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Water resources system study using mathematical modeling for flood and drought problems reduction

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Abstract

Two case studies are proposed for water resources system study using mathematical modeling for flood and draught problems reduction. The first one is the Chi basin, while the second case is the Chao Phraya-Meklong basin. The mathematical models which had been developed, namely: The effective rainfall model and irrigation demand model for rice and other crops growing. Model for calculation of on farm water requirement. Some field data had been collected for model calibration. But more field data collection are still needed for model calibration. The forecast of weekly water scheduling model is still lack of implementation in large river basin. The models to be developed are: the model to forecast the inflow into the reservoir and the model to forecast side flow or uncontrol flow in the river system. If more field data are monitored for model calibration, the forecast of weekly water scheduling model together with irrigation demand model and the new development models can be implemented in large river basins. It is believed that flood and drought problems in these river basins can be managed.

Keywords: Water resources system, mathematical modeling, flood and drought problems, Chao Phraya-Meklong basin

บทคัดย่อ

นำเสนอกรณีศึกษาแหล่งน้ำอย่างเป็นระบบด้วยแบบจำลองทางคณิตศาสตร์เพื่อลดปัญหาน้ำท่วมและภัยแล้ง 2 กรณี กรณีศึกษาที่หนึ่งได้แก่ ลุ่มน้ำชี ส่วนกรณีที่สองเป็นลุ่มน้ำเจ้าพระยา-แม่กลอง แบบจำลองทางคณิตศาสตร์ที่ได้พัฒนาขึ้นมาใช้ในการศึกษาประกอบด้วย แบบจำลองฝนใช้การและแบบจำลองคำนวณหาความต้องการน้ำชลประทาน สำหรับการเพาะปลูกข้าวและพืชอื่น ๆ แบบจำลองสำหรับคำนวณหาความต้องการน้ำบนแปลงเพาะปลูก กับได้เก็บข้อมูลจากสนามมาสอบเทียบแบบจำลองด้วย แต่ยังต้องการเก็บข้อมูลจากสนามมาสอบเทียบแบบจำลองเพิ่มมากขึ้น แบบจำลองสำหรับทำนายการจัดสรรน้ำล่วงหน้ารายสัปดาห์ในลุ่มน้ำขนาดใหญ่ ยังมีการนำไปใช้งานจริงน้อยมาก สำหรับแบบจำลองที่ต้องพัฒนาเพิ่ม ได้แก่ แบบจำลองสำหรับทำนายปริมาณน้ำที่ไหลลงอ่างเก็บน้ำและแบบจำลองสำหรับทำนายปริมาณน้ำที่ไม่สามารถควบคุมได้ แต่สามารถนำมาใช้แทนน้ำชลประทานในระบบลุ่มน้ำได้ ถ้ามีการเก็บข้อมูลจากสนามมาสอบเทียบแบบจำลองที่มากพอ และเป็นเวลานานพอ แบบจำลองสำหรับจัดสรรน้ำล่วงหน้ารายสัปดาห์เมื่อใช้งานร่วมกับ แบบจำลองสำหรับคำนวณหาความต้องการน้ำชลประทานและแบบจำลองที่จะพัฒนาขึ้นมาใหม่เมื่อนำไปประยุกต์ใช้ในลุ่มน้ำขนาดใหญ่ จะทำให้สามารถลดทั้งปัญหาน้ำท่วมและภัยแล้งในลุ่มน้ำได้อย่างมาก

คำสำคัญ: ระบบแหล่งน้ำ, แบบจำลองทางคณิตศาสตร์, ปัญหาน้ำท่วมและภัยแล้ง, ลุ่มน้ำเจ้าพระยา-แม่กลอง

1. Introduction

Generally speaking, large river basin may be consisted of main river channel and several tributaries. And there may be the development of several water resources projects namely: construction of reservoir upstream and irrigation project area downstream.

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There are water uses in each irrigation area and other water uses along the river. At the same time there are flow of water both into the reservoirs and into the river downstream at various locations. When it rains on the river basin at each time, it will effect the available water to the reservoirs, on irrigation areas and other water uses at various locations along the river basin. This is to point out that there are lot of data both water needed and the available water on the river basin. And these data are varying from time to time. Therefore, in order to study of both water needed and water availability. And how to operate the reservoir at various situation including both during flood and draught periods, mathematical modeling are introduced.

2. Why does the study of water resources have to be system?

In order to get the optimum benefit from the development and management of water resources and to reduce the conflict of water uses to be minimum, the water resources have to be studied as river basin. If there is water diversion from one river, to the other, therefore, two river basins have to be studied together.

3. Objective

From the reason in item 2, the main objective is trying to use the uncontrol flow as much as possible. Therefore, the model to forecast both water availability and water demand are introduced in which the flow at various times and various locations in the river system can be forecasted for water balance and for flood studies.

4. Important of field data collection

In large river basin, lot of field data have to be collected. Therefore many responsible and experience people are needed. Many pilot areas have to be selected for field data collection. Many basic data have to be analysed. The main reason for this is to get good study result.

5. Mathematical model

Mathematical models which are suitable for calculation of irrigation water demand for rice growing in Thailand have been developed namely:

1) Models for calculation of effective rainfall which are composed of:

- Model for calculation of effective rainfall for rice growing.
- Model for calculation of effective rainfall for growing of other crops.

2) Model for calculation of irrigation water demand which are composed of:

- Model for calculation of irrigation water demand for rice growing.
- Model for calculation of irrigation water demand for growing of other crops.

3) River basin system simulation model, it is the model for study of water balance in the river basin in which reservoir water seepage loss can be included in the model study.

4) The forecast of weekly water scheduling model.

5) Model for calculation of on farm water requirement.

The details of 5 models can be found in references [1] and [2].

6. The models have to be developed

The models have to be developed are:

1) The models to be used to forecast inflow to the reservoir which seasonal inflow, monthly inflow, weekly inflow and 3 days period inflow can be forecasted.

2) The model to be used to forecast side flow or uncontrol flow in particular points in the river system. Seasonal flow, monthly flow, weekly flow and 3 days period flow at the important locations for water management in the river system can be forecasted.

The two models can also forecast floods which flows into the reservoir and at the important locations in the river system.

7. Field data collection for model calibration

Field data collection for model calibration in item 5 namely: percolation of water in rice growing area, land preparation water for rice cultivation, the relation between weekly rainfall and weekly effective rainfall for rice growing, irrigation return flow from rice paddy area, structure calibration curve to

be used for calculation of irrigation water supply and reservoir water loss by percolation and so on.

It has been mentioned in item 4. that it usually take lot of time, taking lot of money and needs many good and responsible personnel for field data collection. Besides many field data have been collected. But many field data collection still be needed.

Example of some field data collection are in [3]. Details of how to collect data, data have been collected and basic data analysis are in [1] and [2].

8. Proposed case study

8.1 First proposed case study: The Chi River basin

8.1.1 Introduction

The Chi river basin has a drainage area of 49,477 km2 and there are two large reservoirs constructed on the Chi river tributaries namely:

- Ubon Ratana reservoir constructed on the Nam Pong tributary with the reservoir capacity at full supply level of 2,263 MCM.

- Lam Pao reservoir constructed on Lam Pao tributary with increasing the reservoir capacity to 1,600 MCM.

Besides there still be weir and regulators constructed along the Chi river namely: Kangsnamnang weir, Chonabote, Kooycheok, Wangyang, Roi-et, Yasothorn and Thatnoi regulators.

Downstream of Ubol Ratana reservoir along Nam Pong river of about 35 km., there is Nongwai irrigation diversion weir which diverts the water to an irrigation area on both banks of Nam Pong river of 260,000 rai (2.54 rai = 1 acre). While at Lam Pao reservoir,there are main canals taking water directly from the reservoir to irrigate an area on both banks of Lam Paoriver of 310,000 rai. Besides there still be several medium and small scales irrigation areas along both banks of the Chi river and at upstream of both large reservoirs.

8.1.2 Field data collection recommended

More data to be collected in the field are:

1) Pilot area with varying size both in and outside irrigation areas distributed on over the river basin should be set up. The monitoring data are: water percolation on paddy rice area, water uses for land preparation, effective rainfall and return flow from rice growing area.

2) In irrigation project area. Besides data collection in item 1) weekly crop growing activities, and structure calibration curves should be collected. These data will be used to calculate irrigation efficiency at various locations at the end of each growing season.

3) Field monitoring of every size of reservoir water percolation loss.

8.1.3 River basin system study by mathematical modeling

It is the water balance study of the Chi River Basin by mathematical modeling in which system schematic is shown in Figure 1. The models to be used for the study areirrigation demand model and system simulation model. Past hydrological record concerned of at least 25 years long together with additional field data collection explained in item 8.1.2 are used in the study.

The result of the study will be shown in the form of Dry season area reduction curve (DSAR-curve). If volume of reservoir water at the end of the wet season is known, dry season crop area can be calculated from DSAR-curve. In this case, reservoir empty can be avoided, if rainfall is late at the beginning of the following wet season, there still be enough water for land preparation at the beginning of the wet season, if field data collection for the study are corrected. This is the optimum uses of the available reservoir water.

The model development to forecast the reservoir inflow, side flow or uncontrol flow at the weir or regulator or at the main stream gagging stations along the river. This model development should forecast the flow at the selected location on seasonal, monthly, weekly or 3 days period basis. These models can be used for flow forecasting on normal situation, during both flood and drought periods. Therefore during the flood period, the models will be the instrument for making the decision of how to release the water from the reservoir. Because both reservoir inflow and uncontrol flow are known.

In normal situation when rainfall on irrigation area is not enough and irrigation water shortage still be greater than side flow, therefore water released from the reservoir is necessary.

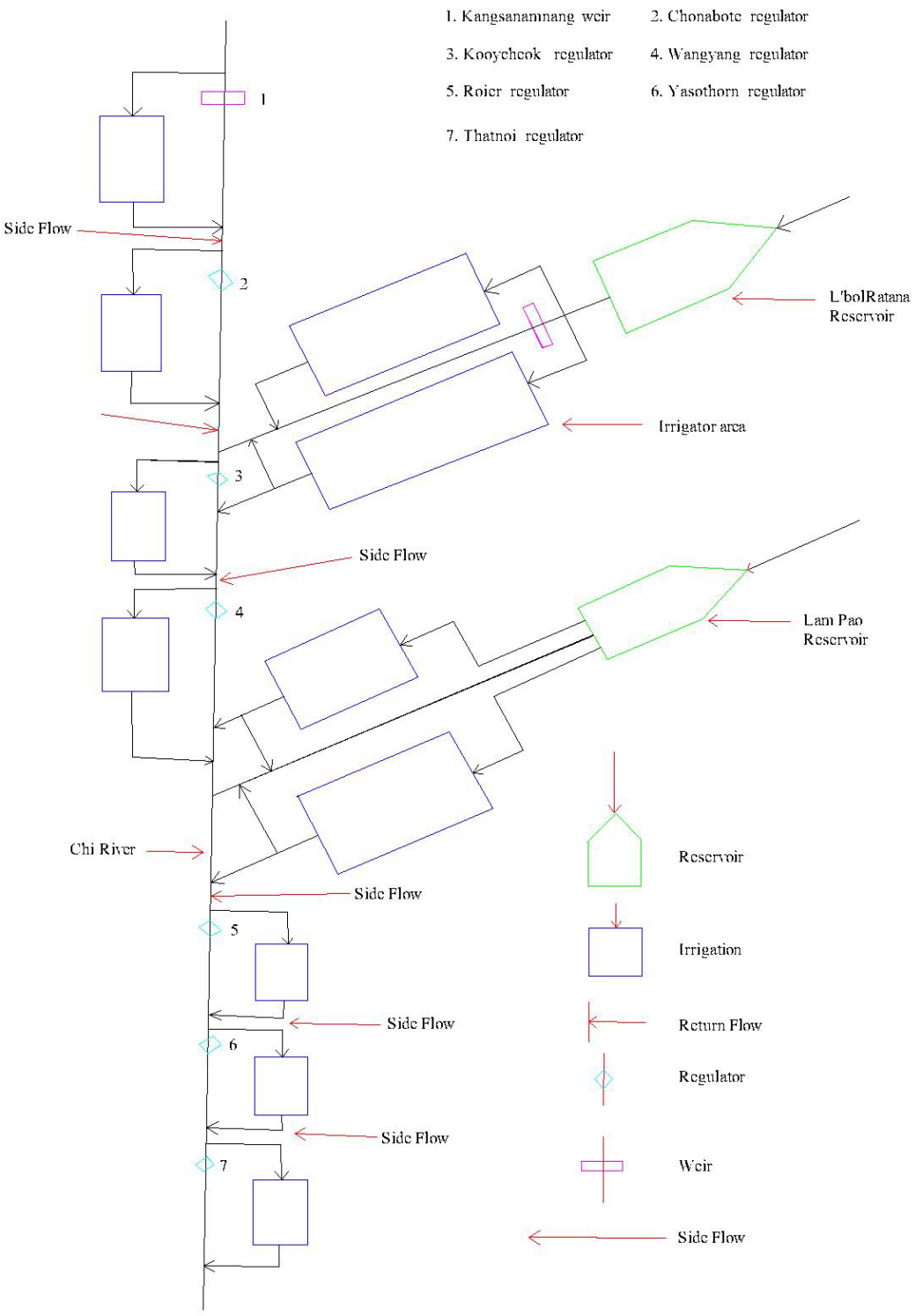

Figure 1. System schematic for water balance of Chi river basin.

8.1.4 Flooded area in the wet season

The low area downstream of the reservoir in which flood is usually taking place almost every year. This area may be modified to be flood detention basin. If reservoir water is enough, this area should start growing rice when flood water level is lower than paddy bund by using flood water for land preparation for rice growing. Then irrigation water supply is needed for rice growing After harvesting, second rice crop should be started to growing and harvesting before flooding.

8.1.5 The forecast of weekly water scheduling by models

When irrigation rule curve which has been explained in item 8.1.3 is studied. For implementation, it is recommended to develop the forecast of weekly water scheduling model in the Chi basin. The details of this model can be founded in reference [4]. This model will be used together with reservoir inflow and important side flow forecasting models.

It can be concluded at this point that the water uses study for irrigation rule curve, past hydrological records are used in the study, while for starting of water delivery to irrigation system, hydrological records are not known yet. Therefore, the forecast of weekly water scheduling model is recommended to be used.

8.1.6 Conclusion of first case study

The water resources system in the Chi river basin had been studied under the name ‘‘The Project for Increasing of Water Resources and Water Uses Efficiency by Piping System in the Northeast" Rule curve of Ubol Ratana reservoir is recommended to be improved. During heavy rainfall period in which flood can be taken place, the reservoir water level will be kept at 180.50 m. MSL. Near the end of the wet season, reservoir water level is raised up to 182.00 m. MSL., which is the design reservoir full supply level. At the level of 180.50 m. MSL., if 100 years of return period flood takes place, the highest reservoir water level will be at 183.30 m.MSL. Which is 0.20 m. lower than top of flood protection dike level at Amphur Nonesang, Khonkaen province. The details of the study is in references [5] and [6]. This is trying to reduce flood magnitude downstream to be equal to the capacity of Nam Pong River downstream.

At the same time, the chance to raise reservoir water level up to the design full supply level near the end of the wet season still be possible almost every year.

In this proposed study, it is recommended to collect important field data as explained in item 8.1.3 at least for two more years. At the same time, the forecast of weekly water scheduling model should be implemented. If water level in Ubol Ratana reservoir can be kept at 182.00 m. MSL. at the end of wet season, it is expected that there will be enough water for growing second rice in low area of Nongwai irrigation project which was flooded in the year 2011 almost every year. After 5 years of the forecast of weekly water scheduling has been implemented, water uses study in the Chi river basin is recommended to be reviewed.

8.2 Second proposed case study: The Chao Phraya-Meklong basin study

8.2.1 Introduction

Besides, there is water diversion from the Meklong riverto the Chao Phraya river lower west bank area, therefore the study has to be carried on together. The Chao Phraya-Meklong basin are the large river basins in Thailand with the total catchment area of 211,000 km.^{2} or about 41% of the country area.

About the year 1977-1978, Acres International Ltd., from Canada was hired to carry on the Chao Phraya-Meklong basin study. The results of the study revealed that the water which can be stored in large reservoirs namely: Bhumipol and Sirikit in the Chao Phraya basin is not enough for growing rice in the dry season for full area (depends on canal capacity) every year.

One of the recommendation in order to increase water uses efficiency is the development of the forecast of weekly water scheduling model. And this model was implemented during that period.

8.2.2 Objective of the study

The main objective is to reduce both flood and draught problems in both river basins by implementation of the forecast of weekly water scheduling and the related model.

8.2.3 Methodology

Besides the development of the forecast of weekly water scheduling model, the model to forecast inflow to the reservoirs and the model to forecast side flow or uncontrol flow at the important locations for water management in the river basin should be developed. These models can forecast the flow on seasonal, monthly, weekly and 3-days period basis. The same as explained in the Chi basin. But in the Chao Phraya-Meklong basin, the important data should be collected for 3 years period and

at the same time, weekly water scheduling in the basins should be proceeded. Then irrigation rule curve should be reviewed together with flood rule curves of various large reservoirs in the basin. Flood rule curves of large reservoirs in the basin may be reviewed in the first year and will be reviewed again at the end of 3 years period after important data are collected. The same method of study as explained in the Chi basin, more details of the forecast of weekly water scheduling model can be found in [4].

8.2.4 Conclusion

The Chao Phraya-Meklong are the two large river basins in which the Chao Phraya basin, the water which can be stored in the large reservoirs is not enough for growing dry season rice at full area every year. Therefore the forecast of weekly water scheduling model was introduced in order to increase water uses efficiency. During the implementation of this model, flood with water flowing through the Chao Phraya diversion dam of 3,800 cms was taken place in the year 1980. But this flood could be proper managed.

8.2.5 Recommendation

1) The first study year, flood and irrigation rule curves of large reservoirs in the basin should be reviewed.

2) For Sirikit reservoir, it is recommended to hire the expert to check the dam stability for temporally storage of large flood at flood surcharge storage as had been designed. This is to reduce flood damage downstream.

3) Field data for calculation of both flood and irrigation rule curves should be collected at least for three years period.

4) The forecast of weekly water scheduling model together with flow forecast model to forecast both inflow into reservoirs and side flow should be used in these two river basins.

5) Flood and irrigation rule curves should be reviewed for every five year period.

6) Select the model for flow calculation along the river with salt water intrusion at river mouth.

9. Conclusion of the proposed case studies

The developed mathematical models were used in the Chao Phraya-Meklong basin study by Acres International Ltd. from Canada [7] which have been improved are:

1) Effective rainfall model.

2) Irrigation demand model.

3) System simulation model.

4) The forecast of weekly water scheduling model and

5) The model for calculation of on farm water requirement.

For models in items 1), 2), 3) and 5) some field data were collected to calibrate the model. But more important field data still be needed for model calibration. For the Chi basin field data had been collected in Lam Pao project [8] for only one year period. For the model in item 4) it still be lack of implementation especially in large river basin.

6) Reservoir inflow forecasting, side flow or uncontrol flow forecasting models, they are not developed according to the present technical advancement yet. These models needs to be implemented for several years period in order to get good result.

If more field important data to be used with the models have been monitored. The model implementation are expected to:

1) Increases the water uses efficiency in the river basin.

2) Reduce flood damage in the river basin.

3) Increase efficiency of new water resources development project.

10. Recommendations

1) The most important item is the personnel concerned both working in the office and in the field have be trained at proper time interval.

2) According to the increasing of dry season rice area especially in the Chao Phraya basin together with the re-excavation of the Chao Phraya river mouth, if the water shortage, the same as in the years B.E.2536-2537 takes place again, raw water supply at Patoomtany province may become salty. In this situation one alternative, it is recommended to improve Phraya Bunlue canal in order to divert the water from Meklong river which releases to Tha

Cheenriver. Then divert the water through this canal to the Chao Phraya river by pumping. It is recommended to be carried on in advance before water shortage taking place.

3) This paper presents non structural measure for flood and draught problems reduction. It is recommended to carry on for several years before implementation of structural measure.

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