The Chao Phraya River basin, the largest basin in Kingdom of Thailand is located in central and northern part of Thailand. This basin has two large-scale dams: Bhumibol Dam in the Ping River and Sirikit Dam in the Nan River. Their large reservoirs have contributed to economic development of the country for supplying increased electricity and irrigated water demands as well as flood mitigation in riparian areas along the Ping, Nan and the Chao Phraya rivers.

Analysis of comparing annual and monthly flow regime downstream of the dams before and after dam construction shows a constant increase in low flow and a drastic decrease about 60% in high flow. As analysis of precipitations shows no long-term increase or decrease tendency of the precipitation, it can be concluded that the reservoir operation is the main cause of the flow regime change.

Spectrum of flow was analyzed by using FFT for daily discharges in Nakhon Sawan and immediate downstream of the Bhumibol dam (Royal Irrigation Department’s code P.12) after the Bhumibol dam construction. Flow in Nakhon Sawan has periodic characteristics of 3.5 days and 7 days, and the released water from the Bhumibol dam at P.12 has periodic characteristics of 2.5 days, 3.5 days and 7 days. Reservoir operation affected the hydrological cycle considerably.

INTRODUCTION

Recently, the Thai economic structure has been greatly modified. In 1960’s, about 30% of the country’s GDP was produced by the agriculture. Now, the proportion of the agriculture product occupies 12% of the GDP. In the meantime, industrial product has been increasing year by year. The farmland has been changed to the industry or housing
Figure 2. Chao Phraya River basin which is located in Kingdom of Thailand.

Figure 3. Reservoirs location and main hydrological station in Chao Phraya River basin.

Figure 1. Map of Southeast Asia and Kingdom of Thailand.

areas. The Chao Phraya River basin has water quality issues because many factories are constructing along the downstream of the Chao Phraya River. Furthermore, it should be noted the disaster prevention. The telemetry system frequency does not work because there is a scarcity of budget for the maintenance of the telemetry system. Hence, the national government in Bangkok sometimes cannot obtain the water level or discharge data on holidays. Although the government of Thailand is required to issue flood forecasting and warning for the second biggest flood of the Chao Phraya River in its hydrological observation history in 2002, they failed to do so because of a problem in data management system (Tebakari, et al., 2003).

As mentioned above, impacts of the change in the socio-economics structure of the basin on the hydrological regime of the lower reach is considerable. We should understand relationship between socio-economic conditions and the hydrological regime in order to enable water resource predictions for future socio-economics conditions. This paper reports impacts of Bhumibol dam and Sirikit dam operation from 1964 and 1977 respectively on flow regime.

HISTORY OF WATER RESOURCES DEVELOPMENT IN THE CHAO PHRAYA RIVER BASIN

Outline
About 5,000-6,000 years ago in the pre-historical period, the people grouped together to find places for settlement along the Pasak, the Ping, the Wang, the Yom, the Nan Rivers which current into the Chao Phraya River. The areas nearby these rivers were developed to the regional communities. Later, the agricultural canals and dikes for the flood
protection had been constructed constantly under the Kings. Thus, the history of the water resources development in the Chao Phraya River basin is very long.

Table 1. Feature materials of Bhumibol and Sirikit dams.

<table>
<thead>
<tr>
<th>Name</th>
<th>Bhumibol</th>
<th>Sirikit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Irrigation</td>
<td>Flood Control</td>
</tr>
<tr>
<td></td>
<td>Power Generation</td>
<td>Power Generation</td>
</tr>
<tr>
<td>Under Operation by</td>
<td>EGAT</td>
<td>EGAT</td>
</tr>
<tr>
<td>River</td>
<td>Ping</td>
<td>Nan</td>
</tr>
<tr>
<td>Drainage Area(sq. km)</td>
<td>26,386</td>
<td>13,130</td>
</tr>
<tr>
<td>Annual Inflow(MCM)</td>
<td>5,256</td>
<td>5,600</td>
</tr>
<tr>
<td>Annual Inflow(mm)</td>
<td>196.2</td>
<td>427.4</td>
</tr>
<tr>
<td>Storage at max. water level(MCM)</td>
<td>13,462</td>
<td>10,508</td>
</tr>
<tr>
<td>Resevoir Surface Area(sq. km)</td>
<td>316.0</td>
<td>260.0</td>
</tr>
<tr>
<td>Dam Type</td>
<td>Gravity Arch</td>
<td>Earthfill</td>
</tr>
</tbody>
</table>

The Chao Phraya River had been named and begun to develop the water resources systematically after the establishment of the Ayutthaya Kingdom in 1350. Ayutthaya was an island, formed by the gathering 3 rivers, the Chao Phraya, Pasak and Lop Buri, before their merging together and flowing to the Gulf of Thailand. Ayutthaya became the main center of administration, economy, society and navigation, and also was the convenient port to get to the sea. At the end of the Ayutthaya Period, water control systems were constructed in various places. After Ayutthaya period, the water resources development for agriculture and domestic use and the construction of canals for communication had been executed. Every king had recognized the importance of the water resources development and executed the outgoing water resources development policy in the Chao Phraya River basin for a long time.

On the Chao Phraya River basin and large-scale dams

Figure 1 shows the map of Thailand where is located in Southeast of Asia. Kingdom of Thailand is located the central of Indochina peninsula (5-21deg. North Lat. and 97-106deg. East Long.), where is bounded on the northwest by Myanmar, the northeast by Laos, the east by the Cambodia and the south by Malaysia. The area of Thailand is about 5,140,000 square kilometers, where is mostly occupied by the plain area.

Figure 2 shows the map of the Chao Phraya River basin where is located in the central of Thailand. The Chao Phraya River basin is the largest basin in the country, 157,925 km², which is almost 30% of the whole country and covers 29 provinces. Figure 3 shows the location of the main hydrological observation stations and dams in the Chao Phraya River basin. The Chao Phraya River basin can be divided the following three physiographic
forms; the upstream in the northern part is mountains, the middle basin is a flood plain and the lower current area is a delta. The Chao Phraya River system consists of four principal tributaries, namely, the Ping (36,018km$^2$), the Wang (11,708km$^2$), the Yom (24,720km$^2$) and the Nan (34,557km$^2$), all originating the northern mountain area. The Wang and Yom rivers join the Ping and Nan rivers in the middle basin respectively. Then, the Ping and Nan Rivers join the Chao Phraya River in Nakhon Sawan, which flows down to the lower basin through Ayutthaya and Bangkok, and then finally pours into the Gulf of Thailand. The Pasak River, a tributary, joins the Chao Phraya River in the lower basin, while the Tha Chin River diverges from the Chao Phraya River in Chainat city.

In 1952, to construct the first multi-purpose large-scale storage dam across the Ping River in Thailand was accepted by the King, which was financed by the World Bank loan, of which the loan agreement was signed in 1957. After the construction was completed in 1964, the King named it Bhumibol Dam. In 1961, the Thai government approved the construction of a multi purpose large-scale storage dam across the Nan River, a tributary of the Chao Phraya River in Uttaradit Province. This dam was undertaken to be a multipurpose project as the Bhumibol dam due to its appropriate location. The project was also funded by a World Bank loan. The construction was finished in 1977 and was named by the Queen Sirikit Dam. The dam provides benefits of electricity and water drainage to the Greater Chao Phraya Project and its merging with water releasing from the Bhumibol dam also provides water for cultivation in the Chao Phraya basin.

Table 1 shows the principal features of the Bhumibol and Sirikit dams. Now, both of dams are operated and managed by Electricity Generating Authority of Thailand (EGAT), one of the main purpose of the two dams is the power generation, however the quantity of weekly water supply form the two dams are determined by the government, especially the Royal Irrigation Department. The purposes of these dams are the power generation, irrigation and flood control. If all purposes of the dams could not be achieved, the economical development in Thailand would be stopped. The Chao Phraya River basin
has so many middle- and small-scale dams. Thus, this paper is aimed at the middle-scale
dams in the upstream from Nakhon Sawan city (see Figure 3).

EFFECT OF LARGE-SCALE DAMS ON HYDROLOGICAL REGIME

Bhumibol dam
Figure 4 shows the change in monthly runoff and rainfall in P.12 observation station
where is located 4km downstream of Bhumibol dam. There is no long-term increase and
decrease tendency on the rainfall since 1952. In the meantime, the runoff decrease clearly
after the Bhumibol dam was constructed completely in 1964. Figure 4 shows the
maximum runoff decreases and the minimum runoff increases. The effect of the dam,
which water resources has been supplied stably to the downstream, has appeared clearly.

Sirikit Dam
Bhumibol Dam

Figure 7. Change in monthly runoff and rainfall in Nakhon Sawan (C.2 hydrological
station).

Figure 5 shows the comparison of before and after the Bhumibol dam was constructed on
annual runoff in P.12 observation station. The variation pattern in runoff and rainfall of
1952 (before the dam was constructed) and 1992 (after the dam was constructed) was
compared. In comparison between 1952 and 1992 of the rainfall, which also meets the
peak in September, and wet season and dry period have been clearly divided. Moreover,
the runoff also meets the peak in September before the dam construction. However, the
runoff shows the convex pattern at the bottom that made September to be a top after the
dam construction. As mentioned above, it is proven that the dam storages the water in the
wet season and uses it in the dry period.
Sirikit dam
Figure 6 shows the change in monthly runoff and rainfall in N.12A hydrological observation station where is located 3km downstream from the Sirikit dam in order to study the effect of the Sirikit dam which was completed in 1977 on the hydrological regime in the downstream. It is noted the moving average curve of the monthly rainfall, then there is no long-term increase and decrease tendency. Monthly maximum runoff has been decreased and monthly maximum runoff has been increased after the Sirikit dam was completed in 1977.

Change of hydrological regime in Nakhon Sawan
Nakhon Sawan city is one of the most important cities in the Chao Phraya River basin, which is joined the Ping and the Nan Rivers. Nakhon Sawan city has the C.2 hydrological observation station (Drainage area: 110,569km$^2$) where is located about 225km downstream from the Bhumibol dam, about 325km downstream from the Sirikit dam.

Figure 7 shows the change in monthly runoff and basin averaged rainfall in C.2 during 1955-2000. There is no long-term increase and decrease tendency in rainfall. After the Bhumibol dam was completed in 1967, minimum runoff has been increased and maximum runoff has not been changed greatly. The maximum runoff had been decreased from the 1980’s to the beginning of the 1990’s. The minimum runoff was compared with before and after the Bhumibol dam construction. The monthly runoff is less than 2mm for 22 months during 12 yeas before the Bhumibol dam construction from 1956 to 1967. On the other hand, Nakhon Sawan has been maintained the stabilized discharge after the Bhumibol dam construction. It seems that the Wang and Yom have few large-scale hydraulics facilities is one of the reasons why the maximum discharge has not been decreased in Nakhon Sawan in spite of the dams construction.

Spectrum analysis using the Fast Fourier Transform
The change of the spectrum characteristics of the daily discharge was analyzed using the Fast Fourier

Transform (FFT). Fast Fourier Transform for time series data of the N piece \( f(1), f(2), \ldots, f(N) \) is according to following equation.

\[
F[k] = \sum_{n=1}^{N} f[n]W^{k-1} \quad (k = 1, 2, \ldots, N)
\]

Where \( W = \exp(-i2\pi/N) \).

The periodicity characteristics in the following 3 periods; (1) before the Bhumibol construction from 1956 to 1967, (2) before the Sirikit dam construction from 1969 to 1976 and (3) after the dams construction from 1978 to 2001 were analyzed using the FFT (see Figure 8). The characteristic of above 3 periods has the 365 diurnal rhythm and the rhythms with the peak in September and July (circle mark in Figure 8). It seems to base it on the year cycle in which the precipitation has two peaks in July and September.

Figure 9 shows the short-term periodicity characteristics of daily runoff from 1978 to 2001 after the two dams construction. It is unique from this figure for two in 3.5th and 7th. This can be easily guessed with that it is clearly based on the human activity.

The 7 diurnal rhythm was indicated by Oki (2002), which was based on the operation of the large-scale reservoir. From the viewpoint of the effect of Bhumibol dam considered as one of the possibilities, it performed spectrum analysis on the daily release water from the Bhumibol. The result showed having 2.5th, 3.5th, period 7th (see Figure 10). As above-mentioned, it can be called the remarkable example in which the flow condition of the downstream is being affected by dam operation that is human activity. It is mentioned that as one of the reasons with such periodicity, the RID required the weekly demand for irrigation for the EGAT, and then the EGAT operated the daily release water.
DISCUSSION AND SUMMARY

The Chao Phraya River basin which has the largest basin in Thailand has been located in the center of socio-economic since thousands years. Every King quite realized the importance of water resources and control the Chao Phraya River. It is guessed that the Bhumibol (completed in 1967) and Sirikit (completed in 1977) dams quite influence on the hydrological regime in the down stream. In this paper, the effect was examined using by the change of river discharge in the downstream of 2 large-scale dams. The following results were obtained:

(1) There is no long-term increase and decrease tendency from 1952 to 1995. On the other hand, it is noticed that the runoff in hydrological observation station where is located in the downstream of the Bhumibol dam before and after the dam construction, and then the minimum runoff increased, the maximum runoff decreased after the dam construction further than before the dam construction. By the dam operation, water resources are stably supplied, and the occurrence of the flood decreases. The equal tendency has appeared even in the hydrological observation station where is located in the downstream of the Sirikit dam.

(2) The minimum runoff has been decreased in Nakhon Sawan (C.2) where is located in middle point of Chao Phraya River basin, which is joined the Ping and Nan Rivers. On the other hand, the maximum runoff has not been decreased because there are a few large-scale hydraulic facilities in Wang and Yom River basins.

(3) The spectrum analysis on daily discharge in Nakhon Sawan using Fast Fourier Transform was carried out. As the results, a period characteristic with the peak in September and July as the tendency equal to the precipitation phenomenon was obtained. And 3.5 days and 7days period, a short-term period characteristic was also obtained. The spectrum analysis on daily release water in Bhumibol and Sirikit dam was carried out, then 2.5 days, 3.5 days and 7 days period characteristic was obtained. As the mention above, the Bhumibol and Sirikit dams cause the effect that is considerable for the hydrological regime of the downstream.

Finally, the two large-scale dams promote the irrigation in the dry season in the middle and the lower Chao Phraya River basin and cause the improvement of the agricultural production quantity and now, the considerable effect for the stabilization of agricultural production is caused. Moreover, the utility form of the water-use also greatly has changed. It is not possible to absolutely disregard the effect that the large-scale human activities as the large-scale dam construction on water circulation. It can be seemed that the integration of human activities to runoff and hydrological model is indispensable.
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REFERENCES