1990 TDRI Year-End Conference on
Industrializing Thailand and Its Impact on the Environment

Water Shortages: Managing Demand to Expand Supply

The 1990 TDRI Year-End Conference

INDUSTRIALIZING THAILAND AND ITS IMPACT ON THE ENVIRONMENT

Session: Natural Resources for the Future

Research Report No. 3

Water Shortages: Managing Demand to Expand Supply

Sacha Sethaputra
Theodore Panayotou
Vute Wangwacharakul

December 8-9, 1990
Ambassador City Jomtien, Chon Buri

List of Researchers in the Project
Industrializing Thailand and Its Impact on the Environment

Policy research is a team effort. The names of researchers mobilized to undertake the various studies in preparation for the 1990 TDRI Year-End Conference and their respective topics of responsibility are listed below:

Project Director: Dr. Dhira Phantumvanit
Project Advisor: Dr. Theodore Panayotou

Theme: **Natural Resources for the Future**

Synthesis Paper #1: Natural Resources for a Sustainable Future: Spreading the Benefits

Researchers:
Dr. Dhira Phantumvanit
Dr. Theodore Panayotou

Research Report #1: Land and Forest: Projecting Demand and Managing Encroachment

Researchers:
Dr. Theodore Panayotou
Dr. Chartchai Parasuk

Research Associate: Khun Chiraphan Kulthubsak

Research Report #2: Deforestation and Poverty: Can Commercial and Social Forestry Break the Vicious Circle?

Researchers:
Dr. Sopin Tongpan
Dr. Theodore Panayotou
Khun Songpol Jetanavanich
Khun Ketty Faichampa
Dr. Charles Mehl

Research Report #3: Water Shortages: Managing Demand to Expand Supply

Researchers:
Dr. Sacha Sethaputra
Dr. Theodore Panayotou
Dr. Vute Wangwacharakul

Research Associate: Khun Nittayaporn Ratanachompoo

Theme: Mineral Resources Development and Its Environmental Implications

Synthesis Paper #2: Mining, Environment and Sustainable Land Use: Meeting the Challenge

Researchers:
Dr. Theodore Panayotou
Dr. Quanchai Leepowpanth
Dr. Duangjai Intarapravich

Research Report #4: Mineral Resource Development: Making the Best of a Limited Resource

Researchers:
Dr. Duangjai Intarapravich
Dr. Quanchai Leepowpanth
Dr. Theodore Panayotou
Dr. Sunt Rachadawong

Research Associate: Khun Panitta Na Nakorn

Theme: Industrializing Thailand and the Impact on Its Environment

Synthesis Paper #3: Industrialization and Environmental Quality: Paying the Price

Researchers:
Dr. Dhira Phantumvanit
Dr. Theodore Panayotou

Research Report #5: The Greening of Thai Industry: Producing More and Polluting Less

Researchers:
Khun Phanu Kritiporn
Dr. Theodore Panayotou
Khun Krerkpong Charnprateep

Research Associate: Khun Amornwan Resanond

Research Report #6: Urbanization and Environment: Managing the Conflict

Researchers:
Dr. Banasopit Mekvichai
Mr. David Foster
Khun Sopon Chomchan
Khun Phanu Kritiporn

Research Associate: Khun Maysaya Chanawan

Research Report #7: Energy and Environment: Choosing the Right Mix

Researchers:
Dr. Tienchai Chongpeerapien
Khun Somthawin Sungsuwan
Khun Phanu Kritiporn
Khun Suree Buranasajja
Resource Management Associates
(Dr. Wesley Foell, Dr. Mark Hanson, Mr. Robert Lopez)

Research Associates:
Khun Pramote Cheowchaiporn
Khun Wannit Arpechatakorn
Khun Watcharee Santisukpisan

Supplementary Document

Supplementary Report: Integrated Information for Natural Resources Management

Researchers: Khun Paul Hastings
Khun Chatchawan Boonraksa

Research Associates: Khun Surassawadee Tanprasat
Khun Surachai Chayawatanakijja

Other Researcher:	Khun Piyanoot Siwabut
Editors:	Ms. Christine Van Roosen Ms. Claudia Winkelman Ms. Nancy Conklin
Secretaries:	Khun Chuchitt Sombunthawong Khun Kwancheevit Pinyakul Khun Rungrat Phurekanokrat Khun Songsiri Suwanjinda Khun Warunee Pariyamekin Khun Haranya Tanaree

This project is a collaborative effort between Thailand Development Research Institute and Harvard Institute for International Development. The services of Dr. Theodore Panayotou, Dr. Wesley Foell, Dr. Mark Hanson, Mr. Robert Lopez, and Mr. David Foster were provided under this cooperation.

List of Institutional Supporters

Financial resources for the project ***Industrializing Thailand and Its Impact on the Environment*** were made available through the support of the following organizations:

1. Department of Technical and Economic Cooperation (DTEC), Government of Thailand.

2. United States Agency for International Development (USAID), under the project *Privatization for Natural Resources Development*.

3. United States Agency for International Development (USAID), under the *Management of Natural Resources and Environment Project* (MANRES).

Contents

List of Tables

List of Figures

ACKNOWLEDGMENTS

In order to prepare this report, the necessary data were obtained from several agencies. Water supply data for Bangkok and Pattaya were obtained from the Metropolitan Waterworks Authority (MWA) and the Provincial Waterworks Authority (PWA) respectively. In particular the MWA's Planning Division and the PWA's No.1 Regional Office in Cholburi were very helpful. The data on industrial statistics were obtained from the Bangpu and Ladkrabang industrial estates and the Department of Industrial Works under the Ministry of Industry. The information on groundwater pumping was obtained from the Department of Mineral Resources. Most input data for Chapter 2 were obtained from the Royal Irrigation Department. Finally valuable comments were also obtained from all the above agencies and the Bangkok Metropolitan Authority.

The authors would like to thank these above-mentioned agencies for their cooperation without which the study would not have been possible.

Chapter 1

Introduction

Thailand's essential water resources—which are a major economic asset—are both abundant and scarce at the same time. Part of the reason for this apparent contradiction is the "skewed" distribution of water in space and time: rainfall is excessive during the few monsoon months and is almost totally absent during the rest of the year. The Central Plains and the South suffer from excessive rainfall and flooding, while the Northeast suffers from drought. In contrast, the demand for water is fairly evenly distributed throughout the country and is currently rising under the pressure of population and economic growth. The fluctuations in the water supply are brought more in line with demand by tapping, storing, and conveying water over large distances.

In the past the response to this growing demand for water has been to increase water storage capacity, but even after the most suitable sites for water storage and diversion have been used up, only 20 percent of agricultural land is irrigatable. At this point additional water for irrigation, power generation, and urban and industrial use can be accessed, but there are general interest problems. The construction of new dams is costly and faces strong opposition from local interests and environmental groups, and the diversion and interregional transfers of water create or exacerbate economic, social, and environmental problems. Groundwater aquifers, especially those around Bangkok and other urban centers, are intensively exploited beyond their replenishment rate resulting in land subsidence, flooding, and saline water intrusion.

In the meanwhile, the demand for water for nonagricultural use is growing rapidly under the forces of urbanization, industrialization, and income growth. The demand for water in the Bangkok Metropolitan Region (BMR) grew at a compound rate of 8 percent per year in the 1980s and is expected to grow even faster in the 1990s. The industrial and tourist sectors' demand for water is growing even more dramatically and is increasingly satisfied by the environmentally destructive and unsustainable method of "mining" groundwater aquifers.

The agricultural sector is by far the largest user of water and accounts for 90 percent of the annual withdrawals. Considering the tremendous structural change of the economy from agriculture to industry and services over the past few years and the relatively small quantities of water used by the newer, nonagricultural sectors, it seems plausible that the water savings from the agricultural sector would satisfy the smaller demand. The nonagricultural sector is even willing, and able, to pay water rates that can more than compensate Thai farmers for any loss of output that might result from diverting relatively small quantities of irrigation water to urban and industrial users.

Unfortunately, this is not the case. First, migrants mainly originate from rainfall areas rather than from irrigated areas. Second, farmers continue to waste water resources despite growing scarcity problems because it is either available to them in large quantities free of change, or not available to them at all. A farmer or water user who is located at a significant distance from the source of supply cannot access water, no matter what his need or willingness to pay, unless there is a surplus closer to the system, no matter how low the value of their use. The use of flood irrigation for rice paddies is, at the margin, roughly the lowest-value use of water in the country. Yet, there is no mechanism whereby the water can flow to higher-value agricultural and nonagricultural users, even though such a diversion could benefit everyone, including the rice farmer.

Considering the fact that irrigation efficiency is below 30 percent (15 percent according to some estimates), improving efficiency to the 50 percent level that has been attained by many countries, including Malaysia, Taiwan, and China, would suffice to supply nonagricultural users well into the 21st century, and at the same time, would increase the actual area irrigated. Improved irrigation efficiency requires some form of water pricing, and although the concept of water pricing has been dismissed as being unfair to the farmer and not feasible in Thailand, China has found water pricing both feasible and equitable.

This study take a different approach to improving water-use efficiency and resolving water resource conflicts. The study's focus is the demand for nonagricultural water uses, not because nonagricultural uses are more important, but because they may hold the key to improving the efficiency of water use throughout the country in an equitable manner that would enable the farmers and rural population in general to share in the benefits of rapid growth and industrialization. First, the water supply and demand situation in the country is reviewed to identify the most rapidly growing sources of water demand: urban areas, especially the BMR, and the industrial and tourist sectors also centered in and around the BMR (Chapter 2). Second, the determinants of demand for water, such as income growth, urbanization, industrial growth, and the expansion of tourism are identified and analyzed; the sensitivity of this demand to the price of water is measured; and future water demand for urban, industrial and tourist uses is projected (Chapters 3, 4, and 5). Third, some principles of managing water, both as a scarce resource and as a market commodity are reviewed, and their applicability to Thailand's water problems is explored (Chapter 6). Finally, in Chapter 7, a system of water pricing for urban areas (nonagricultural users) and water rights for rural areas (farmers) is proposed that aims to accomplish the following:

1. Increase the Quantities of Available Water: Both the urban areas and the rapidly growing industrial and service sectors must have adequate water resources to ensure that water does not become a constraint on economic growth.
2. Increase the Efficiency of Water Use: Both agricultural and nonagricultural water users must increase water-use efficiency, but this should not impose an undue burden on poor farmers and poor urban consumers.
3. Reduce Water-based Problems: By reducing water resource conflicts and promoting water resource conservation and recycling (especially by industry and tourism) wastewater and associated water pollution problems that diminish the quantity and quality of useable water resources would be reduced.
4. Promote Water Rights and Balanced Access to Water Resources: Give the rural population a stake and a share in the benefits from industrialization, urbanization, and rapid economic growth; more than any other policy intervention, a policy of awarding rural people rights over an increasingly scarce resource would help accomplish the dual objectives of reducing income inequality and preserving the desirable features of rural life with large farm subsidies and agricultural surpluses.

Undoubtedly, there are difficulties and problems to be worked out in the overall scheme for water management, but the benefits in terms of growth that is unhampered by water shortages and conflicts, conservation of a precious resource, and a better distribution of income and social and political stability far overweight the costs of dealing with the problems and difficulties involved. The alternatives are increasing water shortages and conflicts, mounting government subsidies, low water—use efficiency in both the agricultural and nonagricultural sector, and the loss of a unique opportunity to spread the benefits of development and ensure peoples' support and participation. The failure to securely title and fully price an increasingly scarce resource today would compromise its sustainable use in the future.

Chapter 2

Managing Water Supply and Demand

The purpose of Chapter 2 is to point out the missing element in the Thai water situation: water management. To do this the chapter describes and contrasts the two extremes of Thailand's water situation: the national (or macro) situation and the local (or micro) situation. While the first two sections in Chapter 2 describe conflicting situations (plenty of water at the macro scale, yet not enough water at the micro scale), the third section puts the two conflicting implications in a proper perspective. Chapter 6 outlines further details of water management.

A MACRO VIEW OF THE WATER SITUATION

The national requirements for water use can be classified into three main types: domestic (and municipal), industrial, and agricultural.

Domestic and Municipal Use

Water is used for domestic and municipal uses including drinking, food preparation, sanitation, washing, cleaning, watering gardens, laundries, swimming pools, restaurants, and medical services. Pipe water is usually used in municipal areas, while in rural areas, water sources may include rainwater jars, shallow wells, deep wells, man-made ponds, or direct sources such as streams and rivers. Compared to other sectors, the quantity of water required for domestic needs is not large, but domestic water quality must be high. The rate of water consumption ranges from 50 litres per person per day in rural areas to ten times that amount in urban areas where pipe water is available. The per capita water consumption tends to increase with living standards, and the annual growth rate of water consumption is expected to be a few percent more than the GDP.

Approximately 60 percent of the water for domestic use ends up as wastewater, and the increase in domestic water usage resulting from higher living standards, population growth, and urban migration will ultimately mean more wastewater to deal with.

Industrial Use

Water is used for industrial requirements including cooling, processing, cleaning, and waste removal. About 85 percent of the industrial water becomes highly polluted wastewater. The total quantity of water required for industrial use is roughly equal to that for domestic. Industrial users with high levels of water consumption are the iron and steel, food, and textile industries. Wastewater from industries usually requires special treatment to remove harmful materials such as heavy metals.

It is expected that industrial water requirements will grow at a higher rate in the future than the past because of economic growth, structural change and rapid industrialization. The amount of water used will grow at about the same rate as that of the domestic sector.

Agricultural Use

Water is used for agricultural applications including irrigation of rice paddies, fish and prawn farms, cash crops, and stock breeding. Approximately 25 percent of agricultural water is returned to the system. This "return flow"contains pesticides and fertilizers and can have a profound effect on the aquatic environment.

In Thailand, as in most countries with a large agricultural sector, agricultural water use is a major component of overall water usage—more than 90 percent—and a small savings in the use of agricultural water would provide increased water for domestic and industrial uses. Ongoing economic development encourages migration from Thailand's rural areas (where most activities are agricultural) to urban areas, and hence frees some water for other uses. Water savings are not large, however, because most people migrate from rainfed areas where little water is used. In addition, crop diversification implies more stringent water requirements in both quantity and quality.

Withdrawal, Consumption, and Renewable Water

The water withdrawn from any surface or subsurface water source—a "withdrawal"—is either used directly (for example, rice paddy irrigation) or treated before use (for example, pipe water). Most of the used water is returned to the system, and this return flow can be either reused and discharged, or withdrawn again from the overall water system for various uses. The process repeats itself (depending on water quality) until the water ends up in the ocean. The return flows from domestic and industrial uses usually have detrimental effects on the environment and require treatment.

The portion of withdrawn water that is fully used and does not return to the system in liquid form is called "consumption". For example, the water that plants use is eventually transferred into the atmosphere as consumption.

"Renewable water" is part of the annual water cycle and of the natural process of condensation and evaporation and includes water that is readily available for use, such as streamflows and groundwater.[1] In fact, most renewable water is not readily available for use, and the unusable forms include clouds, water in the oceans, very deep groundwater, and water in plants and animals.

Present and Future Water Use Quantities

The amount of water withdrawn for domestic, industrial, and agricultural uses is shown in Table 2.1, and Figure 2.1 presents these as percentages of renewable water. An estimation of the water use by sector is discussed in Appendix 1.

Table 2.1 Water Quantity Required by Major Sectors

(billion cubic meters)

Year	Amount of Renewable Resource	Total Amount Withdrawn	Sectoral Withdrawal		
			Domestic	Industry	Agriculture
1990	199	43	2	1	40
2000	199	85	6	3	76
2010	199	167	15	8	144

Figure 2.1 illustrates the fact the domestic and industrial water requirements will be eight times the 1990 rates in 2010, while agricultural water will be only four times today's rates, and the remaining portion of the annually renewable water decreases from 78 percent in 1990 to only 16 percent in 2010. This remaining portion of renewable water can be withdrawn for further use, but the withdrawals would be made with increasing difficulty and higher costs, or at the expense of other intangible benefits such as aesthetic value, recreation, and other environmental considerations.

Water Use in Other Countries

Although different countries face different water use constraints, it may be useful to look at other countries from various water-use perspectives. Table 2.2 summarizes some statistics pertinent to these countries as follows:

- **South Korea** has a newly industrialized country (NIC) status to which Thailand aspires.
- **Israel** represents a country with a sophisticated state of water management. With just 12 percent of remaining water, it is probably an example of optimal water management.
- **Malaysia and Indonesia,** Thailand's neighbors, are jumping on the "NIC bandwagon." In this case, it is interesting to examine whether water could become a limit to economic growth. Thailand may have to be more selective in choosing its type of industries.
- **The Lao People's Democratic Republic and Myanmar (Burma)** are two of Thailand's closest neighbors with plenty of water that could be imported. They are included here to provoke some thought on long- term regional water cooperation among Thailand and her neighbors.

Table 2.2 Sectoral Withdrawal Data from Other Countries

Country	Year	Sectoral Withdrawal (% Annual Renewable Water)			
		Domestic	Industry	Agriculture	Other
Thailand	1990	1	0.5	20	78.5
South Korea	1976	2	2	13	83
Israel	1986	14	4	70	12
Malaysia	1975	1	1	1	97
Indonesia	1987	0.1	0.1	0.6	99.2
Lao, PDR	1987	0.05	0.05	0.3	99.6
Myanmar	1987	0.04	0.03	0.33	99.6
Belgium	1980	8	61	3	28

Source: World Resources (1990-91)

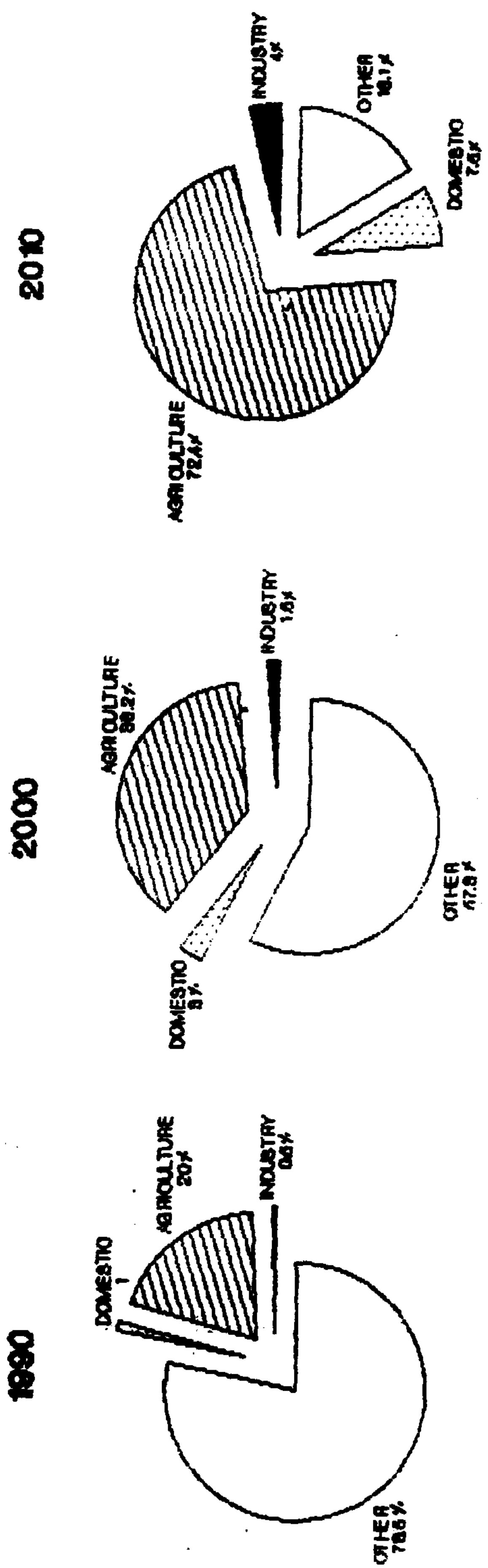

Figure 2.1 Sectoral Water Uses in Thailand

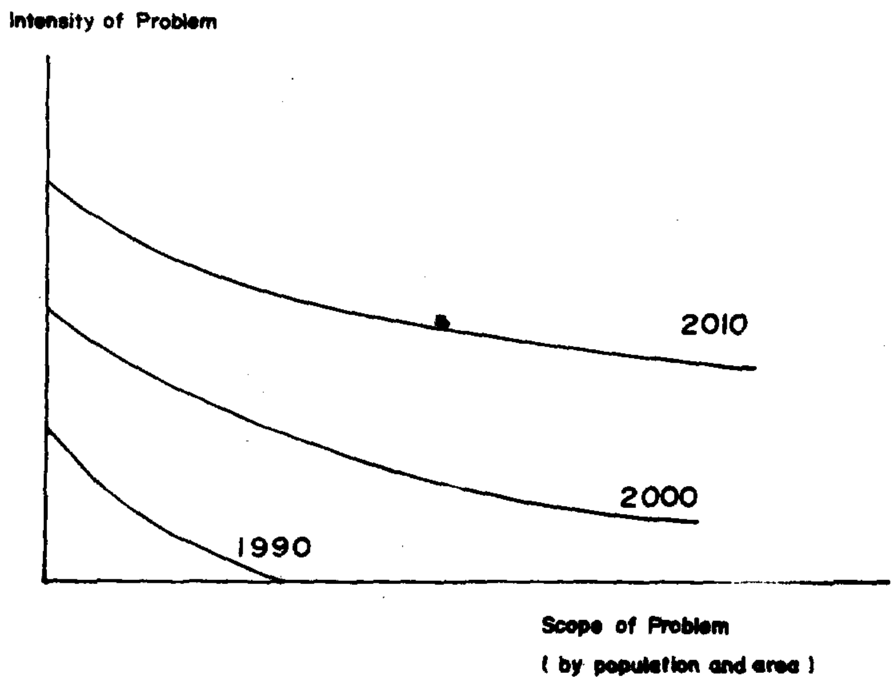

Figure 2.2 Escalation of Water Conflicts

Implications and Limitations of the Forecast

Figure 2.1 presents information showing that the remaining supply of annually renewable water reflects the country's buffer or safety factor against water scarcity and environmental degradation such as saline water intrusion, desertification, etc. It also has value both aesthetically and as an amenity. This buffer will be reduced to less than half of its present size by 2010. With less buffer to rely on, water will become a scarce resource, and Thailand will have to be more disciplined in the use of water. Like any other scarce resource, its utilization must be planned, monitored, and carefully managed.

In addition, an increase in the water quantity required for the sectoral uses described above implies increased wastewater generation, and without proper treatment and control, the wastewater could contaminate the buffer stock, making it unsuitable for further use. From an economic point of view, the increase in withdrawal and the necessity to deal with wastewater will increase the costs of treatment at the expense of other benefits such as the environment.

A major limitation to the above interpretation is that the picture offered by the forecast is only a macro one; it ignores the variations both in time (seasonal) and area of water availability. For example, while Figure 2.1 shows that at this time (1990) Thailand has 78.5 percent of water available for use, Chiang Mai, Pattaya, Phuket, and many other locations of high water demand have problems with their raw water supplies for pipe water. Moreover, Northeastern Thailand is considerably drier than other parts of the country, while the Central Plains and other parts of the South and even the Northeast suffer from excessive amounts of water and floods during parts of the year. This bimodal seasonal distribution of rainfall and the long dry season create extreme seasonal variations and consequently large storage requirements. The macro analysis also ignores the yearly variations including the global climatic change due to man-made environmental degradation such as deforestation and the greenhouse effect.

The macro view of the water situation is therefore insufficient to reflect our water problems and will not serve as a base for shaping future national policy. The next section of Chapter 2 looks at water-use problems in some selected locations to gain insight into their intensity and scale. Another dimension of the water-use problem is to analyze it from a sectoral perspective. This is done in chapters 3, 4, and 5 for urban, industrial, and tourism growth.

CONFLICTS IN WATER USE

Several selected cases of water-related problems occurring in Northern and Northeastern Thailand are examples of emerging conflicts. Although the conflicts originated over water, they have implications beyond water shortage: they reflect people's discontent with water scarcity. This discontent can lead to confrontation between groups with conflicting interests as illustrated in Figure 2.2, and it has the potential to escalate to political instability.

Figure 2.2 presents information showing that in any given year the intensity of conflicts will increase as the scope of conflicts decreases (moving from right to left along any curve). For example, in 1990 the water use conflict in Lam Ta Khong (described below) is confined to several spots along the stream. In ten years, as demand for water grows due to economic development, the conflict will expand to include more people.

The link between conflict and decreasing water availability is emerging throughout the following cases, and in each case, there is strong evidence that water is being overexploited and that a water shortage is looming.

Current Situation in the North

In Northern Thailand, water problems are also becoming more apparent, and competition for water for agriculture, energy, industrial and municipal use, tourism, and fresh water fish production can be found in a number of basins and subbasins in the region. Upland agricultural development, such as poppy replacement programs, are leading to direct competition with already established communal and public irrigation systems, and are particularly problematic. In addition, efforts to promote international tourism and economic development in the more isolated parts of the North are stretching available water supplies and are bringing about conflict with local ethnic groups as well as farmers. This problem is further compounded by deforestation that results in microclimatic changes and declining rainfall and runoff levels.

Northern Thailand covers an area of 170,000 square kilometers[2]—approximately one-third of the total land area of Thailand. Geographically, the Northern Region can be divided into two subregions: the Upper North Subregion and the Lower North Subregion. The Lower North Subregion includes the alluvial plains and terraces that comprise the upper delta of the Chao Phraya River, and the Upper North Subregion contains the main watersheds of the country. Both subregions contain a number of river basins where extensive irrigation projects have already been developed. The river basins in the North can be divided into: (1) international basins that provide part of the flow of rivers such as the Salaween River in Myanmar, the Mae Kok and Mekong rivers (The Lao People's Democratic Republic and Myanmar); and (2) national basins that eventually provide most of the flow in the Chao Phraya River.

Mae Klang: The Mae Klang Subbasin, a major tributary of the Ping River, was selected for this study because it represents a clear case of water conflict between upland and lowland water users. Originating in the western range which stretches north-south along the Thailand-Myanmar border, the Mae Klang River feeds a valley agriculture of about 7,000 hectares. The highest peak, Inthanon, is about 2,500 meters, and the rugged mountains, which stretch southward from Chiang Mai, are rich sources of tropical and subtropical rain forest, wildlife, and water. The Mae Klang River is 23 kilometers in length, and two-thirds of its length runs through steep hills before the river drops downward to serve the small valley prior to entering the Ping River.

The conditions in the Mae Klang Subbasin are favorable for rice, cash crops, and fruits, and the area is able to sustain multicrop agriculture when irrigation water is available. Rice production depends mainly on small, private/communal irrigation systems, but newly developed agricultural land in the upland areas is cultivated under rainfed conditions. There are more than 20 communal irrigation systems which divert water from four subbasins including Mae Klang. In the lowland areas of the Mae Klang Basin, the increased amount of land in intensive agriculture and the expansion of cultivated land has placed pressure on available water resources. This has resulted in a greater chance of conflict between farmers in the upstream and downstream zones during the dry months (from January to April). The short-term solution to this problem has been the use of a pumping system to serve the downstream section of the Mae Klang River which was installed with the full support of the Royal Irrigation Department (RID) and the local government.

An expansion in the number of settlements and population growth (2.5% to 4.5%) in the hill region above the valley has exacerbated conflicts over basin water supplies. With an estimated population of 4,000 families (an average family size is five to six people), hill people are now utilizing 18,000 hectares to support themselves. This has become a major threat to basin water resources because the reliability of the water supply has been dropping throughout the Northern Region as a result of watershed damage and deforestation. In Chiang Mai a total of 1,062 settlements of hill groups are presently settled in areas of Class I Watershed, wildlife sanctuaries, national parks, and public forest. Over the past five years, Chom Thong Watershed has undergone serious changes: 75 hill tribe settlements, of which 10 are located in the ecologically sensitive area, are now permanently settled in Chom Thong.

As a result of these new villages and the introduction of crop practices such as cabbage production to reduce the poppy-growing area, farmers in lowland and upland areas of Chom Thong are coming into direct competition. Out of about 5,000 hectares planted in cabbages in Northern Thailand, it is estimated that Chom Thong has almost 900 hectares in cabbage and produces more than 16,000 tons annually. These cabbage production systems compete directly with lowland farmers for dry season water supplies, and cabbage cultivation on steep slopes leads to erosion and sedimentation problems downstream, which increases the maintenance costs of the communal irrigation systems. A more dangerous problem is the indiscriminate use of agricultural chemicals which are creating a health hazard in the drinking water supplies in Chom Thong.

Despite the increasing concern and participation by local groups and organizations, there has been inadequate understanding on their part, and there has been no application of a basic approach to basin resource management. As can be seen from the letter sent by the Chom Thong Watershed Conservation Club to the prime minister (see Appendix 2). A video casette prepared by the club is also available). The local organization of people at Chom Thong is well organized and powerful. This organization has reported four major problems in the Mae Klang Basin as follows:

1. Irrigation water shortage
2. Sedimentation
3. Toxic chemical runoff
4. Poisoned drinking water

The present situation concerning upstream and downstream users is the result of conflicting policies on watershed conservation and highland agricultural development. Moreover, the current situation in the Mae Klang Subbasin reveals that previous development schemes have pushed two communities into a confrontation when "triple cropping" is encouraged in the lowland and year-round cabbage cultivation recommended in the highland. Without careful basin water resource design, conflict in such cases is almost inevitable. Even now, intensive development in the upper and lower basin is starting to reduce average annual flow in the Mae Klang River as can be seen in Figure 2.3.

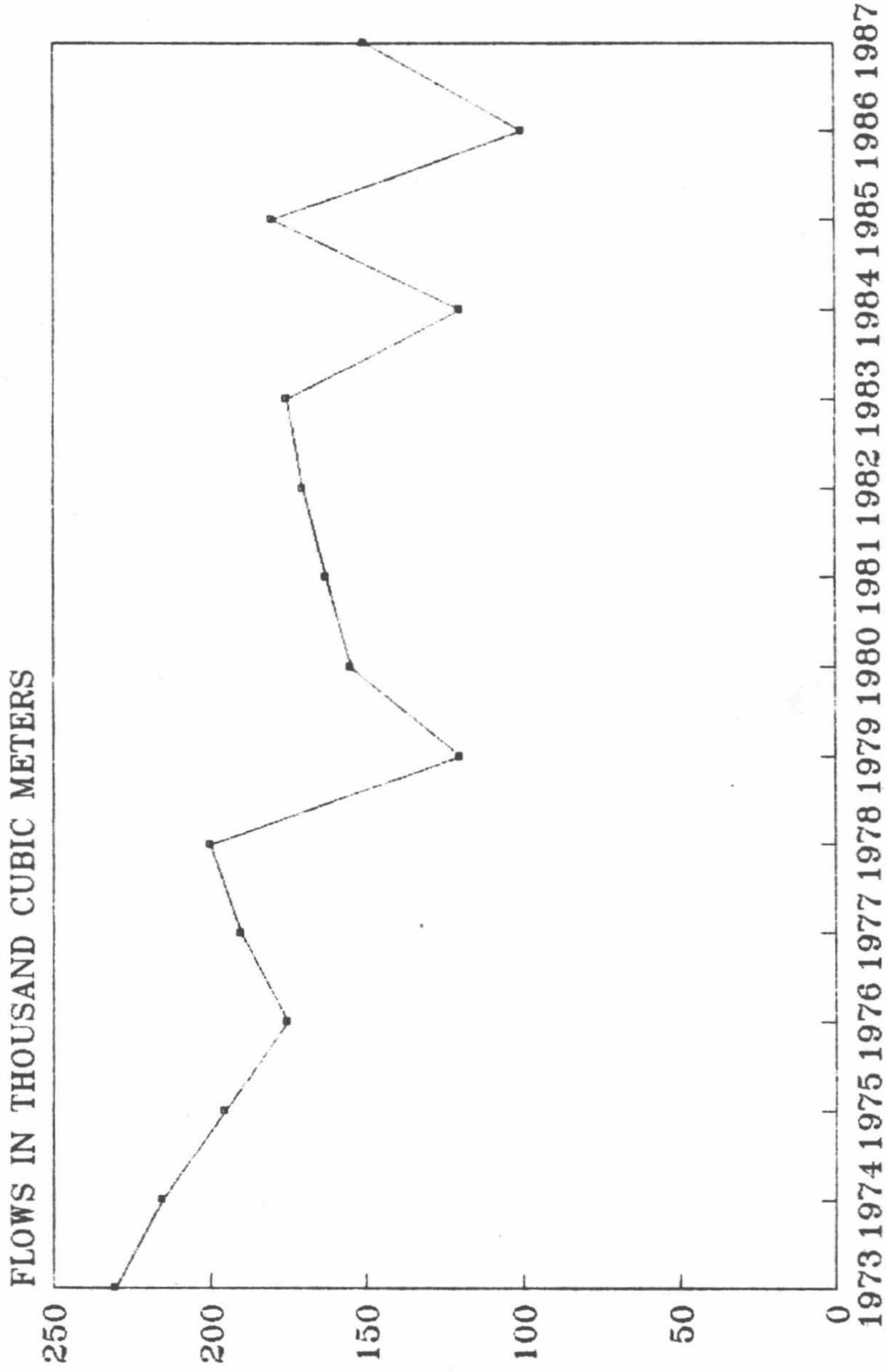

Figure 2.3 Annual Flows in Mae Klang

The most important and the largest river basin in Thailand is the Chao Phraya Basin which primarily serves the Central Region of Thailand. However, the headwaters for the Chao Phraya Basin originate in the mountain regions in the North. The flow in the Ping, Wang, Yom and Nan rivers in Northern Thailand determine, to a large extent, the quantity of water resources available to the Central Plains and to Bangkok. Therefore, even though this study selected subbasins in the North and Northeast regions, it must be recognized that the Northern and Central region are hydrologically linked. Nowhere is this fact more apparent than in the flows from the Ping River in the North into Bhumiphol Dam, one of the two major, large-scale dams supplying the Central Plains and Bangkok. As can be seen in Figure 2.4, the flow into Bhumiphol Dam has declined since 1975, primarily as a result of reductions in the flow of the Ping River.

The declining inflow to Bhumiphol Dam clearly reflects the rapid economic development and growth of the Upper North Subbasin, particularly in the province of Chiang Mai. In addition to the rapid expansion of municipal and industrial water use in the Ping Basin and its tributary basins, since 1975 the irrigated area in the Ping Basin has more than doubled and now is in excess of 300,000 hectares out of a total potential irrigated area of 625,000 hectares. In addition, industrial development has spread out of Chiang Mai and its suburbs and can now be found expanding rapidly in the subbasins of the tributary rivers such as the Mae Taeng and Mae Klang. This indicates that the flow in the Ping River will continue to decline, and the magnitude of water shortage at Bhumiphol Dam is likely to be even more acute in the future.

Current Situation in the Northeast

Northeast Thailand has historically had water problems because its semiarid climate tends to result in more frequent droughts than in the North. Competition for water for agriculture, energy, municipal and industrial requirements, tourism, and freshwater fish production can be found in both the basins and the subbasins in the region. A major source of conflict is evolving when situations where agricultural development for cassava replacement and reforestation programs are leading to direct competition with already established irrigation systems. The efforts to promote tourism and economic development are also seriously stretching the limited water supplies of the region, especially the supplies in the medium-scale irrigation reservoirs. These problems are particularly acute in the Northeast, where deforestation has been the most severe (see Figure 2.5).

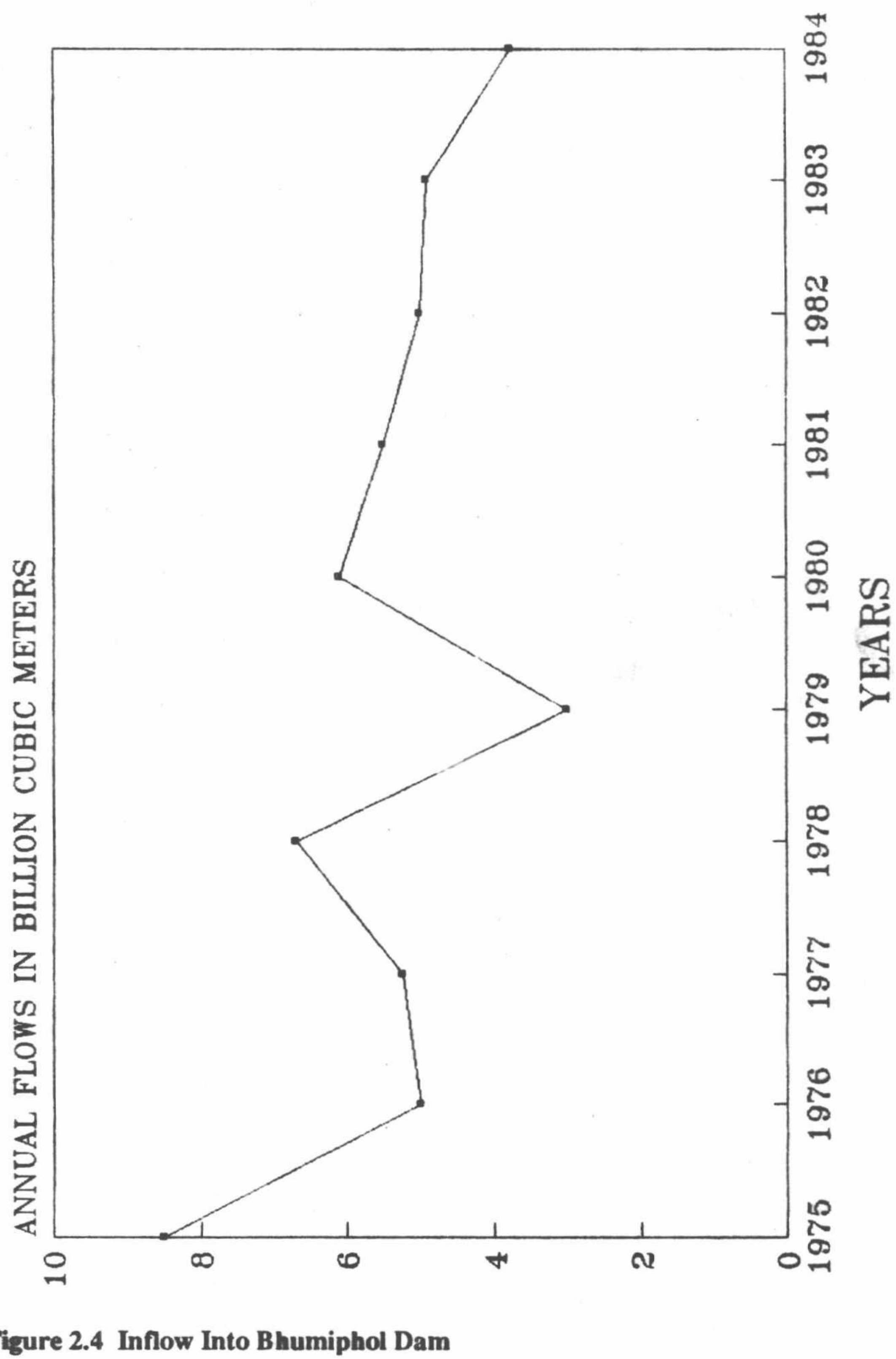

Figure 2.4 Inflow Into Bhumiphol Dam

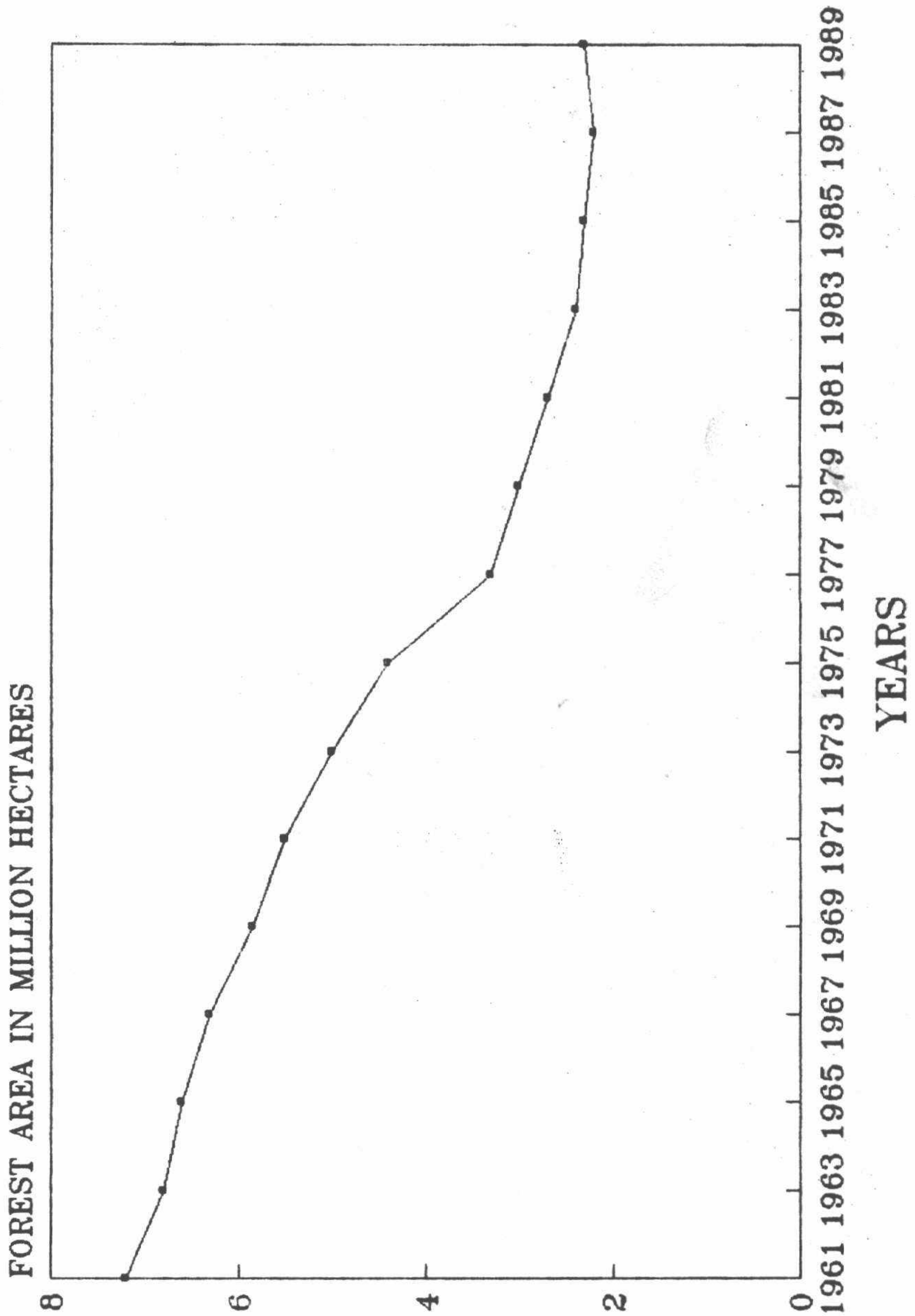

Figure 2.5 Forest Area in the Northeast

Northeast Thailand, which covers 170,000 square kilometers and has a population in excess of 18 million people encompasses one-third of the land area of the country and contains one-third of Thailand's population. In contrast to the Northern Region, Northeast Thailand does not drain into the Chao Phraya River, but, instead, drains into the Mekong River near Ubon Ratchathani due to the natural barrier created by the Korat Plateau. Northeast Thailand has three major basins: one international basin along the Mekong River and two internal basins along the Mun and Chi rivers that eventually join the Mekong River.

Erratic rainfall and generally poor soil condition contribute to low agricultural production and slow economic growth in Northeast Thailand. With the low levels of production and high population, the per capita income in the region is the lowest in the country. In contrast to the rest of the country, Northeast Thailand is classified as semiarid tropics because of the longer dry season. The longer dry season combined with the wide annual variation in rainfall makes irrigation a necessity for much of the region. Of the total 9.73 million hectares cultivated at present, about 0.9 million hectares have access to some form of public or private irrigation. Unfortunately, because of the rather limited water supplies, it is estimated that no more than 20 percent of the agricultural land in the Northeast is even potentially irrigatable.

Lam Ta Khong: The Lam Ta Khong Subbasin is a relatively large and long, contains the second largest city in Thailand, Nakhon Ratchasima, and there is competition for the available water supplies between a large number of users. The Lam Ta Khong reservoir has a storage capacity of 310 million cubic meters and was designed and built as an irrigation reservoir to serve a wet season area of 20,406 hectares and a dry season area of 8,000 hectares. The average annual inflow from 1969 to 1989 was approximately 259 million cubic meters. At present, in addition to the irrigated area along the canal, official and unofficial municipal and industrial users as well as the Thai Army Division II camp are increasingly using a large percentage of the available supplies.

The city of Nakhon Ratchasima pumps its water supply directly from the Lam Ta Khong as the river passes the city. Due to rapid growth in industrial development in the Lam Ta Khong subbasin and to the population explosion in the city and the surrounding district, Nakhon Ratchasima's available dry season water supply has dwindled over the past few years. Since upstream cities such as Pak Chong, large industrial producers such as C.P. Poly, and the Thai Army Area II military camp outside of Nakhon Ratchasima all have had first opportunity to take water from the Lam Ta Khong River, Nakhon Ratchasima's water situation during the dry season has become critical.[2] In order to address this problem, a direct pipeline from the Lam Ta Khong reservoir to Nakhon Ratchasima's treatment plant is in the final stages of construction under World Bank funding. When the 60 kilometer pipeline is completed, Nakhon Ratchasima's municipal and industrial water capacity will increase from 24,000 cubic meters per day to 93,000 cubic meters per day. More important, instead of having the last opportunity to take water from the Lam ta Khong Reservoir, Nakhon Ratchasima will be able to pump directly from the reservoir and, thus, have first opportunity to take as much water as they require; all other public and private users will have secondary access to the remaining water supply. Once the pipeline is completed, agricultural and nonurban industrial users will struggle to operate with an increasingly limited water supply.

Access to the direct pipeline will not only ensure Nakhon Ratchasima of a sufficient dry season water supply, it will also help reduce their treatment costs, since at present, the Lam Ta Khon River is treated as a drain by upstream users to dispose of wastewater. Thus, by the time the river has passed the city of Pak Chong and more than 100 industrial plants on its way down the basin, water quality is marginal. During times of low flow, water treatment costs increase rapidly due to the poor water quality.

THE EVOLUTION OF THAI WATER MANAGEMENT

The messages implied in the past two sections of Chapter 2 are clear but conflicting. The macro view suggests that Thailand has plenty of water to be used, but the micro view reports cases of conflicts resulting from insufficient supply of raw water.

While both of the above implications are true, the missing link is **water management.** In comparing the information on the macro situation between Thailand, Israel, and Belgium shown in Figure 2.6 (both Israel and Belgium are considered representatives of "water-advanced" countries) it becomes clear that with proper water management, water will not be a limitation to growth for Thailand for a long time to come.

The need for proper water management can be confirmed by tracing its evolution through three periods of differing water management focuses in Thailand that can be summarized as follows:

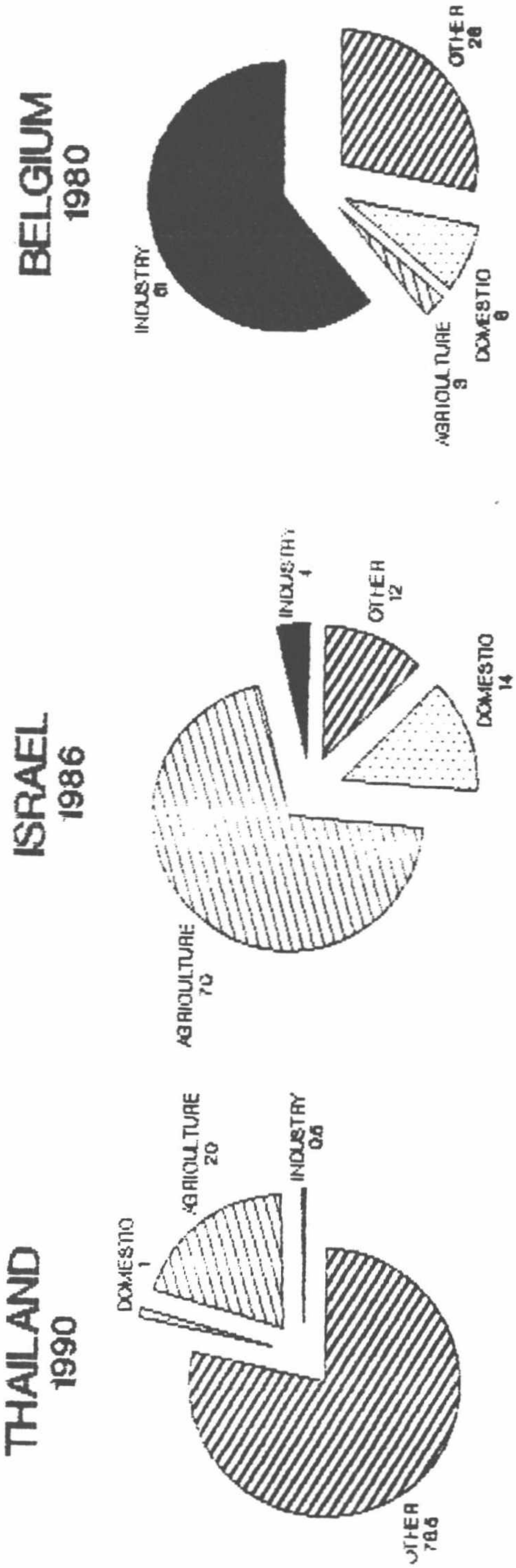

Figure 2.6 International Comparison of Water Quantity

The First Period, 1283 to 1857—*Managing People to Suit Water Conditions*: Water management was accomplished by moving people closer to or away from water sources as necessary; people were moved to areas with enough water for rice production and moved away from flood-prone areas. This could be easily done because (1) there was plenty of land, and (2) seasonal relocation was compatible with military activity and wars.

The Second Period, 1857 to 1990—*Supply-Side Management:* The country was relatively free from war and the stable production of rice for internal consumption and export was feasible. Earlier in this period water was viewed as belonging to the King who then distributed water on an as-needed basis through a government agency—hence the name Royal Irrigation Department. Most of the early water management effort was canal digging and water regulation (for example, the Rangsit canal network) for agriculture and transportation. As the population increased, the later efforts were concentrated on building reservoirs and expanding irrigation areas. During this period, water was still so plentiful that wastewater was sufficiently diluted and hence not an obvious issue.

The Third Period, 1990 to 2010—*Demand-Side Management*: At present Thailand is in a transition period between the end of the second and the beginning of the third period. In the third period, population and economic development pressures will dictate the nature of water management. In contrast to the first and the second periods, water management in the third period will be characterized by transport of water from distant sources to where the people and activities are, by control and regulation of wastewater, and by efforts to conserve water.

The subjects of supply management and demand management are discussed in Chapter 6.

In some aspects, the ultimate level of sophistication in water management will probably reach the level of controls currently used by the mining industry. Mining concessions must clarify the rights and liabilities of users and apply a sophisticated taxing system. As more activities compete for the relatively constant amount of water, water will gradually become more like precious ores; users will have to pay for it as well as for wastewater discharge, which will be charged for both quantity and quality. Water rights and allocation plans will have to be set up to minimize and mediate conflicts.

THE MARKET SHARE OF AGRICULTURAL WATER

Because agriculture uses the largest market share of water among all uses (see Figure 2.1) and its share will increase from the current 22 percent to 72 percent in 2010, and minor water saving in this sector will contribute significantly to the amount of water released for use in other sectors. The increasing percentage of its share also correlates with the urgency of saving efforts. Judging from other countries'experience, by the year 2000 when agricultural water uses account for about half of the total water availability, a systematic saving effort on a national level will be necessary in order to avoid a catastrophic water shortage. Roughly speaking, Thailand has ten years to prepare itself.

The present trend of population migration from agriculture to industry will not result in much water saving because most people are migrating from rainfed areas where little water is used. An alternative water-saving solution is to increase the efficiency of irrigation water use. Irrigation efficiency[3] in Thailand ranges from 30 percent to 70 percent, which is low compared to other water-advanced countries such as Israel, a view shared by RID officials and other experts.

Improving irrigation efficiency requires (1) incentive farmers' know-how and (2) know-how is secondary because it can be acquired if there is enough incentive, which comes from two sides as follows:

- Market Price of Agricultural Products: The price should be sufficiently high to attract farmers.
- Cost of Irrigation Water: Without any cost to use water, from the farmers' point of view, there is no need to save water.

Both of these elements must be applied in the right proportion to bring about improvement in irrigation efficiency. This is a complicated matter and beyond the scope of this study, and the following paragraphs, only the cost of water is discussed.

At present there is no national effort to charge farmers for water use in agriculture, and as in the cases of underpricing of pipe water and groundwater pumping discussed in chapters 3, 4, 5, inefficient water use is the result along with low irrigation efficiency.

The fact that there is no national effort to charge farmers does not mean that farmers are not willing to pay. Field interviews with farmers in irrigation "command" areas[4] indicate that they are willing to pay if water availability is guaranteed[5]. Evidence of farmers willingness to pay—or the fact that they are already paying—are plentiful. For example, in the Mae Klang Subbasin discussed earlier, there are a number of traditional irrigation systems. The irrigation management in these systems is done by farmers and is much more sophisticated than any government-operated systems. The farmers benefitting from the irrigation system pay for its operation and maintenance by contributing labor for annual maintenance and rice for the salary of operators. Fines are also effectively imposed. The management of these irrigation systems has been refined for several hundred years and is fully integrated into the social settings. However, these systems are currently being replaced by concrete dams due to recent economic development.

To require farmers to pay for water, two other components are necessary as follows:

1.The water rights of different groups of users must be clearly specified.

2.A water allocation plan must exist to reflect realistic water-use activities.

The reasons for linking these three components (that is, irrigation water charges, water rights, and water allocation plans) are that the concept of charging for water alone will be met by resistance from those who are required to pay unless they know what they will get in return, and this implies water rights specifications. In order to specify water rights, it is necessary to know how much water is available and the quantity "required" by various users. Without such knowledge, water rights specifications will be unrealistic, which demonstrates the need for water allocation plans. Chapter 7 explores these components as a part of the overall policy adjustment recommendations.

Endnotes

1 The water (or hydrologic) cycle is a natural process whereby water evaporates from the ocean to become clouds. Some clouds move inland and become rain, precipitating onto land below. A part of the precipitation percolates into the earth to become groundwater, while some additional water flows overland to rivers or trapped in reservoirs or other water impoundments. Eventually all land-based sources of water flow back to the ocean, and the cycle repeats itself.

2 At present, 25 organizations, industrial plants, and other assorted water users are paying a monthly water fee to the Lam Ta Khong Project Office for the right to pump water from the Lam Ta Khong Channel. The fee varies from 225 baht per month to 8,205 baht per month for an estimated water supply of 1,500 m^3 per month to 42,500 m^3 per month, respectively.

3 Irrigation efficiency is defined as the ratio between the amount of water that a plant fully absorbs plus the unpreventable loss of water from plant irrigation over the total amount of irrigation.

4 Command areas are under irrigation command by operators.

5 Data are from prepared notes of the RID Deputy Director General. The note was used for presentations on several occasions during 1989.

Chapter 3

Water Management in Bangkok

The Bangkok water supply is analyzed in Chapter 3 in order to identify suitable water-pricing measures. In the process of analysis, the value of price elasticity of demand is determined, and is then used to illustrate how price can be used to control demand.

In addition, a discussion of Bangkok's background leading to the present water supply problems is followed by a review of the agency that is being assigned responsibility of these water problems: The Metropolitan Waterworks Authority (MWA). A subsequent informative section on water pricing history leads to concluding discussions on the following: (1) the response of water demand to water price, (2) how price affects demand and is a measure of its strength (the price elasticity of demand), (3) the interdependency of price and revenue, and (4) future water demand using the results obtained from earlier sections.

BACKGROUND OF BANGKOK

Bangkok,[1] the capital city of Thailand, was founded in 1781 by King Rama I, who probably selected the location for national defense and to be a symbol of prosperity and national pride. At present, Bangkok is not only the capital city, but is also a port city, a commercial center, and an administrative center, and has experienced high levels of population growth for several years as shown in Figure 3.1 At present (1990) the population is somewhere between six million and eight million. (The lower figure represents the population registered under the Ministry of Interior (MOI) census, while the higher figure is believed to be closer to reality.) The National Statistical Bureau (NSB) is in the process of updating the census survey, which should yield a more accurate estimate of Bangkok's population.

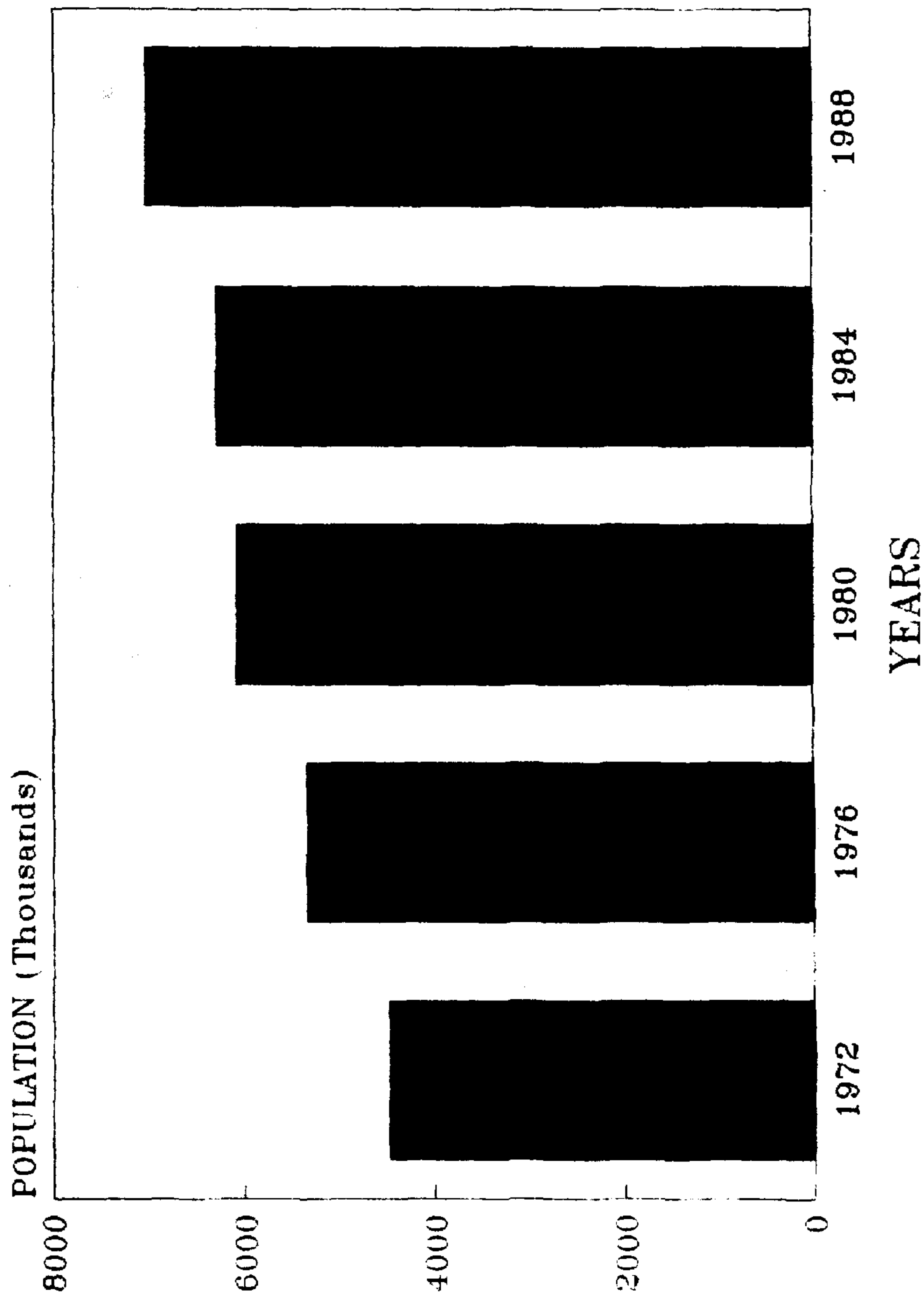

Figure 3.1 Growth of Bangkok

According to the World Bank (1989), Bangkok, which still has sufficient undeveloped land to accommodate considerable expansion, will continue to grow and will remain the leading industrial center of Thailand.

On the other hand, Bangkok is facing several environmental problems including the following:

- Air pollution
- Slums and resettlement
- Traffic jams
- Water-related problems
  - River pollution[2] (caused by wastewater discharge from households and industries)
  - Land subsidence[2] (due to overpumping of groundwater)
  - An apparent lack of raw water supply (to convert into pipe water)—the subject of this chapter

Bangkok's Water Supply

Bangkok pumps the majority of its raw water supply from the Chao Phraya River near Bang Pa-in, and a minor amount is obtained from deep wells that are being phased out to remedy the land subsidence problem. There is a danger of the quality of the raw water supply does not seem to be a problem yet, however, raw water quantity being insufficient. There are alarming indications that the Chao Phraya River will not be able to deliver sufficient flow for various requirements including MWA pumping, irrigation, fighting seawater intrusion, conveying wastewater that is being directly dumped into the river, etc.

To relieve the insecurity of depending on the single raw water source at Bang Pa-in, it is essential that alternative and additional raw water sources be sought. The MWA has pushed for, and has recently obtained, permission to lay canals to bring raw water from the Mae Klong River and the Tha Chin River. These rivers, which are not located in the same basin as the Chao Phraya River, require a transbasin water transfer that is inevitable and logical. There is one danger: in the long run (20 years to 50 years), when the irrigation area of the Mae Klong River is fully developed, there may not be enough water for a transbasin transfer (Chalong 1990).

There are several problems in the MWA's pipe network; the most important one is water that is unaccounted for (for example, pipe leakage). The MWA is well aware of these problems which are being systematically addressed. However, for the sake of strategic planning, three areas must be addressed as follows:

1. **Accessibility**: Pipe water accessibility must be increased to cope with the rapid increase in water requirements and to discourage groundwater pumping, especially in industrial areas.
2. **Reliability**: The unreliability of pipe water encourages seeking alternative sources—usually groundwater pumping. Because groundwater pumping causes land subsidence, pipe water reliability must be increased.
3. **Quality**: At present, pipe water is only potable in limited areas, which partially explains why bottled water has become popular and its processing and sale is a large business. It is unclear whether eliminating bottled water while improving pipe water is good for the country. However, there is no reason why pipe water quality should not be improved so that it can be drunk if desired, as is usually the case in other developed countries.

THE METROPOLITAN WATERWORKS AUTHORITY: ROLE AND RESPONSIBILITY

The MWA is the state enterprise responsible for pipe water supply throughout the Bangkok Metropolitan Area (BMA). The authority is governed by a board of directors comprised of senior government officials and representatives from the private sector.

Data Collection on Water Use in Bangkok

The MWA's in-house data collection procedure is systematic and above average compared to other Thai agencies. Annual reports have been available since 1985, and extracts from annual reports are also available in the form of a colorful leaflet entitled *Annual Performance Statistics*. The analysis done in Chapter 3 relies heavily on data taken from these sources.

HISTORY OF WATER PRICING

The water prices charged to customers by the MWA must be approved by the cabinet.[3] The cabinet approval process is as follows:

- The MWA prepares the price structure subject to the agency's internal and MWA board review.[4]
- The price structure is then passed on to the cabinet through the MOI, which oversees the MWA. The process can take several years and is subjected to many levels of scrutiny.

Water charges have been in effect in Bangkok since 1914, and Figure 3.2 illustrates the ranges of prices charged to customers over the years. Table 3.1 shows the present pricing system. Since the inception of the pricing system, the pricing features (the idea behind price setting) have also undergone tremendous, important changes. These changes are summarized below:

Periods	**Pricing Features**
1914 to 1945	NPR
1945 to 1958	CR
1958 to 1972	CR+Z
1972 to 1981	PR
1981 to 1988	PR+T1
1988 to present	PR+T2

The abbreviations used have the following meanings:

PR = Progressive Rate: The more cubic meters used per month, the higher the unit price charged.

NPR = Inverse Progressive Rate: The opposite of progressive rate.

CR = Constant Rate: A constant unit price is charged irrespective of the amount used.

Z = Zoning, i.e. rate that depends on area.

T1 = Classifies three types of customers:

1. Domestic
2. Business and government and enterprises,
3. Government agencies

T2 = Same as T1, but add Industry as Type 4.

One difficulty with a complex price structure is it cannot be used to compare annual performance or for other accounting requirements, but is only good for charging customers. Another price, the "effective price," is used instead, and is found for each year by dividing the revenues from the sale of water by the amount of water sold in cubic meters. The annual effective price figures released by the MWA are presented in Figure 3.2 and are plotted in comparison with the price ranges mentioned earlier. It is not

Table 3.1 Water Tariffs in Bangkok

Category 1: Residence		Category 2: Business State Enterprise, Government Agency, Others		Category 3: Industrial	
Volume (cu. m.)	Rates (baht/cu. m.)	Volume (cu. m.)	Rates (baht/cu. m.)	Volume (cu. m.)	Rates (baht/cu. m.)
0-30	4.00 (but not less then 20 baht)	0.1	Package rate 50 baht	0-10	Package rate 50 baht
31-40	4.25	11-20	6.20	11-20	6.20
41-50	4.50	21-30	6.45	21-30	6.45
51-60	4.75	31-40	6.70	31-40	6.70
61-70	5.00	41-50	6.95	41-50	6.95
71-80	5.25	51-60	7.20	51-60	7.20
81-90	6.15	61-70	7.45	61-80	7.45
91-100	6.40	81-100	7.70	81-100	7.70
101-120	6.65	101-120	7.95	101-120	7.95
121-160	6.90	121-160	8.20	121-160	8.20
161-200	7.15	161-200	8.45	161-200	8.45
Over 201	7.65	Over 201	8.70	201-2000	8.60
				2001-4000	8.40
				4001-6000	8.00
				6001-10000	7.50
				10001-20000	7.00
				20001-30000	6.50
				30001-40000	6.00
				40001-50000	5.50
				Over 50001	5.00

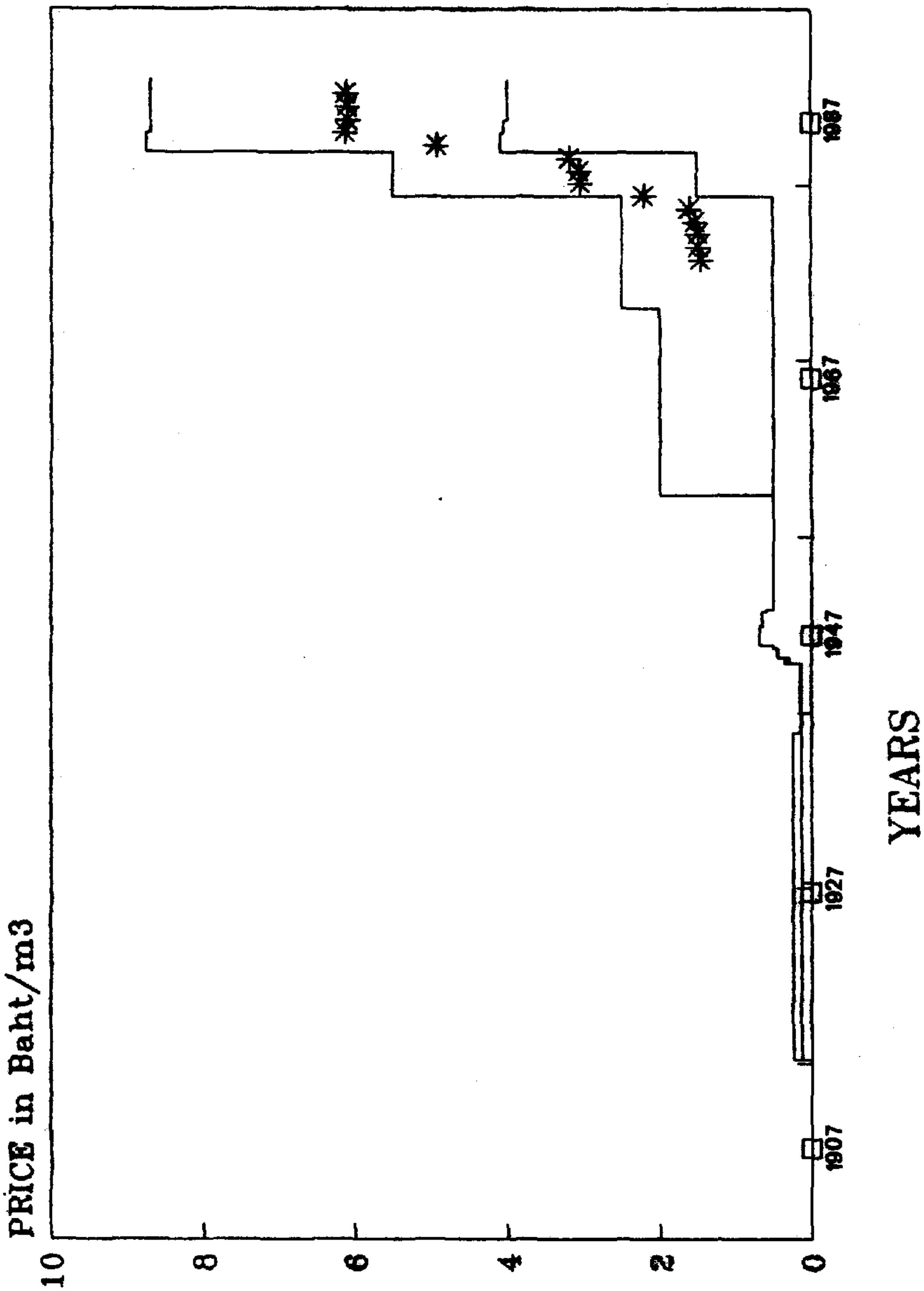

Figure 3.2 Water Pricing: Bangkok

surprising to find that the effective price is always within the price range used in the price structure, and that it is about half way between the maximum and minimum values.

WATER DEMAND RESPONSE TO PRICE CHANGE

Price is not the only factor affecting water demand; other factors include number of users, users' income, service sector output, or even climatic factors. It is impossible to account for all the factors contributing to water demand due to limited data availability. Therefore, only important factors were identified. By using linear regression techniques, it was found that the price of water, the number of users or meter connections, the per capita income, and the output from service sector (including government enterprises and government agencies) are the most important factors determining water demand in BMR. The relationship between water demand and these factors was found to be:

For residential sector water demand:

$$\ln Q_R = -2.55\ln P + 0.81\ln I + 0.68(\ln P)(\ln P) + 0.07(\ln U_R)(\ln U_R)$$

For service sector water demand:

$$\ln Q_S = -4.47\ln P + 0.87(\ln U_S)(\ln P) - 0.2\ln O\ 0.14(\ln U_S)(\ln O)\ 0.13(\ln P)(\ln P)$$

The quantities in these relationships are annual values with the following units:

- Q_R, Q_S = Water sold to residential and service sectors espectively (million cubic meters)
- P = Real minimum price of water (Baht per cubic meter per month)
- I = Real per capita income (Thousand baht)
- U_R, U_S = Number of users in residential and service sectors respectively (Thousand)
- O = Output of service sector (billion baht)

Data used and detailed computations are given in the Appendix. The expression "ln" indicates natural logarithm (logarithm of base 2.72).

The combined water demand (residential and service sectors) is assumed to be the total water demand because it accounts for more than 99 percent of the actual total water demand. Residential water comes from household water uses while services water demand comes from water uses in business, government enterprises, and government agencies. Separation of water demand in this fashion is in line with MWA's practice.

The response of water demand to price is known as "price elasticity of demand" or Ep and can be determined[5] from the above relationship to be -0.28 for residential water. Similarly, other elasticities can also be determined. Their values are shown in Table 3.2.

Table 3.2 Values of Elasticities

Elasticities	Residential Sector	Service Sector
Real price	-0.28	-0.31
Income per capita	0.48	--
Number of users	0.79	0.98
Service sector output	--	0.45

The regression equations, although approximate, can be used to answer two important questions as follows:

1. What will be the effect on demand for water of a price change and the subsequent effect on revenue?
2. What is the expected water demand in the future? The next two sections answer these questions.

THE EFFECT OF PRICE ON DEMAND AND REVENUE

The response of residential water demand to change is water price is slightly less elastic than that of the service sector. The elasticities of demand obtained indicate that a 10 percent increase in price will reduce water demand in residential sector by 2.8 percent and service sector by 3.1 percent.

Demand management can be done through appropriate price setting. Water use should be charged according to its full marginal cost. Appropriate price setting not only regulates water demand but also recovers full cost of supply and provide incentive and resources for supply expansion. The importances of the two effects through price changes are illustrated below.

Table 3.3 Changes in water demand and revenue resulting from a price increase.

Scenario	Price (Baht/cu.m.)	Quantity (Miillion Baht/cu.m)			Revenue (Million Baht)		
		Residential	Services	Total	Residential	Services	Total
Base	6.2	400	300	700	2,480	1,860	4,340
With price increase	9.0	349	258	607	3,141	2,322	5,463
Change	+2.8	-51	-42	-93	+661	+462	+1,123

The estimated water consumption and price for 1990 is used as a base scenario. Based on the price elasticities of demand and assuming water price increases from the effective rate of 6.2 baht per cubic meter per month to 9 baht per cubic meter per month, water demand declines by 13 percent and the revenue increases more than a quarter (Table 3.3). Thus, a less than 50 percent increase in the effective price reduces the pressure on water supply by more than 90 million cubic meters. In addition, more than 1.1 billion baht of revenue is generated. This additional revenue can be used to expand supply by more than 120 million cubic meters of water at an average cost of 9 baht per cubic meter.

The above procedure does not apply to large price increases above the current price. The response to price increases is reduced as consumption approaches the subsistence level. Beyond certain level the increase in price may not result on any reduction in the quantity of water demanded but the resulting grievance and hardship can lead to social and political pressure.

One way to avoid these problems is to be selective in raising prices, for example, in all three categories of Table 3.1 except the top half of Category 1. This action will ensure that low-income families will not suffer from a price hike in water rates while well-off families, business, and industry will pay the proper amount.

FUTURE WATER DEMAND IN THE BANGKOK METROPOLITAN AREA

Given the above elasticities of demand, a constant real price, and the projected growth in income, in output and in the number of users, water demand in the next two decades is projected (Table 3.4). If per capita income grows at 5 percent per year and number of residential users grows at 7 percent per year, residential water demand is projected to grow at about 9 percent per year. At the growth rate of 7 percent per year of service output and service users, water demand in the service sector will increase at 10 percent per year. Water demand of the two sectors more than doubles bringing total water demand in the year 2000 to 1.6 billion cubic meters. At a slightly lower rate of growth of per capita income and service output, total water demand in the year 2010 will be 3.5 billion cubic meters, with about equal share between the two sectors (Table 3.4)

With 30 percent allowance for leakage, total pipe water requirement in the year 2000 will be more than 2 billion cubic meters and reach 4.6 billion cubic meters in the year 2010. The projected growth rate of water demand in the next two decades is more than 10 percent compared to that of MWA of less than 4 percent. In addition marginal cost of water supply of MWA is increasing (more in Chapter 6) due to the increasing distance and scarcity of raw water supply.

Thus, unless prices are allowed to adjust according to the full cost of supply, the continued expansion demand will ultimately result in increasing subsidy of the urban water users by the society at large.

Table 3.4 Water Demand in the Year 2000 and 2010 at Constant Real Price

Year	Growth per Year (%)					Water Demand (Mil.cu.m.)		
	Real Income	Residential User	Service User	Service output	Real Price	Residential	Service	Total
1990	-	-	-	-	-	400	350	700
2000	5	7	7	7	-	858	708	1,566
2010	4	7	7	6	-	1,760	1,766	3,526

Endnotes

1 The name "Bangkok" has two meanings: (1) the inner city area roughly corresponding to the territorial responsibility of the Bangkok Metropolitan Area, and (2) the area in the first meaning plus the surrounding cities. In this paper, Bangkok means roughly the latter.

2 See reference section for Winai (1989) and The Asian Institute of Technology (1987), respectively, for the most up to date situation.

3 The same is also true for the Provincial Waterworks Authority's (PWA) water price charges. However, the MWA and the PWA use different price structures. The MWA's price applies only within its territorial responsibility—i.e. the Bangkok Metropolitan Area. The PWA's price applies uniformly to other areas of the country.

4 A water-pricing structure can be very simple or very complex. In its simplest form, every customer is charged a flat rate irrespective of the amount of water used. This form of water charge requires no water meter. See Table 3.1 for an example. The price structure is also known as "block rate."

5 By definition, Ep = PdQ/Qdp which is equal to d(lnQ)/d(lnP) and can be obtained by differentiating the equation. Therefore E = -2.55 + 0.69lnI. From the same data set used to determined the equation, the mean values of lnI (= 3.09, see Appendix) is substituted into the expression for Ep above to yield Ep = -0.28.

Chapter 4

Water Management in Pattaya

An increase in the price of pipe water is the single most important tool for alleviating the water shortage problems in Pattaya. To support this price increase, Chapter 4 provides readers with the general background of Pattaya, focusing on its rapid growth as a result of the tourism boom and the ensuing water problems. The role and responsibility of the agency assigned to Pattaya's water supply, the Provincial Waterworks Authority (PWA), is discussed mainly to show the agency's responsibility in comparison to its constraints and its built-in inflexibility. A subsequent discussion of the history of water pricing in Pattaya is followed by a section on the determination of response of demand to price changes. The strength of this response in numerical terms is discussed in terms of price elasticity of demand which is used to estimate how much price should increase and how much revenue will be generated as a result. In the process, other factors linking tourism to water demand are also identified. Their effects on water demand are discussed in the last section.

BACKGROUND OF PATTAYA

In 1740 when King Taksin the Great landed his troops in Pattaya on his way to recapture Ayutthaya (which was then the capital of Thailand), Pattaya was a quiet, small, unknown fishing community, and it remained so until three decades ago. Since then, the United States armed forces have also made occasional landings for different purposes. While these two independent events are several hundred years apart, they demonstrate Pattaya's convenience—it can offer rest and housing for a large quantity of people for a short period of time, and a close proximity to the target areas of Ayutthaya and Bangkok which were, and are, urban, cultural and military centers. Today the continuous and increasing stream of short-term visitors and tourists together with supporting local residents consume more pipe water than the available supply. It is important that action be taken to alleviate this problem and to retain Pattaya's fame (and much-needed foreign exchange) as the tourism capital of Thailand.

Pattaya's mass tourism started approximately 25 years ago, but before that, it was well-known only among Thais for its long, clean, quiet sandy beach. The construction of the expressway connecting Bang Na and Cholburi—which also provides convenient access from Bangkok—accelerated Pattaya's growth as a holiday resort initially among Thais, and later for foreigners. Tourism was further boosted by the occasional visits of United States' troops during the Vietnam War. Later, the government's promotion of tourism brought Pattaya to international attention, and it has remained there ever since. Tourism brings not only tourists, to Pattaya, but also local residents, who provide services. At present (1990) the total number of people visiting or residing in Pattaya is 2.5 million: 95 percent are tourists (30 percent Thai, 65 percent foreigners), and the remaining 5 percent of the population are Thais who are primarily in the service industry. The annual growth rates are 22 percent, 17 percent, and 5 percent for Thai tourists, foreign tourists, and the service sector, respectively.[1]

Pattaya's Water Problems

In addition to problems of drugs, prostitution, seashore pollution, and crime, Pattaya has a chronic problem with the shortage of pipe water. For the past three consecutive years during the dry months of March, April, and May, complaints and grievances have been frequently heard, and the problem has been covered in both the local and the national mass media. The degree of shortage can be gauged from the proliferation of water vendors who sell water in truck loads to customers and from the willingness of customers to pay for alternative water in comparison to the price of pipe water: the price of alternative water at peak times ranges from 20 baht per cubic meter to 50 baht per cubic meter, while the price of pipe water is only 10 baht per cubic meter, when and if it is available.

One solution to this problem is to increase the price of pipe water. With the superior quality and accessibility of pipe water, its price (when and if it is available) can be increased up to five times, and the price increase will result in increased revenues and a reduction in water consumption. The increase in revenue can be used to fund an expansion of the raw water collection and pipe network. (The quantity of the revenue increase and the water savings can be estimated from the value of price elasticity of demand which is discussed in a later section.) However, the solution cannot be implemented because of policy obstacles and issues which are discussed in Chapter 7.

An overload of wastewater treatment demand has also created two problems for Pattaya, which has the most modern wastewater treatment plant in the country, but cannot cope with the wastewater load.[2] However, the main problem here is not technical, but rather financial; the collection of the fees from wastewater customers is difficult. One solution that has been successfully used in other countries, however, is to include wastewater fees in the price of pipe water, and Chapter 7 recommends this as part of the package of recommendations.

Development Perspective of Pattaya's Pipe Water Supply

According to the PWA Region 1 records, the pipe water supply in the Pattaya area started in May 1971 with fresh water produced at a capacity of 80 cubic meters per hour and raw water being pumped from the Nong Prue Reservoir. In April 1981 the production capacity was increased to 1,000 cubic meters per hour by enlarging the plant, and raw water was taken from the Mab Prachan Reservoir. The water shortage started to be serious in 1989, and the production capacity was accordingly increased to 37,000 cubic meters per day by overloading the plant. However, even at this overload capacity, the shortage continues, and the PWA estimates the actual requirement to be 45,000 cubic meters per day.

According to PWA officials, the shortage is mainly due to shortage of raw water rather than due to plant production capacity. Plans have been drawn up between the PWA, The Provincial Waterworks Department (PWD), and the Royal Irrigation Department (RID) for short-term and long-term solutions.[3] In essence, these plans rely on building a number of reservoirs and conveying water to Pattaya and its adjacent areas including Cholburi. These reservoirs will be adequate if they are to supply raw water only to Pattaya and its surrounding towns. However, the raw water supply plans for the Eastern Seaboard Development Project, which is a separate set of plans, also call for the services of these reservoirs, and it is doubtful whether the two sets of plans have been coordinated.

ROLE AND RESPONSIBILITY : THE PROVINCIAL WATERWORKS AUTHORITY

According to a Royal Decree in 1979, the PWA is responsible for the pipe water supply in all communities except Bangkok (which is under the Metropolitan Waterworks Authority (MWA). In reality, there are a number of independent systems being operated by municipalities and private enterprises. The government's ministerial cabinet controls pricing, and the process of price adjustment is the same as the MWA's process described in Chapter 3. The PWA's present cabinet-approved price is shown in Table 4.1. This price structure applies to every water system under the PWA including those serving Pattaya. Like the MWA, the PWA is governed by a board chaired by the minister of the interior. Pertinent information on the PWA can be found in a number of references.[4]

PRICING OF PIPE WATER

Historical Perspective

In 1971 when pipe water was first available in Pattaya, the price was two baht per cubic meter. This price was applied until 1981 when the pricing structure changed from a single uniform price to a progressive rate (see Chapter 3 for a description of the progressive rate system). Progressive rates have been used ever since with some adjustment of prices within each price block. Figure 4.1 presents information summarizing the water-pricing history of Pattaya by showing the maximum and minimum price against time, and Table 4.1 shows the present pricing structure which applies to all locations under PWA supervision, including Pattaya. This pricing structure is not the same as that used by the MWA (for Bangkok) or those used by municipalities and private systems beyond PWA control.

The effective water price for Pattaya, which is obtained by dividing the revenue by the volume of water sold, is calculated by the PWA against time as shown in Figure 4.1. The relationship between maximum, minimum, and effective prices can be explained as follows: (1) the minimum and maximum prices are prices set by the MWA, (2) the effective price is the response to the set prices. Rich communities with a tendency for high water consumption rates usually show effective price closer to the maximum end. The behavior of effective price closer to the maximum end. The behavior of effective price during changes of set prices also indicates the elasticity of demand. For example, in 1984 when maximum and minimum prices were raised to 8.5 baht per cubic meter and 3.75 baht per cubic meter, respectively, the effective water price of Pattaya dipped and eventually shot up.

Table 4.1 The PWA's Present Water-Pricing Structure

Volume Used Per Month cu.m.	Rate (Baht per cu.m)
0-10	3.75 but not less than 15 baht
11-20	4.5
21-30	6.5
31-50	7.5
51-80	8
81-100	8.5
101-300	9
301-1000	9.25
1001-2000	9.5
2001-3000	9.75
3001 onwards	10

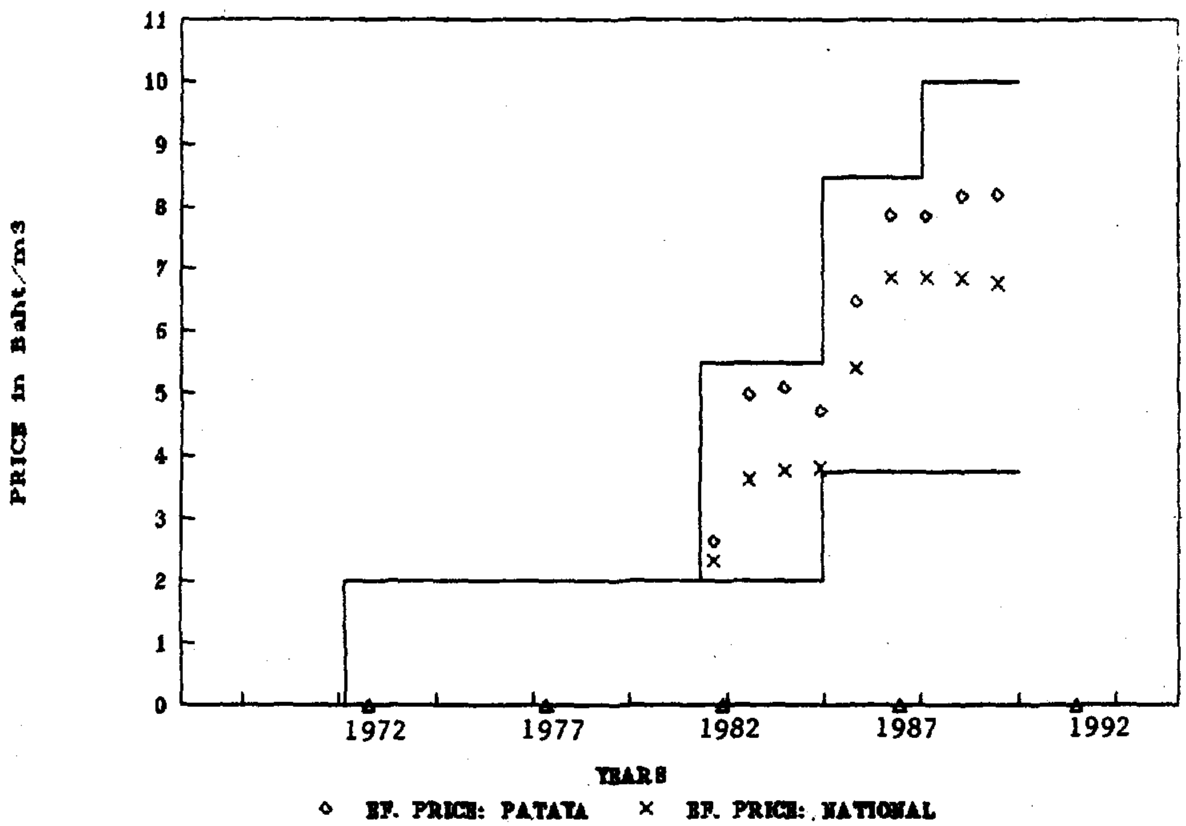

Figure 4.1 Water Pricing: Pattaya

Comparison with the National Average

In Figure 4.1, the effective price determined for the whole country (the PWA revenue for the whole country divided by volume of water sold for the whole country) was also shown to contrast with the Pattaya's effective prices. Two points are noted as follows:

1. Pattaya's effective price is always higher (and thus closer to the maximum) than the national effective price. This implies higher water use by Pattaya's better-off population, including hotels and private homes, when compared to the national average.
2. During a water price change, for example, Pattaya's effective prices fluctuated (down and up) more than the national average. This implies Pattaya's higher sensitivity to price changes. That is, in the more affluent areas of Pattaya, water use is less of a necessity and more of a luxury and, hence, more easily dispensable than the water-use needs of less-affluent consumers.

The two points noted above all lead to one conclusion: pipe water in Pattaya is underpriced, which implies inefficient water use.

Water Demand Response to Price Change

By using the linear multiple regression technique, the price elasticity of demand (E) was estimated to be -0.41. In this technique, the real minimum price of pipe water (P), number of tourists (T), and available hotel rooms (R) were used as independent variables dictating the response of water demand (Q). The equation approximating the relationship was found to be:

$$Q = -0.76P + 3.55T + 0.54R$$

The units for these variables on an annual basis are as follows:

- Q = million cubic meters
- P = Baht per cubic meter per month
- T = Million persons
- R = Thousand rooms

From the equation, Q responds negatively with price and positively with the number of tourists and hotel rooms. Water demand, given price, number of tourists, and hotel rooms, behaves as expected. When this factor is coupled with the relatively high effective price in Pattaya described earlier, it is quite clear that water price in Pattaya can be increased to encourage efficient use without causing hardship.

Pattaya's value of price elasticity is substantially higher than Bangkok's, which is only between -0.28 to -0.31 (see Chapter 3). If Pattaya represents a tourism boom, while Bangkok represents an urban boom, it can be said that a city based on tourism is more responsive to price changes than a city based on stable, domestic growth.

The Use of Price in Demand Management

The existing water shortage in Pattaya, particularly in the dry season, is about 8,000 cubic meters per day. There are two alternatives to resolving the problem—increasing supply or reducing demand. In either approach appropriate price is called for and should cover the full cost of supply and reflect the true value of resources to consumers. The present price setting for Pattaya does not reflect the full cost of supply which includes reservoir construction cost, wastewater cost, and the opportunity cost of water. Thus, part of the PWA profit is essentially an indirect subsidy from the taxpayers. An increased expansion of the water supply simply means more subsidy to the better-off segments of society.

To appropriately allocate water resources to Pattaya, the costs of supply must be reflected in price setting. As mentioned earlier, during water shortage periods, Pattaya's water consumers paid five times as much the pipe water rates for travelled-in water which is of a lower quality. This shortage can be resolved through the price changes which are illustrated below. Let us assume that we want to reduce water consumption from 45,000 cubic meters per day to 37,000 cubic meters per day (a reduction of 8,000 cubic meters per day) by increasing price. To do so, two basic questions are pertinent as follows:

1. How much should the price be increased?
2. Will there be any change in revenue?

The use of elasticity (E) in answering these questions is elaborated below.

The shortage of 8,000 cubic meters per day translates into a shortage (dQ) of 2.9 million cubic meters per year. Using the 1989 water production figure of 12.17 million cubic meters as Q, $dQ/Q = -2.9/12.17 = -0.238$. By definition of E, $E = (dQ/Q)/(dP/P)$, and hence $dP/P = (dQ/Q)/E = 0.58$. (The value of E is -0.41). Since $dP/P = (Pn - P)/P$ where P is the present price (10 baht per cubic meter) and Pn is the new price, Pn is computed to be 15.8 baht per cubic meter. Thus, to reduce water consumption by 2.9 million cubic meters, water price must be increased by 58 percent or from the present effective rate of about 10 baht to 15.8 baht per cubic meter per month.

The change in revenue can be estimated as shown in Table 4.2 in which the figures on prices and quantities are taken from the preceding information, while revenue is the product between price and quantity. The quantities are deducted by 30 percent to account for leakage.

Table 4.2 Estimation of Change in Annual Revenue due to Price Increase

Scenario	Price (P) Baht/m^3	Quantity (Q) Million Baht	Revenue(R) Million Baht
Existing situation	10	70% of 12.17	85.2
With price increase	15.8	70% of 12.17-2.9	102.5

Therefore, with a price increase from 10 baht per cubic meter to 15.8 baht per cubic meter, revenue will increase by 17.3 million baht. This estimate is believed to be on the conservative side. The reduction in Q due to the price increase is likely to be picked up by users who, before the price increase, did not have enough water pressure in their pipes and, hence, no water. The increase in revenue can be used to expand pipe networks or to secure more raw water supplies. A wastewater fee should realistically be added to the above price increase, and the additional revenue should be given to the agency monitoring the wastewater treatment plants.

THE GROWTH OF TOURISM AND WATER DEMAND

The growth of tourism in Pattaya (which is measured in units of "tourist nights") is forecasted by the Tourism Authority of Thailand (TAT) to be 16,397 thousand days in 1996. An extension of TAT's forecast reveals that by the year 2010, tourist nights will increase fourfold from the present. Using an average value of five nights per tourist, the number of tourists can be estimated. Assuming that the number of hotel rooms increases with the number of tourists, according to some specific relationship, the water demand (Q) in million cubic meters can be estimated. Table 4.3 summarized these estimates Appendix 3 provides further details.

Table 4.3 Summary of Growth Predicted for Pattaya

Year	Tourist Nights (Thousand Days)	Number of Tourists (Thousand Persons)	Hotel Rooms (Thousand Rooms)	Water Demand (Million m^3)
1990	8,648	1,729	16	7.2
2000	22,926	4,585	38	26.6
2010	34,049	6,809	55	40.2

The growing tourist industry in Pattaya will require 27 million cubic meters in the year 2000 and 40 million cubic meters in the year 2010. Plans to construct reservoirs in Chon Buri Province have already been drawn up and believed to be sufficient for the demand in the area. However, the project is delayed due to the higher land value and hence compensation to land owners. This case well illustrates the higher cost of raw water supply. Such cost has to be shouldered by the benefiters and hence must be fully reflected in the price of water. Given appropriate prices, demand and supply will be balanced and water will be used efficiently.

Endnotes

1 Estimated from information available in the Japan International Cooperation Agency's " The Master Plan Study for the Development of Pattaya Area " Draft, March 1990.

2 At present there are two wastewater treatment plants in Pattaya. In 1985 when the operation started, the treatment capacity was 5,500 cubic meters per day, covering an area of approximately 650 rai. At present the capacity is 13,000 cubic meters per day covering an area of 2,150 rai. (Reference: Report on the City of Pattaya, 1985-1988 by the Municipality of Pattaya.)

3 The following were used as references in developing the joint solution to raw water problems:
The Provincial Water Works Authority Region 1's document for public relations, February 1990
The Japan International Cooperation Agency's master plan study.
The Royal Irrigation Department's information available at the Rayong Provincial Office.

4 The Provincial Waterworks Authority periodicals, February 1989 and February 1990
The Provincial Waterworks Authority Strategic Plan (1985-1990)

Chapter 5

The Industrial Demand for Water

In Chapter 5, the current industrial water consumption patterns and the sources of water supply are discussed. Following a brief summary and overview of environmental problems, particularly land subsidence and water pollution, the future of water supply and demand is projected and analyzed. In conclusion, policies to solve water problems are proposed.

INTRODUCTION

Manufacturing plants use water for several major purposes including (1) cooling and condensation, (2) washing raw materials and equipment, and (3) conveying production input. In addition, water may be incorporated into the product or used for in-plant sanitary and overhead purposes, such as grounds maintenance or food preparation in a company cafeteria.

The water released from manufacturing plants is effluent generated by the production process and, depending on the technology and the type of production activity, contains certain amounts of water pollutants that effect the environment.

Because manufacturing plants use water for a wide range of activities, they require differing qualities of water. In some cases, the water quality can be lower than that of publicly supplied water, while in other cases, it may need to be higher. The profit-maximizing firms minimize their water costs by optimizing water consumption, and, at present, groundwater is one of the most economical sources of water for manufacturing plants in the Bangkok Metropolitan Region (BMR). The (uncontrolled) use of deep wells in the past, however, has resulted in serious problems of land subsidence in the city, particularly in the Samut Prakan area (Prinya et al. 1988).

Because of the direct link between water use and the environment, the efficient use of water resources not only helps water conservation, it also helps the conservation of the environment. Land subsidence and water pollution are negative externalities that the private sector does not account for; similarly, the current system of water supply pricing does not correspond to the scarcity cost of water.

Despite the problems of land subsidence and water pollution, the exceptionally strong growth of the industrial sector over the last decade shown in Table 5.1 indicates the need to increase the water supply to foster development. Thus, more groundwater will be exploited and/or the Metropolitan Water Work Authority (MWA) must expand its capacity to meet the growing demand. The question of how the MWA could increase its supply to meet future demand is another important issue.

Table 5.1 Real Manufacturing Output and GDP, 1980-1989

(Unit:Million Baht)

Year	Manufacturing	GDP	Industrial Share of GDP
1980	88,091	448,546	0.20
1981	91,965	456,808	0.20
1982	90,922	467,220	0.19
1983	93,773	491,886	0.19
1984	115,066	513,674	0.22
1985	115,639	522,617	0.22
1986	130,826	554,056	0.24
1987	147,743	618,532	0.24
1988	177,436	716,244	0.25
1989	205,335	807,736	0.25

INDUSTRIAL WATER CONSUMPTION AND THE SOURCES OF SUPPLY

Industrial development in Thailand has been concentrated in the BMR; more than one-half of Thailand's manufacturing plants are located in Bangkok, and most of these plants are relatively large compared to those in other regions (see Table 5.2). In terms of industrial output, over 70 percent of the manufacturing GDP is generated in the BMR. This analysis focuses on the BMR's industrial sector which is mostly located within the MWA's water supply distribution system.

Table 5.2 Number of Industrial Establishments in the Bangkok Metropolitan Region (BMR)

Industry	BKK	NKPT	NBR	PTTN	SMPK	SMSK	TOTAL	CTRY	% TT/CTR
Food	1,131	154	91	67	296	163	1,902	10,777	17.65
Beverage	69	13	6	7	7	2	104	262	39.69
Tobacco	8	0	0	1	1	0	10	108	9.26
Textile, wearing appare	2,708	110	38	65	383	139	3,443	3,692	93.26
Leather footwear	474	3	8	13	209	12	719	747	96.25
Wood & cork	1,024	55	135	67	173	63	1,517	3,517	43.13
Furniture & fixture	715	11	46	25	63	12	872	1,536	56.77
Paper & paper product	397	6	6	13	52	12	486	525	92.57
Printing	1,542	1	9	3	18	3	1,576	1,657	95.11
Rubber & ruber product	1,594	64	29	33	225	75	2,020	2,445	82.62
Chemical product	555	37	34	47	174	46	893	1,092	81.78
Petrolium	13	1	1	3	3	5	26	36	72.22
Non-metal	265	49	37	47	77	54	529	2,769	19.10
Basic metal	262	18	6	18	134	81	519	583	89.02
Fabricated product	4,057	39	79	41	492	91	4,799	5,872	81.73
Machinery	1,752	58	59	61	313	83	2,326	5,996	38.79
Electrical machinary	734	10	21	26	118	19	928	1,112	83.45
Transport equipment	2,300	84	100	43	302	89	2,918	6,385	45.70
Other industry	834	65	22	53	112	33	1,119	2,389	46.84
Total	20,434	778	727	633	3,152	982	26,706	51,500	51.86

Note: BKK = Bangkok; SMPK = Samut Prakarn; NBR = Nonthaburi; PTTN = Pathum Thani; SMSK = Samut Sakhon; CTRY = Country; TT = Total

Nakhon Pathom is not included because it is not a groundwater zone.

Source : Department of Industrial Works, Ministry of Industry.

In general, there are three sources of water supply to the industrial sector that differ in quality as follows:

1. Metropolitan Waterworks Authority System Water Supply: The water from the MWA is of good quality, but it is also the most costly.

2. Water from Ground Sources: This water is quite comparable to that of the public supply system.
3. Water from Rivers: This water is of the lowest quality and cost.

The uses of water from the three sources varies depending upon the type of industry and the specific water standard requirement for each particular use. A study on industrial water use in Thailand shows that groundwater constitutes more than 85 percent of "make-up water"[1] used in industry (Japan International Cooperation Agency (JICA) 1989). A negligible amount of the total water was from pipe water supply, and a small proportion of water used was from rivers or other sources. In this study, only groundwater and the MWA's water system are analyzed.

Groundwater as a Source

According to the Department of Mineral Resources' (DMR) records of registered wells, between 1.2 million cubic meters per day and 1.4 million cubic meters per day of well water are extracted in the BMR by more than 9,000 wells, and more than 80 percent of the total amount is consumed by the private sector, mainly factories and housing estates (Table 5.3). The MWA also uses well water to supplement its surface raw water supply. The amount consumed by the MWA is less than 20 percent of the total consumption. The groundwater consumption estimated by the DMR is extraordinarily low, compared to the estimates derived from per factory make-up water consumption reported by the JICA and presented in Table 5.4. Our estimated amount of nearly 3 million cubic meters per day or more than 1 billion cubic meter per year of industrial use is corroborated by independent estimates of industrial wastewater discharge. The large difference between the DMR's estimates and this study's estimates must come from unreported groundwater pumping. As can be seen in Figure 5.1, the index of the MWA water supply increased much more slowly in recent years than that of the GDP and manufacturing output. This not only suggests an increasing deficiency in the water supply, but also indicates the likely expansion of an alternative source of industrial water—groundwater pumping.

Table 5.3 Private Groundwater Consumption in the Bangkok Metropolitan Region (BMR)

(Unit: Cu.m./Day)

Year	Bangkok	Nonthaburi	Samut Prakan	Pathum thani	Samut Sakhon	Total	% Change
1978	339,496	26,472	228,115	59,919	27,835	681,837	-
1979	363,164	29,082	244,534	60,767	29,268	726,815	6.6
1980	418,354	34,368	264,347	75,048	35,431	827,548	13.9
1981	465,361	42,010	285,277	76,793	39,165	908,606	9.8
1982	495,837	45,210	316,153	84,105	52,006	996,311	9.7
1983	522,299	53,409	319,261	98,873	58,281	1,052,123	5.6
1984	542,894	55,777	353,226	114,132	61,337	1,127,366	7.2
1985	499,566	51,709	343,028	110,130	39,040	1,043,473	(7.4)
1986	476,941	46,148	364,001	118,102	78,972	1,084,164	3.0
1987	485,331	56,650	382,350	126,165	86,759	1,137,255	4.0

Note : Use of groundwater in Nakhon Pathom is not included, and because it is not within the announced critica areas, data is lacking.

Source : Wachee and Buapeng (1989).

Table 5.4 Estimated Groundwater Consumption by Industry in the Bangkok Metropolitan Region

Type	Per Fac. (cu.m./day)	% Fac. to Total	% Groundwater to Total	Weighted per Fac.	No.of Fac. in BMR	Groundwater (thousand cu.m./day)
Food	464	0.53	1.69	145	1,748	253.5
Paper	3,380	0.19	5.91	109	480	52.3
Textile	1,943	0.27	4.75	110	1,566	172.3
Metal	425	0.76	2.97	109	501	54.6
Chemical	361	0.49	1.64	108	856	92.4
Average	852	2.24	17.6	108	20,777	2,243.9
Total Groundwater consumption/day						2,869.0

Note: Derived from JICA (1989) and Table 5.2.
Weighted water/factory = (1)*(2)/(3)
a *Number of other establishments.*

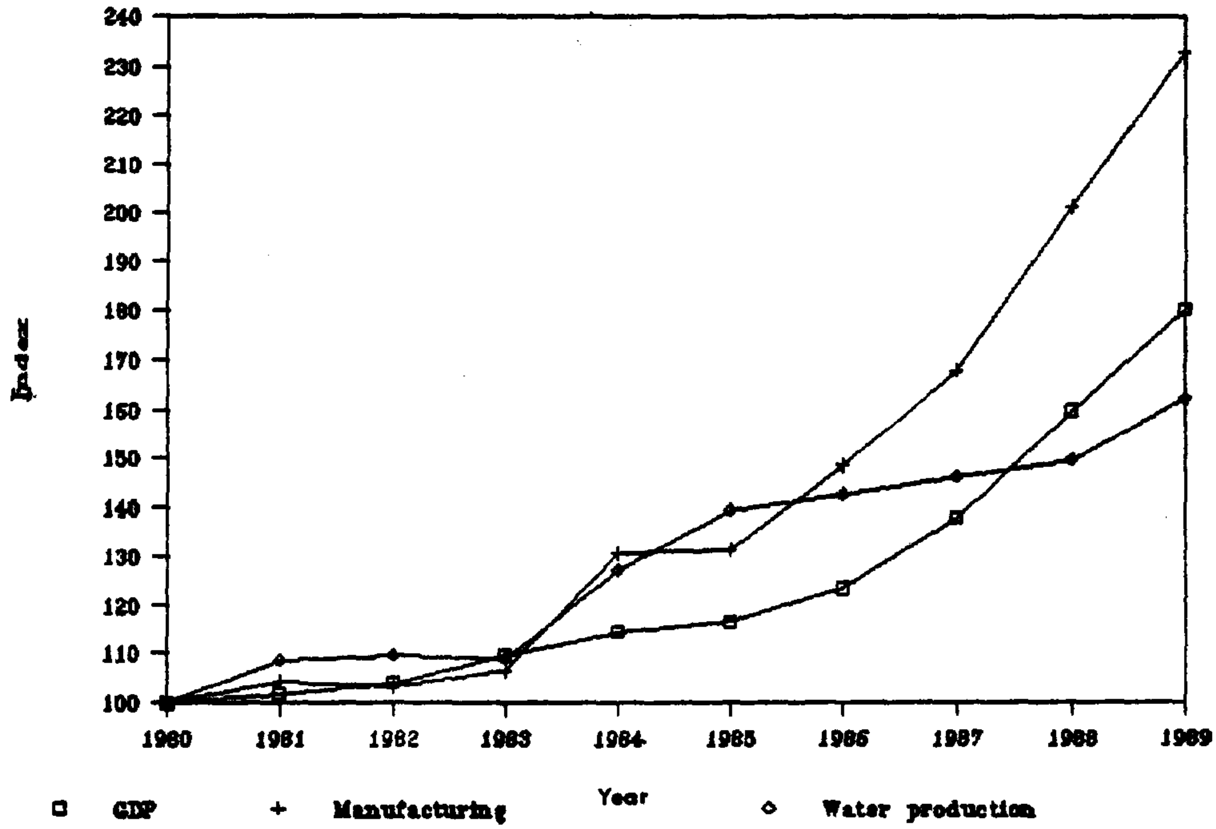

Figure 5.1 Trends in GDP Manufacturing, and Water Consumption

The illegal use of groundwater is most likely due to the lower private cost of groundwater relative to pipe water. The cost of groundwater pumping is less than 1 baht per cubic meter compared to the minimum charge of more than 5 baht per cubic meter[2] for pipe water. It is not surprising to observe that even within the MWA service areas, groundwater is widely used (Metropolitan Waterworks Authority 1988).

Pipe Water Supply

The amount of MWA pipe water used by the industrial sector is small, and unfortunately, there is no data available on the MWA's supply to the industrial sector. Nevertheless, even assuming that 80 percent of the total water supplied to the business, state enterprise and public sectors is supplied to industry, the amount is just less than 250 million cubic meters per year compared to the industrial sector's total consumption of more than 1 billion cubic meters per year. The information collected by the MWA on private groundwater well owners shows that for every ten owners of groundwater wells, about nine are located within the MWA distribution system and six are MWA customers (Metropolitan Waterworks Authority 1987). This fact indicates the significance of the cost advantage of a groundwater supply over a system water supply. Based on JICA's study, pipe water supplied to the five types of manufacturing industries in the BMR is less than 1 percent of their total water consumption.

THE LAND SUBSIDENCE CRISIS, THE INDUSTRIAL SECTOR, AND THE METROPOLITAN WATERWORKS AUTHORITY

Land Subsidence Problem

According to a focused study (Anuchit 1989), the main cause of land subsidence in the BMR between 1978 and 1981 was the excessive pumping of groundwater. The average land subsidence in the eastern part of the BMR was more than 10 centimeters per year and part of the area was already below the mean sea level—which aggravated flooding.

The flood losses and damage in the BMR were estimated in the order of billions of baht. In 1983 a loss of approximately 6,600 million baht was recorded. Strictly speaking only part of the total loss is due to land subsidence, and, hence constitutes part of the social cost of groundwater tapping. There are also other components of social costs from excessive tapping— particularly the increased expenses of construction, and the shorter life of buildings, materials, public utilities, etc.

To solve the land subsidence problem, measures were taken to reduce the land subsidence rate and then to restore the land level to its original stage, or as close as possible. Several urgent measures were approved including the following:

1. A supply of raw surface water would be available to the MWA and the private sector in the most critical areas by 1986.
2. The support and acceleration of pipe water development would be done according to the plans, particularly in the critical areas.
3. The MWA's pumping of groundwater in the critical areas would be stopped by 1987.
4. The enforcement of the Ground Water Act (1977) would be supported.
5. The groundwater rates would be adjusted to approximate the pipe water rate.
6. The Urban Master Plan would be improved to fully consider the land subsidence problems.

Two agencies, the MWA and the DMR, have the main responsibility for implementation these six measures; the MWA was to stop using groundwater by 1987, and the DMR was charged with controlling the private sector use of groundwater, which was to be allowed to increase at a rate not more than 5 percent per year until 1987, and was to be reduced 5 percent per year between 1988 and 1992 and 10 percent per year between 1993 and 1997. It was estimated that by 1998, the use of groundwater would be limited to not more than 200,000 cubic meters per day: a sustainable rate of extraction.

The actions following the mitigation measures have been rather slow, and the enforcement of the Groundwater Act has been ineffective. Despite an imposed groundwater pumping fee of 1 baht per cubic meter, the use of groundwater has increased substantially in the last few years. According to the DMR, until 1987, groundwater extraction had been controlled to expand at a rate of only 2.3 percent per year, compared to the maximum allowable 5 percent per year. Since 1988, however, instead of the targeted 5 percent per year reduction rate, the use of groundwater has conversely increased at a rate of 5 percent per year. Similarly, the MWA has not only been unable to comply with the measures by stopping groundwater tapping, but has occasionally increased the volume tapped due to a periodic shortage of raw surface water supplies. The increase in private groundwater consumption during the rapid industrial growth period indicates a strong growth in water demand and the cost advantage of groundwater. Likewise, the continued use of groundwater by the MWA suggests the importance of groundwater as a supplemental source for its raw water supply. The discrepancy between the industrial sector's apparent groundwater consumption and the official figures suggests extensive illegal groundwater pumping.

Thus, overall, the measures and actions taken to remedy groundwater uses are ineffective, and if land subsidence is to be constrained, these measures must be revised.

Groundwater Substitution and the Major Limitations

A concerted effort must be made to solve the land subsidence problem, and it is necessary to replace groundwater with a substitute water supply from other sources. The MWA system water supply is the only economically feasible substitute for groundwater. However, this substitution is unlikely to be accomplished without certain policy adjustments from the MWA and related agencies. There are three major limitations as follows:

1. **System Water Supply Capacity**: At present, raw water is drawn from the Chao Phraya River, and the increasing demand for other uses limits the available raw water for the MWA treatment plant to about 5.18 million cubic meters per day. The MWA has projected that its raw water supply will reach the limit set by the Royal Irrigation Department (RID) by 1997, and new sources of raw water must be used to supplement the supply from the Chao Phraya River. These new, potential sources of water are more distant and, hence, the cost of raw water intake would increase. In addition, the increasing degradation of raw water quality from the Chao Phraya River further increases treatment costs and lowers the profitability of the MWA's operations. If a pipe water supply is to replace groundwater use, at least an additional 4 millions cubic meters per day of water is required. This demand already exceeds the existing supply capacity of the MWA. Thus, under the present surface water supply conditions, it is unlikely that the MWA can accomplish this task. If new sources of raw water are used, the marginal costs of the supply would continue to increase and make the replacement of groundwater by pipe water even more difficult.

2. **Institutional Constraints**: At present, the DMR oversees the utilization of groundwater and charges a groundwater fee of one baht per cubic meter that is used to discourage the use of groundwater and to cover the social cost of land subsidence. Well owners are charged according to their meter readings, but the DMR lacks the manpower to record water consumption, and the collection of fees is erratic and inefficient. This lack of management efficiency also leads to extensive, illegal water pumping. In contrast, the MWA has staff that are solely responsible for recording and checking water

consumption, and the use of this capacity could substantially enhance monitoring efficiency.

The two agencies' water-pricing mechanisms are independently set and are not comparable. The private pumping cost, including the groundwater fee of one baht per cubic meter, is not more than two baht per cubic meter compared to the minimum charge for water from the MWA of 6 baht per cubic meter (for the lower price block of industrial use). As a result, groundwater is extensively used despite the completion of the distribution system. Meanwhile, manufacturing plants within industrial estates are charged approximately the same rate as that of the MWA—6 baht per cubic meter—for the use of groundwater. In addition, these plants are also charged with pollution treatment costs, while those outside the estates can illegally release effluent into the public water bodies, free of charge, thus imposing a cost on society.

3. **Prospect for More Investment**: Because of the anticipated water supply shortage, the MWA plans to transfer raw water from the Mae Klong Basin to the Chao Phraya Basin to increase its raw water supply. A water canal of approximately 100 kilometers in length is being planned to transfer water from Vajiralongkorn Diversion Dam to the new treatment plant in the BMR. This scheme will cost more than 1.5 billion baht of investment and about 27 million baht for operation and maintenance. It is estimated that the cost of transferred raw water will be as high as 0.44 baht per cubic meter (Chuanpit 1989). This cost does not include the opportunity cost or the scarcity cost of water, the environmental cost of the canal, or the higher land prices that the MWA will have to pay as compensation to landowners. (The actual land prices are several times higher than the government-assessed prices.)

Even without paying for the opportunity cost of water, the MWA earned negative net income from water between 1980 and 1984, and since 1985 it has earned positive net income of only about 500 million baht to 600 million baht per year. The increase in income was mainly due to an increase in water tariffs rather than an increase in the efficiency of the operations. Over the last few years an average cost per unit of water supply was constant at 5.6 baht per cubic meter, while the effective rate charged increased from 4.9 baht per cubic meter to 6.1 baht per cubic meter. In addition, the MWA's changeover from groundwater to surface water will increase costs by about one baht per cubic meter. Thus, a complete phasing out of groundwater would increase the cost to the agency by about 400,000 baht per day. This does not include the cost of construction of a treatment plant at about 1,600 million baht (Metropolitan Waterworks Authority 1987).

As a public enterprise, the MWA will continue to make investments in the water supply to serve demand in the BMR. However, whether the expansion sufficiently meets the demand or not largely depends on the rate of return of such an investment. The present shortage of water supply in many parts of Thailand demonstrates that the supply cannot catch up with the demand under current pricing and cost recovery policies.

As demand for water continues to grow and water becomes scarcer, the cost of importing raw water from greater distances increases. The real marginal cost of supply from the MWA has increased from less than 1 baht per cubic meter to nearly 4 baht per cubic meter over the last five years. Similarly, the marginal cost of reduction of leakages also increased from less than 0.5 baht per cubic meter to more than 2 baht per cubic meter over the last four years (see Appendix 4). Figure 5.2 shows the marginal cost trend of the two means of increasing supply: production expansion and leakage reduction.

4. Water Pollution: Part of the increase in the marginal cost of the water supply is due to the deteriorated quality of raw water intake. Water in the Chao Praya River, the main source of raw water supply to the MWA, is becoming increasingly polluted. Approximately 70 percent of biochemical oxygen demand (BOD) loading is from domestic sources, and the remaining amount is generated mostly by the industrial sector, with a small fraction coming from the agricultural sector.

The optimization of water supply and demand has substantial implications for the generation of water pollution. The industrial sector, although not the largest polluter, is a major one. The conservation of water not only reduces the cost of supply, but also reduces wastewater generated and, hence, environmental impacts. Except for certain types of manufacturing, wastewater from domestic sources and from many types of industry is discharged freely to public waterways and creates social costs. As reported by JICA, there is a great potential for water saving in the five major groups of industries shown in Table 5.5, and the effective use of industrial water, as discussed by JICA (1989), can be achieved by control of water use; use of water recycling; multistaging, or cascading; reclamation of wastewater; application of water-saving apparatus; control of domestic water use; etc.

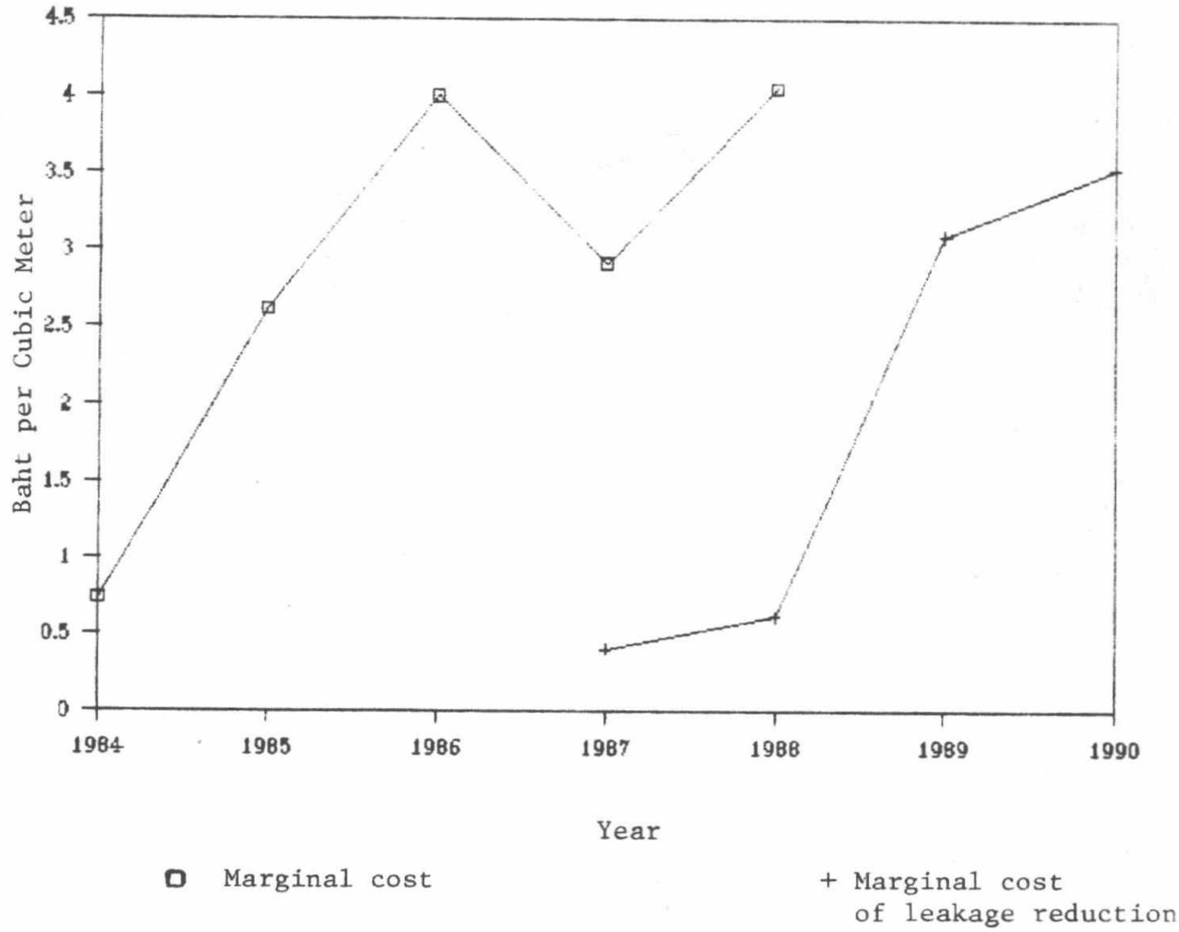

Figure 5.2 Real Marginal Costs of the Metropolitan Water Works Authority (MWA)

Table 5.5 Estimated Water-saving Rate and Average Cost of Improvement

Type of Industry	Water Consumed (cu.m./Day)	% Saving	Per Unit Cost (Baht/cu.m.)
Food	7,025	14.9	3.4
Paper	18,845	31.0	3.3
Textile	13,632	19.4	10.1
Metal	8,594	18.8	1.4
Chemical	4,799	14.8	1.3
Total	52,895	22.2	4.7

Note: This includes water reclamation for certain industries. If water reclamation is excluded, the saving rate is reduced to 10.8 percent and the cost is 1.4 baht per cubic meter.

Source: Japan International Cooperation Agency (1989).

The costs of improving efficiency include (1) construction costs, (2) depreciation costs, and (3) operating costs. Maintenance and personnel costs are not included, but they are generally small. Maintenance costs are normally about 2 percent to 5 percent of construction costs. As reported by JICA, by merely using simple methods (operation control, using water-saving apparatus, and control of water use) in the five major industries, about one-fourth of water use can be saved at an average cost of less than 2 baht per cubic meter. Although the average cost of improving water-use efficiency is generally lower than the rate charged by the MWA, it is not much different from the cost of groundwater extraction, including the groundwater fee. Thus, under the present groundwater rate structure, there is no incentive for these industries to improve water-use efficiency. Note that the per unit cost of improved wateruse efficiency in Table 5.5 has not been adjusted for the treatment cost saving from wastewater reduction. Using an average cost of three baht per cubic meter of water intake, the net cost of water saving is less than 2 baht per cubic meter.[3]

PROJECTED DEMAND AND PLANNED SUPPLY

The basic objective of water management in the industrial sector is to ensure that water, as an important input in industrial production process and as a scarce resource of society, would not hinder the growth of the industrial sector. As has been mentioned earlier, the industrial sector mainly uses groundwater as a water source, and despite the expansion of the MWA's distribution system and the measures of land subsidence prevention, the consumption of the groundwater in the private sector is increasing. Unless effective measures are taken, this trend is likely to continue.

Demand Projection

To project pipe water demand, a demand function is specified. The factors affecting demand for pipe water are hypothesized to be population, income, industrial output, service output, and price. Using the time series data from 1972 to 1981[4], several functions are attempted, including multiple linear, trans-log and semi-log. In all cases, only two variables, industrial output (manufacturing and construction) and price, and found significant in explaining water demand. It is reassuring that water demand elasticities derived from different functional forms fall within a narrow range (see Appendix 3 for details).

The derived equation selected to project demand for water is as follows:

$$\ln(W) = -2.36 \ln(P) + 0.45 \ln(I) + 0.48 \ln(P)*\ln(I)$$

W = water sale of the MWA (mil. cu. m.)

P = real minimum price (baht/cu. m.)

I = real industrial output (bil. baht)

The industrial elasticity of pipe water demand with respect to industrial output is estimated to be 0.61. The estimates are within the range of those in other studies (Gibbons 1986; Krahl 1985).

During the past decade (1980 to 1989), the demand for MWA water grew at a compound rate of 8 percent per annum. Due to the rapid structural change of the economy, water demand is likely to grow faster than the present rate. While the growth of the economy from 1980 to 1989 averaged 7 percent per year, it is expected to grow at an average annual rate of 8 percent during the 1990s. Industry's share of output is projected to increase from 35 percent to 40 percent by the year 2000, and the percentage of urban population to total will increase from 23 percent today to over 30 percent by the year 2000. The water demand of the largest user, the agricultural sector, is unlikely to decrease, despite structural change. This is because a change in the agricultural sector is likely to be concentrated in rainfed areas because of its comparative disadvantage of irrigated areas. Since irrigated areas remain in use and water is provided free or charge, agricultural demand for water is likely to continue at its current level.

Using the industrial output elasticity of demand for water, and assuming the industrial sector of the BMR grows at an average of 9 percent per annum, the industrial sector's demand for water will grow at more than 5 percent per annum. As the pace of growth is likely to slow in later stages of development, the growth of water demand is also likely to diminish.

Based on the above analysis, the industrial demand for pipe water is projected to grow at a rate of 5.4 percent over the next decade and to decline to 4.5 percent from 2000 to 2010. The demand for groundwater is likely to be higher than the demand for pipe water because of the increasing spread of the industry into outlying provinces (within the BMR) which are less well-served by the MWA system. Assuming a slightly higher growth rate of 6 percent per year in the first decade and a decline to 5.5 percent per year in the second decade, industrial demand for groundwater is projected to reach 2 billion cubic meters by the year 2000 and 3.4 billion cubic meters by the year 2010 (see Figure 5.3). If sustainable withdrawal from the aquifer is 200,000 cubic meters per day, or 73 million cubic meters per year, about 3.3 billion cubic meters of industrial water demand must come from surface water by the year 2010. If 95 percent of this amount is to be supplied by the MWA, the demand for MWA water will be further aggravated to reach 3.5 billion cubic meters in the year 2000 and 6.6 billion cubic meters in the year 2010.

Planned Supply

In contrast to the above demand projection, the MWA has projected a doubling of water demand in thirty years that will reach 2.3 billion cubic meters by the year 2017 (Chuahpit 1989) with a growth rate of less than 4 percent per annum. This projection is very low compared to the past or to the future projections of economic growth. Based on the projected demand and the phasing out of groundwater extraction, the MWA projects a requirement of 7.8 million cubic meters per day of raw water in 2017, compared to the maximum of 5.2 million cubic meters per day allocated by the RID from the Chao Phraya irrigation system. Based on our projection, this planned supply would be sufficient only up to the year 2000, excluding additional demand from phasing out groundwater extraction.

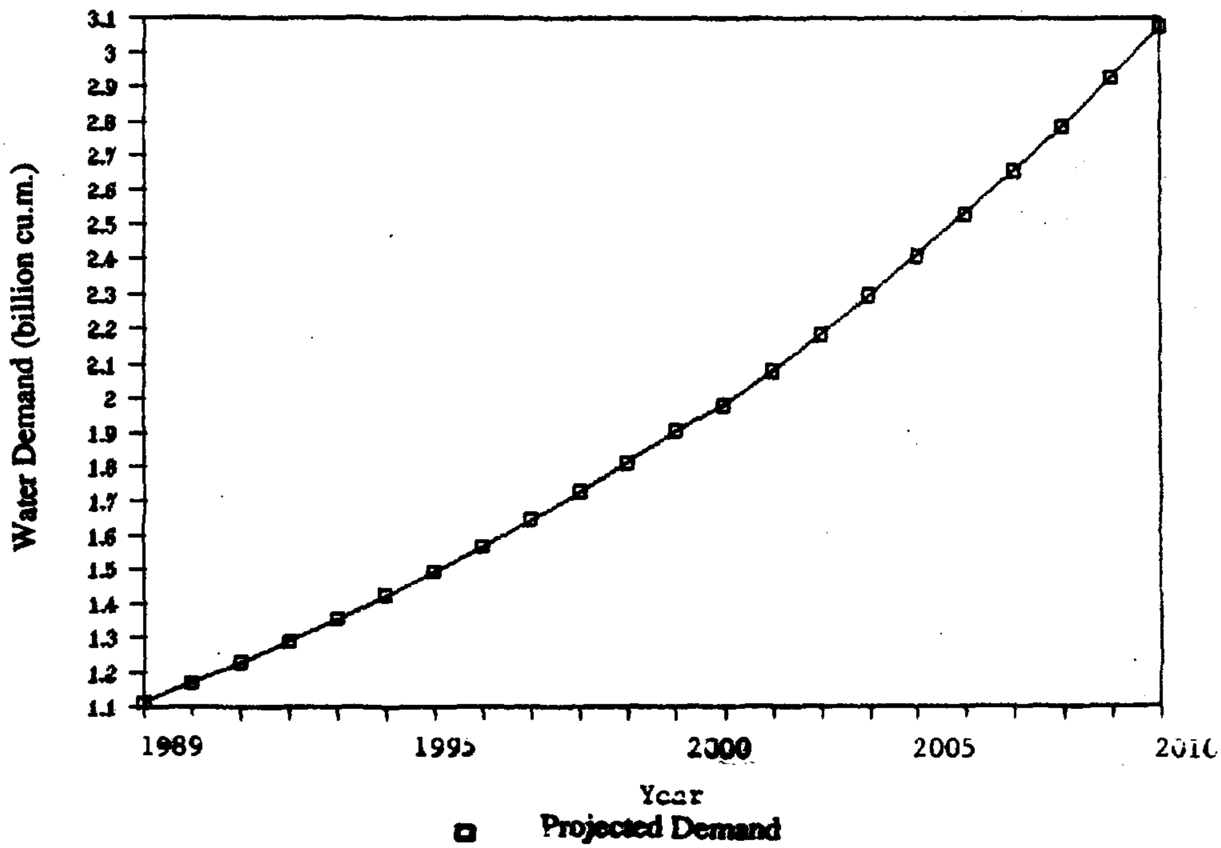

Figure 5.3 Projected Industrial Demand for Water

OPTIONS FOR WATER MANAGEMENT IN THE FUTURE

There are few alternatives that will help to increase the water supply to meet the future demand. The response to emerging water shortages has always been via efforts to increase the supply by seeking new water resources for development. Because the more suitable sites for reservoirs have been used up, any new investment for water supply expansion faces increasing costs in terms of both construction and environment. The latest scheme for the diversion of water from the Mae Klong Basin to the BMR is a case in point.

The increasing use of groundwater, despite the government's policy of phasing it out, is also a response to the increasing demand for and the cost of water. However, groundwater extraction imposes substantial social costs and cannot be allowed to continue indefinitely.

Another approach for dealing with the looming water shortage is to improve the existing system. The MWA has effectively reduced water leakage (unaccounted for water) to 32 percent in 1990 (Metropolitan Water Works Authority 1990). However, a higher level of savings means a higher marginal cost and, at present, the marginal cost of a cubic meter of water leakage reduction is more than 3 baht, which is about the same as the marginal cost of supply.

Demand management has not been widely used in Thailand, despite the tremendous growth in demand in recent years. From 1958 to 1984, pipe water prices increased only three times. Between 1976 and 1984 the real effective rates of water increased only from 2.6 baht per cubic meter to 3.7 baht per cubic meter. In 1985 water rates were allowed to increase and have been frozen ever since—in nominal terms. As a result, the real effective rates of water have declined since 1986. This water-pricing policy, which is illustrated in table 5.6, reflects the neglect of demand management as a means of meeting water shortages.

Table 5.6 Water Pricing in the Metropolitan Waterworks Authority (MWA) area, 1976-1989

Year	Nominal Effective Rate (Baht/cu.m.)	Real Effective Rate (Baht/cu.m.)	Minimum Rate (Baht/cu.m.)	Maximum Rate (Baht/cu.m.)
1976	1.449	3.295	0.50	2.50
1977	1.487	3.223	0.50	2.50
1978	1.494	2.978	0.50	2.50
1979	1.534	2.819	0.50	2.50
1980	1.597	2.551	0.50	2.50
1981	2.198	3.055	0.50	2.50
1982	3.029	3.712	1.50	5.50
1983	3.059	3.557	1.50	5.50
1984	3.190	3.587	1.50	5.50
1985	4.926	5.501	4.10	8.75
1986	6.142	6.646	4.10	8.75
1987	6.092	6.482	4.05	8.70
1988	6.102	6.328	4.00	8.70
1989	6.118	6.118	4.00	8.70

Source : Various Metropolitan Waterworks Authority annual reports.

Industrial water rates are progressive up to the level of 2,000 cubic meters per month and are regressive thereafter. It is not clear whether this price structure reflects (1) an attempt at marginal cost pricing, or (2) an incentive to induce large industrial groundwater users to turn to pipe water. If the price structure is an incentive, it is unlikely to work, since the rate is still higher than the cost of groundwater. In addition, the regressive rate may also induce small- and medium-size users to use more groundwater. As the latter are more difficult to regulate, the policy may ultimately undermine its own goals and achieve antithetical results.

THE ROLE OF WATER PRICING

Water pricing is critical for meeting water shortages and managing growing demands for several reasons: (1) it helps determine the optimal allocation of water resources among sectors; (2) it encourages reduction of waste and promotes conservation, thereby limiting demand; (3) it recovers the cost of supply, thereby making funds available for expanding supply.

The MWA's general mandate, as a public enterprise, is to provide a basic need, water, to society at the lowest possible cost. As there are several sources of supply and several means to deal with water shortages, the questions are: What are the relevant alternatives, and what is the supply cost of each alternative? The four alternatives for the MWA to supply water to industry are specified as follows.

1. Increasing supply (from the Chao Phraya River and diversion from Mae Klong River)
2. Reducing leakages
3. Pumping groundwater
4. Reducing demand through higher water rates

Each of these alternative (supply) sources incurs different scarcity, production, and environmental costs at different levels of supply as shown in Table 5.7.

Table 5.7 Costs for alternatives of Supply Expansion

Component of Mar.Cost	Alternative			
	More Supply	Less leakage	Groundwater	Less Demand
Scarcity cost	yes	no	yes	no
Wastewater	yes	yes	yes	no
Environmental impact	yes	yes	yes	no
Production cost	yes	yes	yes	no
Opportunity cost	yes	no	yes	yes

The preliminary estimates of the marginal costs of different alternatives indicate that the marginal cost of increasing pipe water supply, either by expansion or improvement of efficiency, is close to 4 baht per cubic meter at the current level of supply. In contrast, the cost of groundwater extraction is relatively small. Although the marginal cost can not be estimated given existing information, the average cost of groundwater extraction is at most one baht per cubic meter. This is close to the estimate in the case of Samut Prakan (Japan International Cooperation Agency 1989).

Whatever means are used to expand the supply, there is always a pollution cost. Based on the treatment cost of industrial estates, the average treatment cost for polluted water intake is about 3 baht per cubic meter. Using this cost as a proxy for marginal cost of pollution, the marginal cost of pipe water, including wastewater cost, is approximately 7 baht per cubic meter, while that of groundwater is lower (about 4 baht per cubic meter). However, the environmental costs of the three sources of water supply (expansion, improved efficiency, and groundwater) are varied. While supply expansion through building dams and reservoirs or by diverting water from other sources incurs environmental cost (at the intake stage) in terms of ecological deterioration, overtapping groundwater generates a higher risk of flooding and, hence, social cost of damages, etc. Such costs are inestimable, but it is likely that the environmental cost of groundwater extraction is higher than that of surface water. In contrast, improving efficiency does not impose any environmental cost at the same stage, since it merely reduces the wastage. In fact, it reduces the environmental cost, since it reduces the need for storage dams.

If opportunity costs and scarcity costs of surface and groundwater are not different, a preliminary analysis shows that the marginal cost of the pipe water supply, based on existing capacity, is higher than that of groundwater, probably in the order of 2 baht per cubic meter to 3 baht per cubic meter. Note that increasing the water supply efficiency might be a more effective alternative, but this can only be for the very short run since water loss, at present, has already been reduced to 32 percent (25 percent of water losss is considered normal). On the other hand, the additional costs of water transfer to secure raw water from the Mae Klong Basin were estimated at 0.44 baht per cubic meter (Chuanpit 1989, 6), but this is almost certainly a gross underestimate.

The most important parameter for water demand management is the price elasticity of demand for water, which reflects the scope for controlling demand through pricing. The price elasticity demand for water is estimated at -0.49, which means that a 10 percent increase in the price of water would result in a 4.9 percent reduction in quantity demanded. Thus, if water price is increased from the present average rate of 6.12 baht per cubic meter to 9 baht per cubic meter, water demand would be reduced by 23 percent, or 147 million cubic meters. In other words, if the price was allowed to increase corresponding to the marginal cost, the MWA would have generated 1,414 million baht of additional revenue. These revenues can finance an additional supply of over 150 million cubic meters, at the cost of 9 baht per cubic meter. Thus, with appropriate pricing, not only is the use of water more efficient, but there are also better incentives and a larger capacity to expand supply.

A reduction of demand due to a price increase generates an opportunity cost due to a reduction in industrial output as well. However, at this stage, the opportunity cost of output loss due to demand reduction in the industrial sector is likely to be minimal. In fact, the reduction of demand is mainly to improve water-use efficiency and the reduction of waste and, hence industrial output would not decline significantly. As shown earlier, the water-saving rate in industry can be as high as 22 percent at an average cost of less than 5 baht per cubic meter.

As industrial water demand is projected to be almost 2 billion cubic meters in the year 2000 and more than 3 billion cubic meters in the year 2010. Unless appropriate pricing is allowed, society would have to increasingly subsidize the sector as the marginal cost of supply is increasing. On the other hand, allowing price to increase in accordance with the marginal cost of supply, the demand for water would be curbed, and the cost of water would be priced appropriately. Additional demand also can easily be supplied from the revenues generated through higher prices.

An increase in pipe water charges also increases the cost advantage of groundwater; thus, the groundwater fee must be set at parity with pipe water rates. However, increasing the groundwater fee would induce more illegal extraction and again, more effective enforcement and control of groundwater use is needed. The efficiency in monitoring groundwater consumption and collecting groundwater fees can easily be improved by transferring responsibility from the DMR, which lacks the manpower and necessary infrastructure, to the MWA, which is well-equipped in both areas. Even the action of subcontracting the latter agency could substantially improve overall collection efficiency. Without an appropriate policy on groundwater, increasing the pipe water fee may result in a more rapid depletion of groundwater reserves and an increase in land subsidence.

CONCLUSIONS AND RECOMMENDATIONS

The industrial demand for water over the next 20 years is likely to exceed the present growth rate. The industrial water demand in the BMR in the year 2000 is projected to be double the present level, and a threefold increase is expected by the year 2010. In contrast to the demand, the current water supply for the industrial sector comes mainly from groundwater, which causes severe social costs and land subsidence. The official record grossly underestimates groundwater consumption, which raises the question of the effectiveness of groundwater use, control, and monitoring. The MWA's demand projection also is much lower than our conservative estimate of the future demand at current prices. The MWA's planned supply cannot cope with such a high demand and, more importantly, the marginal cost of supply already has exceeded the prices charged. This creates financial constraints for the expansion of the water supply. Unless demand management is introduced, there will be serious water shortages or huge public subsidies for water. Because groundwater is a close substitute for pipe water, it is essential to adjust present groundwater management techniques by improving collection efficiency and adjusting prices so that they are compatible with those of pipe water. Better law enforcement is needed to guide the individual sectors in the appropriate use of this scarce resource (See Chapter 6 for more detailed policy recommendations.)

Endnotes

1 "Make-up water" is the water intake of a manufacturing plant to substitute water losses in a production process. It is a net consumption of industrial water.

2 The marginal cost of private pumping is close to constant because of the nature of water pump operation and the construction costs of the well. In general, with one major capital investment and a small operating cost, a deep well can last for 20 years. Based on the assumptions below and using a straight-line method, the average cost of the groundwater extraction is estimated as follows:

Assumptions: Project life 20 years; digging cost 150,000 baht; twenty hp pump engine 130,000 baht; salvage value 14,000 baht; water consumption 150 cubic meter per day. Average depreciation of capital = 0.27 baht per cubic meter. Electricity cost = 0.41 baht per cubic meter.

Production cost of groundwater= 0.68 baht per cubic meter.

3 The water pollution cost is estimated from the average treatment charge to manufacturing plants of Bangpoo Industrial Estate in the Bangkok Metropolitan Region (BMR). The formula used to calculate the cost is as follows:

$$c = 1/3\,(vx/2100 + Bx/420 + Sx/570) * 381{,}500$$

Where C = treatment charge (baht)
Vx = effluent (80% of total consumption)
Bx = BOD loading (kgs/day)
Sx = suspended solid loading (kgs/day)

The average water pollution treatment charge in Bangpoo Industrial Estate for 1989 was 2.85 baht per cubic meter of water intake.

4 Strictly speaking, a demand projection for industrial water should cover groundwater consumption and costs. however, due to data constraints, the groundwater-related variables cannot be included in the model. To capture such effects on water demand, data used in the model is limited to the period from 1972 to 1981 in which the real prices of the Metropolitan Waterworks Authority (MWA) water supply were declining and more competitive with the cost of groundwater extraction. The prices of the MWA water supply have increased substantially in the 1980s. The margin between the two prices (MWA water and groundwater) was so large that the cost of substitution of pipe water for groundwater was too high, and the industry tended to be unresponsive to pipe water prices. This hypothesis is supported by the estimated price elasticity of only -0.18 and the industrial output elasticity of more than 1, using 1970 to 1986 observations..

Chapter 6

Water Management Principles and Applications

The need for Thailand to upgrade its water management effort was discussed in Chapter 2. Chapter 6 provides further details for water management and advocates two policy recommendations as follows:

1. **The government adopt integrated watershed management as a principle of the national water policy:** The concept of integrated watershed management is elaborated in a section on watershed management.
2. **The government encourage water conservation and demand management practices:** This can be accomplished by explicitly endorsing the principle that beneficiaries should pay for water and wastewater services by means of appropriate water prices.

To validate these two basic recommendations, Chapter 6 examines water management from a national perspective. First, the principles are outlined that are believed to be appropriate for the evolving water scenario in Thailand. A subsequent section on watershed management, which is based on these principles, discusses the important elements of integrated watershed management and the balance between the supply and demand of water resources. The next two sections discuss measures and recommendations for supply management and demand management.

THE PRINCIPLES OF WATER MANAGEMENT

The experience gained from observing countries that develop effective solutions to water management problems reveals the following underlying principles:

1. The hydrological watershed area (or river basin drainage area) should be used as a unit for defining the geographical scope of water management wherever feasible.
2. Both supply management and demand management for water resources must be concurrently implemented.

3. The environmental and social impacts must be considered together with the traditional economic assessment in planning new water projects.
4. Channels for public participation must be provided that help to avoid confrontation and group pressure and promote reasoning based on scientific evidence.

The use of a watershed area as a unit for water management requires the consideration of elements including the interdependence of land, water, human usage, and the significant natural and man-made[1] processes affecting those living within a watershed.

By using a watershed area as a unit for water management, the opportunity exists to deal with water issues at the local level, where the effects are most strongly felt.

In Thailand, demand management for water resources (for example, efforts to conserve water) has been neglected so far, while supply management (for example, efforts to find or access more water such as reservoir construction) predominates. This methodology is justifiable because when the quantity of water is plentiful relative to its usage, there is no point in water conservation. However, as water requirements increase with the needs of the economy, the demand will eventually catch up with the supply. The growing frequency and magnitude of water use conflicts (discussed in Chapter 2) are evidence that this is the case for Thailand at present. Without demand management for water resources, the long-term, sustainable uses of water for the national benefit will be hampered.

The economic activities and growth of a population lead to the increased exploitation of natural resources including water, and without proper controls, this exploitation results in environmental degradation. The sensitivity of the environment and social fabric to natural resources exploitation is increasing, and a delicate balance exists among the many factors involved. For example, the development of water supply facilities such as reservoirs necessitates population resettlement and disturbs the social structure. In the case of Lam Nam Seao, salt mining disrupted both the environment and the socioeconomic balance. It is crucial, therefore, to carefully consider both the environmental and social impacts in water development.

In a democratic society such as Thailand, public opinion is a critical element of decision making, especially the opinion of the public affected by the decision. Without public participation, water management cannot be effective.

WATERSHED MANAGEMENT

The experience of other countries reveals that successful, integrated watershed management should incorporate the following features:

1. **A Watershed Plan:** To be an effective reference or guideline for management, the watershed plan should be sufficiently comprehensive to take into account all uses that affect water flow and quality. Before the implementation of the plan, watershed studies should be conducted. In an important watershed such as the Chao Phraya Basin, the plan should be synchronized with the National Development Plan.
2. **Information:** As a tool for planning and implementation, information on both the hydrology and hydraulics of the watershed should be systematically collected, updated, and available for management purposes.
3. **Computer Modeling:** It is desirable and feasible to have an analytical model that is capable of revealing the full range of impacts that would be produced by particular uses and development in the watershed.[2]
4. **Management Objectives:** Specific objectives with criteria for assessing management alternatives must be available.
5. **Agency Participation:** A procedure must be worked out for line agency and regulatory agency cooperation.
6. **Public Participation:** Provisions must be available for public participation in determining objectives and management decisions.

The practical difficulties in developing a management system with all these features are formidable. For large river basins, the organizational effort and data requirements are costly, and the separate responsibilities of governmental departments and agencies present barriers to cooperation and agreement on the common objectives and methods to be used. For watershed areas that experience significant public pressure and internal conflicts, such sophisticated plans may lack sufficient relevance, and in the absence of urgent problems, public interest may be insufficient to motivate organized participation. For such reasons, it would be unrealistic to expect elaborate, workable arrangements for the management of all watersheds.

Integrated watershed planning should, nevertheless, underline a flexible, modern approach to water management, and recognize the impracticality of, and lack of necessity for, full application in many watersheds. The critical river systems warrant the most sophisticated arrangements, and in some cases, several watersheds with similar features can be grouped for regional planning purposes. In other cases, a crude plan will suffice. Whatever the individual case may be, the management plans for any watershed area should be sufficiently developed to enable necessary management decisions to be made while considering significant effects on other interdependent uses and values.

The implementation of cooperative management calls for flexibility in meeting different circumstances. One important consideration is the nature and role of the organizational body, which can vary from an informal consultative committee to a board with management responsibilities. Some of the most successful cases, such as the river authorities in England, Australia, New Zealand, and Japan, involve management boards with regulatory powers, and sometimes independent sources of revenue. But this organizational approach requires that the government delegate considerable responsibility, which in many cases will prove difficult for application to Thailand's needs.

At the policy level, the most important step is for the government to adopt integrated watershed management as a principle of the national water policy. The National Water Resources Committee (NWRC) is a suitable channel for endorsing such a principle on behalf of the government.

DEMAND MANAGEMENT

Demand management is a management effort that encourages efficient use of water. Proper demand management and the proper pricing of water can directly and indirectly induce the following results:

- Conservation of water
- Technological advances in water conservation
- Incentives to avoid wasting water

The water management system in Thailand has traditionally focused on managing water supplies; natural water systems have been harnessed, stored, regulated, and diverted in various ways to accommodate needs as they arose. The most convenient sources were typically developed first. Then, as needs expanded, the less accessible (and hence more costly) resources were developed. As long as water was plentiful relative to demand, supply management was a logical and satisfactory approach.

Today, Thailand's policy of simply increasing supplies to meet growing demands is being questioned. First, the cost of providing additional supplies for urban, industrial, and agricultural uses typically rises sharply when the infrastructure must be expanded and delivery systems extended to tap more remote resources. Second, the increasing of supplies, with the diversion, storage, and other work that this typically involves, inevitably disrupts natural water systems, thus disturbing the environment and social structure.

By adopting demand management techniques, Thailand could undoubtedly reduce water management costs and avoid the environmental disruption involved in the process of water resources development. While the traditional reliance on supply management policy cannot be stopped outright, it is logical for Thailand to consider a more balanced policy which would pay increased attention to demand management.

Water Pricing

Water pricing is the most important tool in demand management; other countries such as Canada have experience that suggests that it is the single most effective tool for inducing efficient use of water. A supplementary analysis of price for selected areas representing urban, industrial, and tourism growth is discussed in chapters 3, 4, and 5.

The policymakers who seek to establish a water management scheme can learn valuable lessons from the oil crisis of the mid 1970s when Thailand was confronted with a sharp increase in energy costs. As a result of the crisis, efforts were made throughout the economy to conserve energy, and the effects on industrial processes, building and housing design, automobile usage, and the public's sensitivity to energy conservation have been profound: the growth in demand for energy supplies has been dampened considerably. While the rationale for conserving water is different, the opportunities for controlling demands are comparable.

When water is underpriced, it is not used efficiently, which creates a need for additional supplies and leads to higher costs and added pressures on water resources. Taxpayers bear both the direct and indirect financial and environmental costs, although the burden is not distributed according to the resources they use. These considerations underline the increasing need for water pricing. A suitable water price can serve several useful purposes including the following:

- The use of water pricing will create incentives to avoid waste and encourage efficiency, thus contributing to water conservation.
- By reducing the amount of water needed and the waste disposal capacity, the infrastructure costs will be reduced.
- The resulting lower demand will reduce environmental pressures on water resources.
- By demonstrating users' willingness to pay for water, prices help allocate supplies among both the uses and the users so that the highest values are generated from limited resources.
- The pricing system will generate revenue to cover the costs of water supply and waste disposal.
- Suitable pricing can ensure that the cost of water services is equally borne by the beneficiaries according to the benefits they receive.

The government also should explore opportunities for shifting its water programs' funding from general taxation to revenues derived more directly from beneficiaries. Other possibilities include levying taxes on water-using products, and instituting fees for the services and the use of facilities such as canals.

When considering an adjustment in pipe water pricing, a wastewater charge could generate extra revenue which could then be used for investment in wastewater facilities.

At the policy level it is recommended that the government, through the NWRC perhaps, encourage water conservation and demand management practices by explicitly endorsing the principle that beneficiaries should pay for water and wastewater services by means of appropriate prices.

Supporting Activities

In areas where the water shortage is serious, other supporting activities aimed at efficient water use can be implemented together with pricing. These activities include the following:

- A campaign and education to increase public awareness and knowledge of water conservation
- Research in industrial water recycling, irrigation water reclamation, water-efficient devices such as toilet bowls, etc.
- Water-saving strategies such as water audits
- Reduction of water loss from leakage

SUPPLY MANAGEMENT

The supply management of water resources—which includes activities such as reservoir construction and groundwater pumping—deals with efforts to find and carefully control new sources of water (in contrast to demand management where water resources are used as the need arises). Unlike demand management, supply management, has been practiced for a long time in Thailand, and the easy sources (that is inexpensive, simple water sources and solutions) have been explored and developed. The location of new sources will be harder to do and planning must be subjected to other concerns such as environmental disruption and social dislocation. Because reservoir building is now more expensive than ever, Thailand must pay more (in both economic and social terms) to acquire this additional water, and a stringent assessment of the cost implications must be made before planning new projects.

Several complex policy and technical issues are involved in defining water management in Thailand. Better coordination among government agencies (the Royal Irrigation Department (RID), the Metropolitan Waterworks Authority (MWA), the Provincial Waterworks Authority (PWA), the Electricity Generating Authority of Thailand (EGAT), and the National Environment Board (NEB)) is necessary, but this is easier said than done. The individual agencies are quite efficient in carrying out their assigned water management duties, but when a higher level of national interest requires balanced benefits and shared burdens among many sectors, individual agencies become inflexible and cling to their assigned mandate. As agency mandates were made several years ago under very different circumstances, it may be appropriate now to consider changes.[3]

In cases where water must be transferred from one watershed to another (for example, the transfer of water from the Mae Klong Watershed to the Chao Phraya Watershed), the hydrologic regimes in both watersheds are altered with possible substantial and irreversible environmental change. For example, parasites and other organisms can be introduced into the new environment with unpredictable effects. Although scientific knowledge on the transfer of water is insufficient at this stage, the possible negative consequences should be considered in long-term planning.

In addition to the above measures, strategic planning for the future import of water from other neighboring countries should be initiated. Thailand should take advantage of the current climate, where a cooperative atmosphere prevails and the water value is low, by making bilateral agreements in order to secure water for the future. Finally, systematic channels for public participation should be made available so the opinions of interested groups are aired, and discussion is encouraged based on reason and scientific evidence rather than on group pressure and confrontation.

Endnotes

1 Man-made processes that affect a watershed area include flood and erosion control, soil and water conservation, water quality improvement, forestry, and wildlife conservation. other processes that cut across watershed boundaries are, for example, climatic conditions, acid rain, atmospheric pollution, etc.

2 For example, the Interim Mekong Committee Secretariat has used such model for the Nam Pong River Basin (in Northeast Thailand) since 1981.

3 The Royal Irrigation Department, for example, on its own initiative, is now clearly spelling out that it will consider irrigation in the context of environmental preservation.

Chapter 7

Summary and Conclusions

SUMMARY

The growing conflicts over resource use in Thailand are exemplified by the increasing need for diverting irrigation water to (1) supply the needs of expanding urban centers and (2) the rapidly growing industrial and tourist sectors. The demand for nonagricultural water use is projected to quadruple over the next 15 years to 20 years. Since nonagricultural users are already experiencing shortages, and conflicts over water resources are widespread, a quadrupling of water demand would result either in growth-limiting water shortages or in burdensome government subsidies.

Water demand is moderately responsive to water pricing which can be used to increase water-use efficiency and to induce conservation as well as to raise revenues to finance additional higher-cost supplies. Full-cost water pricing (with due allowance for low-income consumers) would avert water shortages and obviate government subsidies.

However, unless the rural poor also benefit from the increasing urban use of this limited rural resource, its diversion to higher-value uses, without due compensation to farmers, would exacerbate the rural-urban income gap. The allocation of water rights to farmers and rural poor could be a potent instrument for both improving water-use efficiency and spreading the benefits of growth and industrialization to Thailand's countryside.

POLICY RECOMMENDATIONS

The use of water pricing is critical for meeting water shortages and managing growing demands for several reasons: (1) it helps detemine the optimal sectoral allocation of water (for example, among agricultural, industrial, and domestic uses); (2) it encourages waste reduction and promotes efficient water use, thereby limiting demand;

and (3) it recovers the costs of supply, thereby making funds available for expanding the supply. Shielding the users from the rising supply price of water guarantees either growing water shortages, growing water subsidies, or a combination of the two.

Water is an important resource for both agricultural and nonagricultural uses. Full-cost pricing is an indispensable component of the policy package for resolving resource conflicts, averting growth-constraining shortages, and improving efficiency and income distribution. Currently, most farmers don't have to pay for irrigation water and, thus, have little incentive to conserve water or to use it efficiently on high-value crops. As a result, irrigation efficiency is under 30 percent. Urban consumers and commercial and industrial users pay only nominal water fees that do not reflect the marginal cost of supply. Without adequate cost recovery, the development of additional supplies to meet mounting water demands faces tight financial constraints. Without full-cost pricing, supply and demand cannot be balanced, and shortages and conflicts can only grow more severe over time as unchecked demand forges ahead of supply. It is through proper pricing that scarce resources are put to their best possible use.

However, water pricing faces serious problems. The government, concerned that low-income users will be adversely affected, is reluctant to raise urban water rates. The act of raising industrial water prices may simply lead to increased groundwater pumping and further excerbate the problems of land subsidence and flooding. Finally, charging farmers for irrigation water has been considered, but never introduced because farmers might oppose it. Moreover, since agriculture is the lowest-value use of water, farmers would lose in the competition for limited supplies, especially during the dry season and in drought years. Such an outcome would be distributionally regressive. The critical questions at hand are how to improve the water-use efficiency of all sectors and how to induce water conservation without adversely affecting farmers and low-income consumers. A policy package with three related components is recommended.

The first component is to increase the price of pipe water produced by both the Metropolitan Waterworks Authority (MWA) and the Provincial Waterworks Authority (PWA) to reflect the marginal cost of supply, except for the first block, which could be frozen (in real terms) at the current minimal rate to cushion the effect of the price rise on low-income users.

The MWA should be given more authority and freedom to set water rates in line with the marginal costs of supply; the government cabinet need only maintain control over the lowest block rate to protect poor consumers and very small businesses. The MWA also should be given the authority for setting and collecting groundwater rates, while the Department of Mineral Resources (DMR) should continue to have authority over the exploration and monitoring of groundwater resources. The average effective price of MWA water should be raised to a level that fully reflects the opportunity cost of water, the production cost (both fixed and operating cost), and the environmental cost involved. The price should be indexed and authomatically adjusted through a formula that takes into account both inflation and the rising scarcity and supply cost of water.

The second component is the introduction of presumptive use rates for industry based on the type of industry and level of production: the industries within the public water network, which are not connected to pipe water or use less than the average amount for the industry (presumptive rate), would be presumed to be using groundwater and would be charged for the balance at the pipe water price, unless they could prove otherwise. Factories should be required to account for their water use at a level corresponding to their production capacity and type of industry. Factories reporting water use per unit of output at less than 80 percent of the averge use of their industrial group as a whole would be charged the average, unless they could document superior efficiency, which would be confirmed by an independent environmental audit. Firms would be free to use either groundwater or pipe water, or any combination of the two. Both sources would be metered and monitored by the MWA. The price of the two water sources would be comparable: the groundwater fee plus the pumping cost should equal the average tariff for the pipe water.

Currently, the industrial water tariff is progressive through small increments up to 2,000 cubic meters per month, and is regressive thereafter. The justification for this is not evident. To simplify matters, a three-step progressive rate system is proposed:

- 0-100 cubic meters: 8 baht per cubic meter
- 101-2,000 cubic meters: 9 baht per cubic meter
- Over 2,000 cubic meters: 10 baht per cubic meter

This rate should be indexed and automatically increased to maintain its real value. If a more gradual progression is warranted, it should be jointly applied to both pipe water and groundwater to prevent multiple sourcing as a means of reducing the effective tariff rate. In the long run, such a system would limit groundwater pumping to two groups of industries: (1) industries for which reliability of supply is critical, thus warranting a backup system to pipe water, and (2) industries outside the MWA's effective distribution system. In the short-to-medium run, it is necessary to allow for a smooth transition and adjustment to the new system by implementing parity between pipe water and groundwater rates in stages. This is a critical component because, without it, raising the price of pipe water would be self-defeating and would simply lead to more intensive groundwater pumping. Industrial competitiveness would not be affected because the cost of water is a very small fraction of the industry's total operating cost (less than 1 percent).

The third component is equally critical: farmers throughout the country who derive over 50 percent of their income from agriculture should be given water rights in the form of equal capacity shares in public irrigation systems and reservoirs, regardless of whether their land is currently irrigated or rainfed. The absolute amount of water that each farmer was entitled per unit of time would, of course, depend on how much water was in storage, which varies with the season and year. At the end of the rainy season, the Royal Irrigation Department (RID) would announce the amount of water in storage. Each farmer would automatically know the quantity of water he was entitled to (share x water in storage). What he did with it would be his own business: he might use part of it on his own farm, sell it to other farmers, or sell it to the water utilities. Farmers outside the irrigation command area could sell their share for each season to farmers in command areas or to municipalities. The scarcer the water and the higher the demand from urban centers, industry, tourism, and high-value crops, the higher the price that the farmer would command for his share of water. Neither the MWA nor the PWA would have continued access to scarce raw water free of charge, and the RID would not need to impose a limit on these utilities' access to raw water. The water utilities, acting on behalf of the urban and industrial consumer, would purchase water from farmers through the RID which would act as the intermediary between farmers and potential water buyers.

By using this three-step progressive rate sytem, the benefits of rapid industrialization and the growth of the tourism and services sectors would be spread to the rural areas. Water shortages and conflicts would be replaced by beneficial exchanges, and the desirable aspects of rural life would be preserved without costly farm subsidies that lead to over-production and costly surpluses. An increasingly scarce and valuable resource would be put to its highest-value use in a way that benefits, rather than deprives, the farmers and the rural poor. This system is currently being tried in New Zealand, and its implementation in Thailand would require additional investment to properly control and meter water. But the potential benefits would be large enough for the scheme to warrant a serious consideration and study. Bulk water allocation to water-user associations, farmers groups, and communities could help reduce metering and collection costs by leaving water distribution to local organizations which can best monitor water use and prevent meter manipulations or damage.

Appendix 1

Estimation of Sectoral Water Requirements

A. Domestic Water

The input and assumptions in the estimation are:

1. Eighty percent of the population live in rural areas where the average consumption is 50 liters per person per day.
2. Twenty percent of the population live in urban areas where consumption is 250 liters per person per day.
3. The population of Thailand in 1990 is 55 million people.

Based on these information and assumptions, the annual amount of water required for the domestic use of the country is:

$(55 \times 10^6 \times 365 (0.8 \times 50 + 0.2 \times 250))/10^{12}$

or 1.81 cubic kilometers.

B. Industrial Water

This water is estimated from known water requirement in Bangpu Industrial Estate. The table below summarizes the known data and the estimation.

Estimation of National Water Requirement for Industry

Parameters	Bangpu	Whole Country
Number of registered factories, units	211	56,169
Volume of Water used, million cubic meters	3.89	1,035

a. The figures for Bangpu Industrial Estate are from records kept by the estate.

b. The number of factories for the whole country is from the Department of Industrial Works.

c. The lowest right-hand number is estimated by assuming a linear relationship.

The annual amount of water required in industry for the whole of Thailand is therefore estimated to be 1,035 million cubic meters.

C. Agricultural Water

According to the Royal Irrigation Department (RID)[5], the area under irrigation service is 18 million rai. Assuming that the annual water requirement in these areas is equivalent to a height of 1.4 meters, the annual amount required is 40.32 cubic kilometers.

D. Renewable Water

The amount of annual renewable water is assumed to be equal to the annual streamflow, which according to the RID is 198,880 million cubic meters.

E. Estimations of Future Requirements

Starting with the amounts of water requirements in domestic, industrial, and agricultural sectors described above, the amounts required in 2000 and 2010 are estimated by the following assumptions:

1. From 1990 to 2000, the annual growth of domestic and industrial waters is 12 percent.
2. From 2000 to 2010, the annual growth of domestic and industrial waters is 10 percent.
3. From 1990 to 2010, the combined growth (of all three sectors) is 7 percent.

Calculation of National Water Projection: Thailand

Year	Renewable	Withdrawal			
		Domestic	Industry	Agriculture	Total
1990	199	1.8	1.0	40.3	43
2000	199	5.6	3.2	76.1	85
2010	199	14.6	8.3	144.1	167

Appendix 2

Translation of Chom Thong Watershed Conservation Club Letter to the Prime Minister of Thailand

Watershed Conservation club

112 Rim Nam Road, Mu 4

T.Ban Luang, A.Chom Thong

June 25, 1989

Watershed Conservation Club
112 Rim Nam Road, Mu 4
T. Ban Luang, A. Chom Thong

To the Prime Minister :

Referring to our letter of May 20, 1989 sent to the Prime Minister, the Club has now received the letter of 23rd May, 1989 from the Office of Secretariat.

WCC has not yet seen any action taken to solve the problem. People of Chom Thong feel very frustrated and worried due to the continuing problems created by minority groups in this district. WCC again wants to send a request to the Prime Minister to decide and order to all concerned agencies to take action on the following matters:

1) Stop forest clearing by hill people in the watershed headlands.

2) Ban use of chemicals, insecticides which create toxic water in the drinking water supply of the city of Chom Thong.

3) Move out hill people from Khun Klang, Khun Ya of Tambon Ban Luang and Pha Kluay of Tambon Mae Soi due to their threat to watershed without concern of the needs of the lowland farmers. Especially, WCC is requesting to move hill people from Pha Kluay first.

4) WCC humbly requests to have urgent action taken within this year 1989. If any delay occurs, there will be no watershed left, and this will create a serious problem for agriculture in Chom Thong district.

With our sincere, our wills, and not to create any social unrest which threatens national peace, WCC wants to solve this problem. As our traditional practice for several generations, the watershed headlands have to be strictly protected due to its value to sustain our livelihood. If the government is not able to solve this problem, WCC will volunteer to be responsible to solve this problem to preserve this natural area, which means our lives.

With our respectful regards.

(Nai Suwith Namathep)
president
Watershed Conservation Club
Chom Thong

Appendix 3

Data and the Estimation of Coefficients

1. Data used and the estimates of demand equations for residential and service water user

1.1 The data and the estimates for residential use

Year	Residential use water (mil.cum)	Real Minimum Price (baht/cum at (1976 price)	User (,000)	Real Income/Capita (,000)
	Q	P	U	I
1973	67.89	0.67	187.04	11.36
1974	78.43	0.55	202.16	13.78
1975	110.64	0.52	218.52	15.53
1976	121.01	0.50	236.20	17.52
1977	133.61	0.46	244.83	20.36
1978	137.03	0.42	253.91	23.60
1979	143.58	0.38	264.78	27.67
1980	162.96	0.32	301.60	33.87
1981	186.28	0.28	310.00	37.29
1982	194.60	0.81	316.80	39.24
1983	205.00	0.78	329.60	40.89
1984	239.40	0.77	370.40	43.33
1985	280.40	2.05	443.70	44.42
1986	280.00	1.99	491.90	45.70
Mean	167.20	0.75	298.00	29.61

Sources: MWA Annual Report (Various issues); Income data is from National Economics and Social Development Board

The estimates Following various runs of functional forms and Variables, an equation of translog functional form is adopted and shown below (L is for natural logarithm)

The estimates following various runs of functional forms and variables, an equation of translog functional form is adopted and shown below (L is for natural logaristhm)

14 Observations
Dependent Variable is Q

Variable	Coefficient	STD. Error	T-Statistics	2-tailed Significance
LP	-2.5466168	0.9628827	-2.6447841	0.025
LI	0.8057127	0.3178848	2.5346060	0.030
LP*LI	0.6880372	0.2797933	2.4590911	0.034
LU*LU	0.0679665	0.0339982	1.9991226	0.073

R-squared	0.970168	Mean of dependent var	5.037720
Adjusted R-squared	0.961219	S.D. of dempendent var	0.431413
S.E. of regress	0.084958	Sum of squared resid	0.072179
Durbin-Watso	1.637911	F-statistic	108.4045
Log Likelihoo	17.008540		

1.2 The data and the estimates for service use

Year	Use (mil. cum) Q_S	price (baht/cum) P	Output (bil baht/year) O	User (,000) U_S
1973	50.97	0.67	12.03	66.33
1974	58.89	0.55	11.94	71.70
1975	83.07	0.52	14.57	77.50
1976	90.86	0.50	16.02	83.77
1977	100.32	0.46	17.26	86.83
1978	102.89	0.42	19.15	90.05
1979	107.81	0.38	22.85	93.90
1980	121.36	0.32	23.74	85.90
1981	138.73	0.28	24.55	113.10
1982	144.30	0.81	26.55	128.20
1983	162.30	0.78	27.53	138.10
1984	182.70	0.77	29.86	149.30
1985	195.40	2.05	31.74	158.60
1986	204.00	1.99	33.64	167.70
Mean	124.50	0.75	22.24	107.90

Sources: MWA Annual Report (Various Issues); Service Output data is from National Economics and Social Development Board.

The equation is in translog form. The coefficients and the statistics are shown below (L is for natural logarithm)

14 observations
Dependent variable is LQ_S

Variable	Coefficient	STD. Error	T-Statistics	2-tailed significance
LP	-4.4739613	1.7011475	-2.6299668	0.027
LU_S*LP	0.8733891	0.3380148	2.5838786	1.030
LO	-0.2042680	0.1023439	-1.9958988	0.077
LU*LO	0.1416993	0.0207714	6.8218528	0.000
SLMINP	-0.1348978	0.0928143	-1.4534158	0.180

R-squared	0.9831380	Mean of dependent var	4.7465920
Adjusted R-squared	0.9756440	S.D. of dependent var	0.0424112
S.E. of regression	0.0661880	Sum of squared resid	0.0394280
Durbin-Watson stat	1.9304310	F-statistic	131.1894000
Log likelihood	21.2412400		

2. Data used and the estimates in demand equation for Pattaya

2.1 The data

Year	Water Produced (mil.cum.) Q	Room Number (,000) R	Visitor (mil.per.) T	Real Minimum Price (baht/cum at 1990price) P
1979	0.22	3.44	0.337	3.68
1980	0.31	3.79	0.339	3.34
1981	0.89	6.58	0.524	2.78
1982	3.33	7.61	0.599	2.46
1983	5.20	8.65	0.593	2.32
1984	6.59	9.72	0.682	2.24
1985	7.58	10.50	0.796	2.24
1986	8.01	10.76	0.934	4.05
1987	9.32	11.26	1.417	3.98
1988	10.26	14.30	1.727	3.90
1989	12.17	18.10	1.749	3.75
Mean	5.81	9.52	0.88	3.16

Sources: Water produced and price data is from Provincial Water Work Authority; Hotel room and Visitor number data is from Tourism Authority of Thailand

2.2 The estimate The equation is in multiple-linear regression from. The coefficients and the statistics are shown below

11 Observations
Dependent Variable is Q

Variable	Coeffecient	STD. Error	T-Statistics	2-tailed Significance
P	-0.7672617	0.326326	-2.3512123	0.047
T	3.5534035	2.0726299	1.7144419	0.125
R	0.5407751	0.2153154	2.5115486	0.036

R-squared	0.913551	Mean of dependent var	5.807273
Adjusted R-squared	0.891939	S.D. of dependent var	4.163897
S.E. of regression	1.368782	Sum of squared resid	14.98852
Durbin-Watson stat	0.90877	F-statistic	42.27020
Log likelihood	-17.30996		

Q = Water sold; P = real minimum price, T = number of visitor, R = number of hotel rooms.

3. Data and the estimates of demand for water for industry

3.1 The Data

Year	Water sale (mil. cum) W	Real manufacturing (bil. baht) M	Real minimum (baht/cum at 1976 price) P
1972	113.90	30.93	2.26
1973	119.10	31.50	2.02
1974	137.60	31.19	1.64
1975	194.10	43.81	1.57
1976	212.30	51.52	1.50
1977	234.40	58.62	1.38
1978	240.40	65.12	1.27
1979	251.90	58.72	1.15
1980	285.90	73.52	0.96
1981	326.80	78.03	0.85
Mean	211.64	52.30	1.46

Sources: Water sale and price data is from MWA annual report (various issues); Manufacturing output data is from National Economic and Social Development Board.

3.2 Equation to translog form selected from various runs of different forms and variables. (L is for natural logarithm)

10 Observations
Dependent Variable is LW

Variable	Coefficient	STD. Error	T-statistics	2-Tail Significant
LP	-2.3634891	0.7627434	-3.0986684	0.021
LM	0.4507749	0.1540736	2.9257123	0.026
LM*LP	0.4840341	0.1808916	2.6758241	0.037
Constant	3.7434000	0.6539079	5.7246598	0.001
R-squared	0.9891130	Mean of dependent var		5.297937
Adjusted R-squared	0.9836690	S.D. of dependent var		0.366822
S.E. of regression	0.0468770	Sum of squared resid		0.013185
Durbin-Watson stat	2.1903300	F-statistic		181.702700
Log likelihood	18.9670600			

Appendix 4

Marginal Cost of Reduction of Unaccounted-for Water Loss

Reduction of unaccounted-for water loss has been one of increasing efficiency policies of the Metropolitan Waterworks Authority (MWA). In the 1986 fiscal year, MWA adopted a water loss reduction program, and water loss has declined gradually from 41 percent in 1986 to 32.76 percent in 1989, and 32 percent in 1990.

Water saving is derived from water loss statistics and the cost of unaccounted-for reduction is from the programme cost. A formula to derive water loss reduction is as follows:

Saving = Expected loss - Actual loss

define: expected $lost_t$ = $production_t$ * percent $loss_{t-1}$
actual lost = production - $sale_t$

Average extended life of infrastructure, after renovation, is estimated between five years to ten years (MWA, "Water Loss Reduction Policy of MWA," sheet paper). It is assumed here that average extended life of materials and infrastructure as a result of renovation is 7 years. The result is obtained below:

Year	Saving (Mil. cu.m.)	Time (Years)	Real Cost (Mil. Baht)	Real Marginal Cost of Loss Reduction (Baht/cu.m./Year)	Real Marginal Cost of Supply Expansion
1984	-	-	-	-	0.74
1985	-	-	-	-	2.62
1986	-	-	-	-	4.01
1987	25.79	7	72.1	0.40	2.92
1988	35.97	7	153.5	0.61	4.06
1989	8.29	7	179.9	3.10	na
1990	9.50	7	235.8	3.55	na

Note: The 1990 figure is projected. The marginal cost of supply expansion is obtained from Metropolitan Waterworks Authority annual reports.

References

References are grouped according to the chapter in which they appear. References that are not specifically mentioned in any chapter, but are relevant or used indirectly, appear in the "General" section.

Chapter 1

INTRODUCTION

Thailand Development Research Institute. 1987. *Thailand Natural Resources Profile.* Bangkok: Thailand Development Research Institute Foundation.

Thailand Development Research Institute. 1988. *Development of a Framework for Water Quality Management of Chao Phraya and Thachin Rivers.* 2 vols. Bangkok: Thailand Development Research Institute Foundation.

World Bank. 1989. *Thailand: Country Economic Memorandum Building on the Recent Success: A Policy Framework.* Report No. 7445-TH, 2 vols.

Chapter 2

WATER SITUATION IN THAILAND

Johnson III, S.H.L., Sanguan Patamatamkul, and Tongroj Onchan. 1990. *River Basin Water Management Proposal: Preliminary Study Design.* ISPAN, United States Agency for International Development.

World Bank. 1985. *Thailand Irrigation Subsector Review Report.* No. 5847-TH Projects Department, East Asia and Pacific Regional Office, December 12, 1985.

World Resources Institute. 1990-1991. *An Assessment of the Resource Base that Supports the Global Economy with Data Tables for 146 Countries.* International Institute for Environment and Development.

Chapter 3

BANGKOK

Mansfield, Edwin. 1976. *Microeconomics: Theory and Applications.* New York: Norton.

Chapter 4

PATTAYA

City of Pattaya. Administration Report. 2528-2531. (in Thai)

Japan International Cooperation Agency. 1990. *The Master Plan Study for the Development of Pattaya Area.* Draft final report. March.

Provincial Waterworks Authority Periodicals, February 2532 and February 2533. (in Thai)

Provincial Waterworks Authority Planning Division. *Plan for 2528-2533.* (in Thai)

Provincial Waterworks Authority Region 1. Pamphlet for Public Relations Describing the organization and information for new connections. (in Thai)

Provincial Waterworks Authority Region 1. 1990. *Press Release Document in Response to Pattaya Water Shortage.* February 22, 2533. (in Thai)

Chapter 5

INDUSTRY

Dhamasiri, Chuanpit. 1989. "MWA's Present and Future Water Supply Situation." Paper presented at the workshop on Bangkok Land Subsidence - What's Next? June 22-23, Imperial Hotel, Bangkok. (in Thai)

Gibbons, Diana. 1986. *The Economic Value of Water. Washing*ton, D.C.: Resources for the Future.

Japan International Cooperation Agency. 1989. *Final Report for the study on the Effective Use of Industrial Water in the Kingdom of Thailand.*

L., Krahl. 1985 "Marginal-Cost Pricing of Municipal Water:.A Case Study of Braintree, Massachusetts. Energy and Environmental Policy Center, John F. Kennedy School of Government, Harvard University, April.

Nutalaya et al. 1989. "Land Subsidence in Bangkok During 1978-1988. "Paper presented at the workshop on Bangkok Land Subsidence - What's Next? June 22-23, 1989, Imperial Hotel, Bangkok. (in Thai)

Sodarathit, Anuchit. 1989. *Bangkok Flood and Control:* Paper presented at the workshop on "Bangkok Land Subsidence - What's Next?, June 22-23, 1989, Imperial Hotel, Bangkok. (in Thai)

Wachee, Ramnarong, and S, Buapheng. 1989. "Ground Watr Consumption in Bangkok and Its Vicinity, Present and Future. "Paper presented at the workshop on Bangkok *Land Subsidence - What's Next? June 22-23, 1989,* Imperial Hotel, Bangkok. (in Thai)

Chapter 6

WATER MANAGEMENT

Pearse, Peter H., Francois Bertrand, and James W. Mc Laren. 1985. *Currents of Change: Final Report Inquiry on Federal Water Policy.* Ottawa, Ontario: Minister of the Environment.

chapter 7

POLICY CONSIDERATIONS

Hoey, P.M. "Landuse and Catchment Management Considerations. "Report of short-term input to the Thai-Australia, Northeast Village Water Resource Project Khon Kaen, Thailand.

Marshall, T.W. 1990. "An Appraisal of Ground Water Resources in the Nam Phrom and Nam Sieo Catchments of Northeast Thailand." Thai-Australian Northeast Village Water Resources Project Report no. 163.

Weeks, W.D. 1990. "Thai-Australian Northeast Village Water Resource Project." Report on Hydrology Lam Sieo Yai Nam Phrom.

GENERAL

Chaturvedi, M.C. *Second India Water Studies.* The Macmillan Company of India, Limited.

Conservation Foundation. 1984. *An Issue Report: America's Water Current Trends and Emerging Issues*. Washington, D.C.: The Conservation Foundation.

Darr, P., S.L. Feldman, and C. Kamen. 1976. *The Demand for Urban Water.* Leiden: Martinus Nijhoff, Social Science Division.

Gardiner, Vince and Paul Herrington. 1985. *Water Demand Forecasting. Proceedings of a workshop,* sponsored by the Economic and Social Research Council.

Hawksley Watson. 1987. *Samutprakarn Industrial Pollution Control and Management Project*. Vol. 1, Executive Summary, Bangkok: National Environment Board.

International Irrigation Management Institute. 1990. *Review*. Vol. 4, no. 1, March 1990, Printed at Stanford Press, Singapore.

National Economic and Social Development Board. 1989. *Upper Central Region Study*. Vol. 1. Spatial Framework for Development, Japan International Cooperation Agency.

Postel, Sandra. 1984. *Water: Rethinking Management in an Age of Scarcity*. Worldwatch Paper no. 62. Washington, D.C.: Worldwatch Institute. December 1984.

Postel, Sandra. 1985. Conserving Water: The Untapped Alternative. Worldwatch Paper no. 67. Washington, D.C.: Worldwatch Institute.

Ruangdej Srivardhana. *Water Use Conflicts in ASEAN METROPOLISES: The Case of Bangkok Metropolitan Region.*

Siam Society Under Royal Patronage. 1989. Kingdom of Thailand Office of the National Environment Board Control Land Management. Vol. 1, *Executive Summary*, Asian development Bank, UNDP-UNEP Technical Assistance.

Surakiart, Sathirathai. 1987. *Management of Economic and Social Development Laws and Regulations Concerning Natural Resources, Financial Institutions and Exports: Their Effects on Economic and Social Development.* Prepared in accordance with the terms of reference of project supported by United Nations Development Programme, THA/86/009/A/01/99.

Thailand Development Research Institute. 1988. *Development of a Framework for Water Quality Management of Chao Phraya and Thachin Rivers*. 2 vols. Bangkok: Thailand Development Resources Institute Foundation.

Thailand Development Research Institute. 1990. *TDRI Quarterly Review*. Vol. 5, no.3, September 1990 ISSN 0857-2968.

World Resources Institute. 1988. Water and Arid Lands of the Western United States. Edited by Mohamed T. El-Ashry and Dianna C. Gibbons, Press Syndicate of the University of Cambridge.

Worldwatch Institute. 1990. *Worldwatch*. Vol. 2, no. 6. Washington, D.C.: Worldwatch Institute. November-December.

Worldwatch Institute. 1990. *Worldwatch*. Vol. 3, no. 1. Washington, D.C.: Worldwatch Institute. January-February.