Challenges in Managing the Chao Phraya's Water

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1. Thailand's Water Resources

Thailand, a tropical land in the center of Indochina Peninsula, is bordered on the north by the Lao People's Democratic Republic (Lao PDR), on the east by the Lao PDR and Cambodia, on the south by the Gulf of Thailand and Malaysia, and on the west by Union of Myanmar and the Andaman Sea. The total land area is about 512,000 km^2. As of 2003, the estimated population was about 62.8 million with a growth rate of 1.0 percent. The urban population was estimated at about 11 million with high concentration in the capital and the regional centers.

The country is still considered an agriculture based country with a total agricultural area of about 265,200 km^2 and more than 60 percent of the population engage in agriculture, while the agricultural production accounts for only about 12 percent of GDP.

Due to rapid economic development in the past decade, water demand continues to grow and in two of the four regions, namely the Northeast and the Central are experiencing frequent drought while flooding also occurs more frequently due to deforestation. The water resources development budget has been increasing and represents a large portion of the national development budget. However, there are currently environmental constraints for large water resources development projects in the future, which may eventually slow down construction of future projects.

Agricultural sector remains the main user of available water and accounts for 71 percent of total water demand, while industrial use accounts for only 2 percent, domestic use accounts for 5 percent and the remaining 22 percent for ecological balance. However, the trend will change with reduction for agriculture and increase for both industrial and domestic water.

Currently about 98 percent of urban population is served with treated pipe drinking water. For rural population, about 76 percent are served with piped water systems, rain water jars and tube wells for drinking water. Household uses in rural areas still have to rely on other water sources.

1.1 Surface Water Resources

Thailand, with an area of about 512,000 $km.^2$, can be divided hydrological into 25 river basins. The average annual rainfall for all over the country is about 1,700 mm. The total volume of water from the rainfall in all river basins in Thailand is estimated at 800,000 million $m.^3$, of which 75 per cent or around 600,000 million $m.^3$ is lost through evaporation, evapotranspiration and infiltration and the remaining 25 per cent of 200,000 million $m.^3$ constitutes the

runoff that flows in rivers and streams. As the population of Thailand is around 62.8 million, the availability of water resources is 3,264 $m.^3$ per person each year, which is statistically considered to be highly adequate. However, considering each basin this figure is uneven and extremely low in many sub basins especially in the Main Chao Phraya Basin.

1.2 Groundwater Resources

Groundwater is an important source of water supply in Thailand. Public water supplies for one - fifth of the nation's 220 towns and cities and for half of the 700 municipalities are derived from groundwater. It is estimated that 75 per cent of domestic water is obtained from groundwater sources. Groundwater system in Thailand is mainly recharged by rainfall of about 38,000 million $m.^3$ and seepage from the rivers. Some amount of rainfall percolated through the ground to settle in the 101,240 square kilometers of unconsolidated strata which can absorb and retain about 10 percent of annual precipitation.

It was estimated from hydrological balance studies that about 12.5 to 18 per cent of rainfall would infiltrate the soils and about 9 per cent of rainfall would reach the aquifers. However, this estimate is valid only for the basins under favorable geologic conditions such as those in the Northern Highlands, the Upper Central Plain and along the Gulf Coastal Plain. For the other basins such as those in the Lower Central Plain including Bangkok and in the Khorat Plateau, it was estimated that only 5-6 per cent of rainfall reaches the aquifer. In addition, groundwater storage in the southern part of Thailand are beach-sand aquifer and located for 300 kilometers along east coast of Gulf of Thailand and mainly used for domestic consumption.

More than 200,000 groundwater well projects were undertaken by both government and private sectors with total capacity of about 7.55 million $m.^3$/day (2,700 million $m.^3$ /year). It is estimated that 75 per cent of domestic water is obtained from groundwater sources which can serve approximately 35 million people in villages and urban areas.

1.3 Water Provision and Water Demand

The average annual rainfall of the whole country is about 1,700 mm. ranging from 1,200 mm annually in the north and central plain up to 2,000 - 2,700 mm. in the western, the southern and the eastern parts of the country. About 29% of the surface runoff, approximately 70,770 mcm. annually, is kept in various sizes of about 650 large and medium scale together with 60,000 small scale water resources development projects all over the kingdom, covering about 31 million rai (4.96 million ha.) irrigable areas.

Although the water resources development program has been implemented continuously for more than 100 years, rapid rural development, industrialization, tourism development and population growth drastically raise the water demand for domestic use, agriculture and other purposes. Inefficient use of water by various sectors and deteriorating water quality due to excessive use of fertilizer and pesticides, urban sewage and industrial wastes also create more serious problems to availability and adequacy of water resources. In 2000 water demand for irrigable areas and other uses for the whole country was

estimated to be 88,700 mcm./year and expected to be 109,350 mcm./year in 2006. Hence, the nation is facing serious supply constraints for further growth due to various problems in the water resources development scheme.

1.4 Water Resources Management in Thailand

Thailand's past three decades of sustainable and rapid economic development stimulated an explosive expansion of demand for water services:- for domestic and industrial water supply, irrigation, and power. The Government devoted significant resources to meeting these demands, and an approach toward water management in Thailand emerged with an emphasis on expansion of access to services, electricity, irrigation and water supply for domestic purposes.

This approach was successful in giving millions of Thai access to potable drinking water, water to produce cheap and abundant food, and to generate hydroelectricity. However, as water has become increasingly scarce, this approach alone is no longer appropriate. The Government now faces a different and more complex set of challenges, comprising both supply and demand-side questions:

- Is the resource base, including both water and watersheds, being managed in a sustainable manner?
- How can be balance between the use and the conservation?
- Are there opportunities for more effective management of existing sources of supply?
- Who will be allocated the water and how will it be allocated?
- Is participation really needed in water management?
- Who will provide and deliver services and who will pay for them?

2. General Characteristic of the Chao Phraya Basin

2.1 Boundary of the Greater Chao Phraya Basin

The Lower or Main Chao Phraya Basin and the other 7 sub basins which comprised as the Greater Chao Phraya Basin are located in the north and the central of Thailand. Considering the Greater Chao Phraya Basin, which from now on will be called the Chao Phraya Basin, it is the biggest basin covers an area of 157,925 square kilometers representing 30% of the total country area. Physically the Chao Phraya Basin is divided into 2 parts at Nakornsawan province:

- Upper Chao Phraya is mountainous alternately with low land area along the river. It comprises 4 main sub basins namely; Ping River, Wang River Yom River and Nan River. The Upper Chao Phraya covers the area of 102,635 square kilometers representing 65% of the total basin area.

- Lower Chao Phraya is flood plain area. The Lower Chao Phraya consists of 4 main sub basins, i.e., Sakae Krang River, Tha Chin River, Pasak River, and Chao Phraya River. The Lower Basin covers the area of 55,290 square kilometers representing 35% of the total basin area.

The Chao Phraya basin is surrounded by the other basins such as Kok and Mekong basins in the north, Gulf of Thailand in the south, Salawin and Mae Klong basins in the west. The eastern part of the basin is next to Chi and Mun basins. Figure 1 and Figure 2 exhibit the location and boundary of the Chao Phraya and sub basins. Table 1.1-1 presents the area of sub basins in the Chao Phraya basin.

TABLE 2.1-1
THE AREA OF SUB-BASINS IN THE CHAO PHRAYA BASIN

Sub-basin (Code)	Catchment Area	
	Km^2	Million Rai
Ping (06)	33,898	21.19
Wang (07)	10,791	6.74
Yom (08)	23,616	14.76
Nan (09)	34,330	21.46
Main Chao Phraya (10)	20,125	12.58
Sakae Krang (11)	5,191	3.24
Pasak (12)	16,292	10.18
Tha Chin (13)	13,682	8.55
Total	**157,925**	**98.70**

2.2 Climate

Chao Phraya basin is influenced by the south western monsoon and also the north eastern monsoon, and therefore, it creates three seasons in the area. Rainy season starts from May to October. Cool season is from November to the mid of February. Hot season starts from mid February to the beginning of May. In addition, the area is also influenced by depression storm which occasionally come into the area.

The fact and figures of the climate in the area are as follow:

Temperature (degree celcius)	27.08
Relative Humidity (per cent)	72.60
Average Wind velocity (knot)	2.22
Cloud coverage (0-10)	5.73
Evaporating (mm.)	1,699.59

2.3 Precipitation

Based on 706 stations located in the Chao Phraya Basin area the average monthly rainfall in the basin and sub-basins is as follows:

Basin	Number of Station	Average Rainfall (mm.)		
		Rainy Season (Jun-Nov)	Dry Season (Dec-May)	Total
Ping	116	1,013.98	137.91	1,151.59
Wang	27	967.06	135.19	1,102.05
Yom	49	1,042.11	124.73	1,166.84
Nan	70	1,149.94	144.59	1,294.53
Main Chao Phraya	235	970.57	128.02	1,098.58
Sakae Krang	16	1,614.20	165.08	1,179.29
Pasak	64	1,058.36	150.99	1,209.35
Tha Chin	129	967.06	135.19	1,102.25
Total	**706**	**1,097.91**	**140.21**	**1,163.05**

Rainfall distribution is heavily on the east of the basin where Nan and Pasak basins have the rainfall of 1,163.00 mm. The deviation at each station is between 812.47 to 1,464.40 mm. in Petchaboon and Nan provinces. The most rainfall is shown in Nan basin.

2.4 Runoff

There are 273 stations to collect data on monthly water runoff, i.e., 98 stations in Ping basin, 25 stations in Wang basin, 27 stations in Yom basin, 65 stations in Nan basin, 10 stations in Sakae Krang basin. 28 stations in Pasak basin, 15 stations in Chao Phraya (main) basin, and 5 stations in Tha Chin basin. During 1960-1996 the volume of water per area classified by sub-basins is as follows:

Sub-basin	Number of Station	Average Annual Runoff per Area (litre/second/km^2)	
		Range	Average
Ping	98	1.33-55.89	8.23
Wang	25	2.34-9.20	4.77
Yom	27	1.63-43.78	4.95
Nan	65	1.81-56.98	11.03
Sakae Krang	10	3.66-32.05	6.60
Pasak	28	2.08-14.93	5.50
Main Chao Phraya	15	3.31-14.00	6.99
Tha Chin	5	1.20-12.68	5.68

2.5 Water Availability

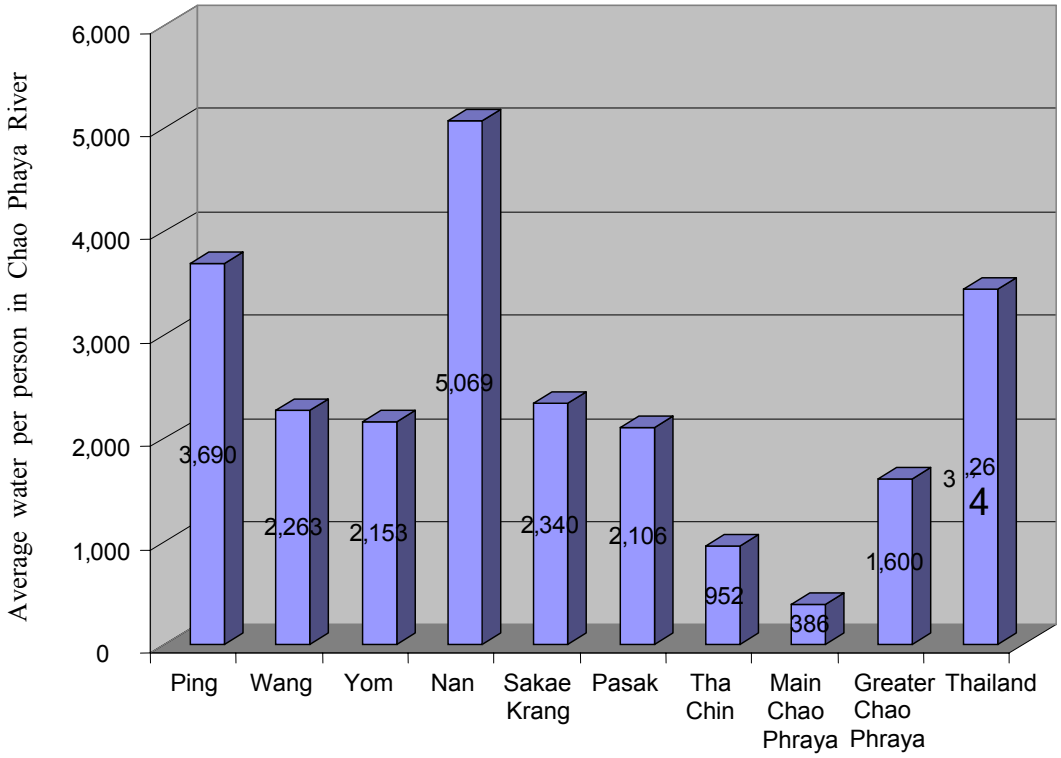

Figure 1 Per Capita Water in the Chao Phaya River Basin

2.6 Water Quality

Water quality in some of the sub basins of the Chao Phraya is rather deteriorated from an excessive discharge of wastewater from various point sources and non-point source. These problems were perceived to be most serious during summer low flow periods when there is minimal dilution capability available. The main pollutants that pose to natural water quality problems are organic wastes, bacteria, nutrients, and other chemical substances. The lower Chao Phraya and Tha Chin rivers are the two rivers that are most deteriorated and are classified into class 4, which is described as fairly clean used for (1) consumption, but requires special treatment process and (2) industry [DO>2 mg/L, BOD<2 mg/L].

In the Tha Chin river, pollutants are discharged into the river from both point and non-point sources. Major point sources of pollutants to the river include domestic and industrial waste discharges as well as some agricultural point sources such as pig, duck, fish and other farms. Although non-point source is also major pollution source in the basin, it tends to be ignored by government authorities and planners. Non-point source includes agricultural areas (mostly paddy fields) and orchards, which are the dominant land uses in the basin.

2.7 Water Resource Use in the Chao Phraya Basin

2.7.1 Irrigation

Surface Water Irrigation Systems. Irrigation development of the Chao Phraya Basin began as early as the 1890's in the southern Chao Phraya Plain. The area was subject to deep and prolonged flooding, and the approach then was to construct canals to provide access to large land areas for the cultivation of flood-dependent rice. The canals also helped to spread the floods more evenly and to promote drainage at the end of the flood season. From 1904, when the Royal Irrigation Department (RID) was formed as the agency responsible for water resource development in Thailand, through the 1930's, this mode of development was applied to more than 500,000 ha. Many more infrastructures were built during 1950 up to present. A summary of the irrigation schemes developed since 1950 is given below.

Projects	No. of Project	Irrigation Area (rai)
1.Large Scale Projects	37	9,001,343
2.Medium and Small Scale Projects	98	490,530
3.Pumping Irrigation Projects	225	359,580
Total	**360**	**9,851,453**

The irrigation systems in the northern part of the Chao Phraya Basin consist of discrete irrigation systems served by their own reservoirs. Many small pump irrigation schemes have also been developed. However, several large dams were built to provide irrigation water to the lower Chao Phraya Basin. It is essential to appreciate that the development of the irrigation systems in the lower Chao Phraya Basin was progressive, often building on and expanding existing systems. The lower Chao Phraya irrigation scheme, the largest in the country was initially constructed to provide supplementary irrigation in the wet monsoon season, but progressively was required to provide ever increasing amounts of irrigation water for the dry season.

The lower basin (delta) irrigation system is complex and consists of some 26 interconnected schemes below the Chao Phraya Diversion Dam. This barrage diverts the flow of the Chao Phraya River into a distribution network and at the same time releases the required water flow for river maintenance and downstream water needs. Water conveyance and regulation facilities of this system, whose operation is a major concern in efficient water management, are now quite old. Canals are unlined earth construction. The whole system is under the management of RID. The 26 irrigation projects may be divided into two categories-gravity irrigation and water conservation irrigation areas. The former covers 20 project areas in the northern part of the delta and the latter cover the southern project areas. In two of the 20 gravity irrigation areas, the water is pumped from a river to the main canal and then distributed by gravity. Within the irrigation projects, farm turn-outs (FTOs), which serve 30-60 ha each, are the terminal level of irrigation water control by RID. The beneficiary farmers control the system below the turn-outs. Farm ditches were limited to only short lengths from FTOs when originally constructed to serve plot-to plot irrigation without any ditch network. Thus the on-farm system was not convenient for practicing an efficient rotational irrigation system. Therefore in 1961, RID commenced the so-called Ditch and Dike Project to provide the system with a farm-ditch network of 25 m/ha, and up till now a million hectares have been covered by this programme in the Central Plain. It was successful in increasing the dry season cropping over limited areas, despite considerable problems in equitable

water distribution; farmers at the head of a canal had a much better supply than farmers located at the tail end.

Despite the many storage reservoirs throughout the Basin, much water flows to the sea during the wet season. Although new dam construction is now more highly socially charged, there is still scope for further construction of dams to store the surplus monsoon water. By contrast, during the dry season the only waters flowing into the Gulf of Thailand are to protect the municipal water intakes from salinity intrusion and to maintain adequate water levels for river transportation. However, even without further dam construction, there is considerable scope for using the limited dry-season water more efficiently. Increased efficiency not only refers to improving system conveyance, but also planting more water-use efficient crops, and timeliness an amount supplied. In addition, there are other critical factors concerned with system performance that relate to equity and fairness in distributing a limited water supply and the conflict and anarchy that arises from stealing and misuse of water. RID seems powerless to control the illegal use of water as they do not have the necessary support to enforce the law. These are very serious factors that adversely affect the effective operation of the delta irrigation system.

The main problems and constraints in operation and management of the irrigation systems in the lower Basin are concerned with:

Stored water resources. The land area now served by irrigation systems in the Chao Phraya Basin far exceeds the water available for dry-season irrigation. The inflow into the Bhumibol and Sirikit reservoirs, the main water supply for the lower Chao Phraya irrigation system, has decreased since their construction due to increase in upstream population, changes in land use and economic growth in the upper Basin. Operation studies have shown that the area irrigated each year in the dry season should be held to about 600,000 ha of rice. In practice, the tendency is to go beyond that figure when the reservoirs are full. Unfortunately this can lead to shortages after several years of low reservoir inflows. At times, this has created situations where the supply of water to Bangkok, that has priority over irrigation, has been threatened.

Water delivery. Water allocation problems occur primarily in the dry season, but also during drought periods in the wet season. The absence of a central unit to resolve problems and coordinate water allocation among government agencies and water users is a serious constraint. There is insufficient coordination between government agencies and farmers in planning coming crop areas and water requirements. The quantity and timeliness of water deliveries to irrigation projects and farm turnouts is a major problem. Inadequacies in water delivery result from poor management, inadequate communication systems and need to upgrade irrigation control structures. There is insufficient water to satisfy the water requirements of all farmers interested in dry season cropping. This creates problems in the sharing of limited water resource in an equitable manner. Serious conflicts arise between water users and anarchy in water abstraction occurs through illegal pumping of water. No water rights system is in existence. Although water user groups have been formed.

Groundwater Irrigation Systems. The use of groundwater for agriculture is mainly to supplement surface water supplies. Groundwater consumption is more acute

during the dry season and in drought years for land preparation, crop needs in the early part of the wet season and as supplementary source of water for farms located at the tail-end of distribution canals. Pumped irrigation schemes are at present being implemented by the Department of Energy and Energy Promotion to secure adequate irrigation water throughout the year in the middle Basin area. Potential exists to further develop the use of groundwater for irrigation purposes, but this should be undertaken after a thorough analysis of the sustainable yields of the relevant aquifer.

2.7.2 Electricity Generation

Hydropower in the Chao Phraya Basin is managed by the Electricity Generating Authority of Thailand (EGAT). At present there are only two major hydropower installations, at Bhumibol (713,000 KW) and Sirikit (500,000 KW) reservoirs respectively, with a smaller installation at Mae Ngat (9,000 KW) in the Upper Ping basin. EGAT is not presently actively pursuing new hydropower projects in the basin. The construction of further large reservoirs with hydropower potential would involve large-scale resettlement making such projects problematic. New reservoir construction in the upper basin has also encountered increasing opposition on environmental grounds.

2.7.3 Industrial Use

Past industrial growth has been greatest in Bangkok and pressure on existing infrastructure has led to new enterprises starting in the provinces surrounding Bangkok where land, labour and other resources are more readily available and infrastructure is less congested. Future growth is expected to be greatest in these areas although there are also initiatives to encourage industrial expansion in a number of provincial centres. The amount of water used for industrial purposes in the Chao Phraya Basin is uncertain. Estimates for groundwater use are only available for the Chao Phraya sub-basin. Considerable inconsistency occurs in data derivation and it is unknown whether figures include system inefficiencies. A study of industrial water use for the eight sub-basins estimated and industrial water demand of about 758 MCM in 1996, of which 94% was estimated to be used in the Chao Phraya/Tha Chin sub-basins. Surface water supplies are less important to industry with about 75% of water use derived from groundwater resources.

2.7.4 Domestic Water Use

Water supplies for domestic purposes are provided by water service facilities in urban areas and by wells in rural areas. At the provincial level, domestic water supply coverage is about 47% of all households. Water supply for domestic purposes for farm households is from piped schemes (56.8%), wells (37.2%) and rivers (6.4%). Overall, 62% of rural households consume water from unprotected sources, such as rainfall collection, rivers, canals and ponds. The majority of piped schemes for farm households are operated and managed by village communities. Nationwide, potable water supplies are generally provided by two agencies: the Metropolitan Waterworks Authority (MWA) and the Provincial Waterworks Authority (PWA). The MWA engages in production and distribution of potable water in the Bangkok metropolitan region while the PWA is responsible for all the provinces in Thailand. The PWA is responsible for water

source development, conveyance, pumping, treatment, storage, and distribution facilities from all urban and rural communities in the provinces. Total domestic water requirements in 1993 was estimated at 3,194 mm^3 per year. In contrast to industrial water supply only 12% of domestic supply was estimated to be met from groundwater sources.

2.7.5 Navigation and River Integrity

Navigation. Since early times, the Chao Phraya River has been a major navigation route far into the central part of the basin. Ships and barges have provided a very important means of transport of commercial goods. However, the increasing diversion of river flow for irrigation has had the effect of reducing minimum flows in critical reaches of the river such that navigation by vessels over a certain size is now restricted during the dry season. A recent study for Harbours Department in 1996 proposes the construction of two barrages to restore navigation capacity in the main Chao Phraya and into the lower reaches of the Nan river. Minimum river flows are also required for navigation in other waterways. Although generally restricted to smaller and declining number of commercial craft, the Pasak river (below Rama VI barrage) and the Tha Chin river are still important waterways as well as a number of the RID's supply canals in the lower part of the basin. Allocation of basin water supplies must take into account needs to maintain sufficient flows for river transport.

River Integrity. The maintenance of river integrity is based on maintaining minimum stream discharges to repel salt-water intrusion at the lower reaches of rivers, minimise levels of pollutants and maintain minimum dissolved oxygen levels to ensure that the quality of the aquatic environment does not fall below acceptable levels. A minimum flow of 16 m^3/s is currently considered sufficient in the lower reaches of the Chao Phraya River to repel saline intrusion. Pollution control is more problematic. Most of the wastewater discharges of domestic and industrial origin have increasingly been controlled and miticated through the enforcement of separate effluent standards by various regulating governmental agencies. In addition, the regulation of streamflow in the Chao Phraya River by releases from upstream reservoirs operated by EGAT and RID can to some extent improve the poor downstream water quality during the dry season. Allocation of basin water supplies must take into account these needs.

2.7.6 Present and Future Water Budget

The water demand for various categories of water users has increased rapidly in the Chao Phraya Basin. The present and projected water demand for various sub-sectors is given below. Irrigation is the main user of water in the Basin followed by the needs for ecological balance in river systems. The demand for ecological balance includes requirements for river maintenance flow, navigation, salinity control and others. The present total water supply in the Basin is estimated at about 25,000 MCM. Water demand in the Basin is already 10% in excess of supply and is projected to increase significantly in the future for all uses, especially for irrigation purposes. This will result in a serious future water crisis in the Chao Phraya Basin, especially in the normal and dry years, unless the present water resources are used more efficiently and/or additional sources of water are accessed. Additional supplies can only come from construction of more reservoirs, re-use of water and greater abstraction of groundwater.

Present and Future Sectoral Water Demand in Chao Phraya Basin

Sector	Annual Water Demand (MCM)			
	1996	**2005**	**2010**	**2020**
1. Irrigation	20,927	22,503	23,797	26,145
2. Urban & Industrial Water Supply*	1,741	1,758	2,088	2,121
3. Industries and Tourism**	21	23	27	39
4. Power (Thermal Plant)	45	61	61	61
5. Ecological Balance	4,661	4,819	4,819	4,819
Total	**27,395**	**29,164**	**30,792**	**33,185**

* Includes industrial demand in and around Bangkok
** Demand upstream of Chao Phraya Dam.
Source: Royal Irrigation Department (1999)

The degree of water shortage varies greatly across the Basin. A summary of the projected water demand, supply, and shortage situation in the various sub-basins is given below. More than 50% of the basin water shortage occurs in the two most populous sub-basins, the Ping and Chao Phraya (including Tha Chin). At present, the average annual water scarcity in the Chao Phraya Delta (including Tha Chin) and the Chao Phraya Basin as a whole is about 619 MCM and 2,440 MCM, respectively, which is projected to increase to 1,426 MCM and 6,164 MCM respectively, in the next 20 years without increasing efficiency of water use and additional supplies being tapped.

Present and Future Area Water Demand, Supply and Shortage in Chao Phraya Basin (in MCM)

Basin/Sub-basin	1996			Future 20 years		
	Demand	**Supply**	**Shortage**	**Demand**	**Supply**	**Shortage**
Ping	42,54	3,654	-600	6,213	4,465	-1,748
Wang	587	515	-72	871	641	-230
Yom	1,095	725	-370	2,574	1,220	-1,354
Nan	3,275	2,949	-326	3,956	3,246	-710
Sakae Krang	738	367	-371	886	421	-465
Pasak	600	518	-82	1,490	1,259	-231
Chao Phraya Delta + Tha Chin	16,846	16,227	-619	17,195	15,769	-1,426
Chao Phraya Basin (Whole)	**27,395**	**24,955**	**-2,440**	**33,185**	**27,021**	**-6,164**

Source: Royal Irrigation Department (1999)

The future challenge for agriculture, as well as for other water users, is to reduce demand through the institution of greater efficiencies of water use. The demand for water for agricultural purposes in the Basin can be reduced through greater efficiencies of use brought about by irrigation system modernization along with an institutional reform programme. Increasing water use efficiency is vital to sustain economic growth dependent on the provision of adequate water services. A concentrated effort has to be given to the proper analysis of water resources, their current use, the inefficiencies in use of water and opportunities to save water and the allocation of water to users. Such analyses are critical to the development of informed policies, strategies and plans for future water use.

Good integrated management and effective control of the water sector is required. Water users must be involved in decision making. An effective legal and regulatory framework has to be established together with strong enforcement of the regulations concerning water use.

2.8 Concerns over Water Uses and Water Quality in the Chao Phraya Basin

It is utmost important that allocation of water has to be carefully done considering competing uses from various sectors and in spatial uses from upstream to downstream areas. In dept analysis was described in 2.7 and most of it concerning water use in agriculture, which is the biggest use sector. Dry season cropping has been increased over time and it causes considerable problems in equitable water distribution. Land area now serves by irrigation systems in the Chao Phraya Basin far exceeds the water available for dry season irrigation.

In order to avoid serious effect of water shortages in dry season in irrigated land, appropriate measures have to be implemented. In the short-run distribution of water on rotation basis for irrigated land is used. In the longer run, measures to increase efficiency in water use are implemented. They not only refer to improving system conveyance, but also planting more efficient crops, and timeliness an amount supplied. Increasing of coordination between government agencies and farmers in planning for coming crop areas and water requirements is also important. Inadequacies in water delivery result from poor management, inadequate communication systems have to be improved and there is a need to upgrade irrigation control structures.

Water pollution from land-based activities is largely associated with urbanization, industrialization, and agricultural activities. Thus, the major sources of pollution are domestic sewage, industrial wastes, and agricultural wastes. Main pollutants that pose problem to water quality are organic wastes, bacteria, nutrient, heavy metals, pesticides, and other chemical substances.

For major rivers of the country, observed water quality problems are dissolved oxygen depletion, fish kills, high ammonia nitrogen, high coliform bacteria, and eutrophication phenomena. Generally speaking, these problems were perceived to be most serious during summer low flow periods when there is minimal dilution capability available. Once water quality problems have been identified, it is necessary to develop targets for restoration to undertake the planning exercise on a basin-wide basis.

Thailand has developed master plans for water quality management for all 25 river basins. Major river basins including the Chao Phraya are planned for water quality management and construction wastewater treatment facilities in municipalities is prioritized and recommended as well as a control of wastewater from industrial and agricultural sources. Water quality modeling and the geographic information system (GIS) have also been continually developed and used as the tools to help decision-makers in water quality management.

Water pollution control practices in Thailand can be concluded as follows:

- *Pollution load assessment*: This is to identify present and expected pollution loads from land-based sources into various receiving waters. Priority for treatment facilities would also be set up.

- *Wastewater treatment and disposal*: This is to identify appropriate and cost effective technologies for each certain location. Fees of waste discharges are also studied and will also be applied to many sites in the near future.
- *Cleaner production and technology*: This is to support private sectors to use cleaner production and technology for reducing environmental impacts.
- *Monitoring and enforcement*: This is to meet a requirement of proper assessment and improvement of water quality. Standard has been used as a tool for enforcement.
- *Cooperation with related agencies and local communities*:

In trying to achieve more clean water, which is an activity that value of water is appreciated, there is an attempt to apply Polluter-Pays-Principle: PPP. Its main objectives are to control water pollution and all over the countries, 87 wastewater treatment plants were constructed which are locally operated. There are 4 municipalities that apply PPP and a few more are working toward the idea. User fee is calculated using 4 principles; 1) different fees for different users and it must reflect cost of plant construction, operations and personals, 2) fee is substantial for continuing effective operation, 3) fee is affordable to all users, 4) wastewater treatment operation is simple and manageable by local authority.

Challenges faced in this area include

1. Public opposition both to construction of the plants and user charges, lack of understanding is a major obstacle and also make it difficult to select the construction site.
2. Lack of data aggregation to correctly calculate user fee.
3. Funding is insufficient, all the construction rely on the government budget which make it difficult to set up.
4. Political interference makes it difficult for regulations to be enforced, polluters may refuse to pay and politicians are too afraid to loose votes by going against the voters.

3. Toward Sustainable Water Resources Management

Thailand's concept for sustainable water resources management has been applied throughout the country including the Chao Phraya Basin. It comprises the following issues.

- Integrated river basin management
- Development of institutions to facilitate the management

In the Chao Phraya Basin, works have been continuously implemented within two areas and some accomplishments can be highlighted as follows.

Integrated river basin management. Thailand has adopted managing water resources in the river basin context since 1999 when river basin management were trialed in the first two pilot sites of the Chao Phraya and the River Basin Committees were established. In doing so, their compositions were carefully determined and their mandates were tested.

An integrated concept of managing water resources coherently from upstream to downstream has been introduced and implemented. In upstream area in the North of the country, conservation of headwater and upper watershed are

implemented. Areas that are affected by flash flood and landslide are being installed with early warning system. Water allocation mechanism and demand management is trying to be introduced.

Interdisciplinary of professional backgrounds working in river basin management is important and should be promoted. It also means considering the river basins themselves and the interactions between land use and the water in rivers, streams and lakes, when making decisions about the development and management of all natural resources.

Administrative integration refers to the coordination of water management responsibilities and activities at all levels of government, including national, provincial and local, and between those levels. Having a well-formulated and clearly enunciated legal and organizational framework for water management is essential. Apart from the need to promote such coordination an inclusion of local communities and people into a decision making process or managing water resources in the river basin. Participation of groups of stakeholders in such a process should be increased in the Chao Phraya river basin management.

Development of institutions to facilitate the management. In order to make the concept of integrated river basin management worked, a River Basin Committee (RBC) was set up for each of the sub-basins of the Chao Phraya as a mechanism for water management. As each RBC comprises various groups of stakeholders that they represent therefore any conflict in water use and the way to prevent it should be managed within the RBC. The RBC mandate in proposing water resources plans for its basin and it coordinates for an implementation of the plans.

In planning process, there are factors that have been taken into account including coherence of projects from upstream to downstream. The RBC also learns many lessons about water allocation and efficiency in water uses. However, time is needed for these people to furnish themselves with proper skill and knowledge. At least the RBC is a good exercise for people participation in water resources management. One future needs is an establishment of the RBC for the Greater Chao Phraya Basin to compile projects and provide coherence for the whole basin.

Draft water resources law is now under drafting process. Its main purpose is to provide criteria and measures to ensure people basic rights to access to save drinking water. The others are a control of water usage, management, sustainable and effective water usage, development, protection, rehabilitation and conservation of water resources, prevention and solution to flood problem and water shortage, water resources fund and river basin fund, decentralization and participation of people at the river basin level and the establishment of water organizations at national, river basin, and sub-basin levels inclusive of water user organizations to serve the said objectives.
