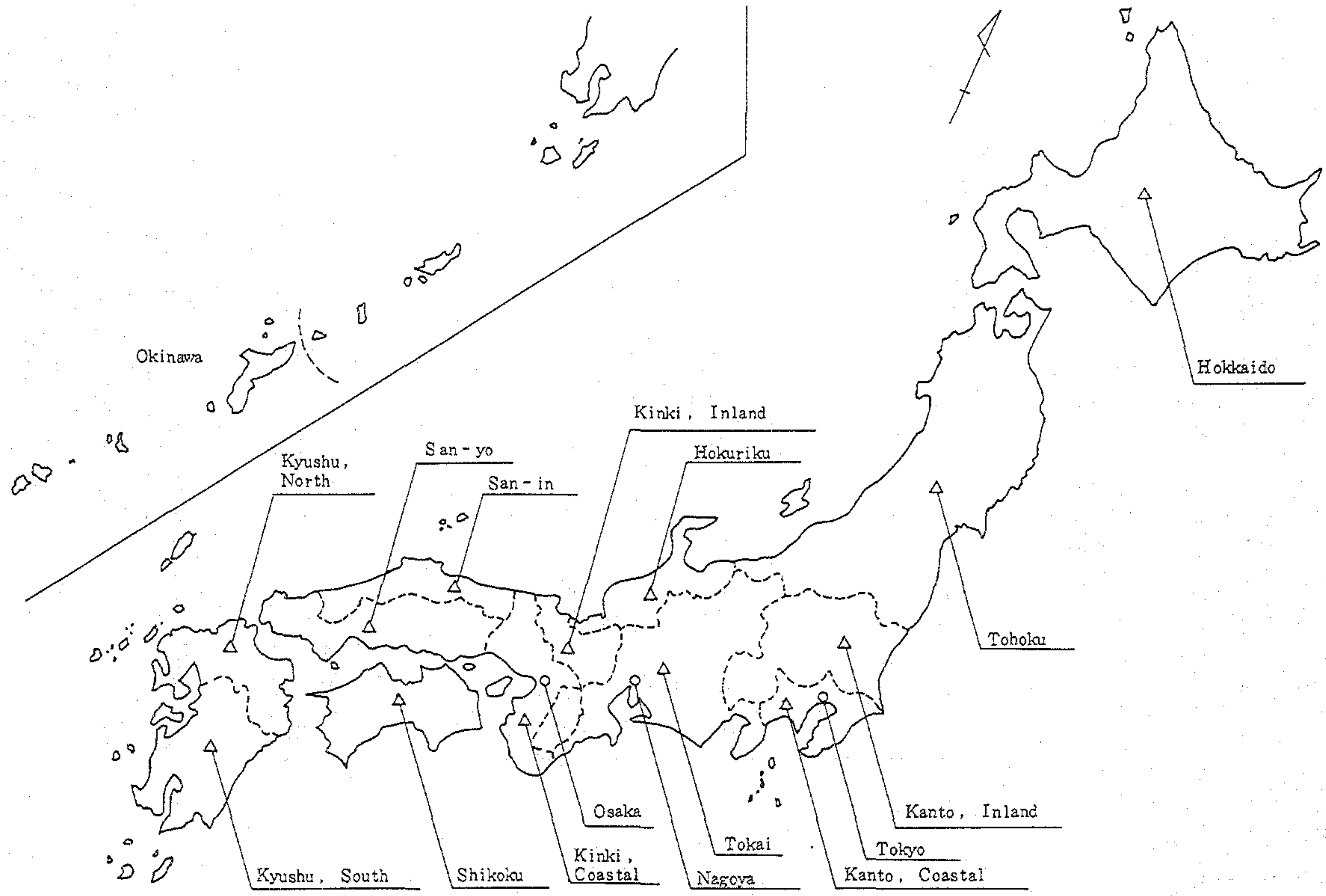
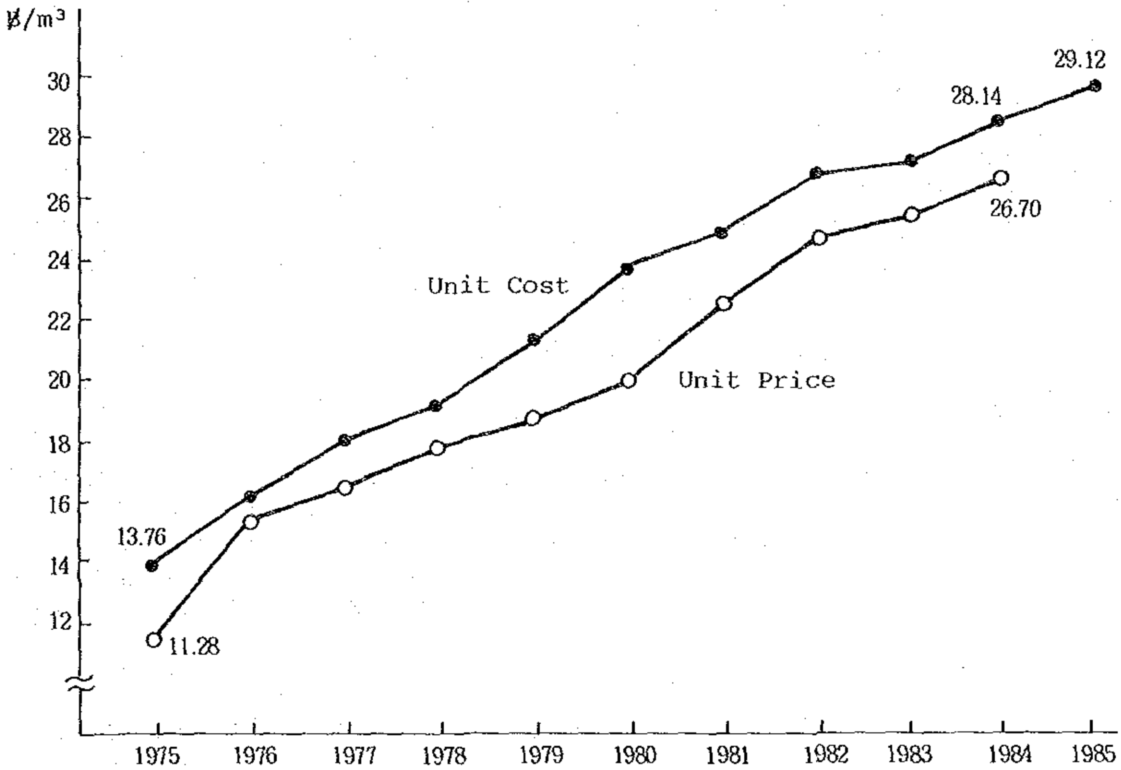


Fig. 2.19: Map of Japan

Fig. 2.20 illustrates the average unit cost and unit price of city water in Japan. The balance of unit cost and unit price is filled by budget of local government and subsidy of national government as city water is supplied by public works.

This figure includes not only the household water but also the industrial water, so that the unit prices here are not the same as those in Table 2.27.



Source: Public Water Works Census
Currency Conversion Rate: ฿ 1 = ¥ 5

Fig. 2.20: Average Cost and Unit Price of Public Water Works in Japan

2.8.3 Rate of Industrial Water

Thailand has yet no public waterworks dedicated to the industrial use. However, as mentioned in 2.7.1, IWD is planning to construct such waterworks in Samut Prakarn. When completed, the waterworks is expected to supply industrial water at 5 to 8 ฿/m³.

Japan, on the other hand, already has public industrial water works, which supply around 35% of the total make-up water for industry. The rates imposed by the public industrial waterworks in various parts of Japan are shown in Table 2.28.

Table 2.28: Average Service Charges of Public Industrial Water Works in Japan

Area \ Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
National Average	2.49	2.55	2.94	3.00	3.00	3.14	3.22	3.31	3.34	3.41
Hokkaido	2.54	2.57	2.57	2.58	2.58	2.58	2.75	2.75	2.75	2.75
Tohoku	1.35	1.55	1.74	1.79	1.91	1.99	2.18	2.23	2.26	2.28
Kanto, Inland	1.81	1.87	1.99	2.17	2.17	2.29	2.23	2.23	2.35	3.17
" , Coastal	3.68	3.72	4.49	4.05	4.05	4.08	4.08	4.62	4.62	4.62
Tokai	2.57	2.59	2.97	3.14	3.15	3.33	3.42	3.45	3.44	3.51
Hokuriku	2.13	2.24	2.39	2.60	2.75	2.76	2.93	2.93	3.05	3.05
Kinki, Inland	3.98	3.69	3.69	3.59	4.13	4.91	4.91	4.91	5.27	5.27
" , Coastal	2.84	2.92	3.51	3.78	3.42	3.64	3.63	3.63	3.63	3.69
San-in	2.01	2.62	2.62	2.62	2.62	2.89	2.89	3.06	3.06	3.06
San-yo	2.08	2.10	2.42	2.50	2.51	2.77	2.92	2.97	2.99	3.00
Shikoku	2.18	2.22	2.50	2.62	2.68	2.82	2.94	2.86	2.94	2.94
Kyushu	2.53	2.58	2.76	3.06	3.26	3.58	3.62	3.64	3.66	3.68

Source: MITI, Japan

Remarks: Currency Conversion Rate: ฿ 1 = ¥ 5

The rates for industrial water are much lower than 21.8 ฿/m³, the average charge for city water in Japan (refer to Table 2.27). The reasons for this comparative cheapness of industrial water are:

(1) the supply areas of the public industrial waterworks are relatively narrow and hence long pipings are not required,

(2) the treatment of industrial water is simple (generally without sand filtration, and, in some cases, even without sedimentation), and

(3) industrial water is usually supplied to large-scale users.

2.8.4 Water Cost in Individual Factories

Water cost in individual factories and its percentage in the total production output is very important in establishing water saving guidelines. Since such data is not easily available in Thailand, same figures in Japan, though not recent ones, are shown here for reference in Tables 2.29 and 2.30.

Table 2.29: Water Cost in Japan Classified by Major Industries and Water Sources

(Unit: ฿/m³)

Item / Industry	Public Water Works		Private Water Source				Recovered Water	Fresh Water Weighted Average
	Industrial Water	Potable Water	Surface Water	Infiltrated Water	Ground Water	Others		
National Average	0.67	3.24	0.32	0.39	0.57	0.39	0.34	0.67
Chemical	0.65	3.00	0.34	0.42	0.38	0.77	0.48	0.59
Pulp, Paper & Paper Products	0.59	1.45	0.31	0.31	0.39	0.26	0.07	0.32
Iron & Steel	0.58	3.23	0.77	0.96	0.65	0.79	0.61	0.84
Textile	1.09	3.03	0.22	0.45	0.63	0.22	0.23	0.71
Food	0.90	3.83	0.40	0.16	0.46	0.15	0.52	0.82
Ceramics, Stone & Clay Products	0.72	3.72	0.38	0.38	0.48	0.26	0.17	0.66
Thermal Electric Power	1.02	3.36	0.08	0.72	0.95	0.10	0.21	0.17

Note: This table includes only fresh water, and does not include sea water.

Remarks: Currency Conversion Rate @ ฿ 1 = ¥ 5

Table 30: Industrial Water Cost of Major Industries
(Practical Data in 1971)

Industry	Water Cost/Product Output (%)
Iron & Steel	1.67
Petroleum Refinery	0.88
Chemical	2.95
Aluminum Refining	1.27
Textile	0.69
Pulp & Paper	1.77

As a concrete example, water cost in an integrated steel mill in Japan was studied. Here, crude steel, an intermediate product (ingot steel), is used as the unit ton to which the water cost is related. The figures in 1970's are as follows:

Item / Water Source	Water Usage (m^3/t)	Unit Price (฿/m^3)	Water Cost per Product (฿/t)	Remarks
Make-up Water of Fresh Water	10	3.0	30	
Recovered Water of Fresh Water	110	1.6	176	
Sea Water	30	0.4	12	Excluding Usage by Power Plant
Total	150	1.45	218	

Note: Currency Conversion Rate: ฿ 1 = ¥ 5

On the assumption that the production cost of this steel mill is 20,000 ฿/t, the water cost (฿ 218) accounts for 1.09% of it.

Compared with this figure, the percentage shown in Table 2.30 (1.67% for the steel industry) seems to be too high.

With the same assumption of production cost (20,000 ฿/t), the water cost ratio of 1.67% would be equivalent to the water cost of ฿ 334 per product (ton), which is higher than the example case by more than ฿ 100.

The above example shows the importance of the water cost for the management of factory. Therefore, though imposing high rates on the use of groundwater is an effective way to curb pumping up, too high rates may endanger the sound management of private enterprises. That is why caution is required in setting up the rates.

Reference

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2) Sitdhirak Sritrakul. "Implementation of the Groundwater Law in Thailand" November 24, 1983

3) Watson Hawksley (Consultant) "Samut Prakarn Industrial Pollution Control and Management Project", August 1987

4) Metropolitan Waterworks Authority "Annual Report, 1986"

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7) NEB Pub. 1981-002 "Investigation of Land Subsidence Caused by Deep Well Pumping in Bangkok Area" Comprehensive Report 1978-1981. Prepared by Division of Geotechnical & Transportation Engineering, AIT

8) P.A.Bank "Water and Environmental Management in the Third World"

9) Feasibility Study of a Giant Water Reservoir and Water Distribution System for Industries in Samut Prakarn Province, IWD, 1984

Chapter 3

Use of Industrial Water in the Surveyed Factories

Chapter 3 Use of Industrial Water in Surveyed Factories

3.1 Selection of the Factories for Survey

There are altogether 2,631 factories in Samut Prakarn Province. Among them, IWD selected 59 factories covering five different industries in accordance with the minutes of discussion on the scope of work. The selection was made in accordance with the following principles.

(1) The selected factories should be large enough to represent the industry concerned. (Some small factories, though, may be added.)

(2) The number of factories in each of the five industries should be well balanced.

(3) The selected factories should be those which can cooperate with the survey (questionnaire survey and visiting survey).

The survey was highly detailed, requiring access to the inside of factory premises. Hence, though (3) above may appear odd, cooperative participation of the factories was indispensable.

In accordance with principles (1) and (2) above, IWD first selected about 200 factories, and then, considering (3) on the basis of the preliminary survey, narrowed the number to 59. The outline of these 59 factories is as follows:

Item \ Industry	Food	Paper	Tex-tile	Metal	Chemi-cal	Total
No. of Factories	14	5	7	20	13	59
No. of Employees	4,840	1,870	5,310	5,590	2,240	19,850
Pumping Up Qt. (m³/d)	6,500	16,900	13,600	8,500	4,700	50,300

The table below shows the relative weight of the selected 59 factories against the active industrial sector in Samut Prakarn Province.

	Samut Prakarn	Selected Factories
No. of Factories	2,631	59 (2.2%)
No. of Employees	130,000-150,000	19,850 (14.2%)
Pumping Up Qt. (m³/d)	286,000	50,300 (17.6%)

As seen in the table, the pumping up quantity of the selected factories accounts for only 17.6 % of the total pumping up quantity of Samut Prakarn factories. This small ratio may be due to the above-mentioned principles (2) and (3).

Thus the selected factories are not necessarily a mirror-like reflection of the situation in Samut Prakarn area. Nevertheless, considering the following facts, the selection was by and large reasonable.

(1) Since this was the first study of its kind in Thailand, the feasibility of the survey had to be given priority in the selection.

(2) The pumping up quantity of the individual factory was made clear only through the survey. Until the survey began, no data had been available.

(3) Because of the need to cover various industries, it was impossible to limit the surveyed factories to those which use a large quantity of water (i.e. textile, paper and steel manufacturing factories)

(4) The survey of the use of water in small factories was also necessary.

(5) IWD regarded the survey as a steppingstone to further studies. Hence the high degree of statistical accuracy was not expected.

3.2 Process of the Survey

3.2.1 Survey through Questionnairing

Before conducting the field survey, a questionnaire was sent to each of the selected factories. (The questionnaire was prepared in Thai. Its English version is included in Appendix Part 2.)

It was IWD that took charge of sending and collecting the questionnaire. Altogether 37 questionnaires (32 in advance of visiting and 5 at the time of visiting) were collected, which was more than initial expectation (about 50 %).

3.2.2 Survey through Visiting

From October to December 1987, the study team visited each of 59 factories to conduct the field survey. The details of the field survey were as follows.

(1) The study team was divided into two sub-teams (A and B teams). Each sub-team consisted of:

JICA members	3 (including sub-team leader)
IWD members	1 or 2
Total	4 or 5

(2) Each sub-team visited either one large factory or two small factories per day.

(3) The survey in each factory followed the sequence below.

* Clarification of the questionnaire items by the factory's personnel in charge
* Questions and answers
* Inspection of the production and other facilities of the factory
* Determination of the measuring points (for flow and other data)
* Measurement
* Clarification of the results of measurement and discussion

The procedure (manual) of the survey is included in the Appendix Part 2 of this report.

In July 1988, the study team revisited five factories to conduct a supplementary survey.

3.2.3 Outline of Results of Visiting Survey

For each factory, the data gained from the survey were sorted out under the following items.

(1) Outline of company and factory (capital, shipment quantity, the number of employees and the like)

(2) Water consumption classified by use and source

(3) Process diagram of production line (from the viewpoint of use of water)

(4) Flow diagram of water supply and waste water discharge (with the flow data attached)

(5) Present situation of the use of industrial water

(6) Waste water treatment

(7) Qualities of supply/waste water (so far as the data are available)

The above data are summarized in Tables 3.1, 3.2 and 3.4 and Appendix Part 2. Chapter 5 gives an analysis of these data on a factory-by-factory basis.

3.3 Outline of the Surveyed Factories

As stated in 3.1, 59 were chosen among more than 2,600 factories in Samut Prakarn. These factories are listed in Table 3.1.

The surveyed factories are characterized as follows.

(1) The sizes of the factories are wide-ranging. Classified by the number of employees, the sizes of the factories are:

Number of Employees	Number of Factories
More than 1,000	2
500 -- 999	7
300 -- 499	14
200 -- 299	8
100 -- 199	12
Less than 99	16

(2) The products are also wide-ranging. Even in the same industry, the products of the surveyed factories barely overlap.

(3) The factories in the metal industry are divided roughly into two categories. One is the manufacturers of metal materials and the other is the manufacturers of finished products such as machines.

For example, steel bar and galvanized steel sheets (M-02) and tin plate (M-15) factories belong to the former, while electric fans, television sets, etc. (M-01) and automobile (M-10) represent the latter. Depending on the type of products, the use of water varies significantly.

(4) A factory specializing in electroplating (C-03) and another one manufacturing edible oil (C-07) are included in the chemical industry. These factories, if in Japan, would not be classified as belonging to the chemical industry.

Table 3.1: Outline of Company and Factory

Type of Indst.	Code No.	Fact. No.	Capital (M฿)	Annual Amount of Shipment (M฿)	Total Area (m^2)	No. of Employ-ees	Main Products	Well Water Qt. (m^3/d)
Food	F-01	170	-	400	12,100	700	Canning of Fish, Fruits & Vegetables	870
	F-02	103	0.4	40 t/Y	48,000	450	Condensed Milk & Evaporated Milk	1,065
	F-03	135	50	200	5,500	100	Jam, Paste, Margarine, Dry Milk	178
	F-04	130	24	-	56,000	214	Fish Sauce	100
	F-05	127	8.0	-	27,200	465	Canning of Fish, Fruits & Vegetables	614
	F-06	114	-	670	33,600	400	Condensed Milk & Sterilized Milk	1,098
	F-07	110	-	48	13,000	130	Frozen Sea Food	163
	F-08	109	-	20-30 t/d	16,400	1,000	Frozen Sea Food	665
	F-09	91	-	-	24,000	150	Vegetable Oil, Fat & Wax	300
	F-10	78	-	-	-	45	Cake	0 PW 54
	F-11	65	5.0	0.6	3,600	75	Candy	37
	F-12	48	120	350	64,000	214	Poultry, Pig, Pet & Aquatic Foods	323
	F-13	43	0.03	459	44,800	880	Frozen Chicken	1,040
	F-14	21	6	3.5	2,000	15	Noodle	68
Paper	P-01	145	-	60	10,000	65	Writing Paper	1,245
	P-02	124	-	54,000 t/Y	30,000	330	Board Paper, Corrugate Medium	1,230
	P-03	107	10	7,491 t/Y	4,800	249	Toilet Paper	2,958
	P-04	84	430	1,100	80,000	900	Printing Paper, Kraft Paper & Cardboard	11,360
	P-05	39	-	264 t/Y	81,600	323	Coated Paper, Aluminum Foil	152
Textile	T-01	146	600	-	144,000	4,530	Fiber, Yarn, Raw Cloth, Finished & Dyed Cloth	10,384
	T-02	197	2	6,000 y/d	19,200	100 (Peak 170)	Dyeing of Cloth	113
	T-03	203	-	2,400 t/Y	6,400	180	Bleaching & Dyeing of Cloth	1,885

Table 3.1: Outline of Company and Factory (Continued)

Type of Indst.	Code No.	Fact. No.	Capital (M฿)	Annual Amount of Shipment (M฿)	Total Area (m²)	No. of Employ-ees	Main Products	Well Water Qt. (m³/d)
Textile	T-04	193	1	3	3,200	50	Printing & Dyeing of Cloth	25
	T-05	200	-	-	12,800	76	Knitwear, Cloth	180 (Plan)
	T-06	198	-	-	6,400	76	Bleaching & Dyeing of Cloth	442
	T-07	189	20	120	4,800	300	Towel	549
Metal	M-01	61	500	544.5	45,108	507	Fan, TV, Refrige-rator & Motor	504
	M-02	96	30	1,200	9,600	684	Steel Bar, Galvanized Sheet	1,190
	M-03	89	-	15	24,000	250	Automobile Parts	162
	M-04	206	7	8	4,000	40	Iron Rod	6 PW 2
	M-05	73	100	143.9	70,400	350	Steel Bar, Aluminum Bar, Sash, Brass	620
	M-06	53	45	50	8,807	390	Air Conditioner	70
	M-07	34	1	-	2,400	87	Parts of Motorcycle	58
	M-08	42	15	72	15,600	201	Automobile Parts	40
	M-09	69	150	-	21,000	200	Steel Angle, Channels Flat Bar, Square Bar	451
	M-10	207	20	15	6,400	60	Drawing Dies, Carbide Tip	17
	M-11	116	126	530	24,300	345	Electrical Parts of Motorcar	212
	M-12	97	-	1,300 t/M	7,200	31	Steel Pipe	107
	M-13	208	-	100 t/d	9,600	90	Fine Steel Wire	20
	M-14	115	65	73.2	83,315	310	Truck (Medium & Large Size) Bus	269
	M-15	101	1,376	2,139	41,600	469	Tin Plate, Tin-Free Steel	3,162
	M-16	100	-	140	12,634	127	Iron Wire, Steel Wire, Spring Wire	529
	M-17	56	40	53,200 t/Y	24,213	413	Coil Spring Leaf Spring	140
	M-18	64	130	5,476	124,800	585	Passenger Car, Pickup Truck	617
	M-19	57	110	2,710	17,600	341	Motorcycle, Engine for General Use	350
	M-20	49	33	70	19,200	105	Piston Ring	23

Table 3.1: Outline of Company and Factory (Continued)

Type of Indst.	Code No.	Fact. No.	Capital (M฿)	Annual Amount of Shipment (M฿)	Total Area (m²)	No. of Employees	Main Products	Well Water Qt. (m³/d)
Chemical	C-01	155	18	100	20,800	67	Medicines (Tablet, Injection, Syrup)	75
	C-02	168	30	450	81,600	102	Resins	330
	C-03	209	2.5	15	275	120	Electro-Plating, a Plating	36
	C-04	210	20	-	32,000	110	Medicine	0 PW 30
	C-05	149	-	-	64,000	325	Caustic Soda, Hydrochloric Acid	1,560
	C-06	147	10	180	32,000	67	Pesticide	27
	C-07	106	-	100	12,000	96	Vegetable Oil Soap, Margarine	83
	C-08	94	12	533	20,336	531	Soap, Cosmetic, Confectionery	752
	C-09	82	360	720	22,400	276	Shampoo, Blucher, Surface Active Agent	226
	C-10	51	-	900 t/M	17,000	100	Latex, Resin	300
	C-11	25	80	Ca 180	80,000	240	Plasticizer, Plastics	1,020
	C-12	7	-	-	20,000	109	Sorbitol, Dextrose	250
	C-13	29	24.5	18.8	25,600	94	Medicines (Tablet, Cream & Liquid)	45

3.4 Present Situation of Use of Industrial Water

3.4.1 Outline

For each of the surveyed factories, the water consumption classified by source is as shown in Table 3.2.

Table 3.2: Quantity of Consumed Water

Item / Industry	No. of Fact.	Industrial Water Consumption (m^3/d)				Recovery Rate (%)
		Make-up Water	Well Water for Make-up	Recovered Water	Total	
Food	14	7,025	6,521	39,301	46,326	84.8
Paper	5	18,845	16,945	11,009	29,854	36.9
Textile	7	13,632	13,578	53,535	67,167	79.7
Metal	20	8,594	8,547	26,565	35,159	75.5
Chemical	13	4,799	4,704	43,693	48,492	90.1
Total	59	52,895	50,295	174,101	226,996	76.7

In total, the water consumed in the factories amounts to about 227,000 m^3/d (i.e. 3,847 m^3/d for each factory), of which make-up water accounts for about 53,000 m^3/d (i.e. 896 m^3/d for each factory). Thus, the water recovery rate (the ratio of recovered water to total water consumption) reaches 76.7 % as a whole.

The details of water consumption for each factory are as shown in Appendix Part 2.

Figs. 3.1 to 3.6 illustrate the surveyed factories' use of industrial water in graphics.

Figs. 3.1 and 3.2 show the water sources. As mentioned above, recovered water occupies the largest percentage, with most (95 %) of the make-up water, on the other hand, coming from wells.

Water consumption in each industry is as shown in Fig. 3.3. The textile and paper industries, though small in the number of factories, use relatively large quantity of water. Considering the fact that both textile and paper production lines require considerable water, this result is understandable. The same can be said of the use of well water (Refer to Fig. 3.5).

The water consumption per factory in each industry is given below.

(Unit: m^3/d)

Item / Industry	Consumption of Water (including Recovered Water)	Consumption of Make-up Water
Food	3,309	502
Paper	5,871	3,769
Textile	9,595	1,947
Metal	1,758	430
Chemical	3,729	368
Average	3,847	896

Fig. 3.4 illustrates the usages of industrial water in the surveyed factories. As seen in this Fig., more than half of water is used for cooling. The large share of air conditioning water is owing to the fact that T-01 factory (which has the largest site area and the largest number of employees among the surveyed factories) uses a great quantity (about 53,000 m^3/d) of air conditioning water. If this factory is excluded, the use of processing and washing water would exceed that of air conditioning water.

Fig. 3.5 shows the consumption of well water for each industry. Compared with the consumption of water including recovered one (Fig. 3.3), the percentage of the paper industry is increased, while that of the chemical industry is decreased. This can be explained by the relatively low water recovery rate (37 %) of the paper industry and the high water recovery rate (90 %) of the chemical industry. (The water recovery rate is described in 3.4.2 below.)

Fig. 3.6 shows the consumption of well water for each use. Compared with the consumption of water including recovered one (Fig. 3.4), the percentage of processing and washing water is greatly increased, while those of cooling water and air conditioning water are decreased.

This can be explained by a low water recovery rate (29 %) of processing & washing water and very high water recovery rates of cooling water (96 %) and air conditioning water (99 %). The most part (75 %) of processing & washing water is consumed in the paper and textile industries.

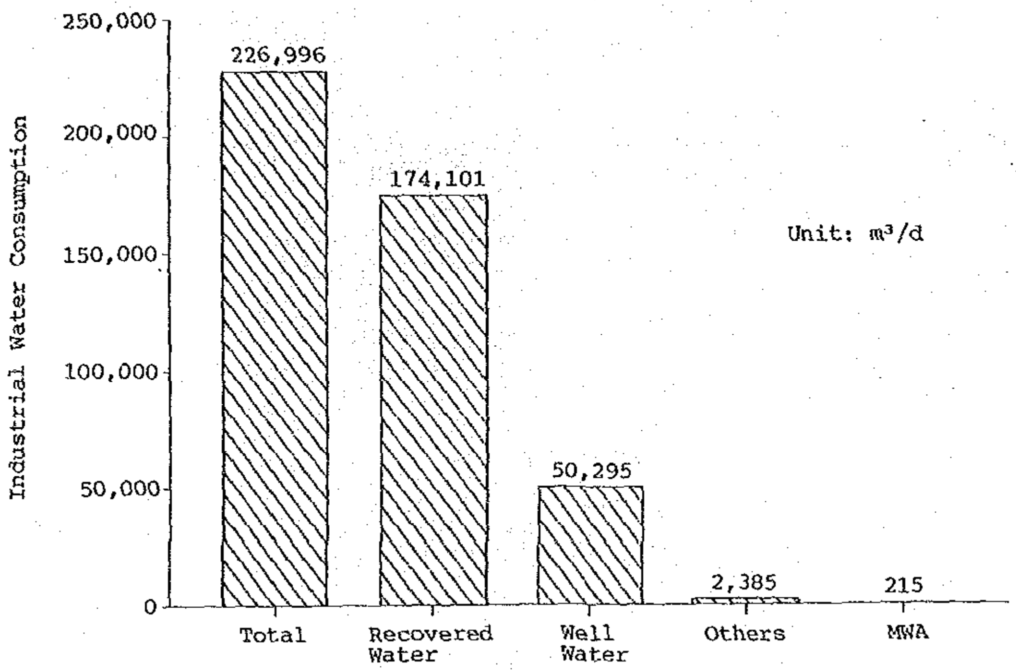

Fig 3.1: Industrial Water Consumption Classified by Water Source

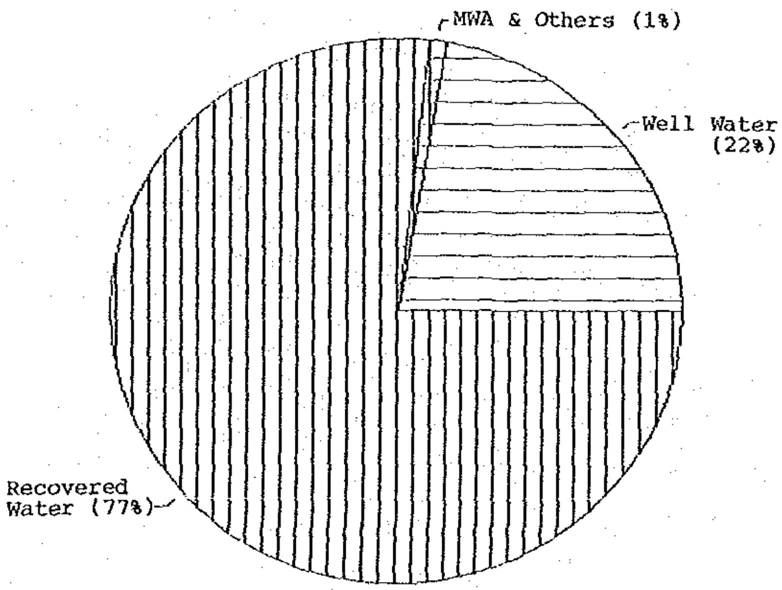

Fig. 3.2: Percentage of Industrial Water Consumption Classified by Water Source

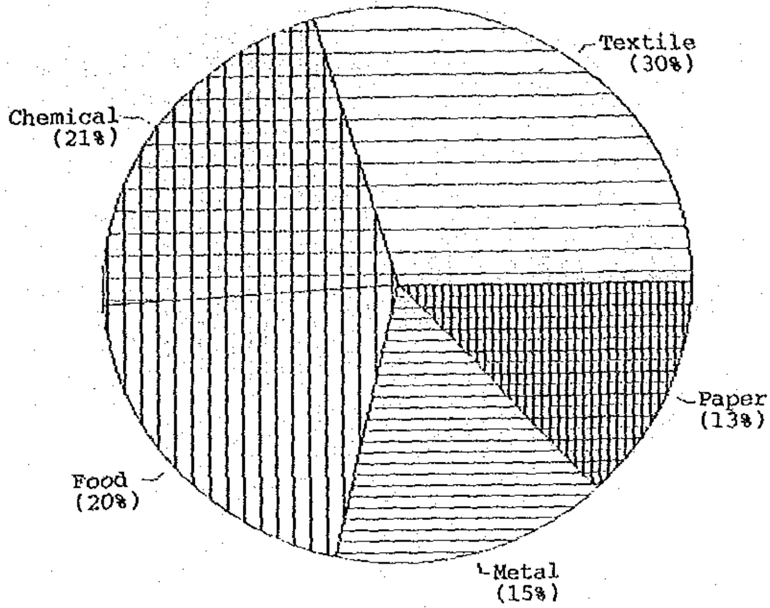

Fig. 3.3: Percentage of Industrial Water Consumption Classified by Industry

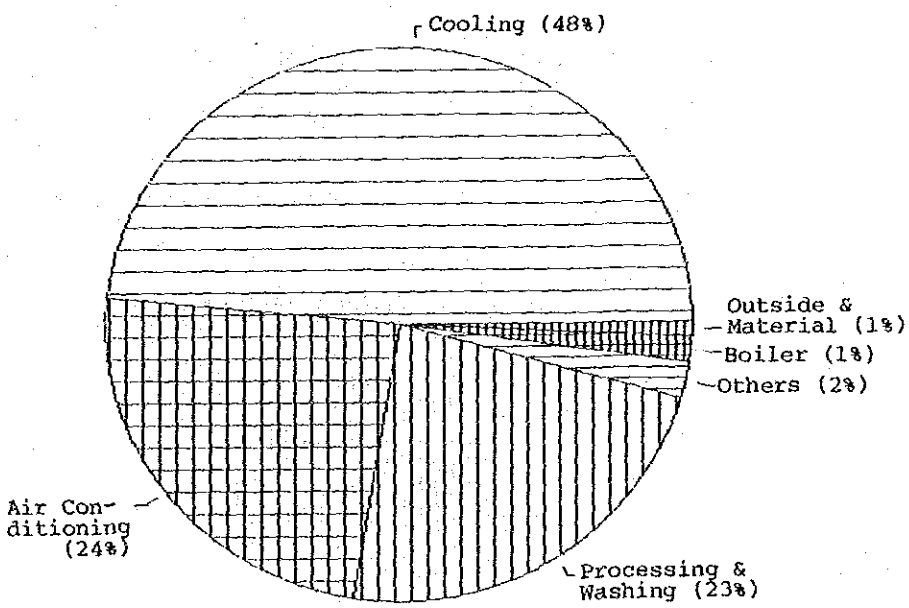

Fig. 3.4: Percentage of Industrial Water Consumption Classified by Use

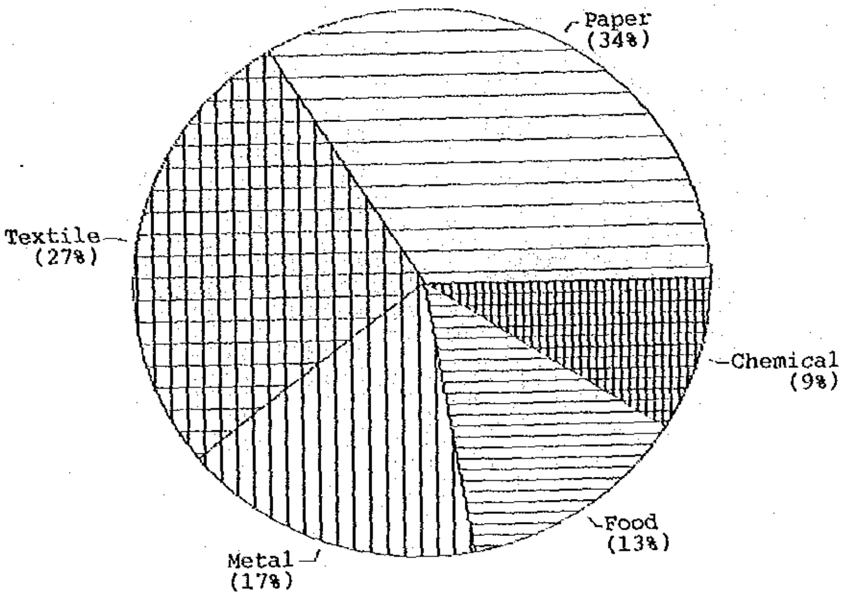

Fig. 3.5: Percentage of Well Water Consumption
Classified by Industry

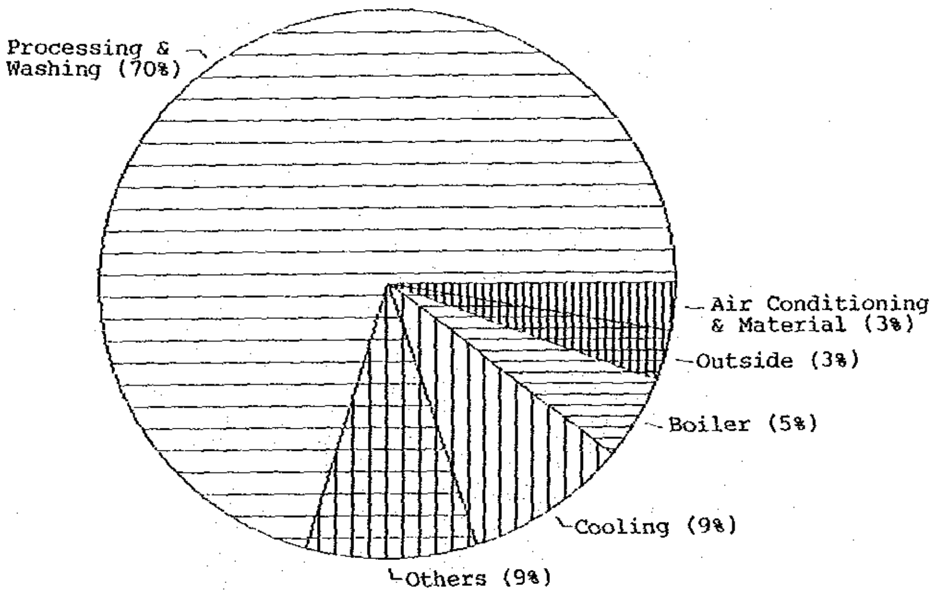

Fig. 3.6: Percentage of Well Water Consumption
Classified by Use

3.4.2 Recovery Rate of Industrial Water

The definition of the recovery rate of the industrial water is given by the formula :

Recovery rate (%) = (Quantity of recovered water)/(Total quantity of water consumption) x 100

Since the total quantity of water consumption is the sum of recovered water and make-up water, the quantity of make-up water can be derived from the following formula.

Quantity of make-up water = Total quantity of water consumption x (1 - recovery rate)

Thus the relation between make-up water and recovery rate (refer to 3.4.1) is obvious.

Generally, the use of water becomes more effective as the recovery rate grows higher.

The water recovery rate of the whole surveyed factories reached 77 %, which is slightly higher than the average recovery rate (75 %) of industrial water in Japan. In the table below, the water recovery rates of the surveyed factories are compared with those of the corresponding factories in Japan (source: the 1986 Industrial Statistics).

Item / Industry	Surveyed Factories in Sumat Prakarn		Factories in Japan		
	Number of Factories	Recovery Rate	Industry	Number of Factories	Recovery Rate
Food	14	84.8	Food	6,656	37.0
Paper	5	36.9	Paper	301	43.0
Textile	7	79.7	Spinning/ textile	957	30.5
			dyeing	642	7.3
Metal	20	75.5	Steel	1,392	89.5
			Electric machine	9,522	69.0
			Transport machine	3,247	92.0
Chemical	13	90.1	Chemical	2,120	80.2
Total/ average	59	76.7	Total/ average	57,978	74.7

On the basis of the table above, the water recovery rates of the surveyed factories for each industry were examined.

(1) Food

The average recovery rate of the surveyed food factories in Samut Prakarn is much higher than that of those in Japan. However, in the case of the surveyed factories, cooling water for the refrigerators in six factories accounts for about 86 % (33,827 m^3/d) of the total quantity of recovered water (39,301 m^3/d).

Hence the high recovery rate of the surveyed factories is owing to the high percentage of refrigerator cooling water in water consumption. Factories in Japan also recycle cooling water for refrigerators, and it is too hasty to conclude that the use of industrial water in the surveyed food factories in Samut Prakarn is already highly effective compared with those in Japan.

(2) Paper

The average recovery rate of the surveyed paper factories in Samut Prakarn is slightly lower than that of those in Japan. In general, factories whose production lines range from woods to pulp and paper consume more water than those producing paper from used paper and pulp.

Paper industry in Japan in the table above includes the factories of the former type, whereas all the surveyed paper factories in Samut Prakarn are of the latter type.

So, the water recovery rates of the paper industry in both countries are not directly comparable. The average water recovery rate of those manufacturers in Japan which produce paper from pulp and used paper is shown below (source: the Water Re-Use Promotion Center)

Item / Product	Number of Factories	Recovery Rate (%)
Toilet Paper/Tissue Paper	35	55
Cardboard	39	62

Judging from the above data, the use of industrial water in the surveyed paper factories in Samut Prakarn seems to be somewhat less effective than that in paper industry in Japan.

(3) Textile

The average recovery rate of the surveyed textile factories in Samut Prakarn is much higher than that of those in Japan. However, this high rate can be attributed to the large volume of recycled air conditioning water of one factory (T-01).

If this factory is excluded, the average recovery rate would be reduced to almost nil. The recycling of air conditioning water is a common practice in textile factories in Japan, too. Thus the use of industrial water in the surveyed textile factories in Samut Prakarn seems to be the same or lesser level of that in textile industry in Japan.

(4) Metal

To make the comparison easy, the surveyed metal factories in Samut Prakarn are further divided into the following three categories.

Surveyed factories:

Item / Industry	Number of factories	Code No. of Factory	Recovery Rate (%)
Steel	10	M-02, 04, 05 09, 10, 12, 13 15, 16, 17	80.8
Electric machine	3	M-01, 06, 11	31.7
Transport machine	7	M-03, 07, 08, 14, 18, 19, 20	61.3
Total/average	20		75.5

The corresponding data in Japan are as follows:

Factories in Japan:

Item / Industry	Number of Factories	Recovery Rate (%)
Rolled Steel	335	79.0
Consumer electric machine	676	56.8
Automobile	2,554	92.9

As seen in the table above, while the water recovery rate of the steel manufacturing factories is the same in both countries, the surveyed factories in the other two fields record lower recovery rates than their counterparts in Japan.

Though the number of samples may be too small to draw a meaningful conclusion, the field survey indicates that the use of industrial water in the metal industry in Samut Prakarn is at the same (steel manufacturers) or lesser (electric machine and transport machine manufacturers) level with and/or than the corresponding industry in Japan.

(5) Chemical

The surveyed chemical factories in Samut Prakarn showed a very high (90.1 %) recovery rate of industrial water. This data was obtained through detailed surveys and measurements at the time of visiting. Since manufacturing factories often fail to recognize cooling-tower-recycling water as recovered one, mere questionnairing surveys cannot provide reliable data.

In fact, it is not rare that a visiting survey reveals a higher recovery rate than reported. This discrepancy is particularly notable in chemical factories where cooling-tower-recycling water takes up the most part of recovered water.

Thus the survey suggests that the use of industrial water in the chemical factories in Samut Prakarn is as effective as that in chemical industry in Japan.

Summing up the above observations, it is not unreasonable to conclude that the use of industrial water in the surveyed factories has reached the level of effective use close to chemical industry in Japan.

Nonetheless, in the light of the fact that the effectiveness of the use of industrial water in Japan is not yet satisfactory, there is still plenty of room for further improvement in the use of industrial water in the surveyed factories.

3.4.3 Unit Water Usage

(1) Definition

In case of industrial water, "unit water usage" is defined as the quantity of water consumption related to a certain production unit. In general, the production unit designates any one of the following four cases.

(a) Shipment amount (production output value)

The unit water usage is a daily water consumption required to manufacture a unit amount (value) of products. For example, the unit water usage usually adopted in Japan is a volume of water per day required to manufacture 100 million yen of annual products (m^3/d/100 million yen/Y).

(b) Area of site

The unit water usage is a daily water consumption to unit area of factory. For example, usually "100 m^2" is taken as a unit (m^3/d/100 m^2)

(c) Number of employees

The unit water usage is a daily water consumption to per employee (m^3/d/employee).

(d) Amount of products

The unit water usage is a daily water consumption required to manufacture a certain unit of products. Different units may be adopted for different types of products. For example, "ton" for steel, pulp and paper, "kiloliter" for alcoholic drink, "unit product" for automobiles and bicycles, and "meter" for textile and dyeing.

(2) Application of unit water usage

(a) The unit water usage may be applied to compare

1) the water consumptions of the same factory in different years or

2) the water consumptions of different factories in the same industry. For this purpose, the unit (d)--amount of product--is suitable. This unit is applicable only for the same type of product.

(b) The unit water usage may be applied to estimate the demand for industrial water. In case a new industrial estate is built or a regional industrial plan is established, it is necessary to estimate the aggregate demand for industrial water. The unit water usage provides an effective tool for this kind of estimation.

(3) Unit water usage applied for the surveyed factories

The surveyed factories cover a variety of industries, so that the unit water usage based on product amount cannot be applied. Also, the unit water usage based on shipment amount, although technically applicable to all the factories, has little significance when the types of products vary greatly. The unit water usage employed for the survey is explained in the Appendix Part 2 of this report.

3.4.4 Use of Domestic Water

Domestic water consumed in a factory is, in a broad sense, included in industrial water. In Fig. 3.7, the domestic water consumptions of the surveyed factories are plotted against the numbers of employees. The water consumption in this Fig. includes that for employees' dormitory, but excludes the domestic water supplied to the outside of a factory.

The average of domestic water consumption is around 210 liters per person per day. There is a big difference in the consumption of domestic water between factories with employees' dormitories (400 lit/capita/d) and those without any dormitories (180 lit/capita/d).

Although the optimum quantity of domestic water consumption depends on various conditions and hence is hard to determine, Fig. 3.7 and the unit domestic water usage (refer to the Appendix Part 2) suggest that 500 lit/capita/d (for factories with dormitories) or 300 lit/capita/d seems to be optimum quantity for the surveyed factories.

Thus Fig. 3.7 clearly shows that some factories exceed the optimum quantity of domestic water consumption.

3.4.5 Qualities of Well Water

Table 3.3 shows the qualities of well water for each of the surveyed factories. The figures in this Table were for the most part provided by each factory. (Those figures which were obtained through the measurement by the Study Team are marked with asterisks.)

Compared with the qualities of well water in Japan, Table 3.3 shows the following characteristics.

(a) The water temperature is high--often of ten above 30°C (cf. 15 - 20°C for well water in Japan). This is a disadvantage when well water is used for cooling.

(b) The turbidity is fairly high. It is for this reason that many of the surveyed factories apply coagulation/sedimentation or sand filtration treatment to well water.

(c) The salt concentration is high. This is indicated by the high degree of alkalinity, total hardness, chloride ion and electrical conductivity. Saline water is prone to cause scaling or corrosion and hence unsuitable for industrial use. In fact, many of the surveyed factories apply softening or ion exchange treatment to well water.

Judging by the qualities above, well water of the surveyed factories is not suitable for industrial use.

Yet, since river water in the surveyed area also include a lot of salt (i.e. sea water is mixed with river water), there seem to be no alternative but to use well water.

For the purpose of comparison, the qualities of well water used in 60 pulp/paper factories in Japan are shown in Appendix Part 2.

3.4.6 Waste Water Treatment

Waste water treatment, though not a central part of the study, is closely related to the effective use of industrial water. Its present situation is summarized in Appendix Part 2.

Compared with the waste water treatment in Japan, though systems employed by the surveyed factories are by and large of the same types as those in Japan, the processing capacities and operations tend to be insufficient.

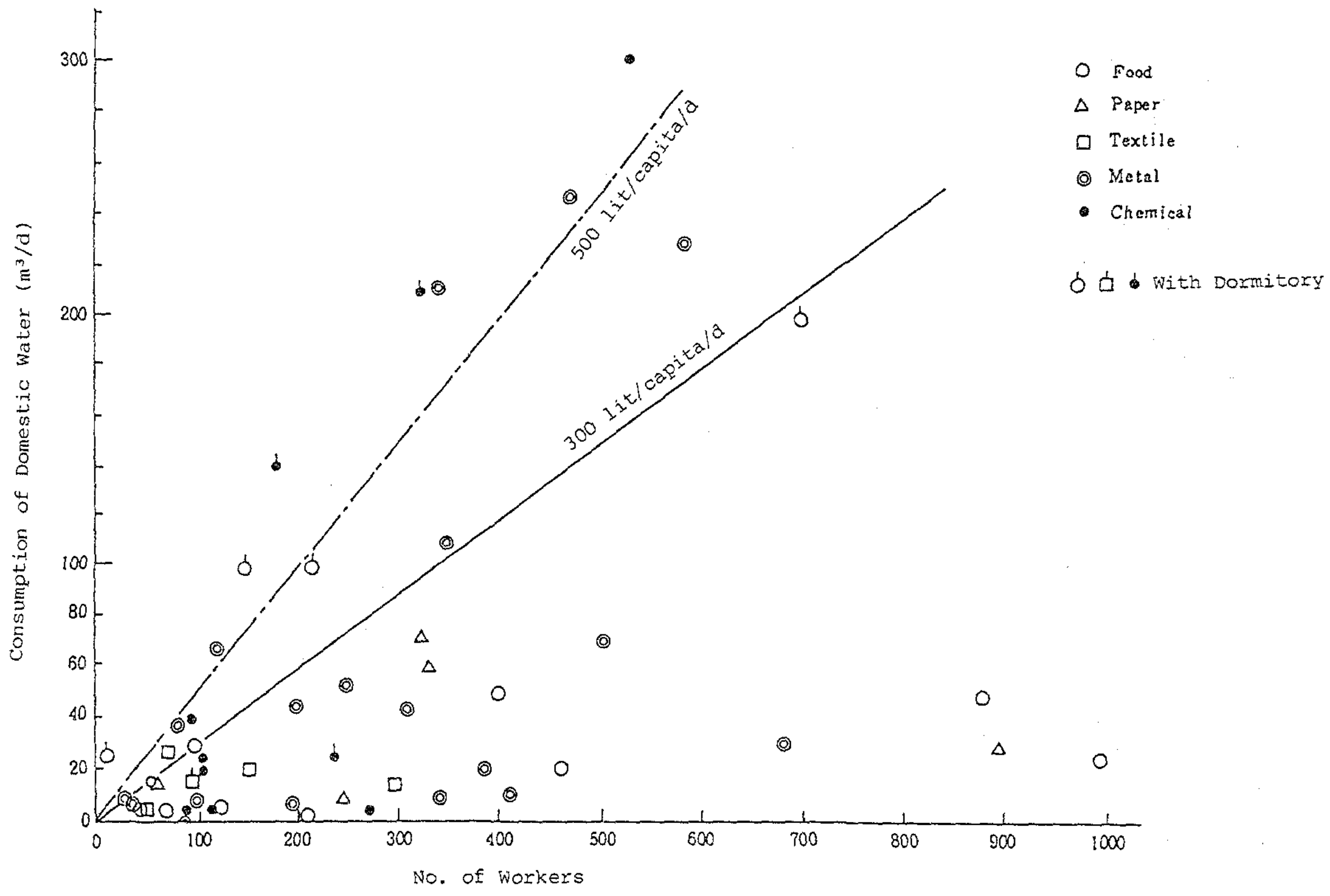

Fig 3. 7: Consumption of Domestic Water in Surveyed Factories

Table 3.3: Quality of Well Water

Code No.	Fact. No.	Temp. (°C)	Turbidity (°)	pH	Alkalinity (mg/l)	T/Hardness (mg/l)	Chloride (mg/l)	T/Iron (mg/l)	TDS (mg/l)	Elec. Cond. (μS/cm)	Well Depth (m)
F-01	170	* 28.1	* 3	* 7.0	-	-	-	-	-	* 2,020	-
F-02	103	27-30	* 14	7-8	210-250	32-160	250-375	0.3	1,070	1,200-1,800	140
F-03	135	* 33.2	* 0	* 7.01	329	56	24	0.02	-	* 725	110
F-04	130	* 36.5	* 4	* 7.80	-	-	-	-	-	* 750	140
F-05	127	-	2.4	6.7	268	185	188	0.1	672	960	150
F-06	114	36	-	* 7.95	380	76	35	0.05	-	* 788	140
F-07	110	-	0	* 7.64	-	-	-	-	-	* 760	-
F-08	109	* 35	* 0	* 8.02	-	102	96	0.4	688	* 762	-
F-09	91	-	1.7	7.7	302	125	124	0.32	-	965	130
F-10	78	-	2.70	6.95	-	750	838	0.25	2,196	-	120
F-11	65	* 33	* 0	* 7.07	342	89	17	0.19	-	* 705	60
F-12	48	-	Dirty	10.95	825	0	423	-	-	9,200	-
F-13	43	27-34	Ca. 1-2	5-7	400	136	37.5	0.3	-	* 678	-
F-14	21	* 34.1	* 1	* 7.24	-	-	-	-	-	* 711	110

Note: Figure under * was measured by the Study Team.
mg/l = mg/lit

Table 3.3: Quality of Well Water (Continued, 2/4)

Code No.	Fact. No.	Temp. (°C)	Turbidity (°)	pH	Alkalinity (mg/l)	T/Hardness (mg/l)	Chloride (mg/l)	T/Iron (mg/l)	TDS (mg/l)	Elec. Cond. (µS/cm)	Well Depth (m)
P-01	145	* 35.6	* 15.0	* 7.40	250	460	655	0.28	1,542	* 2,980	100
P-02	124	–	–	* 6.84	–	–	–	–	–	* 2,510	100
P-03	107	* 36.0	* 16.0	* 7.20	315	181	145	0.17	25.5	* 1,333	220
P-04	84	32–	96	7.48	256	260	315	0.86	1,200	–	90
P-05	39	–	–	–	–	–	–	–	–	–	–
T-01	146	39	0	7.7	2.70	90	39	0.4	390	1,050	210–234
T-02	197	* 30.8	* 19	* 7.29	–	176	662	0.05	1,500	* 1,786	60
T-03	203	* 31.1	* 2	* 7.4	225	–	375	0.03	1,162	* 1,852	–
T-04	193	* 30.5	* 2	* 6.98	–	–	–	–	–	* 1,925	54
T-05	200	* 31.4	* 0–2	* 7.02	225	320	403	0.1	865	* 1,880	–
T-06	198	* 30.8	* 12	* 6.87	–	–	–	–	–	* 1,824	80
T-07	189	* 30.6	* 14	* 6.93	186	380	485	0.2–0.6	900	* 1,849	–

Note: Figure under * was measured by the Study Team.
mg/l = mg/lit

Table 3.3: Quality of Well Water (Continued, 3/4)

Code No.	Fact. No.	Temp. (°C)	Turbidity (°)	pH	Alkalinity (mg/l)	T/Hardness (mg/l)	Chloride (mg/l)	T/Iron (mg/l)	TDS (mg/l)	Elec. Cond. (μS/cm)	Well Depth (m)
M-01	61	* 33.8	9	7.10	-	-	-	-	-	711	80-100
M-02	96	30	-	7	216	200-300	200-400	0.3-1.0	500	1,680-2,000	80
M-03	89	* 33.3	-	* 6.71	-	312	-	2.31	-	* 1,350	120
M-04	206	* 31.5	* 9	* 6.52	-	-	-	-	-	* 4,680	83
M-05	73	* 28.1	* 16	* 6.94	-	-	-	-	-	* 1,820	90
M-06	53	-	-	-	-	-	-	-	-	-	-
M-07	34	-	* 2	* 7.25	-	-	-	-	-	* 975	54
M-08	42	-	-	-	-	-	-	-	-	-	100
M-09	69	* 31.9	* 3	* 7.06	-	-	-	-	-	* 1,068	-
M-10	207	* 29.8	* 37	* 6.92	204	582	760	2.12	1,890	* 2,710	60
M-11	116	* 33.4	* 6	* 7.47	311	47	114	0.005	445	* 1,250	135
M-12	97	-	-	6.3	469	385	355	0.5	1,101	1,573	84
M-13	208	* 30.0	* 7.0	* 7.4	-	-	-	-	-	* 1,989	
M-14	115	* 34.1	* 0	* 7.24	342	80	80.6	1.79	-	* 1,100	150
M-15	101	-	-	6.8-7.9	234	80.1	17.6	0.2-0.4	441-462	630-660	100-120
M-16	100	-	-	7.10	320	98	63	0.16	-	794	-

Note: Figure under * was measured by the Study Team.
mg/l = mg/lit

Table 3.3: Quality of Well Water (Continued, 4/4)

Code No.	Fact. No.	Temp. (°C)	Turbidity (°)	pH	Alkalinity (mg/l)	T/Hardness (mg/l)	Chloride (mg/l)	T/Iron (mg/l)	TDS (mg/l)	Elec. Cond. (μS/cm)	Well Depth (m)
M-17	56	* 33.8	* 4	* 7.05	-	83	90	0.98	526	* 863	-
M-18	64	* 28.3	0.9	7.0-8.1	279	97	84	-	-	* 850	118
M-19	57	33.0	4	6.3	260	278	450	0.3	1,155	1,650	125
M-20	49	* 32.7	* 0	* 7.61	292	124	116	0.07	-	* 1,283	140
C-01	155	* 30.4	* 92	* 7.45	-	102	194	1.45	-	* 1,700	126
C-02	168	* 35.4	* 0	* 7.42	300	45	120	0.04	-	* 1,010	120
C-03	209	28	1	7.0	188	57	400	1.7	452	770	75
C-04	210	-	128	7.35	-	879	1,114	4	2,124	-	-
C-05	149	* 31.4	* 0	* 6.88	-	-	-	-	-	* 2,600	60-80
C-06	147	* 33.6	* 7	* 7.6	-	-	-	-	-	* 720	42
C-07	106	-	-	7.75	300	33.3	203.2	0.19	-	1,280	150
C-08	94	-	6.5-7.2	-	180-220	180-380	250-450	2-7	600-900	* 1,360	90
C-09	82	30	-	7.25	-	87	90	-	488	-	-
C-10	51	* 32.6	* 0	* 7.47	-	-	-	-	-	* 887	36
C-11	25	* 36.4	* 0	* 7.52	-	70	-	0.12	-	* 1,027	115
C-12	7	* 34.5	* 0	* 7.27	-	-	-	-	-	* 987	-
C-13	29	* 33.4	* 0	* 7.58	364	192	-	-	-	* 715	80

Note: Figure under * was measured by the Study Team.
mg/l = mg/lit