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Impact of climate change on reservoir operation in Central Plain Basin of Thailand

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Abstract

Based on the bias-corrected MRI GCM data, the trend and impact of climate change in the Central Plain Basin of Thailand during present period (1979-2006), near future (2015-2039) and far future (2075-2099) were determined and presented. The air temperature will increase, but the relative humidity will decrease. The rainfall and the inflow to the reservoir will increase. The evapotranspiration and irrigation water demand will increase. The impacts of climate change to dam operation using the general rule curves (rules before year 2012) and the flood rule curves (rules in the flood year 2012) were studied. In Bhumibol Dam, the amount of water deficit and number of deficit years will decrease in the near future and the far future. In Sirikit Dam, the amount of water deficit and number of deficit years will increase in the near future and decrease in the far future. For the possible adaptation measures for mitigating the problems due to impacts of the future climate change, the non structural and structural measures were recommended for implementation.

Keywords: Impact of climate change, reservoir operation, adaptation measures, Bhumibol dam, Sirikit dam

บทคัดย่อ

บทความนี้นำเสนอผลศึกษาแนวโน้มและผลกระทบของการเปลี่ยนแปลงภูมิอากาศในพื้นที่ลุ่มน้ำภาคกลางของประเทศไทย ใน 3 ช่วงเวลาได้แก่ช่วงเวลาปัจจุบัน (ปี ค.ศ. 1979-2006) ช่วงเวลาอนาคตใกล้ (ปี ค.ศ. 2015-2039) และช่วงเวลาอนาคตไกล (ปี ค.ศ. 2075-2099) โดยใช้ข้อมูลจากแบบจำลองภูมิอากาศโลกของสถาบันวิจัยอุตุนิยมวิทยาของประเทศญี่ปุ่นที่มีการปรับแก้ความเอนเอียงแล้ว พบว่าอุณหภูมิอากาศจะเพิ่มขึ้นและความชื้นสัมพัทธ์จะลดลง ปริมาณน้ำฝนและน้ำท่าไหลเข้าอ่างเก็บน้ำจะเพิ่มขึ้น ปริมาณค่าการคายระเหยของพืชอ้างอิงและความต้องการน้ำชลประทานจะเพิ่มขึ้น มีการศึกษาผลของการใช้เกณฑ์ปฏิบัติงานของอ่างเก็บน้ำ 2 แบบ คือ เกณฑ์ทั่วไปที่ใช้ต่อเนื่องมาจนถึงก่อนปี ค.ศ.2012 และเกณฑ์ที่ใช้กับเหตุการณ์น้ำหลากที่พัฒนาขึ้นในปี ค.ศ.2012 พบว่าพื้นที่ที่ใช้น้ำจากเขื่อนภูมิพลจะมีปริมาณและจำนวณปีที่น้ำขาดแคลนที่ จะลดลงทั้งช่วงเวลาอนาคตใกล้และไกล พื้นที่ที่ใช้น้ำจากเขื่อนสิริกิติ์จะมีปริมาณและจำนวณปีที่น้ำขาดแคลนที่จะเพิ่มขึ้นในช่วงเวลาอนาคตใกล้แต่จะลดลงช่วงเวลาอนาคตไกล มีการเสนอแนะมาตรการปรับตัวเพื่อบรรเทาปัญหา อันเกิดจากผลกระทบของการเปลี่ยนแปลงภูมิอากาศในอนาคตทั้งมาตรการที่ไม่ใช้โครงสร้างและใช้โครงสร้างเพื่อนำไปปฏิบัติ

คำสำคัญ: ผลกระทบของการเปลี่ยนแปลงภูมิอากาศ, การปฏิบัติงานของอ่างเก็บน้ำ, มาตรการปรับตัว, เขื่อนภูมิพล, เขื่อนสิริกิติ์

1. Introduction

The climate change induced direct affect to reservoir operation and irrigation areas in the Central Plain Basin or Chao Phraya Basin particularly in the dry year when the reservoir storage amount is not adequate for summer rice and caused water deficit in many irrigation projects. Though in the Central Plain, two large reservoirs, *i.e.*, Bhumibol and Sirikit Dams,can store large water amount to be used during dry period and most of agricultural areas are in

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the irrigation project areas, water allocated is limited and caused water shortage during dry season.

This paper presents the study result of Research Project on Impact of Climate Change on Irrigation Systems and Adaptation Measures (Dam Operation Analysis), Final Report, done by Water Resources System Research Unit, Faculty of Engineering, Chulalongkorn University, February 2013. The research had been conducted under the good collaborations from Japan Institute of Irrigation and Drainage (JIID) and Royal Irrigation Department (RID) of Thailand [1].

2. Objective of study

The objective of the study is to analyze the impacts of the climate change on reservoir operation on agriculture and irrigation areas in 3 time periods: present (1979-2006), near future (2015-2039) and far future (2075-2099). The study comprised of water/agricultural data collection and statistical analysis, GCM data modification to study area conditions, water balance analysis to determine water deficit conditions and recommended possible adaptation measures.

3. Study area

The study area is in the Greater Chao Phraya River Plain or Central Plain Basin. The Chao Phraya-Tha Chin Group River Basin is the most important and the largest group river basin in Thailand and consists of 8 main river basins; namely of Ping, Wang, Yom, Nan, Sakrae Kang, Tha Chin, Chao Phraya, and Pa Sak. It covers the major areas in central and northern regions of Thailand. The boundary of study area is shown in Figure 1.

4. Study area

The climate conditions in the study area are summarized as shown in Table 1. The monthly average precipitation of the study area are shown in Table 2.

5. Reservoir operation rule curves

Due to the large flood event in year 2012, RID had improved the reservoir operation rule curves as general (old) and flood (new) rule curves are shown in Figure 2.

6. Methodologies used

1) Hybrid bias correction method for MRI GCM Model (Japan), 2) rainfall - runoff analysis (Inflow to reservoir), 3) water demand estimation and 4) Water balance of reservoir.

7. Study result

7.1 Hydrological data analysis

7.1.1 Bias corrected MRI-GCM climate data

Hybrid bias correction method was applied to correct the bias of raw MRI GCM output rainfall data in Bhumibol and Sirikit dams.

7.1.2 Climate change

Mean air temperature and relative humidity in Bhumibol dam in present, near future and far future are analyzed and shown in Figure 3.

The results show that annual mean air temperature values tend to increase in near and far futures. In present period, the annual mean relative humidity values have trend to increase and widely fluctuate. In near and far futures, the annual mean relative humidity values have trends to decrease and less fluctuate.

7.1.3 Rainfall change

The annual mean rainfall in Bhumibol dam has a trend to increase with decreasing range in variation in near and far futures as shown in Figure 4.

7.1.4 Rainfall-Runoff analysis

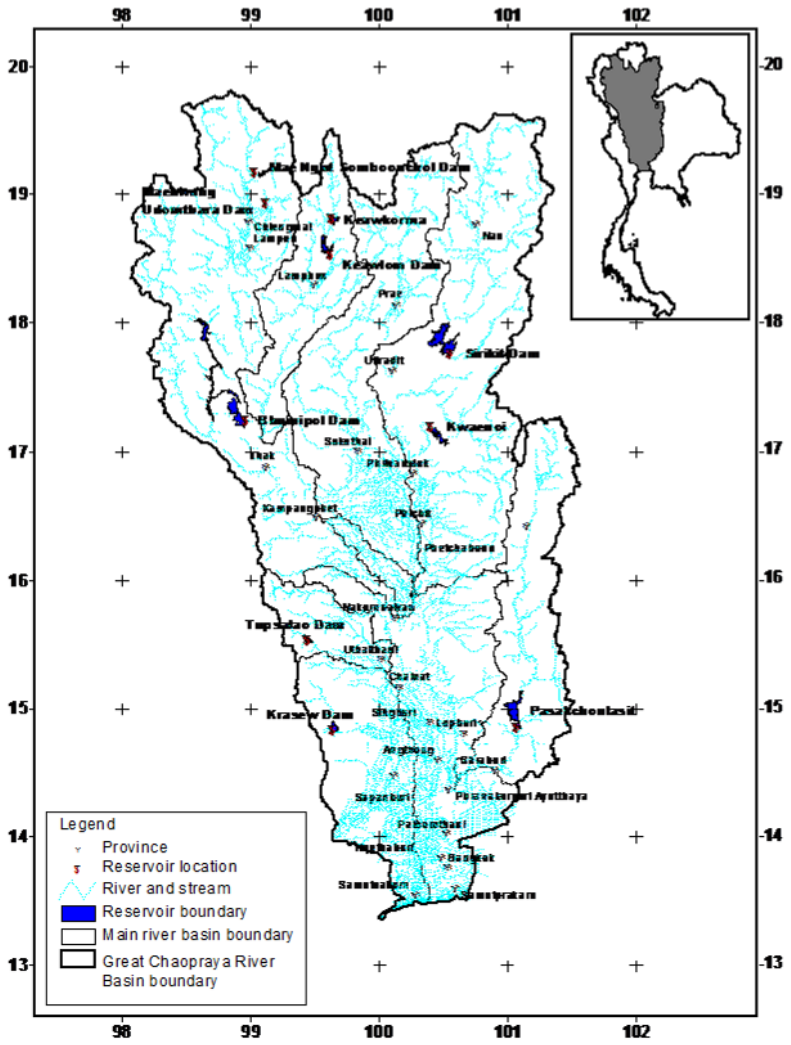
The inflow to Bhumibol Dam during present, near future and far future are shown in Figure 5.

7.1.5 Evapotranspiration and irrigation water demand

The annual evapotranspiration and irrigation water demand of Bhumibol Dam in present, near future and far future periods were estimated and shown in Figures 6 and 7.

7.2 Dam release data analysis

With reservoir operation using the general rule curves, the values of monthly reservoir operation of Bhumibol Dam in present, near future and far future periods are shown in Figure 8.



Source: GIS data of Department of Water Resource, 2003).

Figure 1. Boundary of study area (Central Plain Basin of Thailand).

Table 1. Climate conditions in Chao Phraya River Basin.

Climate parameters	Range from average monthly data	Average annual data
Temperature (°C)	24.6 – 31.5	28.1
Humidity (%)	59.0 – 82.0	73.0
Wind Velocity (knot)	1.2 – 6.3	3.3
Cloudiness (0-10)	2.7 – 8.9	6.3
Pan Evaporation (mm)	122.8 – 243.5	1 890.0

Table 2. Average monthly precipitation in Chao Phraya River Basin (Unit : mm.).

Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Wet Season	Wet Season	Annual
59	143	117	125	169	236	144	28	6	6	12	29	935	142	1 076

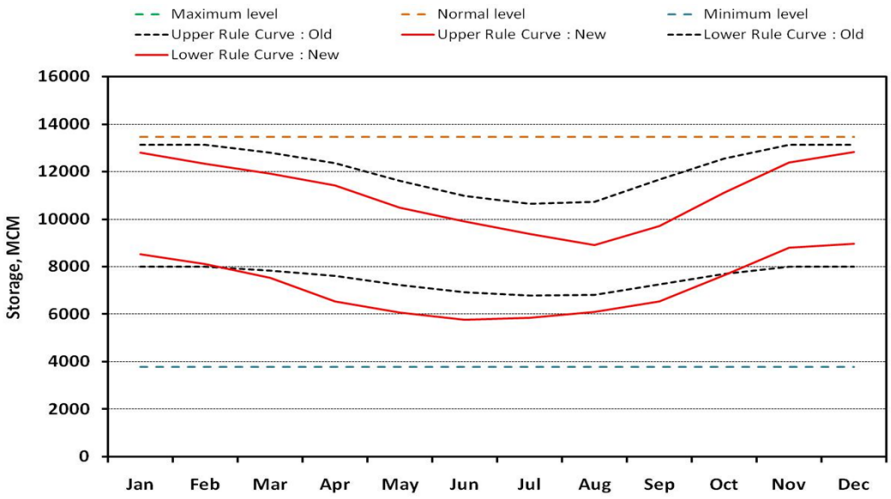


Figure 2. General and flood reservoir operation rule curves of Bhumibol Dam.

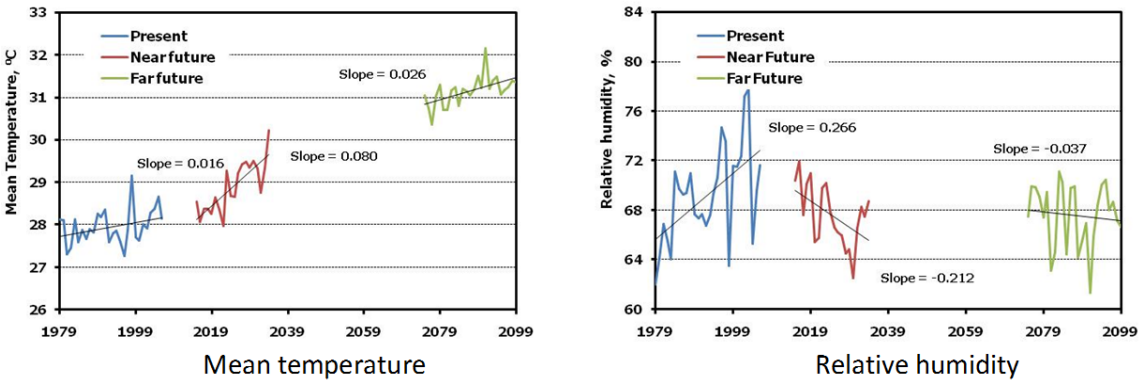


Figure 3. Trend of annual air temperature and relative humidity of Bhumibol Dam.

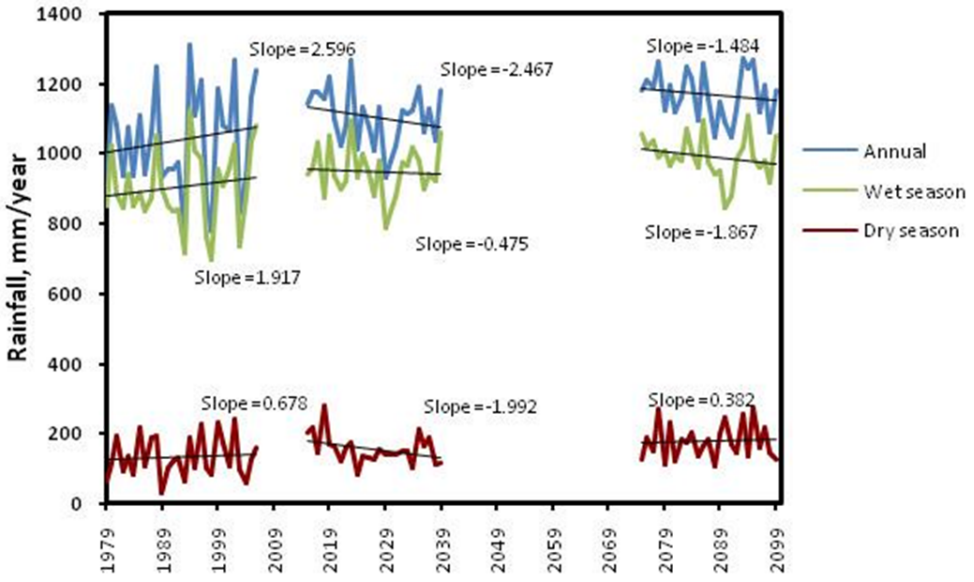


Figure 4. Trend of annual mean rainfall of Bhumibol Dam.

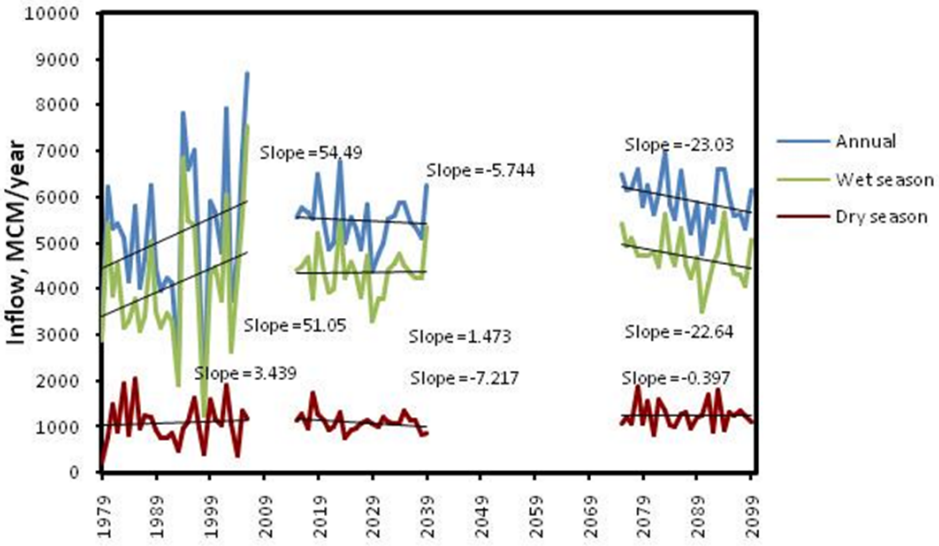


Figure 5. Trend of annual inflow of Bhumibol Dam.

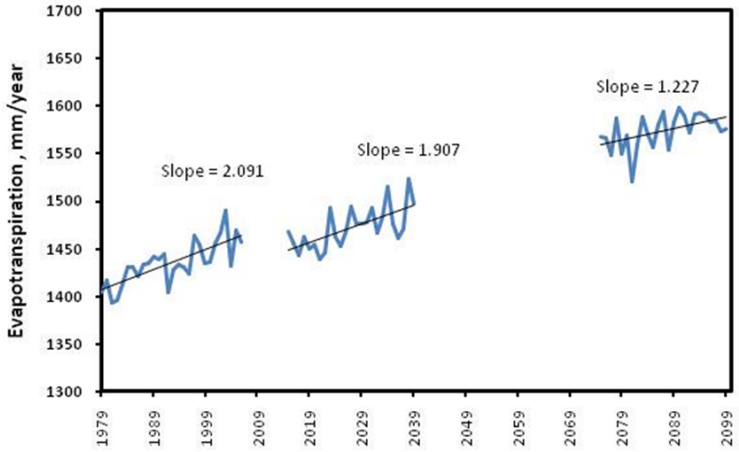


Figure 6. Trend of annual evapotranspiration of Bhumibol Dam.

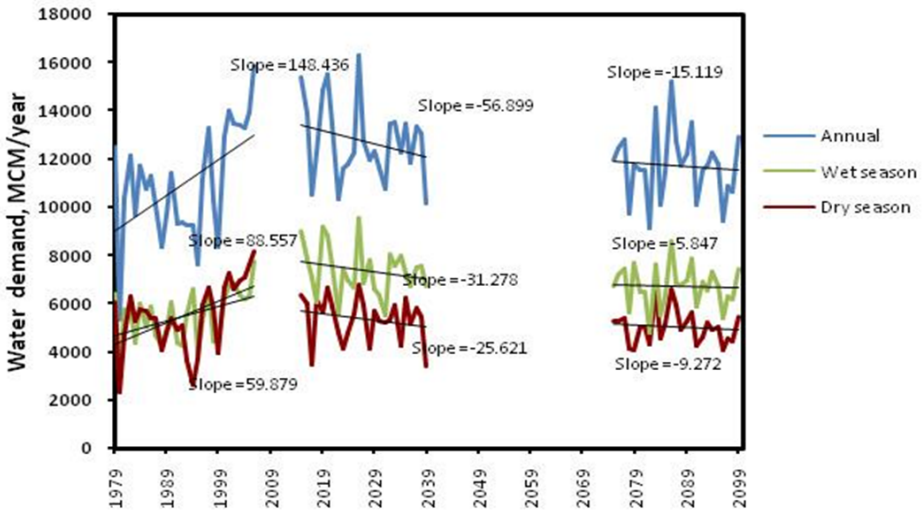


Figure 7. Trend of annual water demand of Bhumibol Dam.

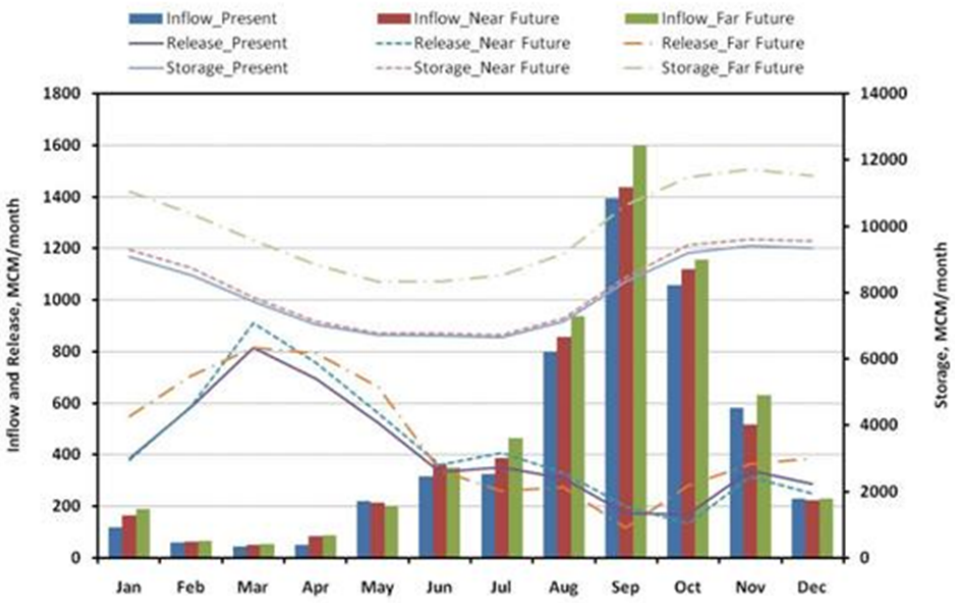


Figure 8. Comparison of reservoir operation of Bhumibol Dam using general rule curves in present, near and far future.

Table 3. Annual and seasonal water deficit of Bhumibol Dam using general rule curves (Unit : Mm^3).

Period	Dry	Wet	Annual	No. of Deficit year
Present	625.16	1097.76	1722.92	14
Near Future	350.96	1011.86	1362.83	6
Difference	-274.2	-85.9	-360.1	-8
Far Future	491.25	868.40	1359.64	4
Difference	-133.9	-229.4	-363.3	-10

Table 4. Annual and seasonal water deficit of Sirikit Dam using general rule curves (Unit : Mm^3).

Period	Dry	Wet	Annual	No. of Deficit year
Present	41.47	171.78	213.24	7
Near Future	44.36	219.49	263.85	12
Difference	2.9	47.7	50.6	+5
Far Future	33.55	104.49	138.04	3
Difference	-7.9	-67.3	-75.2	-4

7.3 Impact from climate change and reservoir operation on water deficit

The impacts to water deficit due to dam operation using the general rule curve under new climate conditions (change in water demand and supply) were assessed. The summary of annual and seasonal water deficit conditions in Bhumibol Dam and Sirikit Dam are shown in Tables 3 and 4, respectively. In Bhumibol Dam, the amount of water deficit and number of deficit years will decrease in near future and far future. In Sirikit Dam, the amount of water deficit and number of deficit years will increase in near future and then decrease in far future.

8. Possible adaptation measures

For the possible adaptation measures for mitigating the problems due to impacts of the future climate change, the following non structural and structural measures should be considered for implementation. The recommended non structural measures are to monitor climate warning, adjusting crop pattern and agricultural area, adjust reservoir operation rule curves, have more participation of stakeholders/water users, disseminate knowledge and improve telemetering system. The recommended structural measures are to improve irrigation efficiency, improve watershed management, prepare temporary water storage (such as ponds), promote reforestation, increase reservoir storage (via enhancing dam embankment, dredging sediment and sediment control).

9. Conclusion

Based on the bias-corrected MRI GCM data, in the Central Plain Basin of Thailand, the trend and impact of climate change during 3 periods (present, near future and far future) were determined and presented. The air temperature will increase and the relative humidity will decrease. The rainfall and the inflow to the reservoir will increase. The evapotranspiration and irrigation water demand will increase. The impacts of climate change to dam operation using the general rule curves (rules before year 2012) and the flood rule curves (rules in the flood year 2012) were studied. In Bhumibol Dam, the water deficit and number of deficit years will decrease in the near future and the far future. In Sirikit Dam, the water deficit and number of deficit years will increase in the near future and decrease in the far future. For the possible adaptation measures for the future climate change, the non structural and structural measures should be considered for implementation.

References

[1] Water Resources System Research Unit. (2013). Research Project on Impact of Climate Change on Irrigation Systems and Adaptation Measures (Dam Operation Analysis), Final Report, Faculty of Engineering, Chulalongkorn University, February 2013. The research had been conducted under the good collaborations from Japan Institute of Irrigation and Drainage (JIID) and Royal Irrigation Department (RID).