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# Development of Water-Management Institutions in the Mae Klong River Basin, Thailand

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## Introduction

The "Regional Study on Development of Effective Water Management Institutions" project was originally planned for five countries: China, Indonesia, Nepal, Philippines and Sri Lanka. In 2001, during a regional workshop held in Indonesia, Thailand expressed interest in participating in the project. A new work plan was created for Thailand and research was begun on the Bang Pakong and Mae Klong river basins in Thailand. This chapter presents the findings from the study of the Mae Klong river basin.

A goal of the project was to develop methods to link assessments of physical characteristics, water accounting, irrigation-performance assessment, and socioeconomic analysis in a manner that would improve the management of scarce water supplies within river basins. The overall purpose was to develop a framework for water management that would be comprehensive and integrated, participatory and responsive, and dynamic and strategic. Within this framework, policies and institutions could be improved and strengthened that would, in turn, improve the management of water resources. This chapter starts with an overview of the Mae Klong basin, and is then organized according to the three components of the study: water accounting, socioeconomic analysis and irrigation-performance assessment, and institutional analysis, followed by conclusions and recommendations.

## Mae Klong River Basin

The Mae Klong basin drains approximately 30,800 square kilometers in the western part of Thailand. Thailand is subject to the southwest monsoon during the period from May to October and tropical cyclonic storms from the South China Sea during the end of the rainy season between September and October. Annual rainfall ranges between 900 and 1,500 mm per year, with an average annual rainfall of between about 1,000 to 1,300 mm per year. Due to Thailand's location in the tropical latitudes, temperature is uniform throughout the year with small seasonal variation around the mean of 28 °C. The average temperature in the hottest month (April) is 32 °C while the average temperature in the coldest month (December) is 25 °C.

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Among the twenty-five main river basins in Thailand, the Mae Klong river basin has some of the most abundant water resources. Forest covers more than 55 percent of the total basin area, compared to less than 25 percent for the country as a whole. The Mae Klong river is fed by two main tributaries: the Khwae Yai and the Khwae Noi, which are regulated by large multipurpose reservoirs, Srinagarin and Vajiralongkorn, respectively. Both supply water to the Mae Klong diversion dam in the downstream region of the Kanchanaburi City. The most intensive water-use zones are located in the lower part of the basin. It comprises a number of urbanized areas along the river and the Greater Mae Klong Irrigation Project (GMKIP), one of the largest irrigation-service areas in Thailand.

A large amount of water originates in the upstream drainage basin to feed the three million *rai* (480,000 hectares, 1 *rai*=0.16 ha) of the GMKIP. Yet, inadequate water supply for downstream irrigated paddy cultivation and domestic uses persists. Current plans call for water from the Mae Klong river to be diverted for the domestic water supply of the Bangkok area by the Bangkok Water Authority.

For this study, the basin was divided into seven areas: Khwae Noi upper basin, Khwae Noi lower basin, Khwae Yai upper basin, Lam Pachi, Lam Taphoen, Mae Klong Plain, and the GMKIP (see annex 1). These subdivisions are based on topography, land use, and the existing location of gauging stations for the convenience of water-accounting analyses. The seven areas were assigned abbreviated codes as shown in table 1. Khwae Noi and Khwae Yai are primarily forested areas with only a small portion of agricultural land. The Lam Taphoen is a tributary of Khwae Yai and most of the area is used for rain-fed agriculture. However, a medium-scale reservoir in the Lam Taphoen basin has almost been completed, with irrigation canals under construction and the project is expected to be operational within a few years. Lam Pachi is the only subbasin that has no medium or large-scale irrigation systems, and it has a serious problem with soil erosion. The plains area is divided into two: the upper plain area, which has no big irrigation systems and the GMKIP where most of the area is irrigated.

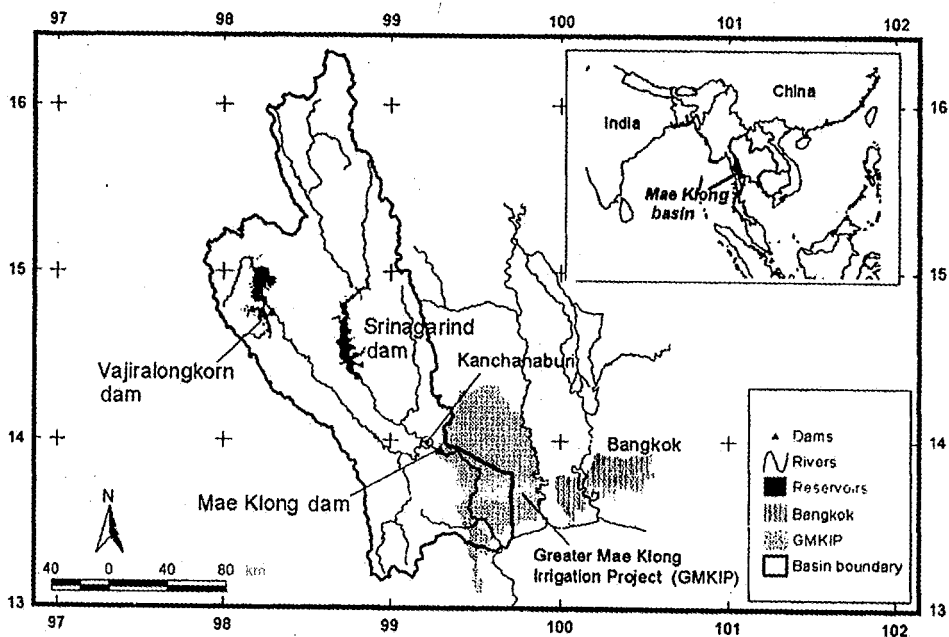
*Table 1. Code abbreviations for study areas in the Mae Klong river basin.*

Area Names	Code
Khwae Yai Upper	KHY
Lam Taphoen	LTP
Khwae Noi Upper	KHN-U
Khwae Noi Middle	KHN-M
Lam Pachi	LPC
Mae Klong Plain Upper	MK-PU
Greater Mae Klong Irrigation Project	GMKIP

The GMKIP consists of 10 irrigation projects: Phanomthuan, Songphinong, Banglen, Kamphaengsaen, Nakhonpathom, Nakhonchum, Thamaka, left bank Ratchaburi, right bank Ratchaburi, and Dumnernsaduak projects. The Dumnernsaduak project is a combined irrigation and flood-control project. As shown in figure 1, the official boundary of the Mae Klong river basin encompasses only 45 percent of the GMKIP, while more than half of the GMKIP's irrigated area is in the Thachin river basin. In order to consider the entire water uses in the basin, the GMKIP is totally included in the analysis.

In this report, data are usually presented from upstream to downstream. The map in figure 1 provides a more accurate illustration of the rivers. The upstream areas are generally more forested and less densely populated than downstream areas. Movement downstream corresponds to increased proximity to more densely populated urban centers, particularly Bangkok.

Figure 1. The Mae Klong river basin.



## Water-Accounting Analysis

Water accounting was carried out to provide a basin-level summary of water availability and use across sectors. Water accounting for this study was done based on methods developed by IWMI researchers (Molden 1997; Molden and Sakthivadivel 1999).

*Rainfall.* Daily rainfall data from the Royal Irrigation Department (RID) were available for the study. More than 300 rain-gauge stations in 10 provinces that share the area with the Mae Klong river basin were investigated. However, only 58 stations were found to be within the boundary of the Mae Klong river basin. Among these, a limited number of stations provide usable information due to the intermittent recording and the regulated streamflow from the upstream dams. Two or three stations per subbasin, with a total of 20 stations, were selected on the basis of representative characteristics of the stations and data availability. Most of the stations have rainfall data in digital format beginning from 1952. The consistency of the rainfall records was carried out by the double-mass analysis technique, before the estimation of monthly and yearly mean annual rainfall using the Thiessen polygon method.

*Inflow.* The estimation of inflows in the main tributaries of Mae Klong river was based on the data from the gauge stations and water budget analyses at the storage dams. Some information from previous studies (AIT 1994; Kositsakulchai 1997, 2001; Rajasekaram 1997) was also taken into consideration in order to validate the data.

*Storage change.* The reservoirs of Srinagarind and Vajiralongkorn storage dams constitute the main surface storage in the basin. Information on reservoir operation, including the reservoir-storage variation, was provided by the Electricity Generation Authority of Thailand (EGAT). For the annual accounting, the changes in storage appear negligible. Conversely, they play an important role in the seasonal water-accounting analysis between dry and wet periods.

*Trans-basin diversions.* Water is now diverted to the Tha Chin river via two main drains of the GMKIP; Jarakae Sampham and Thasan-Bangpla canals. The maximum discharge of 80 m<sup>3</sup>/s is anticipated from January to June during the dry-season cultivation in the Lower Chao Phraya West Bank area of the Central Plain.

The Metropolitan Waterworks Authority (MWA) initiated the Bangkok Metropolitan Water Supply Project in order to ensure potable water supply for a forecast population of 15 million in 2017. The MWA pumps water directly from the Tha Chin river. The diversion from the Mae Klong river at the design discharge of 45 m<sup>3</sup>/s will begin within the next 15 years, when the construction of the new delivery canal is completed.

*Crop consumption.* The estimation of water volume depleted by crop evapotranspiration is based on water balance analyses. The potential evapotranspiration is derived from Class-A-pan-evaporation data. The adjustment factors for the derivation are those recommended by the FAO. The results of estimation by the main types of land use are summarized in table 2.

The depletive uses by crops can be divided into three groups. The beneficial process depletion is found in agricultural and irrigation-service areas. Evaporation from the forest area is also considered as beneficial, but non-process, depletion. Finally, water evaporated from other types of land cover, such as water bodies, is categorized as non-beneficial, non-process depletion.

*Table 2. Area and estimated evapotranspiration (ETa) of the main crops in the Mae Klong basin.*

Crop type	Area		ETa
	km <sup>3</sup>	%	km <sup>3</sup>
Paddy field	2,872.90	8.80	3.1
Sugarcane	4,370.30	13.40	4.5
Field crop/Vegetable	929.5	2.90	0.7
Orchard	969.8	3.00	1.4
Aquaculture	76.2	0.20	0.1
Forest	20,487.60	63.00	16.4
Water body	881.6	2.70	1.2
Others	1,943.70	6.00	1.8
Total	32,531.60	100.00	29.3

*Domestic and industrial uses of water.* Studies on domestic and industrial use of water in the Mae Klong river basin were conducted by AIT (1994) and the Mahidol University (1994). The AIT study estimated an annual volume of 17.6 million cubic meters (m<sup>3</sup>) for use in 1996 and 30.7 million m<sup>3</sup> in 2001. The Mahidol University reported the use of 27.7 million m<sup>3</sup> for five provinces situated in the lower part of the Mae Klong river basin. According to the previous studies, the volume of 30 million m<sup>3</sup> per year is estimated for the domestic and industrial uses of water in the Mae Klong basin.

*Outflow.* Outflows from the Mae Klong basin consist of two parts: surface outflows from the river and from drains. Records of stream flow of the Mae Klong river and its tributaries were used for estimating the outflow from the area of interest. A monthly water-balance model was applied in order to estimate the excess water drained from the irrigation-service area.

*Commitments.* A discharge of 40 m<sup>3</sup>/s is recommended by AIT (1978) in order to control salinity intrusion at the mouth of the Mae Klong river. The minimum releases of 50 m<sup>3</sup>/s from the Mae Klong dam are adopted for this purpose. This discharge, considered as committed flow, also incorporates the uses of water along the river.

*Water accounting at the basin level.* At the basin level, annual data were analyzed by using 10-year average data between 1989 and 1998. Rainfall represents the entire inflow of 39 km<sup>3</sup> into the basin (table 3). Constant storage is assumed for the annual analysis. Around 75 percent

Table 3. Mae Klong river-basin water accounting: Current condition, with planned trans-basin diversion in 2017 (km<sup>3</sup>).

	Current Volume	Planned for 2017	
		Total	Volume Total
<i>Inflow</i>			
Gross flow		39.151	39.15
Precipitations	39.15		39.15
Surface inflow	0.00		0.00
Storage change		0.00	0.00
Surface	0.00		0.00
Net flow		39.15	39.15
Depletive use			
Process depletion		9.88	9.88
Evapotranspiration	9.85		9.85
Municipal and industrial uses.	0.03		0.03
Non-process depletion		19.43	19.43
Beneficial (forest evaporation)	16.42		16.42
Non-beneficial (others evaporation)	3.01		3.01
Total depletion		29.31	29.31
<i>Outflow</i>			
Total outflow		9.87	9.87
Surface outflow from river	6.31		3.92
Surface outflow from drains	3.16		3.16
Trans-basin diversions	0.40		2.79
Committed water		1.98	4.37
Trans-basin diversions	0.40		2.79
Saltwater intrusion	1.58		1.58
Uncommitted outflow		7.90	5.50
Utilizable	7.66		5.26
Non-utilizable	0.24		0.24
Available water		36.93	34.54
Available for irrigation		36.90	34.51
<i>Indicators</i>			
Depleted fraction (gross)		0.75	0.75
Depleted fraction (net)		0.75	0.75
Depleted fraction (available)		0.79	0.85
Process fraction (depleted)		0.34	0.34
Process fraction (available)		0.27	0.29

of inflow is depleted by evaporation and transpiration from the basin. Since the forest covers more than 60 percent of the basin area, its evapotranspiration has a volume of  $16.42 \text{ km}^3$  or half of the depleted water from the basin. From the environmental point of view, this evaporation is considered as beneficially depleted water.

The stream flow appears to be the highest outflow, of  $6.3 \text{ km}^3$ , from the basin; this includes the committed water of  $1.58 \text{ km}^3$  ( $50 \text{ m}^3/\text{s}$ ) for protecting agricultural areas close to the coastal zone from saltwater intrusion. Another important outflow is due to the drainage water from the GMKIP irrigation system. The estimated volume of  $3.16 \text{ km}^3$  calls for attention to the utilization of basin water. Available water could be increased by reducing the drainage outflow. Under the existing uses of water in the basin, almost 80 percent of available water has already been depleted.

*Situation in the next 15 years.* With the ongoing trans-basin projects, the diversions will attain a maximum volume in 2017, for the Bangkok Metropolitan water supply of  $45 \text{ m}^3/\text{s}$  and for contribution to the dry-season irrigation in the Lower Chao Phraya Left Bank. The committed water will increase from  $1.98 \text{ km}^3$  to  $4.37 \text{ km}^3$ . Although the average data analyses permit these planned diversions, the more frequent droughts during the last 10 years signal caution for water management.

*Seasonal water-accounting analysis.* The first 6 months of the year, January to June, are analyzed as the dry period and the last 6 months as the wet period. In general, all components of water accounting during the wet period are greater than those during the dry period with the exception of the trans-basin diversions. Twice the gross inflow can be observed in the wet period, while the depletive uses vary less, especially in the irrigation-service area (beneficially depleted water). The higher inflow in the wet period also introduces more outflows from the basin, which can be observed in the uncommitted outflow component. The committed water practically aims to maintain minimum stream flow and to contribute to dry-season cultivation in the Central Plain. The surface storage in the basin allows the depleted water in the dry period to exceed the gross inflow into the basin as indicated by the indicator  $DF_{\text{gross}}$ . The storage plays a significant role in sustaining water availability over the deficit period.

*Water accounting in the Mae Klong subbasins.* The second part of the water-accounting analysis considers the spatial variation of water use in different parts of the Mae Klong river basin. The basin was divided into seven parts according to hydrological characteristics and water-control facilities. The limits in the upper part of the basin can be defined by the drainage areas of the main tributaries: Khwae Yai (KHY), Khwae Noi (KHN), Lam Pachi (LPC) and Lam Tapheon (LTP). The Khwae Noi basin is divided into two subbasins at the location of the Vajiralongkorn storage dam (KHN-U and KHN-M). The Upper Mae Klong Plain (MK-PU) receives all flows from the upper part of the basin before diverting some water into the GMKIP.

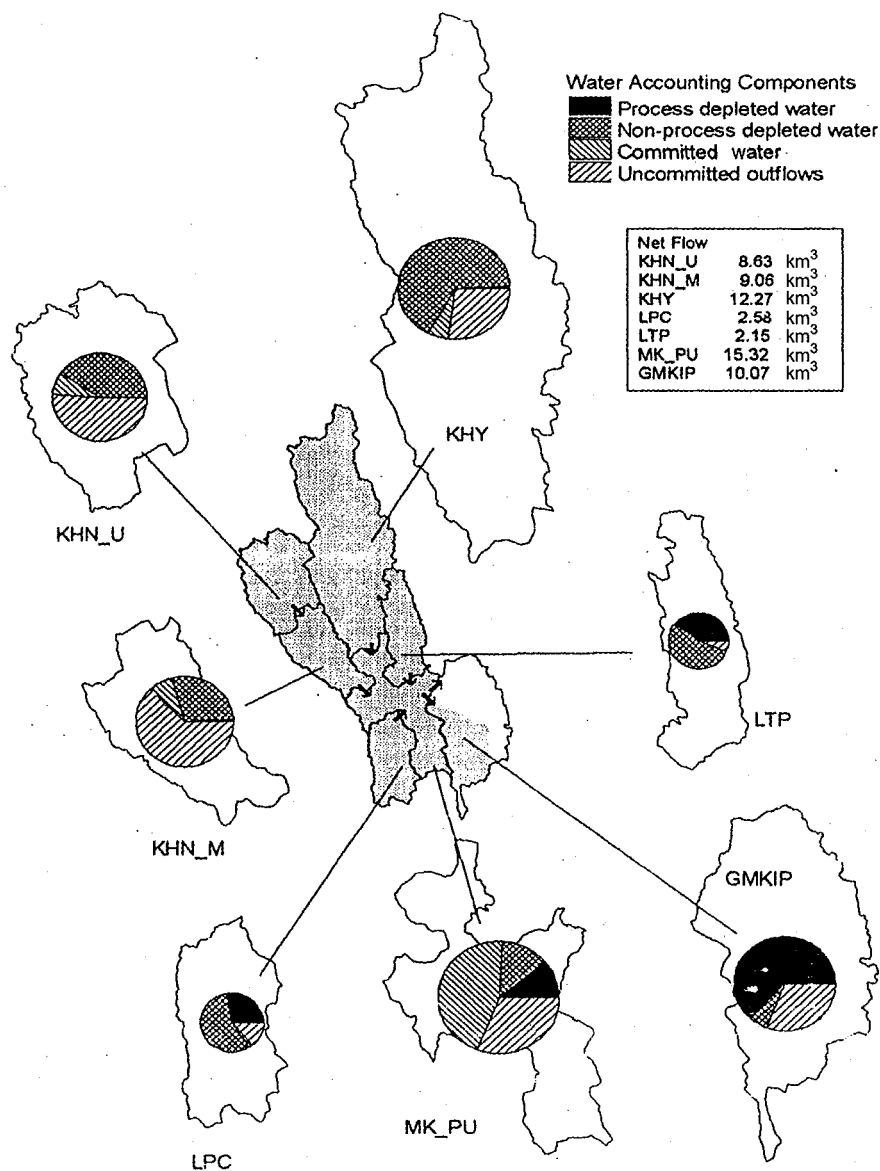
The water-accounting components and indicators of each unit are presented in table 4 and figure 2. Three portions of the basin with different conditions of water uses can be noted according to the water-accounting indicators. In the upper part of the Mae Klong river basin (KHN-U, KHN-M and KHY), the moderated depletion fractions are mainly due to the evaporation from forest, while water uses by humans are very small as observed from the low process fractions. Two other tributaries of the Mae Klong river (LPC, LTP) produce a high depletion



Table 4. Water accounting in the Mae Klong subbasins.

Components (km <sup>3</sup> )	Subbasins					
	KHY	LTP	KHN-U	KHN-M	LPC	GMK-IP
<i>Gross flow</i>	12.27	2.15	8.63	9.06	2.58	15.32
Precipitations	12.27	2.15	8.63	4.02	2.58	4.32
Surface inflow	0.00	0.00	0.00	5.04	0.00	11.00
<i>Storage change</i>	0.00	0.00	0.00	0.00	0.00	0.00
<i>Net flow</i>	12.27	2.15	8.63	9.06	2.58	15.32
<i>Depleted water</i>	8.22	2.03	3.59	2.64	2.17	3.73
Process (irrigation evaporation)	0.17	0.86	0.03	0.10	0.72	1.68
Beneficial (forest evaporation)	7.48	1.06	2.90	2.10	1.33	1.51
Non-beneficial (other evaporation)	0.57	0.11	0.66	0.44	0.11	0.54
<i>Outflow</i>	4.05	0.11	5.04	6.42	0.41	11.60
Committed water	0.73	0.01	0.73	0.73	0.05	6.86
Uncommitted utilizable outflows	3.32	0.11	4.31	5.69	0.36	4.49
Uncommitted non-utilizable outflows	0.00	0.00	0.00	0.00	0.00	0.24
Available water	11.54	2.14	7.90	8.33	2.53	8.22
<i>Indicators</i>						
Depleted fraction (gross)	0.670	0.947	0.416	0.292	0.840	0.243
Depleted fraction (net)	0.670	0.947	0.416	0.292	0.840	0.243
Depleted fraction (available)	0.712	0.949	0.455	0.317	0.856	0.453
Process fraction (depleted)	0.020	0.425	0.007	0.036	0.333	0.450
Process fraction (available)	0.014	0.403	0.003	0.011	0.285	0.204
						0.686
						0.686
						0.686
						0.911
						0.625

Figure 2. Main water-accounting components in the Mae Klong subbasins.



fraction and a moderate process fraction. These low-yield catchments encompass moderate agricultural activities outside of the irrigation-service zone. The concentrated zone of human activities downstream of the Mae Klong river is found in the irrigation-service unit (GMKIP); it has a relatively high depletion fraction and a high process fraction, which are due to intensive agriculture and urbanization.

## **Socioeconomic Analysis**

This section profiles socioeconomic conditions in the river basin, analyzes performance indicators for irrigation, and draws lessons to link with the results from the institutional analysis and water accounting.

### ***Macroeconomic Context***

Thailand has been one of the more successful developing countries over the past few decades in terms of economic growth. Its GDP grew at an average annual rate of 7.6 percent during the 1980s. From 1980 to 2000, agriculture dropped from 23.2 percent to 10.5 percent as a component of GDP, while industry climbed from 28.7 percent to 40.1 percent. Approximately 40 percent of total labor is still employed in agricultural activities (Bank of Thailand 2002), but the greater part of the national income is now generated from the industrial sector. Thailand's GDP per capita for the year 2000 was reported as US\$1,788 (Bank of Thailand 2002). According to World Bank statistics, the population of Thailand was 60.7 million in 2000 with an annual population growth rate of 0.8 percent. Using a poverty line of \$1.50 per day, the poverty rate for all of Thailand in 1999 was 16 percent.

In 1997, Thailand was hit by the financial crisis that caused a dramatic increase in unemployment. While Thailand has undertaken several economic restructuring initiatives to address causes of the crisis, there remain several risks to the future of the Thai economy. Chief among these is the strong reliance of the Thai economy on exports. Even though the overall global slowdown appears to be abating, entry into the World Trade Organization by China will provide strong competition for Thai businesses (Maneerungsee 2002). While Thailand has taken great strides in strengthening its administrative structure and economic base, there are still great challenges ahead. It will become ever more critical for Thailand to maintain its advantages and resources.

### ***Demographic Characteristics of the Mae Klong River Basin***

The basin is characterized by high levels of employment in agriculture. Population and population density increase significantly in the downstream section of the Mae Klong and the GMKIP. The basin also experiences high rates of poverty according to Thailand's official poverty line (see table 5). The rates of poverty within the upstream portions of the basin are especially high when compared to the national poverty rate of 16 percent. However, the overall rural poverty rate for the basin is 11.5 percent. It can be seen in the table that the percentage of the poor who are employed in agriculture is very significant for those areas excluding the GMKIP. The percentage of poor females is roughly the same as poor males, averaging 49 percent for females (excluding the GMKIP study area).

Table 5. General socioeconomic indicators of the Mae Klong river basin.

Area name	Population	Rural population	Population density /km <sup>2</sup>	Rural poverty rate	Female poor (%)	Poor in agriculture (%)
Khwaie Yai Upper	78,919	72,359	14.1	79	51.4	83.0
Lam Taphoen	130,326	106,623	71.4	79	48.7	71.3
Khwaie Noi Upper	39,039	35,634	10.2	46	46.0	81.9
Khwaie Noi Middle	44,934	41,542	14.5	19	51.2	76.5
Lam Pachi	66,776	54,460	45.8	30	47.4	54.5
Mae Klong Plain Upper	395,085	278,337	144.6	2	51.3	76.5
GMKIP	1,446,490	1,046,652	342.0	0	0.0	0.0

### *Socioeconomic Stakeholder Analysis*

An analysis of the various stakeholders in the Mae Klong river basin was conducted. The purpose of this exercise was to determine the relative wealth and influence of different groups as related to the role the stakeholder plays in water management. This information is summarized in table 6. A highly relevant aspect is that the irrigators are the least influential stakeholders in the decision-making process, despite the fact that irrigators are the largest users of water.

It can be further seen that the water user associations (WUAs) that have been formed in the basin raise the influence level of these stakeholders (although WUAs include all uses except hydropower). Given the relatively poorer status of irrigators this may indicate a need to extend and strengthen the capacity and role of the WUAs. The river-basin committee should include representatives from the WUAs in order to further strengthen the influence of this important user group. Irrigators and WUAs are the only stakeholders reported to suffer from seasonal water shortages. According to the constitution of WUAs, the management of irrigation is to be transferred to the local elected level (Tambon).

Another striking feature is the relatively influential position of the environment. One dam project, the Nam Chone Dam Project, has been rejected based on environmental concerns. This indicates the success that environmental groups are having in Thailand at raising awareness among, and influencing, key decision makers.

### *Poverty Situation in the Mae Klong River Basin*

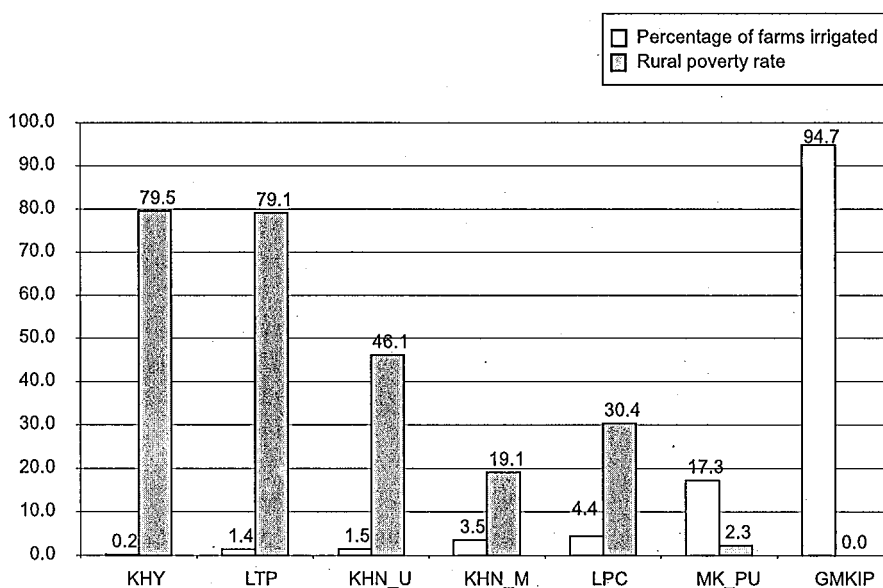
The rates of poverty within the upstream portions of the basin are especially high when compared to the national poverty rate of 16 percent. However, the overall rural poverty rate for the basin is 11.5 percent. As seen in table 6, most of the poor are engaged in agricultural activities. However, when comparing rural poverty rates with the percentage of farms irrigated, there appears to be an inverse correlation between poverty and irrigation (see figure 3). In the Lam Taphoen, it was reported that a new irrigation project is being constructed. However, the project is too new for any impacts on poverty to be realized. In the Khwaie Noi study area, it was also reported that there are currently unofficial water withdrawals for irrigation that might

Table 6. Stakeholder analysis in the Mae Klong river basin.

Stakeholder	Source of water	Management level	Role in management	Relative wealth position	Relative influence position	Suffer from water scarcity
Irrigators	Field ditch/gravity	On-farm	Plan with WUA and RID about amount and timing	Poor	Low	Seasonal
Domestic users	Pumping from surface water or groundwater	Project level at each water supply system	Provide source and deliver water to user	Non-poor	High	no
Industry	Pumping from surface water or groundwater	Project level for each factory	Extract the required amount from source	Non-poor	High	no
Environment	Reservoir/Main river	Water quality at basin level	Control of water quality to meet the standard	—	High	no
WUA	Canal systems	From tributary to field ditch	Request in amount and timing	Non-poor	Moderate	Seasonal
RID	Basin	Irrigation system	Control and deliver water to tributary	—	High	no

explain the lower poverty rate. It must be remembered that the GMKIP and the Mae Klong Plain are the two areas most suitable for agriculture due to their flat landscape, while the upstream portions are mountainous and covered by forests. The use of irrigation as a potential instrument for poverty alleviation in the upstream portions would need to be carefully investigated. Additional factors that impact the poverty rates are access to significant markets and choice of crops.

*Figure 3. Comparison of poverty rate versus percentage of farms irrigated, moving downstream on the Mae Klong.*



### *Description of Agriculture in the Mae Klong River Basin*

Agriculture claims larger portions of the total land area further downstream (table 7). This corresponds to the more favorable agricultural conditions in downstream areas. Agriculture accounts for about 85 percent of land use in the GMKIP. Moreover, this corresponds to an increase in the number of farms that are farmer-owned. However, in the downstream section there are over 90,000 landless farmers, which number is far greater than in any other section. Given the fact that there is no official poverty in the GMKIP, this gives another indication of the strength of irrigation's poverty-alleviation potential, especially beyond the owned farm unit.

The most significant crops in the basin are paddy and sugarcane, accounting for 27 percent and 34 percent, respectively, of total agricultural land in the basin (see table 8). Sugarcane is currently a largely under-irrigated crop. Areas where sugarcane is grown lack field ditches, have unsuitable terrain, or the farmers lack proper knowledge to irrigate sugarcane efficiently. Concerns were raised by some experts that potential changes in these patterns are not properly considered by current water-development plans, for example the interbasin transfer to send water to Bangkok. There has also been an increase in shrimp and prawn farming that makes unofficial use of the water in the GMKIP. These farms can have serious impacts on downstream water quality and adjacent land quality. However, effective arrangements do not exist for handling this conflict.

There are several trends that can be observed in paddy agriculture. There appears to be a declining trend in the income potential of paddy as measured as income (baht per rai). Within the basin, the two remote areas of the Khwae Noi Upper and Middle reaches experience lower income per rai than the other areas of the study. The Mae Klong Plain and the GMKIP have significantly higher incomes.

Another trend for major paddy is higher yields corresponding to locations further downstream. In all years reported, the GMKIP had the highest paddy yields of any area. The upstream areas experienced lower yields attributable to the less-favorable growing conditions, including a lack of irrigation. Khwae Noi Middle experienced the lowest yields, while having a relatively low poverty rate. This is explained by the relatively low area cropped with paddy. The Khwae Noi Middle area relied much more heavily on maize, cassava and sugarcane. Paddy prices were significantly lower upstream. Upstream farmers have fewer options in reaching potential markets and thus have less bargaining power when selling.

Table 7. Agricultural land use in the Mae Klong river basin, 1999.

Land use	KHY	LTP	KHN-U	KHN-M	LPC	MK-PU	GMKIP
Total (rai)	6,215,479	1,366,188	2,533,328	1,793,035	966,261	2,390,169	2,600,208
Agriculture (rai)	465,242	677,097	86,838	256,687	418,676	1,004,757	2,225,723
Forested (rai)	5,359,701	669,701	2,049,275	1,531,297	531,444	1,324,216	115,716
Reservoirs (rai)	378,571		391,245				
Urban (rai)	11,964	19,390	5,971	5,051	16,141	61,196	258,769
Irrigated farms (%)	0.22	1.38	1.52	3.55	4.4	17.32	94.75
Farmer land tenure situation							
Own number	10,431	12,542	2,672	5,233	6,417	30,530	90,300
Rent number	2,376	3,390	382	838	1,574	6,778	29,805
Landless number	8,102	11,072	1,612	2,716	3,433	24,304	115,900
Farm income (baht/year)	32,055	44,097	37,694	40,058	34,560	44,190	80,020

Note: 1 rai = 0.16 ha.



Table 8. Land area for each crop in the Mae Klong river basin (rai).

	KHY	LTP	KHN-U	KHN-M	LPC	MK-PU	GMKIP
Major rice	31,746	30,060	3,321	805	24,880	183,429	630,346
Second rice	0	6,408	88	578	6,050	91,211	497,057
Maize	33,751	36,108	27,393	51,987	509	23,659	7,443
Cassava	12,920	52,760	18,399	30,467	73,027	123,113	14,187
Sugarcane	238	294,335	308	40,806	87,028	293,238	415,727
Orchard	0	9,078	0	0	16959	18,821	85,643
Prawns	0	0	0	0	0	0	27,644
Fish	30	551	555	123	640	2,300	56,574

## Irrigation-Performance Assessment in the Mae Klong River Basin

Indicators of irrigation performance were calculated based on methodology developed by IWMI. The data and calculated irrigation performance indicators of the major irrigation projects are given in table 9. All reported irrigation systems are located within the GMKIP. The most striking feature is that no irrigation revenues are reported. Irrigation management in Thailand does not include the collection of irrigation fees from farmers. This situation can create several problems for the irrigators and irrigation management. First, financial sustainability is not possible under the current conditions. The irrigation system will be completely dependent on government financing to remain operational. Second, dependence upon the government for operation financing weakens farmers' bargaining position within the water-management process. Dialogue with various experts indicated that a reversal of this practice is highly unlikely in the near future. A reluctance to charge and collect water fees removes a potential instrument to help regulate the use of water.

The performance indicators indicate a significant variation in performance across the different systems, especially in output per unit of land area. Given the relative proximity of these systems the variation would be an interesting point of investigation. The output per unit of irrigation water and output per unit of water supply are roughly equal for each system, but vary in accordance with variations in output values. Finally, the relative water supply and relative irrigation supply are roughly equal within and across systems.

Table 9. Irrigation-performance indicators.

	Irrigation system				
	Phanom thuan	Song phinong	Right Bank Ratchaburi	Nakhon pathom	Nakhon chum
Gross value of output (million baht)	2,335	2,682	5,607	8,474	7,631
Irrigated area (rai)	289,300	307,000	234,111	291,040	191,945
Command area (rai)	330,400	313,600	304,000	337,900	259,000
Water diverted to irrigation systems (mcm)	515	597	711	502	488
Total annual rainfall (mcm)	51	54	42	53	35
Rainfall (mm)	1,100	1,100	1,120	1,130	1,140
Crop water demand (mcm/year)	468	542	647	456	444
Total water supply (mcm/year)	566	651	-	-	-
Total irrigation supply (mcm/year)	515	597	711.00	502.00	488.00
Total O&M expenditure (baht/rai/year)	98	101	153	112	149
Government revenue from irrigation (baht/rai/year)	0	0	0	0	0
Output per unit of cultivated area (baht/rai/year)	8,071	8,736	23,950	29,116	39,756
Output per unit of command area (baht/rai/year)	7,067	8,552	18,444	25,078	29,463
Output per unit of irrigation water (baht/m <sup>3</sup> )	4.5	4.5	7.9	16.9	15.6
Output per unit of available water (baht/m <sup>3</sup> )	4.1	4.1	7.4	15.3	14.6
Relative water supply	1.21	1.20	1.16	1.22	1.18
Relative irrigation supply	1.23	1.22	1.18	1.24	1.19
Financial self-sufficiency	0	0	0	0	0

## ***Competition and Conflicts for Water in the Mae Klong River Basin***

There are a number of conflicts in the Mae Klong river basin. Many problems revolve around the issue of water quality. In a field visit to Damnernsaduak (along the coast), it was reported that upstream waste from pig farms and irrigation was negatively affecting water quality. Currently, the problem can be mitigated through dilution. However, if water scarcity continues to grow, this method of addressing the problem may no longer be feasible. Water-quality issues were also observed upstream where prawn farming is beginning to grow in scale. Currently, both the development of prawn farms and their use of water go largely unregulated. This conflict will be difficult to resolve as prawn farming yields much higher income per unit of land area than crops. As influence tends to be positively correlated with wealth, this could prove particularly troublesome to crop farmers. One possible approach to resolving this issue is the zoning of land, based on use, although enforcement would be a major hurdle.

Another major conflict in water use involves the irrigators and hydropower producers. Reservoir releases are controlled by EGAT whose objective is to produce electricity. While releases are planned in cooperation with the demands of irrigation, it is done only on a weekly basis. Daily releases are based on hydropower demands, which may conflict with the needs of downstream farmers. Greater cooperation would be needed between RID and EGAT to resolve this issue. A possible realignment of responsibilities and authority would be another avenue to explore.

Annex 3 lists other conflicts. In general, the conflicts persist due to a lack of proper enforcement of existing laws. Additionally, a lack of effective cooperation and the exclusion of relevant stakeholders are other major causes of persistent conflicts. While the Government of Thailand seems to have recognized these problems to the extent that they have formed an apex coordinating body that had established river-basin committees, there are still significant lapses in realizing the full potential of what has been established. Additionally, gaps in the current system (e.g., lack of a national water law) will continue to hinder the management of water resources within the basin.

## ***Discussion of Socioeconomic Analysis***

The analysis has offered a general profile of the socioeconomic situation in the Mae Klong river basin. Additionally, the report offers an analysis of the performance of irrigation within the basin. The results of the analysis show that, in general, an improvement in the management of water resources can have significant benefits to society. For example, the GMKIP appears to have a significant impact on poverty alleviation. However, localized improvements may create greater polarization of incomes within the basin. As incomes and influence on water-resources management seem to be correlated, this could create new problems unless deficient areas are made the target of development programs.

This is especially important in the still largely forested upstream portions of the Mae Klong river basin. These areas will need to be preserved in order to protect the quality of the water resources of the basin. However, increasing poverty can lead to detrimental effects on the health of the environment. Therefore, the improved management of water resources within the basin will also need to address poverty issues and the welfare of its inhabitants.

The results of the socioeconomic study strengthen the call for an improved water-management framework and institutions. While less than optimal water-resources management may result from a weak institutional structure, poor water-resources management may also

have negative impacts on the socioeconomic aspects of the basin. These negative impacts may amplify and feedback on existing problems and conflicts in water management.

## **Institutional Analysis**

### ***National Institutions***

There are more than thirty national agencies with various roles in water-resources management and delivery of services to water users. The three most dominant ministries in terms of water management have been the Ministry of Agriculture and Cooperatives (MOAC), the Ministry of Science Technology and Environment (MOSTE) and the Ministry of Industry (MOI).

At the policy development and coordinating level, several national committees play an important role regarding water-resources management. These include the National Economic and Social Development Board (NESDB), National Environment Board, Thai National Mekong Committee and the Chao Phraya River Basin Committee. These committees have carried out several aspects of coordination and regulation of water-resources management; however, none of these agencies have been responsible for the full range of required activities.

There are at least 28 water-related laws administered by over 30 departments overseeing water issues in eight ministries. Table 10 presents the titles of these laws classified as they pertain to quality or quantity issues.

Water-resources management has been complicated by gaps and overlaps in management responsibilities. The problems related to water-resources management in Thailand include:

- Policy and planning—there is no coordinated policymaking by the agencies concerned.
- Budgeting—at present, the budget is allocated to each agency upon request.
- Legal framework—there are several acts concerning water resources but no single act directly relates to water-resources management.
- Availability of information—because there are too many implementing agencies, information on water-resources development is not organized in a centralized manner.

There are many government agencies and private parties involved in the development and exploitation of surface-water and groundwater resources; however, cooperation and coordination between the different parties have been weak. Even when cooperation between operating agencies led to plans for equitable allocations of water, the plans were often challenged by affected parties. The result was often a compromise that simply postponed the problem to a later date. Recognizing the lack of coordination, the government decided to establish a central agency in water-resources management in order to formulate plans, coordinate plan implementation, and carry out other work concerning the management of water resources.

Table 10. Legislative enactments relating to water quantity and quality in Thailand.

Water quantity	Water quality
Canal Maintenance Act, 1903	Canal Maintenance Act, 1903
Water Hyacinth Elimination Act, 1913	Water Hyacinth Elimination Act, 1913
Private Irrigation Act, 1939	Navigation in Thai Waters Act, 1913
Royal Irrigation Act, 1942	Royal Irrigation Act, 1942
Dike and Ditches Act, 1962	Fishery Act, 1947
Minerals Act, 1967	Minerals Act, 1967
Metropolitan Waterworks Authority Act, 1967	Revolutionary Council Announcement No. 286, 1972
Electricity Generating Authority of Thailand Act, 1968	Groundwater Act, 1977
Groundwater Act, 1977	Provincial Waterworks Authority Act, 1979
Provincial Waterworks Authority Act, 1979	Building Control Act, 1979
Waterworks Canal Maintenance Act, 1983	Factory Act, 1992
Civil and Commercial Code	Public Health Act, 1922
	City Cleanliness and Tidiness Act, 1992
	The Enhancement and Conservation of National Environmental Quality Act, 1992
	Penal Code

In 1989, the Prime Minister's Regulation on National Water Resources Management created the National Water Resources Committee (NWRC) intended to be an apex body for water-resources management in Thailand. The NWRC was given the leading role in coordinating concerned agencies in planning and systematizing an information system in order to facilitate effective water-resources management. However, this goal has not been achieved because the NWRC lacked any permanent organization and recognition. Therefore, the Office of the National Water Resources Committee (ONWRC) was legally established late in 1996, which has carried out various activities to support improved information, policy and planning for water management.

The enactment of Thailand's new Constitution in 1997 has had significant influence on the government's natural resources and environmental policies, the implementation and operation of government projects, and the interpretation of relevant laws and regulations. The new Constitution not only provided for participatory management of natural resources, including water, but also established an obligation on the government administrations to implement this approach.

In a collaborative manner, the ONWRC and other relevant agencies formulated the National Water Vision in 1999. "By the year 2025, Thailand will have sufficient water of good quality for all users through an efficient management, organization, and legal system that will ensure equitable and sustainable utilization of water resources with due consideration to the quality of life and the participation of all stakeholders." Shortly thereafter, the national water policy was further developed in consultation with other stakeholders and was approved by the Cabinet in 2000.

Since its establishment, the NWRC has worked to strengthen the mechanism of integrated water-resources management in Thailand. A notable step forward was the drafting of a water-resources law. In order to implement the law, river-basin organizations or commissions would be established in each of Thailand's river basins. This recognized the need for decentralized management of water resources. According to the draft law, each river-basin committee would consist of qualified persons drawn from public and private sectors. A committee would develop policies on water-resources planning, development, operation of facilities, and water allocation. The river-basin committee would oversee all related activities in the river basin including the resolution of water-related conflicts between various water users.

### ***Basin-Water Management***

In the Mae Klong river basin, RID and EGAT are responsible for deciding how much water will be required by each sector, which is summed into the aggregate amount of water required to be distributed from reservoirs. Large-scale allocations refer to the distribution of water to the different sectors, such as domestic, industry, control of seawater intrusion and agriculture. Bulk allocation is made to resources managers and users, e.g., Provincial Waterworks Authority and WUAs. However, monitoring of the volume of water withdrawn by each customer is rarely done.

Small allocations for each sector are defined as follows:

- Household and industry—water fee is paid to service providers as the amount varies with the volume used.
- Control of seawater intrusion—oversight by RID.
- Agriculture—main canal overseen by RID and secondary and tertiary canals and on-farm level managed by WUAs. There is no water charge but farmers may pay the WUA for system maintenance.
- Allocation of groundwater—groundwater in the basin is free for use in terms of both price and control by law or regulation.

### ***Reservoir Management***

Coordination between RID and EGAT is made at the departmental level in order to make decisions on weekly reservoir releases and at the basin level for daily regulation of control structures. The operation of the Khao Laem and Srinagarind reservoirs is presently carried out responding to water demands of GMKIP, Mae Klong salinity control, and the Tha Chin river diversion. Lower and upper rule curves are established for the two reservoirs. At the departmental level, EGAT and RID cooperate in making decisions on weekly water releases for GMKIP, based on weekly RID requests for irrigation water use and other requirements.

Large-scale water-resources infrastructure, such as Khao Laem, Srinagarid and Tha Tung Na reservoirs, is operated by EGAT through its dam-site offices. As discussed above, the major water user for these reservoirs is the GMKIP, which is administered by RID through the Region Ten Office. At the basin level, there exists coordination between the EGAT dam-site offices and the RID Region Ten Office in the daily operation of regulating structures. However, the final decision is up to EGAT due to hydropower generation that has to be satisfied.

Past performance records show no shortage occurrences in either reservoir. In other words, all water requirements relying on the reservoirs were met. So far, there have not been any disputes concerning the amount of water release between RID and EGAT. However, it was reported during field visits that water releases do not conform to optimal timing for use by the irrigators; rather the weekly quantity requested is released in a manner most beneficial for the production of hydropower.

### ***Water Management in the GMKIP***

For many years, a computer model has been used to forecast weekly water demand at head regulators of the irrigation canals. Wetness conditions of paddy fields are observed and used as real-time input data for the model. The higher the field wetness, the lower the expected water demand for the next 7-day period. The model is installed at the computer center of the GMKIP office (in the RID Region Ten Office) and run by RID officers. To date, there have been no reported water-shortage problems in the GMKIP areas. Field interviews confirmed that water management within the GMKIP is able to satisfy the farmer demands. In other words, the timing and adequacy of irrigation water controlled by the GMKIP office are generally acceptable.

### ***Small-Scale Irrigation***

For small-scale irrigation systems, there are no RID workers stationed at the site. After construction is completed, the project is entrusted to the local Tambon Administrative Organization (TAO), which makes decisions on operations and maintenance. Occasionally, the Provincial Irrigation Office (PIO) will inspect the project for structural and hydraulic failures. The PIO will give technical advice to the TAO. Any repair budget is the responsibility of the TAO.

### ***Pump Irrigation***

*Pump-irrigation projects* are planned and developed by the Department of Energy Development and Promotion (DEDP), based on requests. Water is usually pumped directly from rivers. The energy cost for pumping water is charged to beneficiary farmers who form a water user group.

### ***Waterworks***

Waterworks for large cities are generally administered by the Provincial Waterworks Authority (PWA). The PWA scheme office will report to the PWA in Bangkok. The revenue derived from the particular scheme is sent directly to the PWA. A few waterworks schemes are administered by private concessionaires. Schemes in smaller cities are usually administered by the municipality, which reports to the Provincial Governor. The budget and personnel are handled by the municipality with consent from the Governor. Village waterworks are managed by the TAO. Their budget derives from local taxes and budget support from the central government. By 2006, all small water-resources projects will be transferred to TAOs.

### ***Groundwater***

The groundwater resources in the Mae Klong river basin are primarily obtained from the unconsolidated deposits of floodplains, deltas and terraces. In Tha Muang, Tha Maka, and

Ban Pong districts, at least three aquifers have been recognized at depths of up to 200 meters. The aquifers are very productive and yields from a well may range from 20 to 100 m<sup>3</sup>/hr. Higher yields of around 150 m<sup>3</sup>/hr can be obtained from a well with screening to allow water in from more than one aquifer. The groundwater quality of the three aquifers is generally good except in the areas south of Ban Pong to the Gulf of Thailand where shallow aquifers produce brackish to salty groundwater. Wells penetrating cavities of limestone in highland areas give high yields, but high hardness of water quality is normal. Yields of a well can be up to 50 m<sup>3</sup>/hr or more and the water must be treated before use.

### ***Mae Klong River-Basin Committee***

For water resources of the Mae Klong river basin, the development and management activities are undertaken by a combination of the EGAT for large-scale reservoirs, RID for medium and small-scale reservoirs and irrigation areas, DEDP for small pump-irrigation projects, PWA for large domestic water-supply projects, and individual municipalities for municipal water-supply projects.

The Mae Klong riverbasin area consists of three provinces: Khanchanaburi, Ratchaburi and Samutsongkram. A letter from the Samutsongkram Province submitted on February 22, 2000 requested the ONWRC to establish the Mae Klong River Basin Committee (MKRBC) in order to more effectively manage floods, regulate saltwater intrusion, and address problems of freshwater scarcity and water pollution.

The ONWRC and Samutsongkram Province held a stakeholders' meeting on May 3, 2000, which involved participants from concerned government agencies, local administrators, representatives from water users from the agriculture and industrial sectors, and other relevant stakeholders. The purpose of the stakeholder meeting was to determine the composition, responsibilities, process and the selection of representatives that would make up the committee. The result of the meeting called for the establishment of an MKRBC as soon as possible.

In 2001, the MKRBC was established by the ONWRC with the cooperation of the governors of four provinces located within the river-basin area and other concerned government agencies. The objective of establishing the committee was to form an institution that would be responsible for water-resources management coordination and regulation of the river basin.

While its ultimate level of operations encompasses many perspectives and includes the bulk allocation of water as one of its functions, because of its recent establishment, the committee does not currently possess adequate capacity to perform the required work. Therefore, an implementing agency like the RID will need to be a key actor in allocating water both for large and small groups of users until the proper level of capacity is built.

### **Conclusions and Recommendations**

The water-accounting component indicated the current situation of the basin. Currently, water is still adequate on an annual basis, but this situation may reverse under a number of scenarios that could come into being in the future. Among these scenarios is increased irrigation by sugarcane growers and increased diversions to Bangkok. Either of these scenarios could create a situation where water quantities are insufficient to meet demand.



The socioeconomic analysis and irrigation performance analysis highlighted the important role that irrigators play in water management of the basin. In particular, agriculture plays a significant role in the basin, both in terms of livelihoods and as a factor in poverty alleviation. However, it is also the sector with a significant portion of poverty. In general, farmers are not very influential in policymaking and decision making. They are, however, among the most vulnerable. If, as the water-accounting section seemed to indicate, the upstream portions become the targets of conservation programs, then careful planning will be needed to avoid environmental damage from an increasingly desperate population. It is a common occurrence in the region that when yields decrease and poverty increases in upland regions, then environmental degradation is accelerated.

Prawn farming is becoming an increasingly popular agricultural activity. The returns per rai are far higher than for any crops. However, prawn-raising activities can have many serious negative impacts, such as reduced yields in surrounding fields, polluted water released downstream, higher quantities of water used, and illegal abstraction of water to fill the ponds. An effective method needs to be implemented to balance the needs of all the various stakeholders. These methods can involve stricter enforcement of policies, incentives to discourage creation of externalities by prawn farmers, and compensation for injured parties.

In general, the position of farmers within the decision-making process needs to be strengthened. Farmers must have a stronger ability to influence policy. This can involve larger groups of farmers such as federations of water user groups. It can also involve high-level representation or membership in a high-level decision-making body.

Another significant conflict is between hydropower production (EGAT) and irrigators. Daily release schedules are determined, based on hydropower production needs, while weekly demand requests are made by the irrigators to EGAT. Since daily releases are made to suit hydropower-production needs, water is not delivered in a manner that is optimal for farmers. An examination of this conflict should be conducted to determine a more optimal operating schedule.

The institutional-analysis section indicated that many positive steps have been taken toward more effective management of river basins. These are, in particular, the recognition of the need for river-basin organizations to manage water from the basin perspective, the need to establish farmer organizations to represent farmers, and the need to better coordinate water-resources management among the many diverse agencies. However, more progress needs to be made to realize the ultimate goals of these changes. Foremost is the need to enact an effective and comprehensive national water law. The law should not only clearly spell out the duties and responsibilities of the different agencies but also clearly specify the authority each agency will have in enforcing its duties and regulations.

Recognition of the need for stronger local management has led to the formation of river-basin committees. This is a good fundamental move for better coordination of different agencies and representation of stakeholders at a more decentralized level. However, the current membership structure omits two important stakeholders; these are the Bangkok Metropolitan Water Authority and EGAT. As these are two of the most influential water users, their ability to manage water outside of consultations with the proposed river-basin committee's members could seriously undermine the effective management of the Mae Klong river basin.

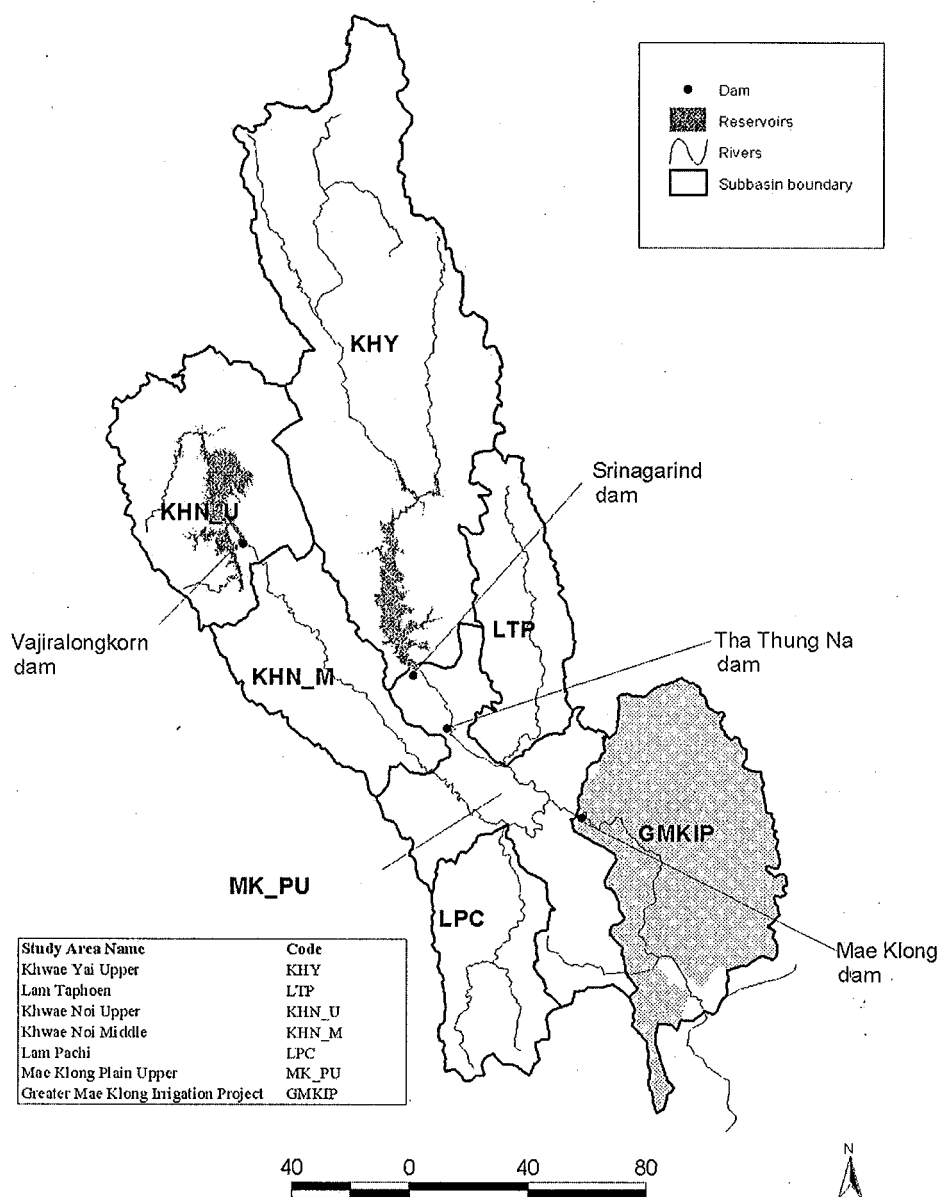
There are many important water-management issues and problems in Thailand. In particular, the issues of water scarcity, poor water allocation, and a lack of a formal system of

water rights create negative impacts for many water users, particularly those in downstream locations. Many agencies are involved in water-resources development and the provision of water services, but their activities are uncoordinated and often conflicting, resulting in poor efficiency in use and significant cumulative impacts on the resource. Additionally, there are concerns regarding watershed management; flood and drought problems; overuse of groundwater (particularly in the Bangkok area); water-quality concerns relating primarily to industry, municipal, and non-point source pollution; high cost of public water services; and inadequate sharing of costs with the beneficiaries. Information on water resources is not adequately shared between agencies or with water users. There is little involvement of water-resources stakeholders in the management decision process. Transparency and accountability need to be improved while the degree of polarization in the water sector needs to be decreased.

The biggest challenges facing the effective management of water resources in the Mae Klong river basin are:

- The improvement of interagency and stakeholder communication and cooperation.
- The effective enforcement of policies and regulations.
- The creation of effective institutions that are responsive to farmer needs and can influence the decision-making process.
- The creation of an incentive system to regulate/control/compensate for water-use patterns.
- The recognition of, and response to, increasing water scarcity.

Annex 1. Map of the Mae Klong river basin and seven study areas.



*Annex 2. Legal setting of water-resources management in Thailand.*

Title of Law and classification number:	Draft Water Resources Act	Groundwater Act 1977	Land Consolidation Act 1975	Classification of River Basin Act *	Ditch and Dike Act 1962	Irrigation Act 1942
Issuing authority:	ONWRC	Department of Mineral Resources	Office of Land Consolidation for Agriculture	Royal Forest Department	Royal Irrigation Department	Royal Irrigation Department
Scope	National	National	National Land	National	National	National
Aspect addressed:	All aspects of water resources management and utilization.	Registration of tube well.	Land consolidation program	Allowable land use for each basin classification.	Existence and maintenance of ditch.	Issued to support irrigation development.
Description of implementation procedures:	River Basin Committee is established by NWRC to perform function as assigned. In cases of dispute, RBC suggests resolution, can refer to NWRC for higher resolution procedures	All private boreholes must be registered, new boreholes must obtain a permit and annual fee should be paid. No permit is needed for government agency.	If the majority of farmers in the area agree with land-consolidation program. The OLCA will announce the land consolidation area and partially pay for the cost.	It prohibits all development including dam construction at the river basin class 1 (sloping area with good forest condition).	Farmers cannot invade the ditch and must do some maintenance at appropriate time.	Giving RID and its officers the authority in construction, operation, and maintenance of irrigation projects and systems.
Responsible parties:	NWRC, RBC	DER	OLCA	RFD	RID	RID
Enforcement mechanisms:	NWRC issues national policy and RBC issues basin strategy and management.	DER should monitor and check number of well and amount of pumping.	The target area is irrigation area and should be initiated by farmers.	RFD controls land use according to the classification of basin.	RID should inform farmers to do some maintenance of field ditch.	RID is recognized and authority was granted for its duty.

*Annex 3. Trade-off analysis for the Mae Klong river basin.*

Competing groups	Level of parties (macro, meso, micro)	Description of conflict	Trade-offs	Possible resolution and source
Hydropower/ Irrigators	Macro/Micro	Quantity of water released is enough for both purposes, but timing is determined solely by hydropower needs on a weekly basis.	Nonoptimal irrigation timing (indirectly reduces crop production) or loss of hydropower production.	Adjust the release policy for hydropower or construction of regulating dam (by RID) downstream of storage dam.
Rice/Freshwater shrimp farm	Meso	Shrimp farms use too much water (about 8 times as much as rice) so that there are water shortages at the tail end of the canal.	Rice and shrimp farms are in the same area. The shrimp farm is normally located at the head of canal.	Implement zoning for rice and shrimp farms; shrimp farms may treat and reuse the water to reduce the amount of water use.
Rice/Black tiger shrimp farm	Meso	Drainage water from shrimp farms reduces quantity of rice production and deteriorates soil condition.	Rice and shrimp farms are in the same area.	Implement zoning for rice and shrimp farms; the latter may be prohibited in the freshwater areas.
Fisherman/Pig farm and sugar mill	Meso	Wastewater from pig farms and sugar mills destroys the fish industry.	Pig farms and sugar mill factories are in the upstream area.	Wastewater should be properly treated before release to the watercourses.
Irrigators/Trans-basin diversion of water by BWA	Macro/Micro	Water diverted for Bangkok water supply.	Less water available in the basin. Irrigators may experience water shortages in the future.	BWA may pay water rights fee or compensation for the basin. The government must make a decision on this issue.
Irrigators/Villagers	Meso	Irrigators want to have a storage dam, but villagers want to preserve the land.	No irrigation or loss of land.	Negotiation between RID, irrigators, and villagers before construction. Reasonable compensation and benefit from the project to the villagers.
Water supply/ Villagers	Micro	Excessive groundwater pumping causes land subsidence in the area around the river mouth.	Available water supply or damage from flooding because of land subsidence.	Surface water should be used for DWS. The DWS must be enough for both water supply and industry.
RID/Villagers	Meso	Some villagers do not agree with the construction of flood-protection dike.	Control of freshwater and saltwater area or natural condition	Discussion between RID and villagers about the appropriate design of flood-protection dike.

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