The study of efficient water management system based on the advance telemetry technology

Monthita Chimkuarwan, Vissarut Aksornnum
Foreign Project Management Branch, Bangkok, Thailand

Arisa Jong-u-suk
Regional Irrigation Office 9, Chon Buri Province, Thailand

● **Abstract:** The Bangpra reservoir is Chon Buri's most important major reservoir (more than 100 million cubic meters), located in Eastern Economic Corridor (EEC), with storage capacity of 117 million cubic meters. There are 6 water user groups; Provincial Waterworks Authority, Chon Buri Branch (Special Level), Provincial Waterworks Authority, Si Racha Branch, Provincial Waterworks Authority, Pattaya Branch (Special Level), Eastern Water Resources Development and Management Public Company Limited (East Water), Thai Oil Public Company Limited, and Electricity Generating Authority of Thailand (Bang Pakong Power Plant). Water requirements including evaporation and seepage losses are approximately 90 million cubic meters per year. However, average annual runoff filling the reservoir has been only 40 million cubic meters, and tends to decrease due to change of land uses in the reservoir area. Without further concrete management, Bangpra reservoir's water quality might be affected by community's wastewater. Royal Irrigation Department (RID) foresees the importance of allocating water budget for activities in Chon Buri. Water pump and diversion system thus constructed to divert excess water from Phra Ong Chao Chaiyanuchit Canal to Bangpra Reservoir during rainy season with capacity of 70 million cubic meters per year. East Water's pump and diversion system also help diverting water from Bang Pakong river into Bangpra reservoir at approximately 20 million cubic meters per year. Upstream water is standardized by water quality telemetry system prior to diversion process. For the purpose of having effective, real-time water and water quality management for Bangpra reservoir, RIO cooperated with Japan's Agriculture Development Consultants Association (ADCA). Phase 1 is to install 7 telemetry stations for Bangpra Reservoir's inflow measurement, by monitoring the amount of water, rainfall, and runoff flowing into the reservoir. The difference between data obtained from the telemetry, staff gauge and rain gauge were at an acceptable level.

● **Key words:** Bangpra reservoir, real-time, telemetry, water quality management.

1. Introduction

In the eastern Thailand, water resources development and irrigation projects are being implemented by the Ninth Regional Irrigation Office (9th RIO) of the Royal Irrigation Department (RID). The center of water resource use in the eastern Thailand is Bangpra Lake which is located in Chon Buri province adjacent to the 9th RIO office. Bangpra Lake not only received water from 7 small river basins around the lake but also other water basins outside the lake. Main water sources from the other basins are Phra Ong Chao Chaiyanuchit Canal of Chao Phraya River system, Bang Pakong River, and river basins of other provinces in eastern Thailand (Rayong province and Chanthaburi province), especially the Prasae Lake in Rayong province and Wantanod pumping station in Chanthaburi province. In future, Prasae Lake and Wantanod pumping station will be the most important sources of water. Bangpra Lake provides water for irrigation, urban water, industrial water for such as Laem Chabang Industrial Estate, and sightseeing spots such as Pattaya in Chon Buri province.

Based on the result of preparatory study in fiscal year 2016, ADCA exchanged letters with RID in March 2017 and agreed each other to study water management (balance) of reservoir by basin. In June - July 2017, after consultation with RID and 9th RIO, TM equipment was installed at 7 places, namely, Bangpra Lake, discharge canal of Bangpra Lake, and 5 rivers inflowing to Bangpra Lake. Immediately after the installation of TM equipment, monitoring of water level and rainfall has started. The outline of TM equipment and location is as shown in Table 1 and Figure 1 shows the location map of the TM equipment.

2. Objective

1. To study for RIO's water management system improvement.

2. To introduce advanced TM systems for automatic measurement and transmission.

3. To study the possibility of distributing TM system to other irrigation systems.

3. Hypothesis

Data collection of water volume is currently done manually by sending authority to the measurement area. The obtained data are to be analyzed via Excel program which is not online real-time system. Due to inaccurate, non-real-time, and inefficient data, water management system is not effective. In case of changing responsible authority in collecting data, a new training must be conducted. Thus, obtaining the auto system is certainly rather sustainable and appropriate.

4. Guidelines for solving problems

To solve the issue by using ADCA's system which is more efficient and sustainable than the manual system, with the following framework;

• Preparatory discussions to finalize a work plan

• Determination of the location to install the TM system and discussion of the operation and maintenance structure of the TM system

• Production of the TM system in Japan and its shipment

• Examine the current situation of water and infrastructure management

• Installation of the TM system

• Operation and maintenance of the TM system

• Training of data processing and analysis

• Monitoring of water supply management by use of TM data

• Proposal of model concept for the water management

• Verification on functionality of the system in Thailand

5. Solution method

How to choose a Pilot site and Model Site from all 6 stations.

1. According to Bangpra Reservoir is large reservoir (Capacity more than 100 MCM.) which is the major reservoir in Chonburi province. Bangpra Reservoir capacity is 117 MCM. The main users

are household consumption and industry which is the water distribution center of Chon Buri and Chachoengsao provinces

2. The reservoir is located in Eastern Economic Corridor (EEC).

3. There are seven important natural canals flows to Bangpra reservoir.

In additional, the other water sources are pumped to Bangpra reservoir such as Phra-Ong Chaiyanuchit-Bangpra reservoir Water Transfer pump system, East Water Company from Bangpakong river Water Transfer pump system. In the future, Royal Irrigation Department intends to create new project for example Pumping water system from Prasae reservoir to Nongkho reservoir and distribute water to Bangpra reservoir by open channel canal. The amount of water and rain that flows to the reservoir shall real-time data therefore, it is necessary to install a water measuring instrument at the reservoir.

4. Royal Irrigation Office 9 is located at Bangpra reservoir which able to closely monitor and maintenance the equipment of telemetry systems.

Table 2 The active storage of storage dams allocated to Chao Phraya river at 31 August from 2007 to 2019

Location	Water level measurement range	WL Length of cable	Protection
1 Bangpra lake	0-20 m	30 m	No
2 Huay Song Thon river	0-10 m	20 m	No
3 Tha Sai river	0-10 m	20 m	No
4 Huay Gru river	0-5 m	20 m	Yes
5 Bang Thang Tong river	0-5 m	20 m	Yes
6 Nong Kho- Bangpra canal	0-5 m	20 m	Yes
7 Bangpra embankment	0-5 m	15 m	No
Total		7	

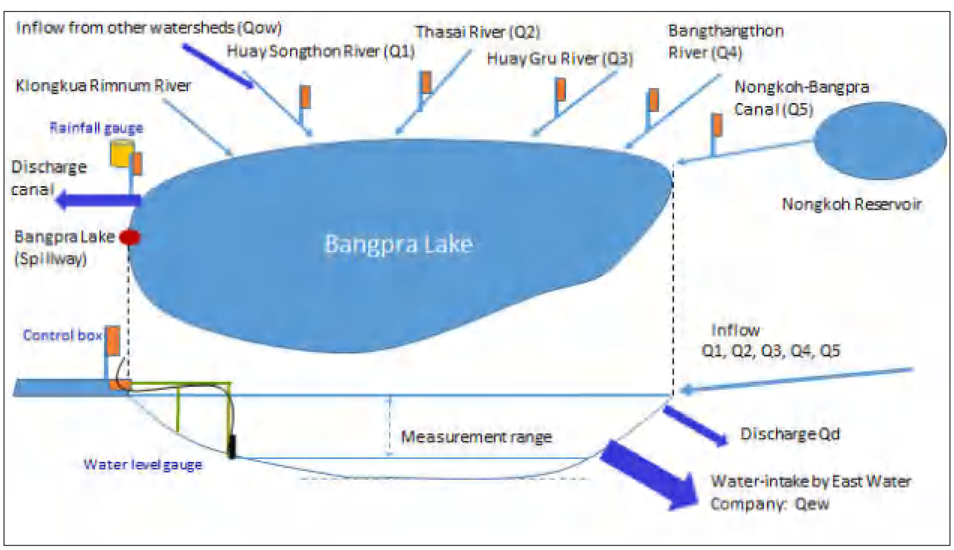


Fig. 1 Location map of TM equipment in Bangpra Lake basin

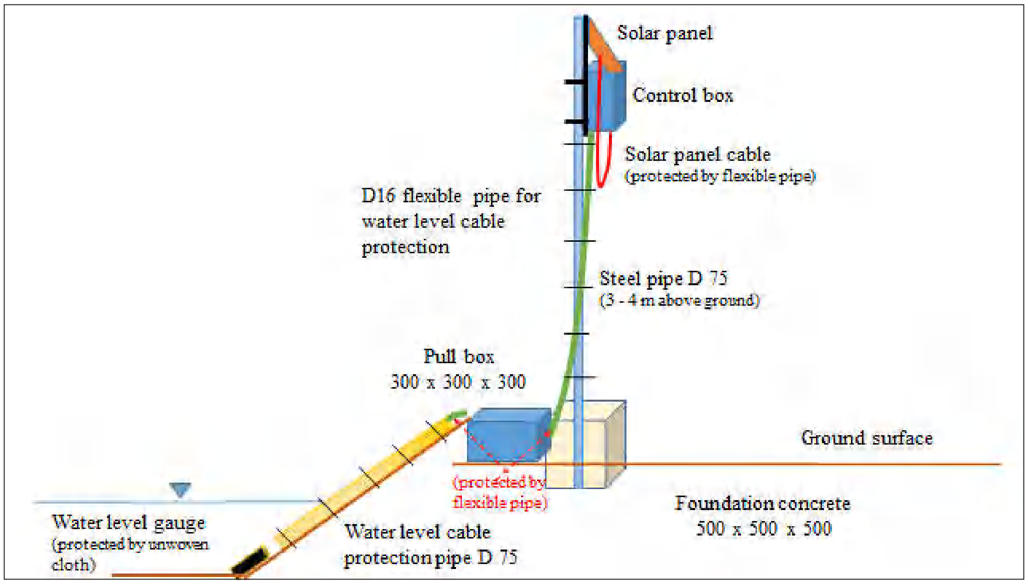


Fig. 2 Schematic layout of TM installation

In the SESAME system of Midori Engineering Laboratories (MEL) introduced by ADCA, monitored data is transmitted to a cloud operated by a global cloud service company (Amazon Web Services: AWS) through a mobile phone network, uploaded to the web after processing, and received by a personal computer or a smartphone through internet. However in Thailand, regulations restrict to handle government agencies' data in the servers located outside the country. This means that the TM data should be transmitted to the RID cloud operated by RID TM center. ADCA decided to develop a new system to receive, process and display the TM data.

ADCA started to develop a new data receiving / display system (ADCA system) from March 2018. In July 2018, ADCA did work successfully to shift from AWS to RID cloud by using the developed ADCA system. Also ADCA installed a monitor to display TM data in 9th RIO office. The structure of the ADCA system is shown in Fig. 3.

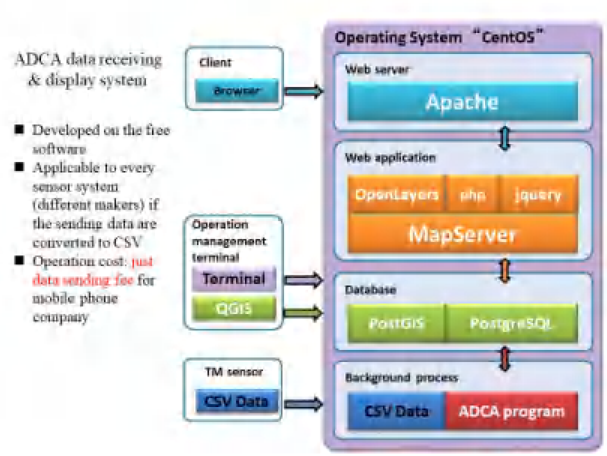


Fig. 3 Structure of ADCA system

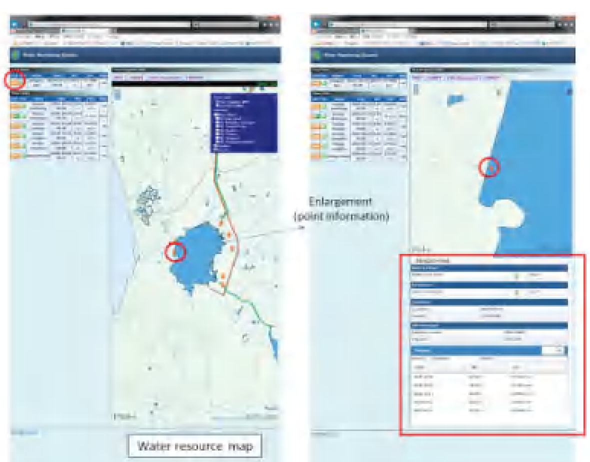


Fig. 4 Example display screen of ADCA syste

6. Results of operation

After setting up the TM equipment, in September 2017, ADCA brought in a digital current meter and asked 9th RIO to measure the flow rate at 5 rivers. 9th RIO carried out cross-section surveys shown in Figure 5.1 to 5.2 of the river and conducted flow measurement.

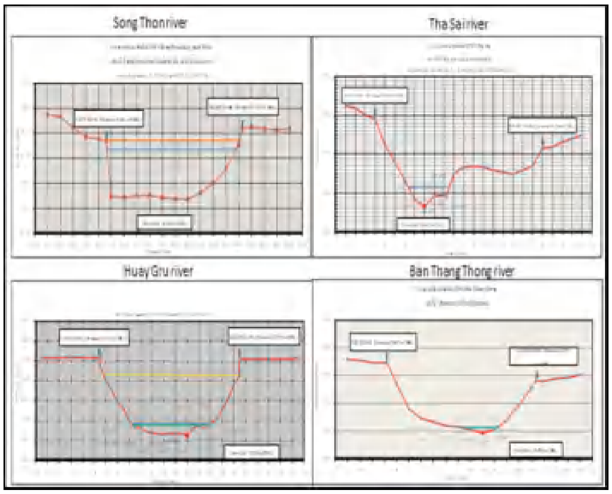


Fig. 5.1 Cross-section of Song Thon River, Tha Sai River, Huay Gru River, and Ban Thang Thong River

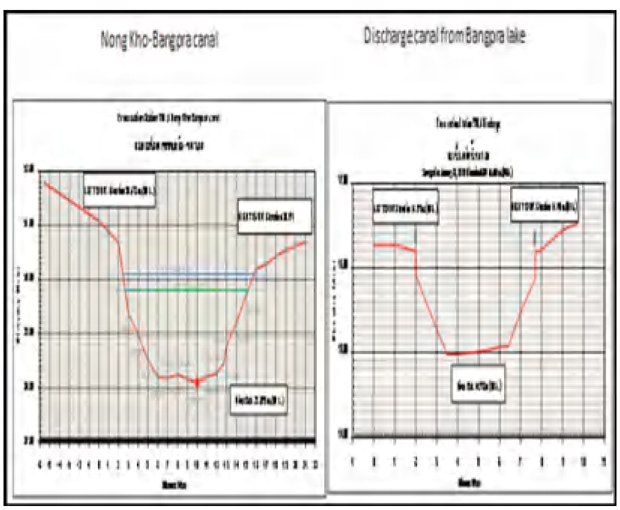


Fig. 5.2 Cross-section of Nong Kho-Bangpra Canal and discharge canal

From the cross sectional drawing of river/ canal at each TM point, the flow rate was estimated at three or more water depths by Manning formula, and then the flow rate equation was developed by consisting with the flow rate measurement result. Table 2 shows the calculation results. at three or more water depths by Manning formula, and then the flow rate equation was developed by consisting with the flow rate measurement result. Table 2 shows the calculation results.

The flow measurement method adopted by 9th RIO did not conform to the standard two point or three point method (Fig. 6), and the range of the measured water level was insufficient. Also, since the cross section of the river changed due to the flood afterward, as well as TM equipment has been relocated due to flooding of TM equipment or sedimentation on the sensor, the flow rate measurement result is currently inadequate. In this study, the water level -flow rate equation is estimated with reference to the measured data. In order to improve the accuracy, it is required to implement flow rate measurement again.

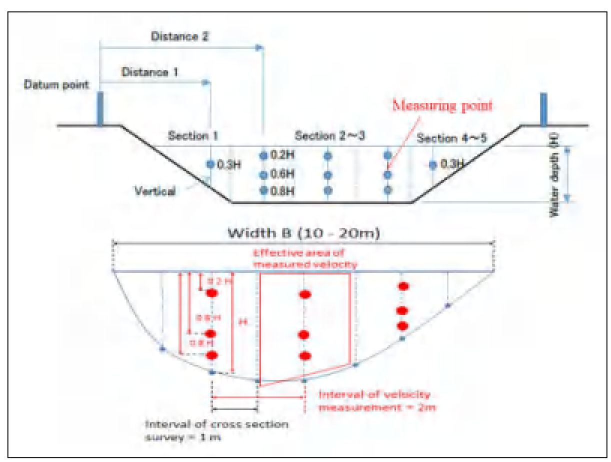


Fig. 6 Schematic diagram of standard flow rate measurement

Table 2. Comparison of measured flow rate and flow rate calculated from cross sectional drawing of river/ canal

TM location	Flow rate: Q (m^3/g)		Flow rate measured (m^3/g)
Huay Song Thon	1	23.3	
	2	18.0	
	3	12.1330	12.1330
	4	2.2	
Tha Sai	1	3.3	
	2	1.2	
	3	0.1784	0.1784
Huay Gru	1	59.9	
	2	18.9	
	3	1.8092	1.8373
	4	1.2408	1.2408
Bang Thang Tong	1	35.0	
	2	9.5	
	3	0.2395	0.2566
	4	0.1448	0.1448
Nong Kho - Bangpra canal	1	8.7	
	2	6.3145	6.3145
	3	1.7	
	4	0.2	
Discharge	1	2.4	
	2	0.3	

In order to approximate the estimated flow rate to the measured flow rate, adjustment was made by changing the roughness coefficient and the waterway gradient in the Manning formula. Ultimately, the roughness coefficient and the gradient were set such that the “Flow rate measured” in the rightmost column of Table 2.1 agrees to the “Flow rate: Q”. Based on Table 2, the water depth- flow equation (HQ equation) is developed as shown in Fig. 7.1 to 7.6.

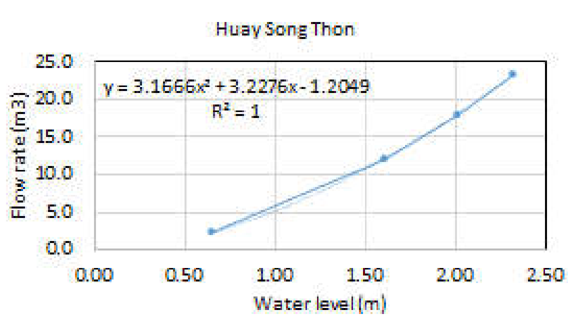


Fig. 7.1 the water depth- flow equation (HQ equation) of Huay Song Thon River

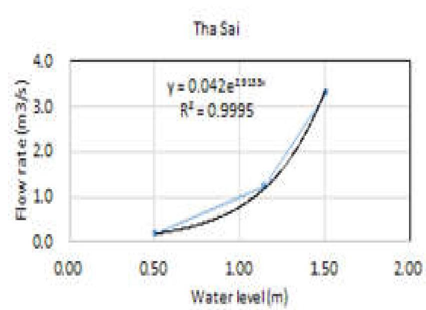


Fig. 7.2 the water depth- flow equation (HQ equation) of Tha Sai River

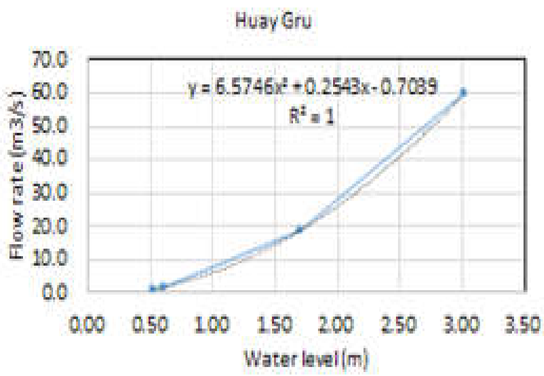


Fig. 7.3 the water depth- flow equation (HQ equation) of Huay Gru River

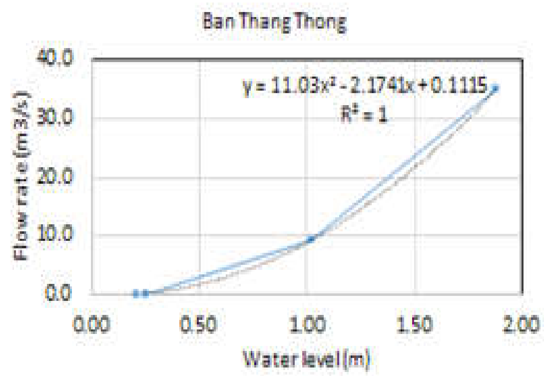


Fig. 7.4 the water depth- flow equation (HQ equation) of Ban Thang Thong River

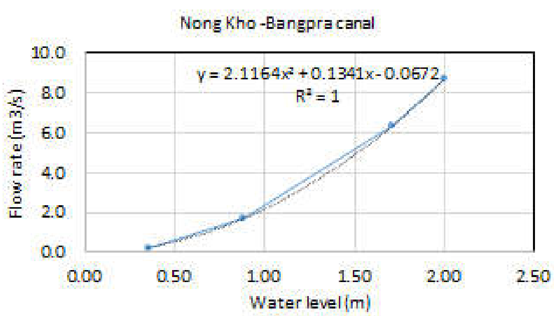


Fig. 7.5 the water depth- flow equation (HQ equation) of Nong Kho-Bangpra Canal

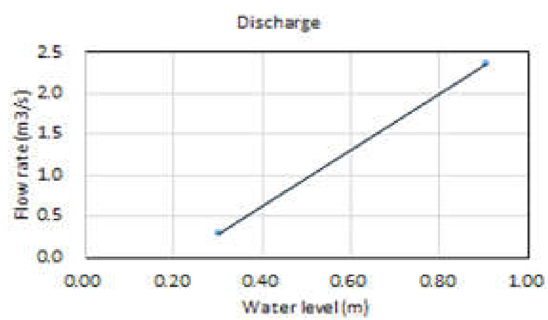


Fig. 7.6 the water depth- flow equation (HQ equation) of discharge canal

Since the calculation result of the flow rate obtained from the HQ equation is also displayed on the TM display system, it is expressed as a linear between measurement values, not a curve, in order to quickly calculate a large amount of data. Table 3 shows the linear HQ equation.

Table 2. Comparison of measured flow rate and flow rate calculated from cross sectional drawing of river/ canal

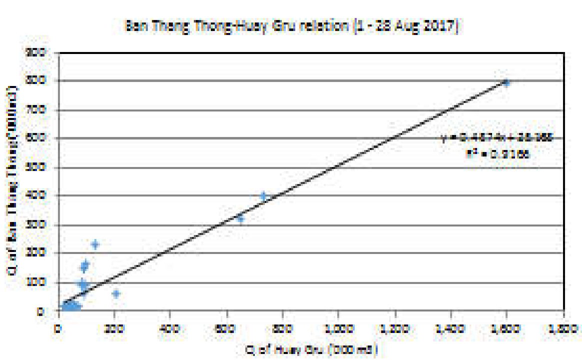
TM location	Water level range (m)	Flow rate measured (m^3/g)
Song Thon River	0.00-0.65	Q=3.4021*H
	0.65-1.61	Q=10.3528*H – 4.4832
	1.61-2.01	Q=14.6578*H – 11.3927
	2.01-	Q=16.9216*H–15.9317
Tha Sai River	0.00-0.50	Q=0.3560*H
	0.50-1.15	Q=1.6336*H – 0.6401
	1.15-	Q=5.7641*H–5.3860
Huay Gru River	0.00-0.52	Q=2.3770*H
	0.52-0.60	Q=7.1054*H–2.4682
	0.60-1.71	Q=15.4712*H – 7.5045
	1.71-	Q=31.3233*H – 34.5957

TM location	Water level range (m)	Flow rate measured (m^3/g)
Bang Thang Thong River	0.00-0.20	Q=0.7171*H
	0.20-0.25	Q=1.8925*H – 0.2374
	0.25-1.03	Q=11.9473*H – 2.7712
	1.03-	Q=29.8762*H – 21.1484
Nong Kho –Bangpra Canal	0.00-0.35	Q=0.6834*H
	0.35-0.88	Q=2.7362*H–0.7185
	0.88-1.71	Q=5.6062*H – 3.2441
	1.71-	Q=7.9829*H–7.2963
Discharge canal	0.00-0.30	Q=0.9585*H
	0.30-	Q=3.4362*H–0.7458

The water depth data in the missing period is estimated from the correlation formula with the target TM and other TMs without data missing. Fig. 8.1 to 8.4 shows the correlation graph of the water depth between the two rivers. Relational equation obtained between selected 2 TMs applied as follows;

- Ban Thang Thong-Huay Gru River:
  y = 0.4874x + 25.168 R^2 = 0.9166
- Ban Thang Thong-Tha Sai River:
  y = 10.368x - 331.64 R^2 = 0.6536
- Huay Gru-Tha Sai River:
  y = 22.687x - 791.7 R^2 = 0.8111
- Song Thon-Tha Sai River:
  y = 1.7754x + 2.0359 R^2 = 0.5592

Regarding Nong Kho- Bangpra Canal, relational equation is unable to be developed because water is not only coming from river basin but also from Nong Kho Lake. Therefore, the outflow water of Nong Kho - Bangpra Canal during missing period is estimated by multiplying the average flow rate of the measurement period with the missing period.



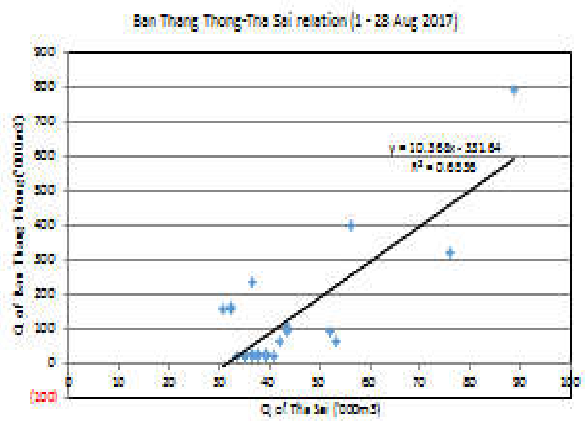


Fig. 8.2 Correlation diagram of water depth between TM locations of Ban Thang Thong + Tha Sai River relation

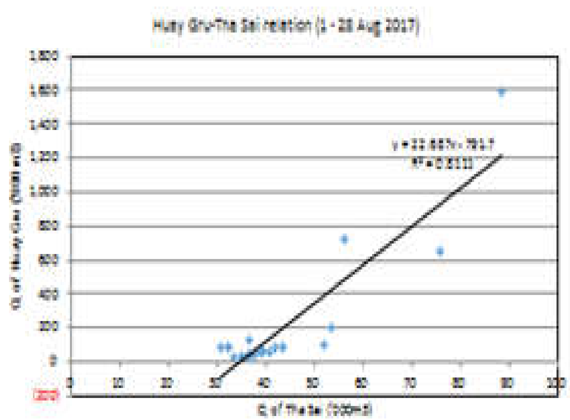


Fig. 8.3 Correlation diagram of water depth between TM locations of Huay Gru + Tha Sai River relation

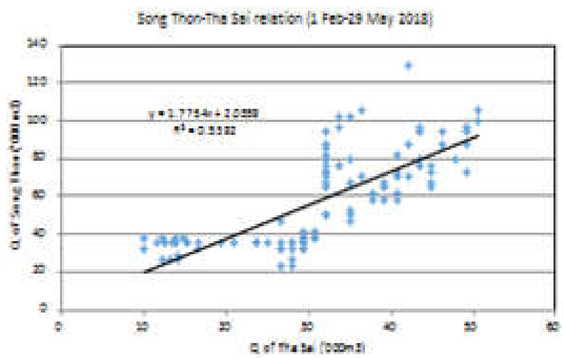


Fig. 8.4 Correlation diagram of water depth between TM locations of Song Thon + Tha Sai River relation

6. Comparion of calculated outflow with runoff water from watershed

Estimate the annual runoff from the watershed of Bangpra Lake and compare it with the runoff calculated by the above flow rate equation.

The watershed and catchment area size of Bangpra Lake are as shown in Fig.9

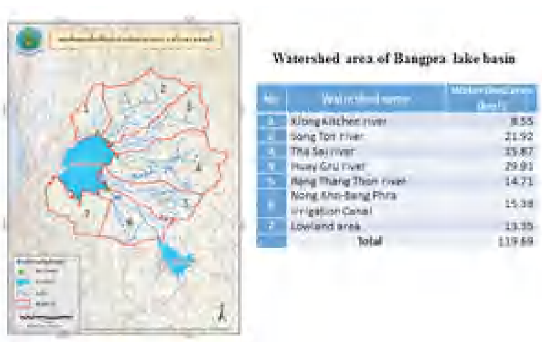


Fig. 9 Watershed area by river name of Bangpra Lake

To calculate the runoff amount from the watershed, the Curve Number (CN) method developed by The US Department of Agriculture (DA 2004) is applied. The calculation formula of the outflow by the CN method is as follows.

When $R>0.2S$;

$Q=(R-0.2S)^2/ R+(0.8S)$

$S=254(100/CN-1)$

When $R\leq 0.2S$, $Q=0$

Where, Q: Runoff (mm), R: Rainfall (mm), S: Potential maximum retention (mm), CN: Curve Number. Conclusion

7. Manual System

- There is a staff who reads the staff gauge and records water level at 6.00 AM everyday.

- It may take 5-10 minutes to read the water level.

- The measured water level shall be compared to the capacity curve for evaluating the amount of water which could calculated by using Microsoft Excel.

- Work efficiency depends on:

1. Reading error due to individual eyesight and reliability of each person

2. Wind wave might cause an inaccurate reading data

3. Heavy rain might cause the staff gauge unclear reading

4. The data should be recorded more than one time per day. However recently there is insufficient personnel problem hence the water level is measured once a day.

<u>ADCA System</u>

Since the ADCA system is composed of license-free software, there is no charge for using the system as long as the RID cloud is used. The expenses necessary for operating the system are only the communication fee paid to the mobile phone company. This communication fee is inexpensive as THB 20 /month / SIM when using AIS as of January 2019.

Effectiveness;

1. The accuracy of the amount of water in the reservoir can be used to make water management decisions

2. Able to make plans for water management without shortage in the event of the drought

3. Realtime reporting enables the decision to drain water in reservoirs efficiently and on time in case of heavy rain.

8. Suggestion

ADCA's system used in water volume measurement is an effective system, benefitted in water management. The system needs to be continuously developed together with water quality measurement, owing to RID's duties to manage both water volume and quality for the raw water needed in water supply process. Not having sufficient water quality means unfulfilled SDF 6 (Clean Water and Sanitation) which are;

1. Management of water for consumption
2. Water security for production sector
3. Flood and inundation management
4. Water quality management
5. Rehabilitation of forest watersheds and degraded areas
6. Management and administration

REFERENCES

[1] USDA. 2004. "National engineering handbook, Chapter 9 Hydrologic soil-cover complexes." The U.S. Department of Agriculture (USDA).

[2] Tachikawa Y., Fujita Y., Shiiba K., Yorozu K., Kim S. 2013. "Water resources projection at Pasak river basin in Thailand under a changing climate." Journal of Japan Society Civil Engineers B1 (Water Engineering) 69 (4): P1445-1450