CHAPTER 10 GROUNDWATER BASIN MANAGEMENT

10.1 Immediate Management Actions

10.1.1 Setting of Permissible Yield as Target

The water level decline, land subsidence and saline water intrusion are the negative responses of the natural aquifer system to human activities. Since deterioration of water quality and land subsidence are anathema to the rational utilization of groundwater, preventive measures are necessary for sound groundwater management.

Groundwater management must be forwarded under a pertinent selection of management objective. The objective, in other word, "target" of the management may be represented by the "permissible yield".

Though the MWA's water supply projects are ongoing, water supply in the Bangkok Metropolitan Area shall still for a long time be depended on groundwater sources, not only for domestic use but also for institutional, commercial and industrial uses.

An objective of groundwater management is to sustain the use of groundwater, with land subsidence in Bangkok Metropolitan Area being prevented. Thus, the permissible yield may be determined by giving importance to the *rate of land subsidence*.

Response of the 3-D simulation model suggested that scenario 6 is permissible in terms of the rate of land subsidence. The total pumpage in year-2005 is estimated to be about 1.62 MCMD and in year-2010 about 1.49 MCMD. Because pumpage is not regulated outside the proposed new critical zone, scenario 6 assumes that pumpage will again increase and reach 1.57 MCMD in year-2017. Scenario 6 also allows pumpage to increase annually from year-1995 to year-2000 at a regulated rate of about 2.7% of the 1992 pumpage level. This increase may be unavoidable considering the present economic growth of the country. In conclusion, a pumpage of 1.79 MCMD is proposed as a tentative target in year-2000 and 1.62 MCMD in year-2005.

10.1.2 New Critical Zone and Pumpage Regulation

To achieve the target, it is necessary to designate a new critical zone. The Groundwater Act B.E. 2520 includes provisions regarding the designation of a "Groundwater Area". Based on these provisions, the Cabinet designated six (6) provinces, namely, Bangkok, Nonthaburi, Pathum Thani, Samut Prakan, Samut Sakhon and Ayutthaya. In addition, "Critical Zones" were designated in the Bangkok Metropolitan Area since 1985 in order to recover groundwater levels and mitigate land subsidence in these zones.

The existing Critical Zones were defined considering the rates of land subsidence and of decline of groundwater levels. However, the proposed new critical zone (Figure 10.1.1) considers the recent conditions of groundwater level and land subsidence in the Study Area.

The regulation of pumpage in the new critical zone must start in year-1995. As assumed in scenario 6, pumpage in the Study Area will be regulated to 1.79 MCMD in year-2000. In the new critical zone, new water permit applications must be carefully investigated, and the number of water permits must be reduced to control the total pumpage. After year-2000, the target regulated pumpage will be reduced to 1.62 MCMD in year-2005 and further to 1.49 MCMD in year-2010.

10.1.3 Expansion of Monitoring System

The first step in groundwater management is the collection and arrangement of accurate observed data. The DMR has already established an excellent network of monitoring stations in Bangkok Metropolitan Area, mainly observing the three major aquifers, i.e., Phra Pradaeng, Nakhon Luang and Nonthaburi, through the 258 wells and 86 benchmarks. However, this network must be expanded to cover a much bigger area and to observe the much deeper aquifers.

The existing monitoring network must be extended to the surrounding areas, i.e., Pathum Thani, Lat Krabang and Samut Sakhon. A set of wells, monitoring Bangkok, Phra Pradaeng, Nakhon Luang, Nonthaburi and Sam Khok Aquifers, must be constructed per monitoring station. These wells must be designed to facilitate automatic measurements of groundwater levels and land subsidence and periodic collection of water samples for laboratory analysis.

Benchmarks must be installed at every monitoring station, and leveling must be conducted to determine the top elevations of wells, concurrently with that of DMR, RTSD and BMA.

Pumpage is one of the important components of a monitoring system. In this Study, it was estimated from the well inventory data and existing records of water meter readings. Nevertheless, some factors were assumed in the estimation. Since management target is pumpage itself, its future estimation must be based on the actual groundwater consumption readings from water meter installed in every well in the basin. Actual pumpage data from other agencies must be collected, stored and processed in the well inventory database installed at DMR.

Water quality is also an important component of the monitoring system. The Study reveals that the water quality of samples taken by submersible pump has no siginificant difference with that of samples taken manually using containers. It is recommended, however, that periodic sampling and analysis of water from the monitoring wells be undertaken in order to assess the deterioration of water quality in the basin.

The groundwater monitoring system used conjunctively with the groundwater database and simulation models is expected to become a permanent tool in groundwater basin management. The tentative permissible yield can be re-evaluated through analysis and evaluation of monitored data using the groundwater simulation models.

10.2 Comprehensive Measures for Land Subsidence

10.2.1 Substitutional Water Supply

Substitutional water supply system must be available prior to the implemention of the pumpage regulation. In MWA's Master Plan, the measure for substitutional water supply is the development of surface water in Mae Klong River to cover soonest particularly the east of Bangkok by MWA's network. According to this Master Plan, all 2×2 km^2 elemental zones within MWA's area of responsibility, having a projected water demand greater than 20 liters/sec, shall be served with piped water from MWA's central system by year-2017. Of the total water demand of 5.32 MCMD in year-2017, 91.4% shall be met by piped water supply. The rest will be supplied by a variety of sources including wells and direct extractions from khlongs.

On the other hand, PWA shall implement a water supply expansion project north of Bangkok, which will involve the construction of a new intake at Samkho point of Chao Phraya River in Pathum Thani. The production capacity will be expanded to 155,650 CMD by year-1995 and further to 311,300 CMD by year-2001.

The water supply projects mentioned above must be implemented on schedule or completed much earlier than planned.

Meanwhile, there is still no sound water supply plan that covers Samut Sakhon area at present even if there are already many industrial and residential areas existing and being developed in this area. Hence, construction of waterworks for industries is urgently needed, if this area is to be included as part of the proposed new critical zone and likewise pumpage has to be regulated.

10.2.2 Rational Use of Groundwater

Considering how slow a water supply project progresses, it is therefore difficult to rely only on the substitutional water supply. Present industrial use alone accounts for about 55% of the total groundwater abstracted in the Study Area. A bulk of this percentage is used by food, chemical and textile industries. Accordingly, saving and rational use of groundwater should be a must in these types of industries. In addition, the domestic users should also be involved.

Definite measures for the rational use of groundwater can be classified into **technical** and **institutional measures**.

Technical Measures

The technical measures are composed of the following:

1) Saving water by means of improving the design of sanitary and plumbing fixtures, such as water closets, faucets, showers, etc., and other appliances utilizing water, e.g., washing machines;

2) Stepwise or cascade utilization of water by means of rearranging the water supply and drainage facilities; and

3) Recycling water by means of installing water treatment plant.

As an example, an ordinary faucet reducer can be replaced by the water-saving-type reducer which is quite effective in saving water since it controls the rate of flow of water.

Cooling water can be recycled by installing cooling tower. Empirically, the amount of cooling water used can be reduced by 10% to 20%.

The basic principles of saving water are summarized as follows.

1. Reduction of the number of objects to be washed
2. Cutting of unnecessary volume of water
3. Multi-stage washing
4. Recycling of water for single purpose

In order to design the method of water saving in an industry, it is necessary to measure the present volume of water being used at every stage or step in the manufacturing process and at every place in the factory and office. The standard guideline for the method of water saving must be prepared based on this investigation.

In Japan, the technical guideline for saving water was established in the mid-70's, and it was applied to save water being used for cooling, bottle washing, machine washing, plating, painting , dyeing, etc. This saving of water was implemented as part of the measures against land subsidence in Tokyo (Tokyo Metropolitan Office, 1976). This guideline can be applied in Bangkok in the future.

A survey conducted in Tokyo revealed that the groundwater pumpage of 18 factories (located in Tokyo itself) had decreased drastically from 30,890 CMD to 6,760 CMD. These factories are involved in bottling (milk and beer), bakery, printing, pharmacy, making of sensitive paper, machine tool, plating, electronics and automobile manufacturing. The technical guideline mentioned above required each factory to submit its water use improvement plan to the government and to rationalize the water use by installing cooling tower and improving washing methods. The table below shows the results of the survey (RIPW, 1978).

Pumpage Reduction by Rational Use of Water at the 18 Factories Surveyed in Tokyo

	Before (CMD)	After (CMD)	Reduction (%)
Cooling Water	(15,990)	(1,470)	(91)
Direct	14,420	1,250	91
Indirect	1,570	220	87
Washing Water	(6,730)	(2,080)	(69)
Bottle	510	330	35
Intermittent	890	480	46
Plating	1,960	270	86
Printing	1,810	620	66
Ventilation	370	20	95
Others	1,190	360	70
Other Water	(8,170)	(3,210)	(61)
Toilet	1,940	650	67
Boiler	280	110	61
Filter	1,220	340	72
Others	1,730	2,110	55
Total	(30,890)	(6,760)	(78)

Institutional Measures

The institutional measures include:

1) Generation of public consciousness to save water through campaigns

2) Enactment of rules and regulations for water users

In the campaign to save water, leaflets may be distributed to the users to explain the necessity, method and advantages of saving water. Improvement or rehabilitation of existing water supply facilities through some financial support from the goverment may be needed to minimize leakage.

Still, further study on the rational use of groundwater is required.

10.2.3 Artificial Recharge

Artificial groundwater recharge is a technical measure to recover groundwater levels and reduce land subsidence rate. This method must be promoted together with the other measures, such as pumpage regulation, substitutional water supply system construction, etc.

Methods of artificial recharge are classified into two: the spreading method and the recharge well method.

The spreading method is most popular in alluvial plains with unconfined aquifer systems. Spreading method can be done using channels, ponds, ditches or shafts or by flooding.

These methods are, however, not suitable for the Bangkok area, because its uppermost layer consists of the so-called "Bangkok Clay". This clay bed constitutes an impervious layer with thickness ranging from 17 meters in northern Bangkok to 30 meters in the south near the Gulf of Thailand. The first aquifer, "Bangkok Aquifer", is overlain by Bangkok Clay; it is composed of sand and gravel, but already intruded by saline water. The spreading method may be applied north of the Study Area, from Ayutthaya to Chainat, where alluvial fan deposits covered the area and where no Bangkok Clay exists.

The recharge well method is generally applied to confined aquifer systems. Water can be injected into sand and gravel formations through the recharge well. The Study Area consists of a multiple confined aquifer system, where the water levels of the main aquifers, i.e. Phra Pradaeng, Nonthaburi and Nakhon Luang Aquifers, have declined to 50m to 60m below MSL. Direct injection to these aquifers is expected to recover the groundwater levels and reduce the rate of land subsidence.

The main technical issue regarding the application of the recharge well method is the clogging of well screens. Clogging may be caused by the following:

- movement of particles
- oxide adhesion to particles
- growth of bacteria
- chemical reactions between chemical constituents contained in the normal groundwater and recharged water
- binding of dissolved air
- oxidization and corrosion of the casing

Suspended materials in the recharged water can be removed but the dissolved air cannot be. An air barrier is formed in the surroundings of the well when warm water is injected into a relatively cold groundwater. Growth of bacteria and adhesion of their remains also clog well screens. However, clogging may seldom occur if water is recharged without aeration. A supply-recharge well facility is often constructed in order to return groundwater directly to the original aquifers without aeration after being used for industrial cooling or air conditioning. For such kind of water use, the supply-recharge well system is indeed appropriate.

Direct recharge of surface water through the well should also be considered. Surplus water in the rainy season could be stored in the underground aquifers. Recharge water may possibly be taken from the Chao Phraya River, but has to be treated because of its high turbidity. A pilot projet of a recharge scheme is recommended to assess its potential in Bangkok.

Since implementation of a large scale recharge project entails considerable investments, a recharge scheme being contemplated must first be assessed not only from the technical but also from the economic and legal viewpoints.

10.2.4 Price Policy

As mentioned in the previous chapter, land subsidence caused by heavy groundwater withdrawals has brought tremendous economic loss chargeable to the social cost. On the other hand, groundwater is commercially utilized at a relatively cheap cost as compared with the social cost. Therefore, a price policy may be needed to make the groundwater fee the same as the water tariff charged by the public waterworks in supplying surface water.

The relationship between water demand and water price can be empirically expressed as illustrated in Figure 10.2.1 (Yasui, 1970). The water demand slightly decreases from δ_1 to δ_2 when the cost is raised from π_1 to π_2 on the BC line. However, the water demand significantly decreases from δ_3 to δ_4 when the cost is raised from π_3 to π_4 on the AB line. Generally, the domestic water has a low cost elasticity and stays on the BC line. On the other hand, the industrial water has a high cost elasticity, and many kinds of industries are thought to be on the AB line.

Presently, the MWA's water tariff is 4.0 bahts/m^3 for domestic purpose and 50 bahts/m^3 for commercial and industrial uses, while the groundwater fee, which was just raised in 1994, is 3.5 bahts/m^3. Of course, there will be many opinions or discussions on the price of water. However, water today is not a free commodity but rather an economic goods. An economic goods in the sense that it can only be provided by investing huge amount of money in the construction of dams, canals, pipelines, etc. Unless this situation is broadly understood, people may take water for granted and waste the same as illustrated on the CD line.

10.2.5 Legal and Organizational Measures

As a legal measure against land subsidence, the government enforced the Groundwater Act B.E. 2520 in July, 1978. Through this Act, the Groundwater Committee was organized and tasked to advise the Minister of Industry in establishing regulations and in making recommendations. Under this Act, groundwater utilization, exploitation, development, conservation and protection shall be controlled and regulated by the government through the DMR.

With regard to monitoring of the groundwater levels and land subsidence, a technical sub-committee should be organized under the Groundwater Committee. Data collected by other related agencies (e.g., DMR, PWD, MWA, PWA, DOH, ARD, IEAT, RTSD, BMA, etc.) should be gathered, processed, analyzed and evaluated by this sub-committee. For example, past levellings of benchmarks were conducted separately by RTSD, DMR and BMA. There was no coordination as to the date and frequency of levelling among the said agencies. Such problem can be discussed at the technical sub-committee level in order to ensure the availability of all leveling data so that a uniform, authoritative land subsidence contour map can be prepared.

The DMR should remain the administrator of all groundwater data and information.

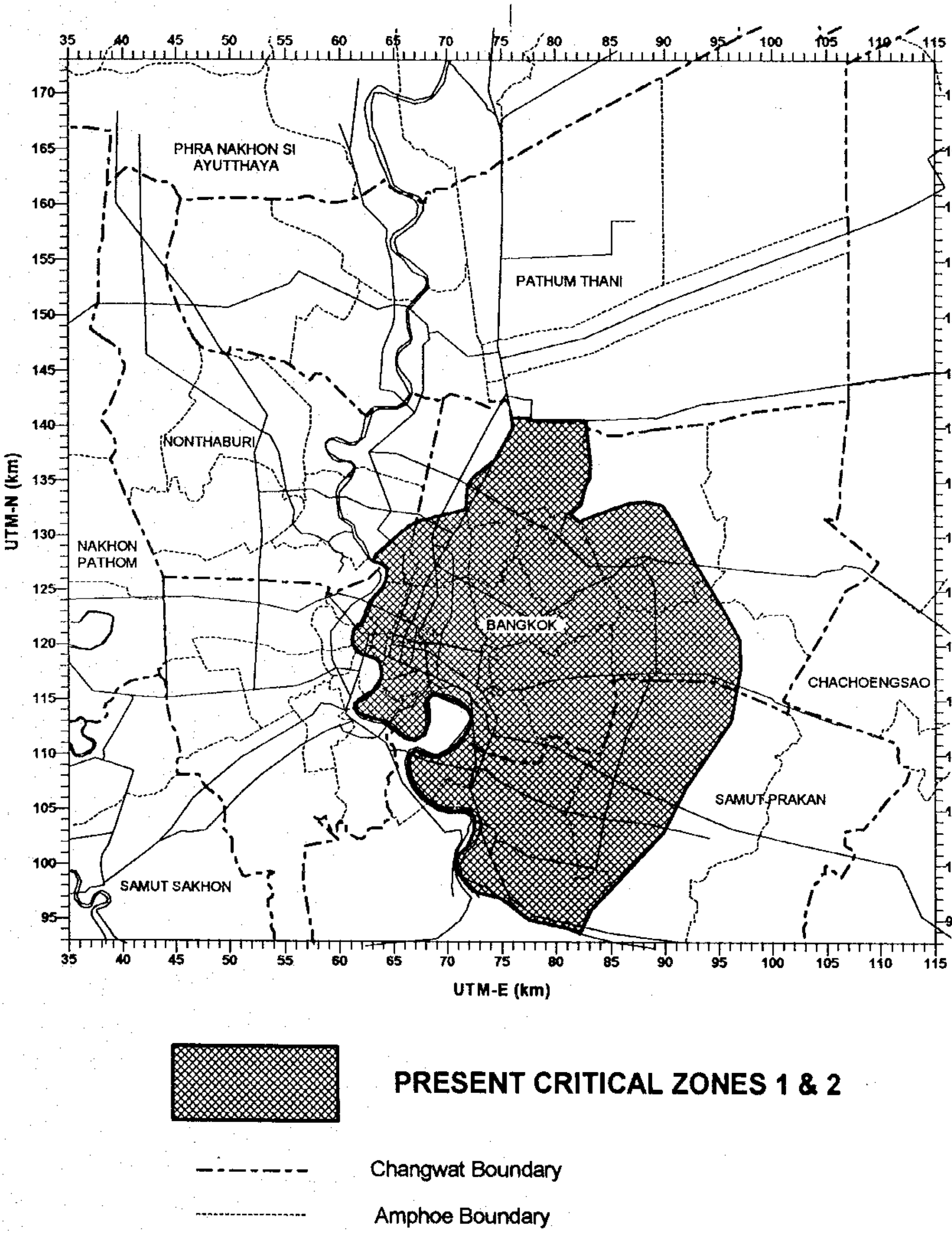

Figure 10.1.1	PRESENT CRITICAL ZONES 1 & 2
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

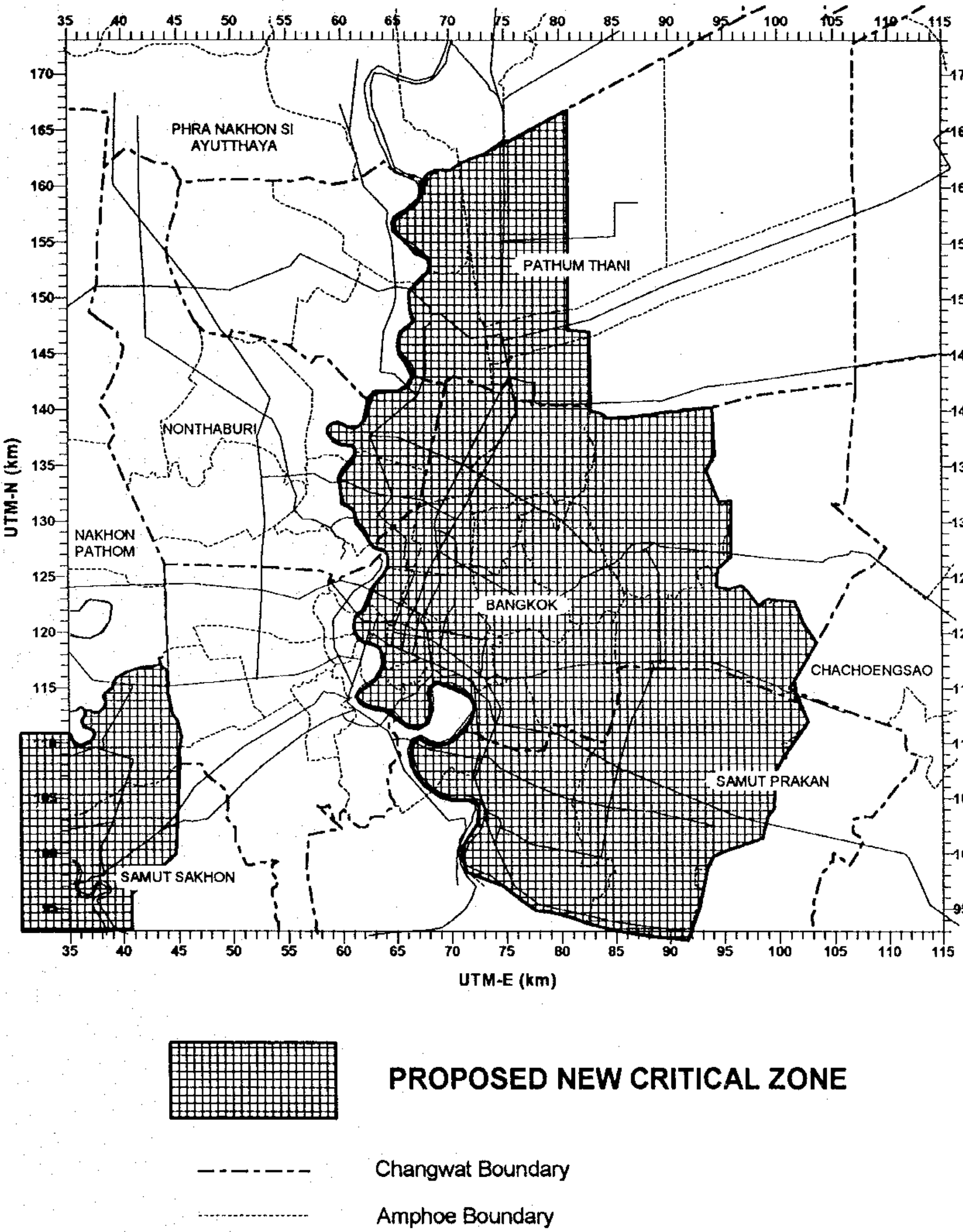

Figure 10.1.2	PROPOSED NEW CRITICAL ZONE
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

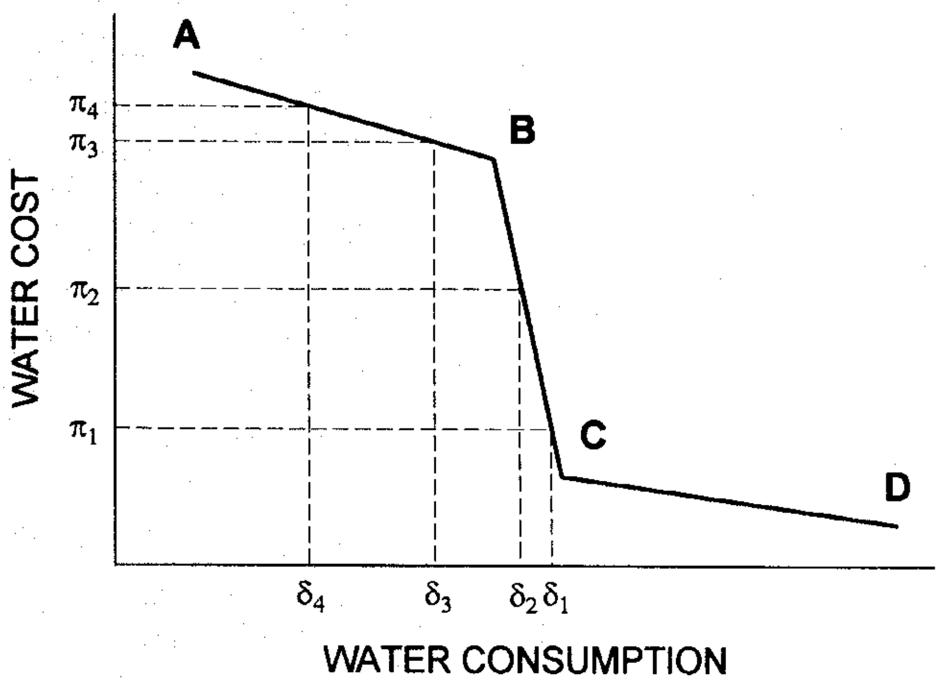

Figure 10.2.1	RELATION BETWEEN WATER COST AND WATER CONSUMPTION
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

CONTENTS

CHAPTER 11 CONCLUSIONS AND RECOMMENDATIONS

11. 1 Conclusions

The Study which was conducted for 33 months from July 1992 to March 1995 had established the following major pillars for the management of groundwater and land subsidence in the Bangkok Metropolitan Area and its vicinty.

1) Development and Installation of Groundwater Database System
2) Construction of Monitoring Stations at Lat Krabang, AIT and Samut Sakhon
3) Groundwater Modeling and Predictions

From the data collected, processed and analyzed throughout the Study, the following conclusions were derived.

(1) Groundwater Use

Groundwater is being pumped out from the aquifer system in Bangkok Metropolitan Area and its vicinity for domestic, institutional, commercial and industrial uses. The total groundwater pumpage of the Whole Area, which is including wholly the eight provinces, was estimated from the well inventory database at 1.80 MCMD ,while the total pumpage of the Study Area which is inside the Whole Area, was estimated at 1.48 MCMD. Pumpage is recently increasing in Bangkok's vicinity, e.g., Lat Krabang, Pathum Thani and Samut Sakhon, but has decreased in the central part of Bangkok Metropolis as a result of the regulations.

(2) Groundwater Levels

Piezometric levels of main aquifers, i.e., Phra Pradaeng, Nakhon Luang and Nonthaburi, have declined from 30m to 60m below MSL in Pathum Thani, Samut Sakhon and from eastern Bangkok to Samut Prakan. In these places, the rate of piezometric level decline of 1.0 to 2.0m/year was observed in Phra Pradaeng Aquifer, 3.0 to 5.0m/year in Nakhon Luang Aquifer and 3.0m/year in Nonthaburi Aquifer. In the central area of Bangkok, groundwater level recovered significantly since 1983, but recently it is lowering because of the effect of the regional decline of groundwater level caused by overpumping in its vicinity.

(3) Land Subsidence

Land subsidence occurs at more than 20mm/year in Bangkok Metropolis, Samut Prakan, Samut Sakhon, central part of Pathum Thani, and part of Nonthaburi. High land subsidence rate is observed in areas where groundwater levels have dropped extensively. Subsidence of 50mm/year to 60mm/year were recorded in Samut Prakan, 40mm/year to 55mm/year in Min Buri and Lat Krabang areas, 30mm/year to 40mm/year in Pathum Thani and Samut Sakhon. Recently land subsidence has slowed down in the central part of Bangkok.

(4) Chloride Concentration

High chloride concentrations were observed from Samut Sakhon to Pathum Thani along the Chao Phraya River and in the coastal areas of Samut Prakan. Concentrations partly exceeding 5,000 mg/L were detected in Phra Pradaeng Aquifer. High chloride concentrations ranging from 3,000 to 16,000 mg/L were observed in Nakhon Luang Aquifer and 2,400 to 13,000 mg/L in Nonthaburi Aquifer.

(5) Monitoring Stations

New land subsidence and groundwater level monitoring station was constructed in Lat Krabang (Site A; 8 wells), at AIT (Site B; 5 wells) and in Samut Sakhon (Site C; 5 wells). Each observation well automatically records the groundwater level and land subsidence in the different aquifers. Data were processed and stored in the groundwater database system which was established during the Study. Together with the DMR's existing 103 monitoring stations (258 wells), the new monitoring stations would be utilized for the groundwater management.

(6) Groundwater Modeling

Groundwater flow and land subsidence models were made for the prediction of future groundwater level and land subsidence. A solute transport model was also prepared for the analysis of saltwater intrusion.

The groundwater models have shown that the groundwater flows towards the piezometric level depression zone both laterally and vertically. Downward and upward leakages resulted from squeezing of clayey layers. Subsidence mainly occurred at the Bangkok Soft Clay due to downward leakage. Deep clayey layers also contribute significantly to land subsidence.

(7) Prediction of Groundwater Levels and Land Subsidence

Calibrated groundwater flow and land subsidence model was used to predict future groundwater levels and land subsidence up to year-2017 using different future pumping scenarios.

Using the worst scenario, which assumed that groundwater pumpage would continue to rise at the present rate, the model predicted that land subsidence would reach a maximum of 200cm by year-2017 and groundwater levels would lower extensively in the entire groundwater basin.

On the other hand, the best scenario assumed that groundwater pumpage would be regulated and reduced starting year-1995 in the proposed new critical zone, and using this scenario, the model predicted that the maximum total land subsidence would be 35cm and the present lowest groundwater level would decline further to 80m below MSL by year-2001 but would recover to 70m below MSL by year-2017.

(8) Tentative Permissible Yield

A tentative permissible yield was determined by giving importance to the rate of land subsidence. The response of the models was carefully reviewed and assessed. This assessment concluded that the tentative permissible yield for the Study Area would be 1.60 MCMD (PD Aquifer: 355,000 CMD, NL Aquifer 693,000 CMD, NB Aquifer 427,000 CMD and Others :125,000 CMD).

(9) Groundwater Basin Management

The tentative permissible yield that was determined in the Study is a management target. In order to achieve this target, it is necessary to expand the present critical zone and regulate the groundwater pumpage. Monitoring of groundwater level, land subsidence and groundwater pumpage coupled with the use of the groundwater database and simulation models are prerequisite to an effective implementation of the groundwater basin management.

11. 2 Recommendations

11.2.1 Groundwater Management

(1) Expansion of the Critical Zone

Groundwater level has been declining heavily, and land subsidence is progressing in Lat Krabang, Pathum Thani and Samut Sakhon areas. It is predicted that by year-2017 the total land subsidence will reach more than 180cm/year and the groundwater level will drop to 170m to190m below MSL. To mitigate such situations, it is therefore necesssary to expand the present existing critical zone to cover those areas.

(2) Regulation of Pumpage

In the medium-term, the tentative permissible yields (target pumpage) in the Study Area are 1.79 MCMD in year-2000 and 1.62 MCMD in year-2005 (Scenario 6). In order to achieve this target, the pumpage must be regulated according to the following schedule.

1995-2000: Regulate pumpage within 2.5% increase annually
2000-2010: Reduce pumpage stepwise at 5% decrease annually
2010-2017: Keep pumpage constant at year-2010 level

(3) Construction of New Monitoring Stations

Monitoring of groundwater level and land subsidence is necessary not only to assess the effectiveness of regulations but also to obtain accurate groundwater data to be used in improving the groundwater models for the evaluation of the permissible yield of the basin. The monitoring system constitutes an essential component of the groundwater basin management, and it is therefore recommended that more new monitoring stations be constructed in Pathum Thani, Samut Prakan and Samut Sakhon where groundwater level continues to decline and land subsidence is progressing.

(4) Leveling of Benchmarks

Leveling surveys are conducted by RTSD, BMA and DMR. However, the date and frequency of their levelings must be coordinated, and their data must be integrated to prepare an authoritative, uniform land subsidence contour map.

(5) Installation of Water Meter

Estimation of pumpage is also an important part of the groundwater basin management. In the Study, the pumpage of private wells was estimated from the water rights records stored in the well inventory database and actual pumpage records of about 2500 wells installed with water meters. Since pumpage estimates were used to set the tentative permissible yield, they must therefore be estimated as accurate as possible in the future evaluation of permissible yield.

Presently, the water permit applicants are obliged to install water meters for industrial and commercial uses of groundwater. This requirement must be extended to other users of groundwater so that a more accurate pumpage estimate can be obtained using the actual groundwater consumption readings from the water meters.

(6) Application of the Groundwater Database System

The groundwater database system established in DMR processes groundwater levels, land subsidence, water quality data, well inventory, etc. These data must be stored continuously in the future. Particularly, the well inventory database must be used, operated and maintained conjunctively with the water permit registration records of DMR.

(7) Improvement of Groundwater Models

The accuracy and reliability of groundwater models established in DMR must be improved in the future. This may be achieved by a more accurate pumpage estimates, by collection and analysis of a more accurate aquifer parameters, and by continuous monitoring of groundwater levels, land subsidence and water quality, etc.

(8) Model Applications and Permissible Yield

The groundwater models jointly with the groundwater database and monitoring systems shall be applied as tools in groundwater management, i.e., in assessing and predicting groundwater levels, land subsidence and water quality and in evaluating the permissible yield of the basin. Since the permissible yield is the management target, it must be re-evaluated according to the monitored data. It is, therefore, recommended to modify the tentative permissible yield and set a more accurate and updated target according to the future monitored groundwater conditions.

(9) Hydrogeological Investigations

The Study Area is located only at the southern part of the Lower Central Plain which itself constitutes a huge groundwater basin, while recent urbanization tends to move towards north and east of Bangkok Metropolitan Area. Hydrogeology of the entire groundwater basin has not been investigated in detail yet, though several studies had been conducted and data had been gathered in the past. It is, therefore, recommended to expand the Study Area to cover the entire groundwater basin and to investigate the long-term prospect of its development.

11.2.2 Comprehensive Measures

(1) Substitutional Water Supply

Since the supply of surface water is a necessary condition for implementing the pumpage regulation, the MWA and the PWA should therefore implement their expansion projects on schedule. It is strongly recommended that waterworks for industrial water use be constructed, particularly, in Samut Sakhon area. The lack of water supply may become a factor obstructing investments in industries, which will finally affect the regional economy.

(2) Rational Use of Water

Technical and institutional measures should be undertaken to save groundwater. In order to find out technical measures in commerce and industry, investigation on the rational use of groundwater is recommended. In addition, campaign to save water should be done vigorously through media and through distribution of leaflets.

(3) Groundwater Fee

Groundwater fee is presently 3.5 bahts/m^3. This rate should be raised to the same price level charged by MWA and PWA. Payment should also be based on the volume of groundwater actually consumed. In addition, groundwater fee should be implemented to other heavily pumped areas as well, not only limited to the present six groundwater areas designated by the Groundwater Act.

(4) Artificial Recharge

One of the measures for recovering groundwater levels and mitigating land subsidence is artificial recharge. However, a pilot artificial recharge well system is recommended to be implemented first before constructing a large one. During the piloting, the main technical as well as economic and legal issues must be investigated and assessed thoroughly through experiments.

(5) Strengthening of the Technical Sub-Committee

To be tasked with assisting the Groundwater Committee in assessing the groundwater situations, the function of the technical sub-committee is recommended to be strengthened within the organization. The sub-committee should deal with the preparation of the groundwater management options from the basin-wide hydrogeological viewpoints.

(6) Organization

The Groundwater Division and the MGL Project of the DMR is tasked to conduct the investigation, observation, analysis and evaluation of groundwater and land subsidence in Bangkok Metropolitan Area. Aside from this, the DMR is deputized by the Minister to investigate and assess water permit applications. Considering the importance of the role of the Groundwater Division and the MGL Project in the management of groundwater and land subsidence in Bangkok Metropolitan Area, it is important that these organizations be strengthened by beefing up their manpower.

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