THE 2024 FLOOD SITUATION IN CHAO PHRAYA RIVER BASIN THROUGH CO-RUN AND RESERVOIR OPERATION MODELING

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ABSTRACT

This study demonstrated the application of the Automated Reservoir Management System (ARMS) which was developed as the AI–based decision support system (DSS) for real time reservoir operation during the 2024 Flood in the Chao Phraya River Basin. From late August to late September 2024, several powerful storms such as Yagi, Soulik, have hit many Asian countries including Thailand resulting heavy rainfall and causing flooding and landslide particularly in northern and central Thailand in the Chao Phraya River Basin (CPYRB). Accordingly, the water situation including the observed and predicted rainfall across the country, reservoir operational status of major dams in CPYRB, and the model outputs generated by the ARMS as well as analysis of flooded area size, was closely monitored and analysed during this severe flooding. The results revealed that the flooded area size is approximately 1,347,033 rai (2,155.25 sq.km.) across 20 provinces in northern and central Thailand. In early October, the severe flooding worsened in the Lower CPYRB, leading to the increase in additional inundated area up to 4.99%. Moreover, the substantial increases of heavy rainfall and reservoir inflow during the powerful storm periods hitting the region brought to the increase of reservoir water storages of major dams in the basin. The results generated from ARMS showed that Constraint Programming (CP) model recommended maintaining a minimum controlled release from the Bhumibol (BB) reservoir during storm periods, as the available water storage was not exceeded URC and potential side-flow downstream of BB dam remained high. From August to September, CP also recommended to release reservoir water from Sirkit(SK) dam with minimum controlled release. However, it recommended to increase the higher volume of reservoir release varying from 26.12 to 34.07 MCM/day since Oct. 1 until now as the reservoir water storage has climbed up nearly full reservoir level indicating the operational flood management risk.

Keywords: Automated Reservoir Management System, Reservoir Operation Modelling; Chao Phraya River Basin.

1. INTRODUCTION

From late August to late September 2024, several powerful storms have hit many Asian countries causing heavy rains and severe flooding such as Tropical Storms Yagi, Bebinca, Pulasun, and Soulik. It was reported that Tropical Storm Yagi originated in Palau on August 30. On September 2, it combined with the southwest monsoon, causing heavy rains across mainland China, the Philippines, Hong Kong, Vietnam, Myanmar, and Thailand. In Thailand, heavy rains from Yagi and continuous rainfall since September 8 led to severe flooding in Chiang Rai and Nan provinces on September 10. On September 14, Tropical Storm Soulik formed east-northeast of Manila and brought heavy rainfall to the north-eastern, central, and northern regions of Thailand. Meteorological Department of Thailand has warned that about 50 provinces, including Bangkok, would encounter heavy rain due to the impact of these storms. Consequently, the flood situation across the nation has been closely monitored since the mid-August until now, especially in the Chao Phraya River Basin (CPYRB) which has been served as lifeline for millions

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of people in the central region. This study presented the results of co-run activity which has been conducted by collaborative researchers from academic institutions including Mahidol University, Kasetsart University, and Chulalongkorn University under the Spearhead Program funded by the National Research Council of Thailand (NRCT). The study aimed to apply the developed models for real-time reservoir operation and to monitor water situation during the 2024 flood crisis focusing in CPYRB.

2. METHODOLOGY

This study utilized the Automated Reservoir Management System (ARMS) which was developed as the AI–based decision support system for real time reservoir operation during the 2024 Flood in CPYRB. The Constraint Programming (CP) model (Sawangphol et al., 2024) developed for multiple reservoir operation system in CPYRB is core model embedded in the ARMS to determine the optimal daily releases of four main dams namely, Bhumibol (BB), Sirikit (SK), Khwae Noi Bumrung Dan (KNB), and Pasak Cholasite (PS). In addition, the reservoir inflow prediction model developed using Machine Learning (ML) technique (Kraisangka et al., 2022) was also included as one of the influential factors for reservoir decision making. The key input data for these models such as reservoir data, predicted rainfall, estimated potential side flow, and estimated satellite–based water demand was automatically accessed through an API from the National Hydroinformatics Data Center (NHC) and related agencies of Thailand. ARMS can be fully processed and visualized their results in terms of 14-day ahead predicted inflow and recommended release by CP model through a user–friendly web service platform as shown the user interface in Figure1.

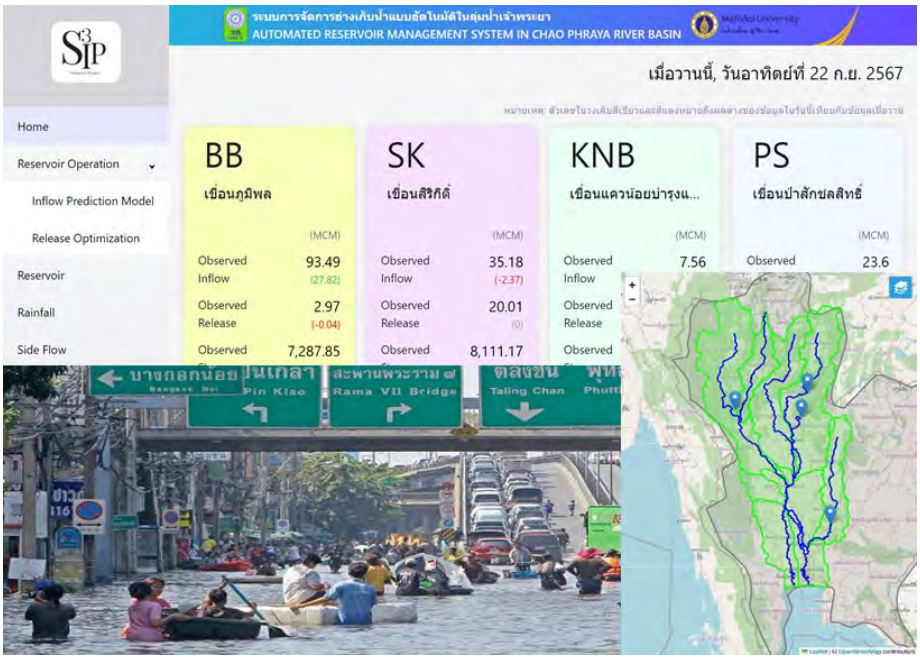


Figure 1. The Automated Reservoir Management System in the Chao Phraya River Basin

Accordingly, the water situation in Thailand during the 2024 severe flood since late August including the observed and predicted rainfall across Thailand, reservoir operational status of four main dams in CPYRB, and the model outputs generated by the ARMS as well as analysis of flooded area size, were analysed and presented.

3. RESULTS AND DISCUSSION

3.1 Flooded Area Size in Thailand

The analysis of Sentinel-1A satellite imagery collected from the Geo-Informatics and Space Technology Development Agency (GISTDA) on September 23-28, 2024, found that the flooded area size is approximately 1,347,033 rai (2,155.25 sq.km.) covering 20 provinces in northern and central Thailand;

Chiang Mai, Chiang Rai, Phayao, Lamphang, Lamphun, Prae, Sukhothai, Uttaradit, Phetchabun, Phitsanulok, Phichit, Tak, Nakhon Sawan, Chainat, Lopburi, Saraburi, Sing Buri, Ang Thong, Phra Nakhon Si Ayutthaya, and Suphan Buri as illustrated in Figure 2. Most of the affected area were along the Chao Phraya river and its tributaries including Ping, Wang, Yom, and Nan and Mekong tributaries. In addition, it is revealed that in the early September, some areas in the upper north particularly in the Chiangrai province was hit by a series of storms resulting in heavy rainfall, flooding, and landslides. In mid-September, the most severe flooding was occurred in the area along Yom river and the upper reaches of Nan river in the Yom and Nan River Basins. During late September to October 5, the severe flooding worsened in the Lower Chao Phraya River Basin, a prone area to frequent flooding, leading to the increase in flooded area up to 4.99% compared to the previous analysis on late September.

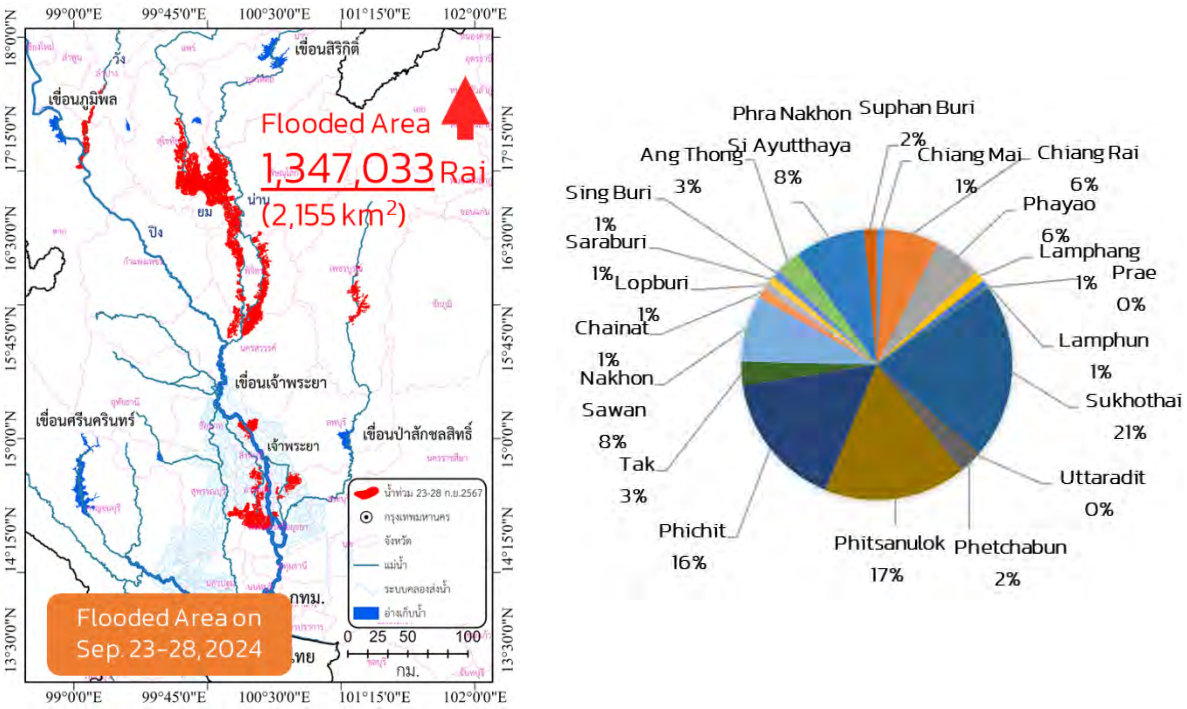
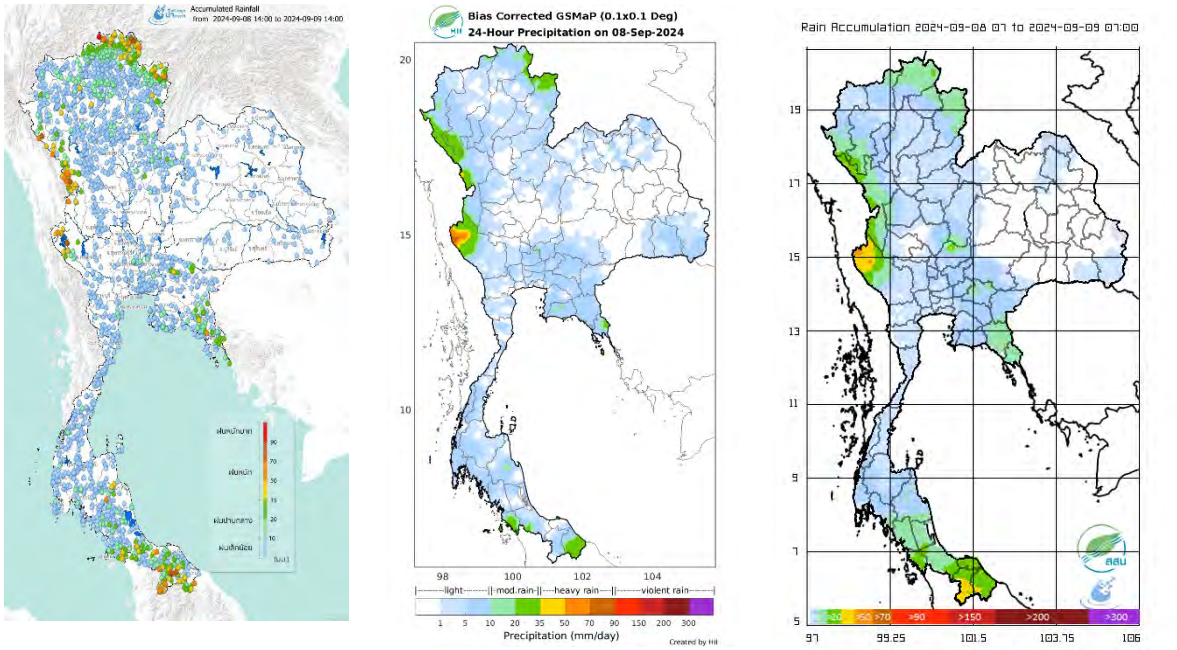


Figure 2. Flooded area size during tropical storms Yagi and Soulik evaluated on September 23-28, 2024 in Thailand

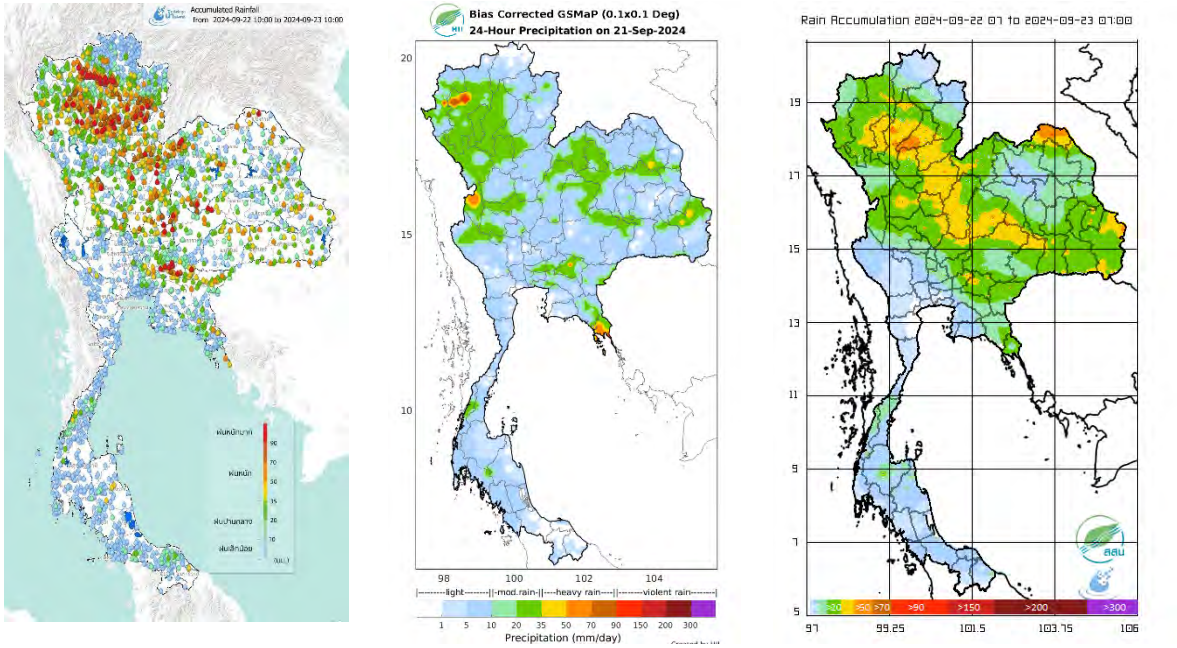
3.2 Rainfall across Thailand during Tropical Storms

It is revealed in Figure 3 that during the Tropical Storm Yagi in early September, three sources of rainfall provided by the Hydro-informatics Institute of Thailand (HII) including observed rainfall measured at ground stations, satellite rainfall, and telemetering rainfall across Thailand was high approximately 100 mm/day in Northern Thailand especially in Chiangrai and Nan provinces in Meklong and Nan River Basins. Heavy rainfall and landslides occurred in the border region between Thailand and Myanmar resulted in significant damage and loss of life. During Tropical Storm Soulik on Sep. 22-23, the rainfall exceeded 200 mm/day particularly in the northern region as shown in Figure 4. This led to widespread flooding in the northern and central regions inevitably. Moreover, the distribution of heavy rainfall was found across the entire country.



(a) Observed Rainfall (b) Satellite Rainfall (c)Telemetering Rainfall

Figure 3. Observed, satellite, telemetering rainfall across Thailand during the Tropical Storm Yagi on Sep. 8, 2024 (*Source: Thaiwater, HII, 2024)*



(a) Observed Rainfall (b) Satellite Rainfall (c)Telemetering Rainfall

Figure 4. Observed, satellite, telemetering rainfall across Thailand during the Tropical Storm Soulik on Sep. 22-23, 2024 (*Source: Thaiwater, HII, 2024*)

3.3 Predicted Inflow and Reservoir Status

The 14-day ahead predicted inflows of two large storage dams; BB and SK as the results from ARMS are presented in Figure 5 and Figure 6. It is illustrated that since early August, reservoir inflow of BB dam has increased especially during the storm periods in late September. The predicted inflow during Oct.1-7 reached highly from 66.71 to 116.49 MCM/Day. Moreover, it is expected to increase in a range from 63.51 to 133.18 MCM/Day during Oct. 7-21. This led to a substantial increase in the reservoir storage of the BB dam, rising from 47% to 70% of active storage between late August and early October (Oct. 8). The predicted inflow of SK dam was high in late August to early September, reaching nearly 200 MCM/day due to the impact of the Tropical Storm Yagi. However, the predicted inflow decreased from mid-September to mid-October ranging from 33.70 to 45.08 MCM/day during Oct. 1-21. It is also revealed that from late August and early October (Oct. 8), reservoir storage of the SK dam raised considerably from 78% to 94% of active storage indicating the flood management risk in the region.

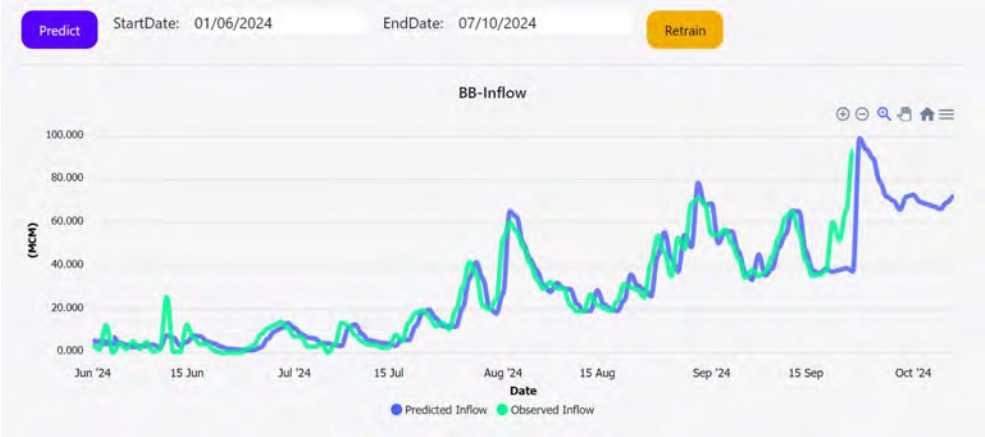


Figure 5. 14-day ahead predicted inflow of BB dam obtained from ARMS

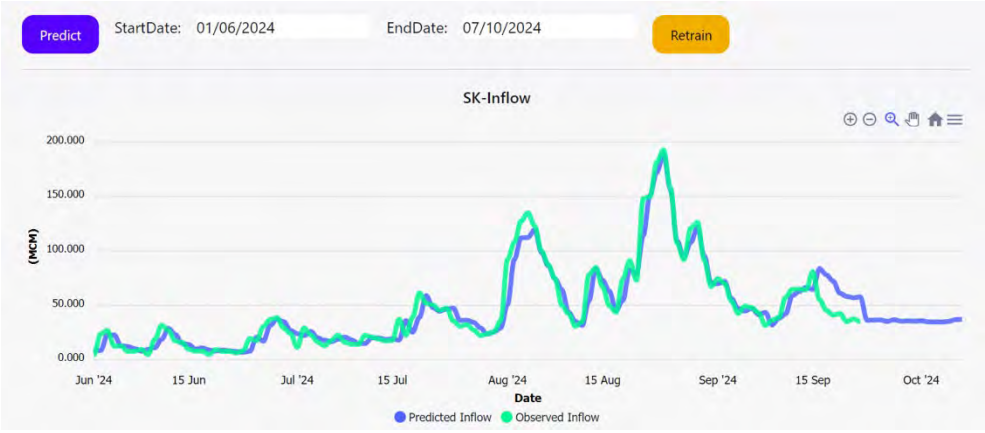


Figure 6. 14-day ahead predicted inflow of SK dam obtained from ARMS

For the predicted inflows of KNB and PS dams obtained from ARMS during Oct 7-21, it ranged from 5.01 to 10.49 MCM/day and from 19.68 to 30.56 MCM/day, respectively resulting in the significant increase of these two reservoir storages up to 80% (KNB) and 70% (PS) of active storage in early October (Oct. 8).

3.4 CP Release

The results performed by ARMS during the 2024 flood also provided the recommended CP releases from four major reservoirs. It is revealed that CP recommended maintaining a minimum controlled release from the BB reservoir during storm periods, as the available water storage was not exceeded URC and potential side-flow downstream of BB dam remained high as illustrated in Figure7. From August to September, CP also recommended to release reservoir water from SK dam with minimum controlled release. However, it recommended to increase the higher volume of reservoir release varying from 26.12 to 34.07 MCM/day since Oct. 1 until now as the reservoir water storage has climbed up nearly full reservoir level as shown in Fig.8.

Figure 7. Recommended CP Release of BB dam obtained from ARMS

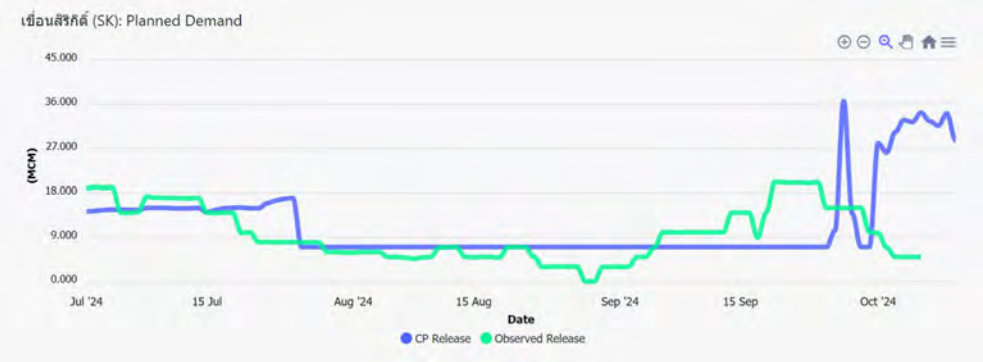


Figure 8. Recommended CP Release of SK dam obtained from ARMS

For the CP releases of KNB and PS dams, the ARMS recommended to determine the minimum releases from these two dams to help moderate the potential flooding especially in low-lying area in the Lower CPRRB.

4. CONCLUSION

The Automated Reservoir Management System (ARMS) developed from the research project allows users to proactively analyse diverse outputs and explore the system's capabilities for real time reservoir operation in CPYRB particularly during the 2024 Major Flood. It provides crucial information such as 14-day ahead predicted inflow and CP release recommended by the model for decision making, allowing the Office of National Water Resource of Thailand (ONWR) and related agencies such as the Royal Irrigation Department (RID) and Electricity Generating Authority of Thailand (EGAT) to conduct flood monitoring and warning system and reservoir decision making to moderate flood risk in Central Thailand.

5. ACKNOWLEDGEMENT

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