Impact of climate change on reservoir water storage and operation of large scale dams in Thailand

by

Donpapob Manee

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Declaration of authorship

I declare that this thesis titled 'Impact of climate change on reservoir water storage and operation of large scale dams in Thailand' and the work presented and analyzed results in its overall are my own investigation and original research , except where specifically indicated in the text. I confirm that this research was done wholly at Kyoto University. Any part of this dissertation has not been submitted for a degree or any other qualification at any other University or institution.

Donpapob Manee

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Abstract

Reservoir plays an important role to address of flood and drought problems. It is the effective tool to store water when severe flood occurs for mitigation of the huge loss, damage of lives and economics. Not only the excess water resource problem, but the inadequate water supply in Thailand also experienced the extreme drought. Therefore, to investigate the current reservoir operation is an important and interested finding to respond to future climate change for water management effectively and cope with future flood event as well. The main goals of this dissertation are to develop the hydrological methodology for acquiring proper future discharge prediction under a changing climate and assess uncertainty of reservoir water storage and operation of large scale dams in Thailand.

Chapter 2 proposes the development of a regional distributed hydrological model for water resources prediction based on a concept of the kinematic wave equation which is including distributed topographic data, input forcing data and information about each reservoir and study area in Thailand are described.

Chapter 3 applies the Mann-Kendall (MK) statistical trend test to analyze increasing, decreasing or trendless characteristics of precipitation, temperature, inflow to dam reservoirs, release from dam reservoirs, and storage volume in dam reservoir in Thailand from historical operation recorded data. The five large scale dam reservoirs located in the northern and central parts of Thailand are selected to analyze the trend of the Ping River basin (Bhumibol Dam), the Nan

River basin (Sirikit Dam), the Pasak River basin (Pasak Jolasid Dam) and the Mae Klong River basin (Srinagarind and Vajiralongkorn dams). Those reservoir operation time series which consist of daily inflow, release, rainfall and temperature were analyzed and examined in association with various aspects of dam reservoir operations.

Chapter 4 proposes the assessment of future water resources availability in term of inflow through large scale reservoirs in Thailand by using Atmospheric General Circulation Model (MRI-AGCM3.2S). The output of runoff generation data also used as input forcing based on land surface model inside the MRI-AGCM3.2S to simulate reservoir inflow of the five large scale dam reservoirs for two different climate experiments: the present climate (1979-2003) and future climate (2075-2099) with various future sea surface temperatures (SST) scenarios.

Chapter 5 applies the differential split-sample test (DSST) to evaluate appropriate bias correction methods for future river discharge projection using the present climate GCMs data for dry and wet years and observed data for validation. A distributed flow routing model (1K-FRM) is used to obtain the dry and wet years in the present climate experiment by inputting the runoff generation data output from MRI-AGCM3.2S, a 20 km spatial resolution general circulation model (GCMs) developed by the Meteorological Research Institute, Japan. The Nan River Basin in Thailand is selected and several kinds of bias corrected inflow to Sirikit reservoir located at midstream of Nan River Basin are evaluated for a time period of 1979-2003. An effective bias correction method is proposed with suitable statistical performance considering a non-stationary condition for applying the bias correction methods for future discharge estimation.

Chapter 6 applies the future reservoir inflow after removing the suitable bias correction method for reservoir operation assessment in term of future water storage and release flow under different scenarios. The effective bias-corrected input forcing data method in Sirikit reservoir as mentioned in previous chapter also uses for reservoir operation algorithms. The artificial neural network (ANN) technic is used to estimate the daily released flow based on a large number of historical reservoir inflow and water storage inputs for evaluation the changes of water storage and release in the various future climate scenario.

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Abbreviations

1K-FRM	1 Kilometer Distributed Flow Routing Model
AGCM	Atmospheric Global Circulation Model
ANN	Artificial Neural Network
APHRODITE	Asian Precipitation-Highly-Resolved Observational Data Integration Towards Evaluation
BB	Bhumibol Dam
CDFs	Cumulative Distribution Functions
CMIP5	Couple Model Intercomparison Project Phase 5
DEM	Digital Elevation Model
DSST	Differential Split-Sample Test
EGAT	Electricity Generating Authority of Thailand
EDCDFm	equidistant Cumulative Distribution Functions matching
EQCDF	equiratio Cumulative Distribution Functions matching
eQM	empirical distribution Quantile Mapping
GCMs	Global Circulation Model or Global Climate Model
GHGs	Greenhouse Gas
gQM	gamma distribution Quantile Mapping
HydroSHEDS	Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales
IPCC	Intergovernmental Panel on Climate Change
JMA	Japan Meteorological Agency
MAE	Mean Absolute Error
MCM	Million cubic Meter
MK	Mann-Kendall
MRI	Meteorological Research Institute
PS	Pasak Dam
RCP	Representative Concentration Pathway
RID	Royal Irrigation Department of Thailand
SiB	Simplified Biosphere Model

SK	Sirikit Dam
SR	Srinagarind Dam
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperatures
TMD	Thai Meteorological Department
VRK	Vajiralongkorn Dam

Chapter 1

Introduction

1.1 Background

Water is indispensable for all forms of life and is needed, in large quantities, in almost all human activities. According to the 2013 Intergovernmental Panel on Climate Change (IPCC), the global water cycle will change, with increases in disparity between wet and dry regions, as well as wet and dry seasons, with some regional exceptions.

Water resources is an increasingly limited and highly essential resource for many countries where agriculture is the main income of the economy corresponding with ensures the well-being of the people. The proper planning of water resource availability based on uncertainty climate change impact is very necessary; because, the projection of hydrologic inflow data can support and help government stakeholder and reservoir operator to adapt their decision making to release the water subjected to the rule or constraint in advance and be consisted of the sustainable development plan in future. In second half year of 2011, Thailand, climate change has been observed to show the significant impact on the hydrological processes and flow characteristics of main river basins especially in term of rainfall pattern and runoff change; Moreover, unexpected early rainfall started in the rainy season with high intensity of storm series causes devastating flood.

Reservoir plays an important role to address of flood and drought problems. It is the effective tool to store water when severe flood occurs for mitigation of the huge loss, damage of lives and economics. Not only the excess water resource problem, but the inadequate water supply in Thailand also experienced the extreme drought. Therefore, to investigate the current reservoir operation is an important and interested finding to respond to future climate change for water management effectively and cope with future flood event as well.

1.2 Objectives

The main goals of this dissertation are to develop the hydrological methodology for acquiring proper future discharge prediction under a changing climate and assess uncertainty of reservoir water storage and operation of large scale dams in Thailand. The specific objectives of each attention are as follows:

- To develop a regional distributed hydrological model for estimation the amount of reservoir inflow to each large scale reservoirs in Thailand
- To investigate the trend of hydrologic variable changes based on an observation data by applying the statistical trend analysis
- To predict future reservoir water resources availability in term of inflow through each large scale reservoir by using atmospheric General Circulation Model (AGCM)

- To propose an appropriate bias correction methods for corrected daily river discharge projection by adoption the operational testing of hydrological simulation models method
- To project future river discharge and evaluate the reservoir water storage and water releases under various climate change scenarios

1.3 Outline of the thesis

The overall dissertation is organized to a series of seven related chapters to accomplish all objectives described in the previous section. The overall research framework also is illustrated in Fig.1-1 for summary the data and methodology used and expected output on each process.

In Chapter 2, the development of a regional distributed hydrological model for water resources prediction based on a concept of the kinematic wave equation which is including topographic data input forcing data and information about each reservoir and study area are described.

Chapter 3 is to mainly examine a confirmation of the change of hydrologic variables to propose an adaptive dam release operation rules by adopted the Mann-Kendall (MK) statistical trend test to analyze increasing, decreasing or trendless characteristics of precipitation, temperature, inflow to dam reservoirs, release from dam reservoirs, and storage volume in dam reservoir in Thailand from historical operation recorded data. The five large scale dam reservoirs located in the northern and central parts of Thailand are selected to analyze the trend of the Ping River basin (Bhumibol Dam), the Nan River basin (Sirikit

Dam), the Pasak River basin (Pasak Jolasid Dam) and the Mae Klong River basin (Srinagarind and Vajiralongkorn dams).

Chapter 4 is to demonstrate of developed regional distributed hydrological model that describe in Chapter 2 by using raw directly outputs of Atmospheric General Circulation model (AGCM) which is an existing version of MRI-AGCM3.2S. The output of runoff generation data also used as input forcing based on land surface model inside the MRI-AGCM3.2S to simulate reservoir inflow of the five large scale dam reservoirs for two different climate experiments: the present climate (1979-2003) and future climate (2075-2099) with various future sea surface temperatures (SST).

Chapter 5 is proposed to apply the differential split-sample test (DSST) to evaluate appropriate bias correction methods for future river discharge projection using the present climate GCMs data for dry and wet years and observed data for validation. A distributed flow routing model (1K-FRM) is used to obtain the dry and wet years in the present climate experiment by inputting the runoff generation data output from MRI-AGCM3.2S, a 20 km spatial resolution general circulation model (GCMs) developed by the Meteorological Research Institute, Japan. The Nan River Basin in Thailand is selected and several kinds of bias corrected inflow to Sirikit reservoir located at midstream of Nan River Basin are evaluated for a time period of 1979-2003. An effective bias correction method is proposed with suitable statistical performance considering a non-stationary condition for applying the bias correction methods for future discharge estimation.

Chapter 6 is to conduct the future reservoir inflow after removing the suitable bias correction method for reservoir operation assessment in term of future water storage and release flow under different scenarios. The effective bias-corrected input forcing data method in Sirikit reservoir as mentioned in previous chapter also uses for reservoir operation algorithms. The artificial neural network (ANN) technic is used to estimate the daily released flow based on a large number of historical reservoir inflow and water storage inputs for evaluation the changes of water storage and release in the various future climate scenario.

Finally, Chapter 7 provides the concluding remark of this dissertation. This chapter also lists the achievement of the thesis.

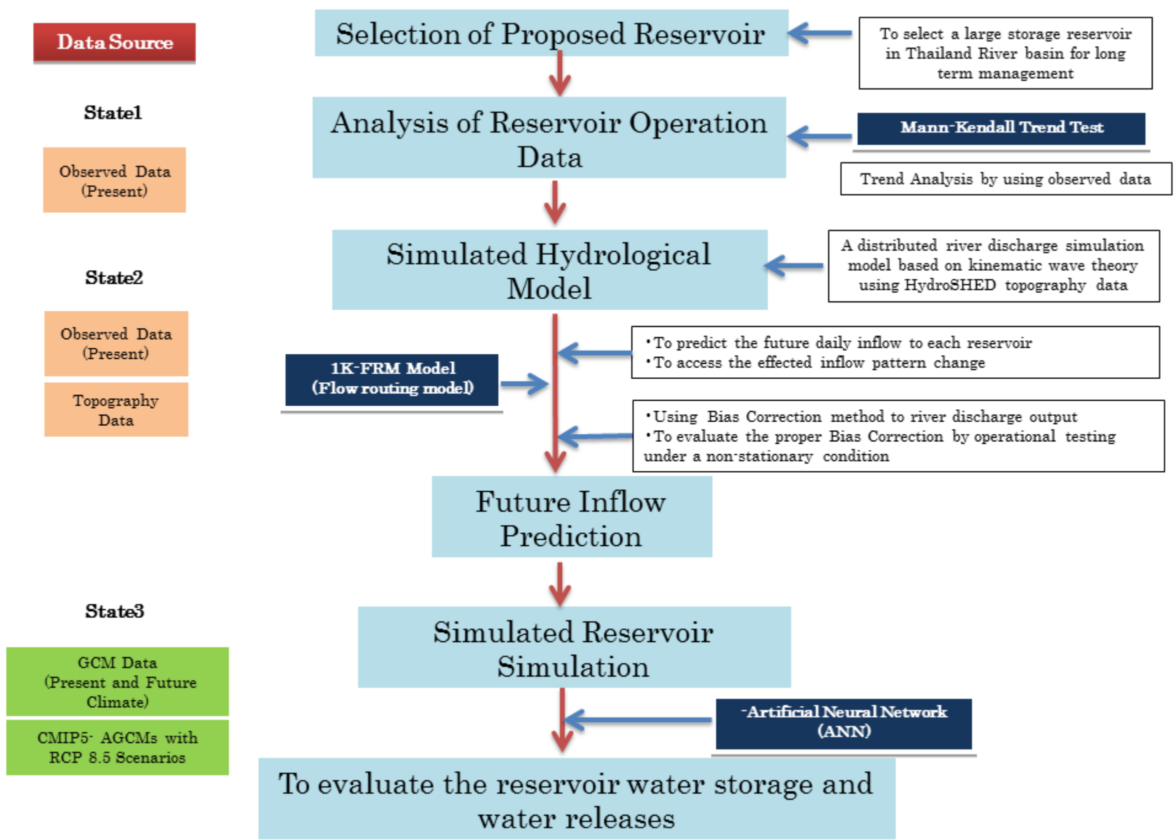


Fig. 1-1 Overall research framework.

Chapter 2

Developing a regional distributed hydrological model for water resources assessment through large scale reservoir in Thailand

Abstract *This chapter proposes the development of a regional distributed hydrological model for water resources prediction based on a concept of the kinematic wave equation which is including distributed topographic data, input forcing data and information about each reservoir and study area in Thailand are described.*

2.1 Introduction

To estimate river flow for water resource assessment, the hydrological model is widely represented the interaction between hydrologic cycle element such as precipitation, soil Moisture, river flow and evapotranspiration. There are numerous hydrological models which can be divided into single lump model and distributed hydrological model. An amount of water balance of the whole catchment in the lumped model consider a single unit of input, internal state variable and output of each hydrologic cycle element. On the other hand, the distributed hydrological model has advantage than single lump model because this model divided and handles the catchment into a sub basin and interaction of each hydrological component, and then combines the outputs to achieve results in the some particular interested point.

Several impacts of climate change studies with distributed hydrological model were conducted at the Chao Phraya River Basin in Thailand (Wichakul *et al.*, 2015; Hunukumbura and Tachikawa, 2012). In this study, the 1K-FRM distributed flow routing model was chosen to handle input spatial data such as gridded rainfall; therefore, this model can applicable to access reservoir inflow under a changing climate as well. 1K-FRM is originated development in Hydrology and Water Resources Research Laboratory at Department of Civil and Earth Resources Engineering, Kyoto University.

The main objective of this chapter is to propose the development of a regional distributed hydrological model for water resources prediction based on a concept of the kinematic wave equation which is including topographic data, input forcing data and information about each reservoir and study area are described and showed in Fig. 2-1.

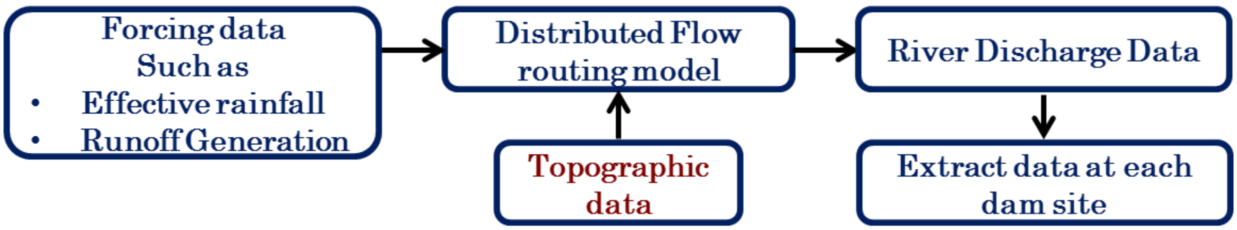


Fig. 2-1 Flowchart of distributed hydrological model simulation.

2.2 Modeling approach

1K-FRM is a distributed flow routing model based on kinematic wave flow approximation. The kinematic wave model is conduct to all rectangular elements gridded to link the water to downstream associate with the derived catchment model. Basically, the selecting of Digital Elevation Model (DEM) data used in catchment model is HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) provides hydrographic information in a comprehensive and consistent format for both local and global-scale applications (Lehner, 2006). HydroSHEDS is based on elevation data of the Shuttle Radar Topography Mission (SRTM) at 3 arc-second (~ 90 meter) resolution. In this research, 1K-FRM used 30 arc-second resolutions (approximately 1 kilometer at near equator area) as a catchment model. The flow direction is defined into 8 directions which assigns flow depends on the different elevation with in a direction of steepest downward slope as illustrated in Fig. 2-1.

In 1K-FRM model, a typical flow routing model for hill slope flow and river flow are determined by the flow that is calculated using rainfall input to the cell and discharge from the upper cells as the boundary condition, So the number of upper cells and its upslope cell is compared with thresholds values which is set to 250 for in this study. If each slope unit larger than thresholds values, the cell will consider as a river unit (river channel cell); otherwise, it is classified as a slope unit (slope runoff cell). The schematic drawing of flow modeling in 1K-FRM is shown in a Fig. 2-2.The basic kinematic wave equation for each rectangular slope elements is

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q_L(x,t) \tag{2.1}$$

where t denote time ; A is the cross-sectional area ; Q is discharge ; and $Q_L(x,t)$ is the lateral inflow per unit length of each slope element. Another equation used to solve above equation is the relationship of Manning type of the discharge and a rectangular cross-section area of each cell as follows:

$$Q = \alpha A^m, \alpha = \frac{\sqrt{i_o}}{n}\left(\frac{1}{B}\right)^{m-1}, m = \frac{5}{3} \tag{2.2}$$

where i_o is slope gradient; n is the Manning's roughness coefficient ; and B is the width of the flow.

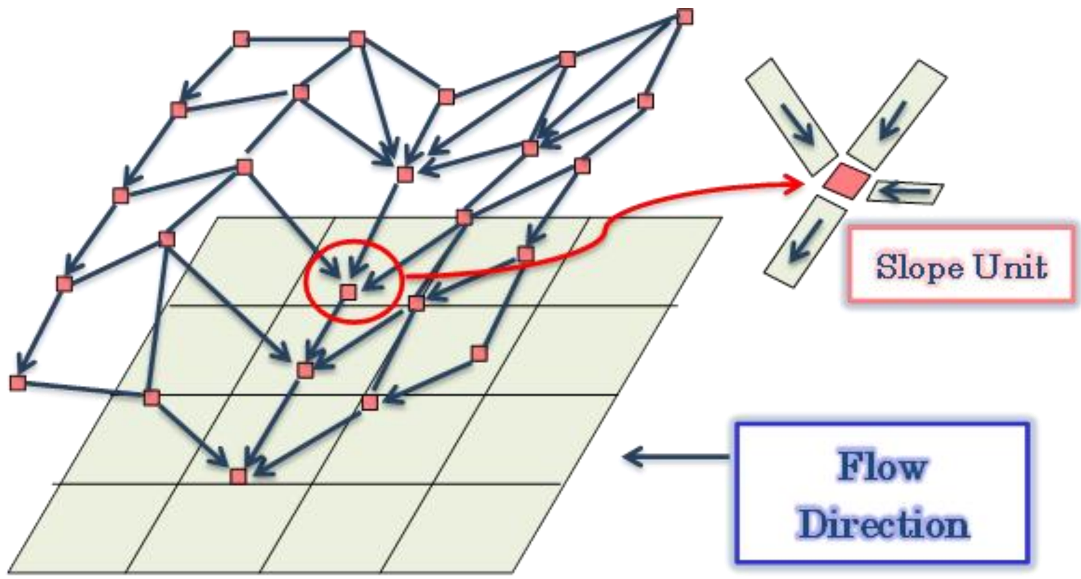


Fig. 2-2 Schematic drawing of a catchment model using DEM.

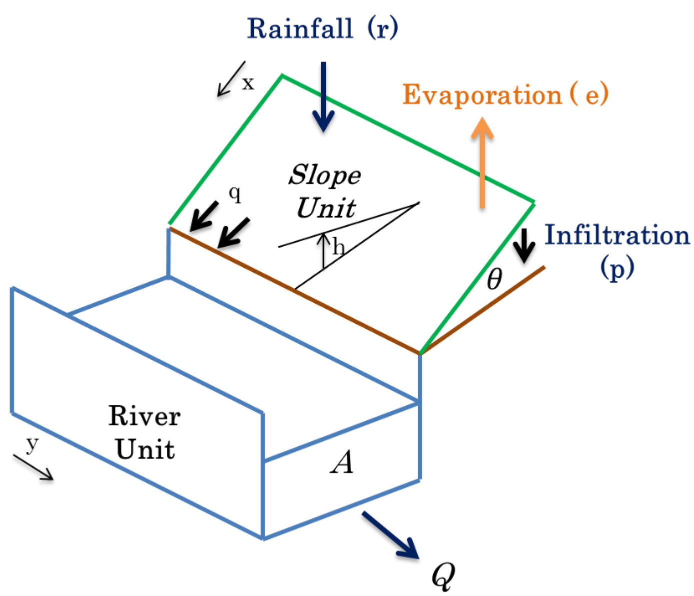


Fig. 2-3 Schematic drawing of flow modeling in 1K-FRM.

2.3 Study area

The study area is Thailand which is located in the Southeast Asia with an approximately area 500,000 km^2. Over 90% of the area of the Basin is either used for agriculture or covered with forest, with the proportions of these land uses being roughly equal. Within the Basin, the largest sub-basins (in terms of area) are in descending order, the Ping, Nan, Chao Phraya and Tha-Chin. The Yom and Pasak sub-basins are intermediate in size and the two smallest sub-basins are the Wang and the Sakae Krang. Agricultural land is concentrated in the southern sub-basins and ranges from 78% in Chao Phraya, 63% in Pasak and 55% in Tha Chin compared to 20 to 45% in the four northern sub-basins (Ping, Wang, Yom and Nan). The majority of forest cover occurs in the northern sub-basins where the percentage of forest ranges from 50-75% in Ping, Wang, Yom and Nan to 30% in Pasak and only 7% in Chao Phraya (WWDR, 2009).Its climate is tropical climate with distinctly clear dry and wet seasons. The seasons are defined as follow: the dry season starts from November until April and the wet season starts from May until October in the central and northern part of Thailand. In the western River Basins dry season starts from January until June and wet season begins July until December. There are four River Basins with five large-scales reservoirs located in the northern, central and western parts of Thailand which are used to evaluate the impacts on water availability in term of reservoir inflow as dominant source for downstream water utilization. The four basins consist of the Ping River basin with the Bhumibol Dam (BB), the Nan River basin with the Sirikit Dam (SK), the Pasak River basin with the Pasak Jolasid Dam (PS), and the Mae Klong River basin with the Srinagarind dam (SR) and Vajiralongkorn dam (VRK). The flow direction move from north to south, Furthermore, there are four reservoirs with the storage capacity of more than 1,000 MCM (million cubic meters). The figure of large scales reservoir of study area is shown in Fig. 2-3.

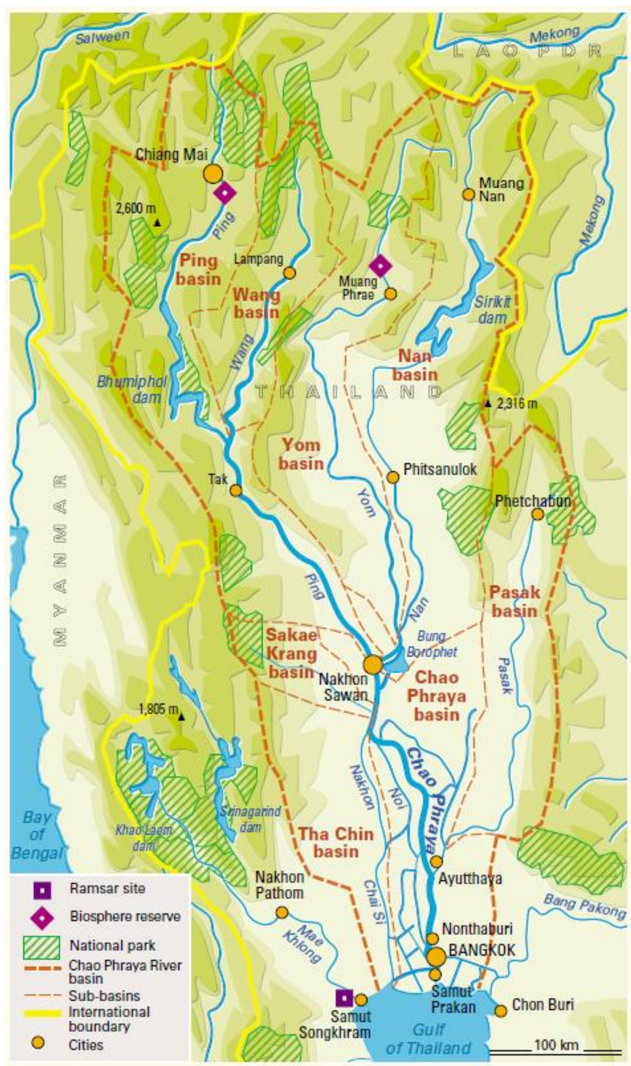


Fig. 2-4 Basin map of Thailand.

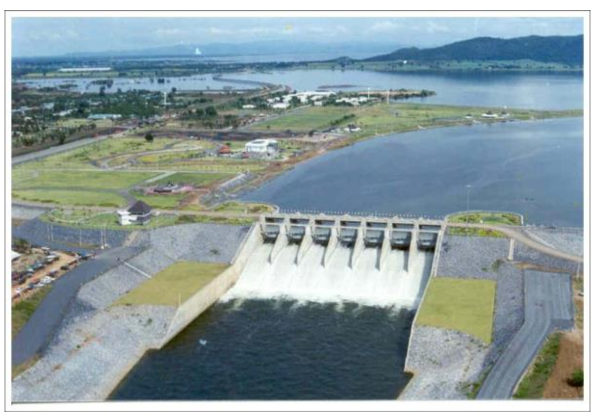
(Source: the World Water Assessment Programme, 2009)

Bhumibol Reservoir

Sirikit Reservoir

Srinagarind Reservoir

Vajiralongkorn Reservoir



Pasak Reservoir

Fig. 2-5 Large scales reservoir of study area.

(Source: Electricity Generating Authority of Thailand and Royal Thai Irrigation)

2.4 Model parameter identification and validation

There are two main parameters inside 1K-FRM model which consist of the Manning's roughness coefficient for the slope unit n_s and Manning's roughness coefficient for the river channel unit cell n_r. In this study, the parameter of $n_s = 0.03$ $m^{-1/3}s$ and $n_r = 0.1$ $m^{-1/3}s$ were used for the suitable values by trial-and-error method.

The comparison of daily observed and simulated reservoir inflow at each reservoir in 2004 is selected for validation. The observation effective rainfall grids were used as forcing data into the 1K-FRM model. Fig.2-6, Fig.2-7, Fig.2-8, Fig.2-9 and Fig.2-10 showed the well simulated hydrograph results from the April until November compared to the observed inflow at each dam site.

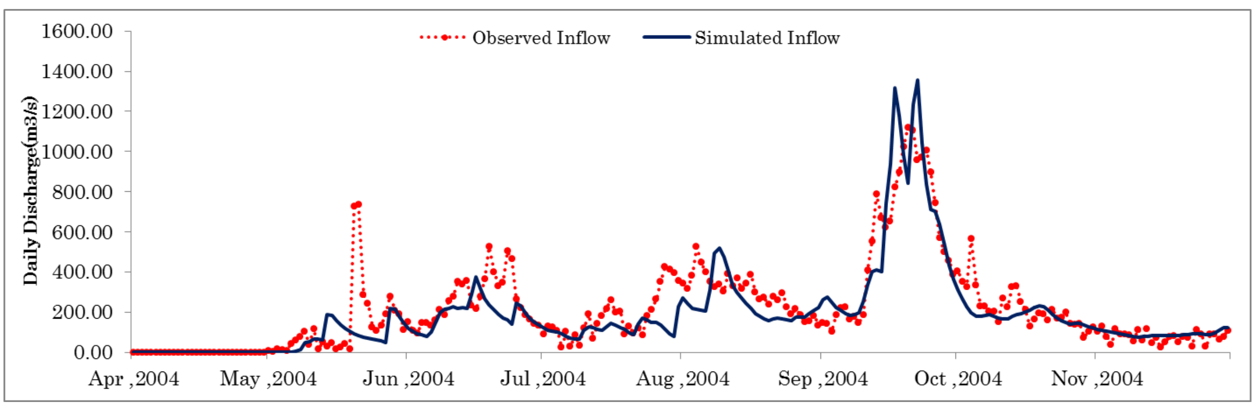


Fig. 2-6 Comparison of reservoir inflow at the Bhumibol dam for the model validation, 2004.

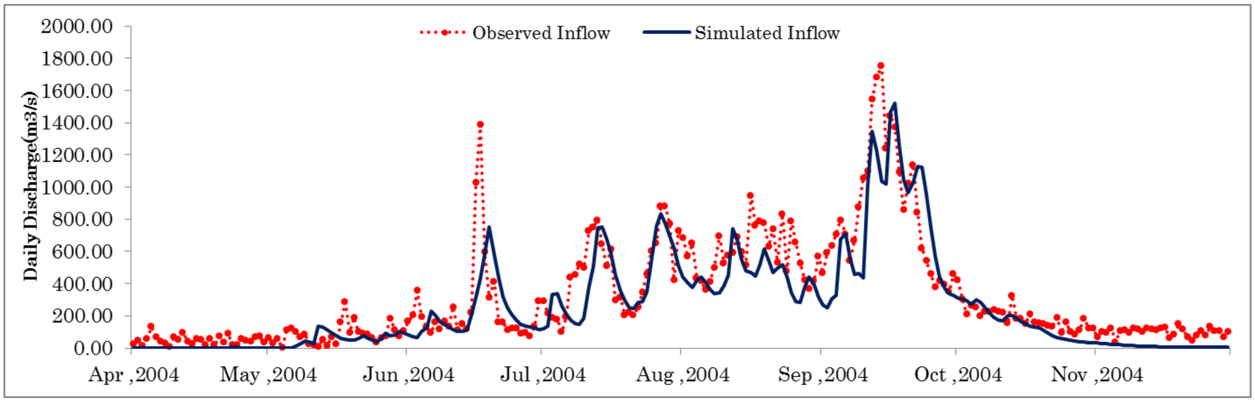


Fig. 2-7 Comparison of reservoir inflow at the Sirikit dam for the model validation, 2004.

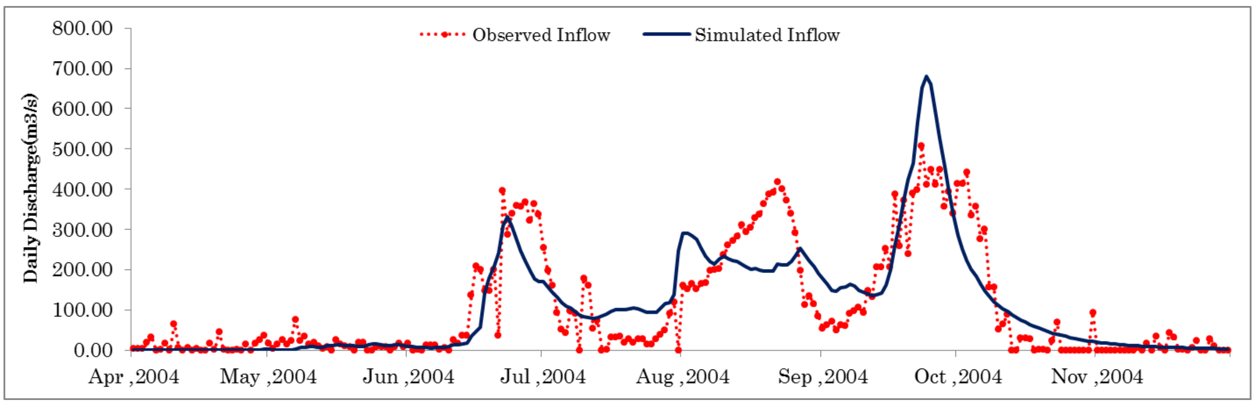


Fig. 2-8 Comparison of reservoir inflow at the Pasak dam for the model validation, 2004.

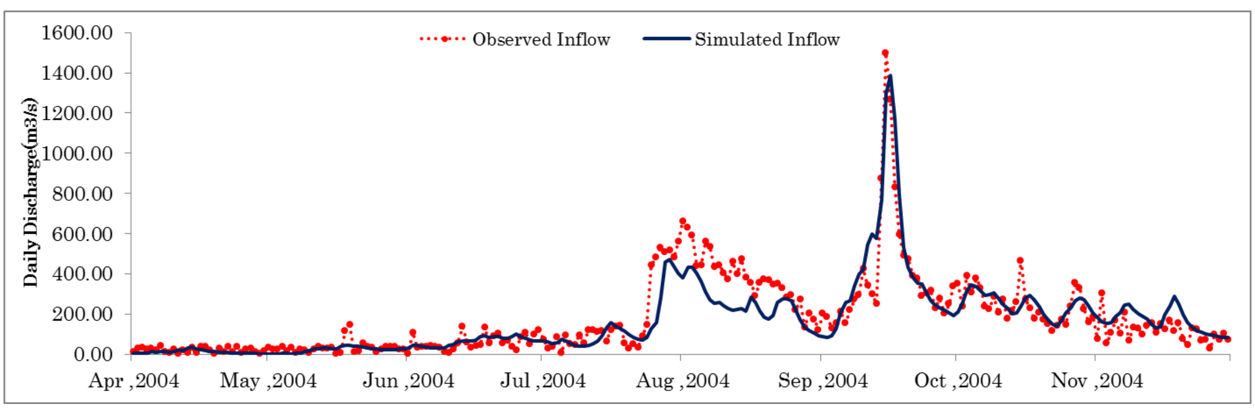


Fig. 2-9 Comparison of reservoir inflow at the Srinagarind dam for the model validation, 2004.

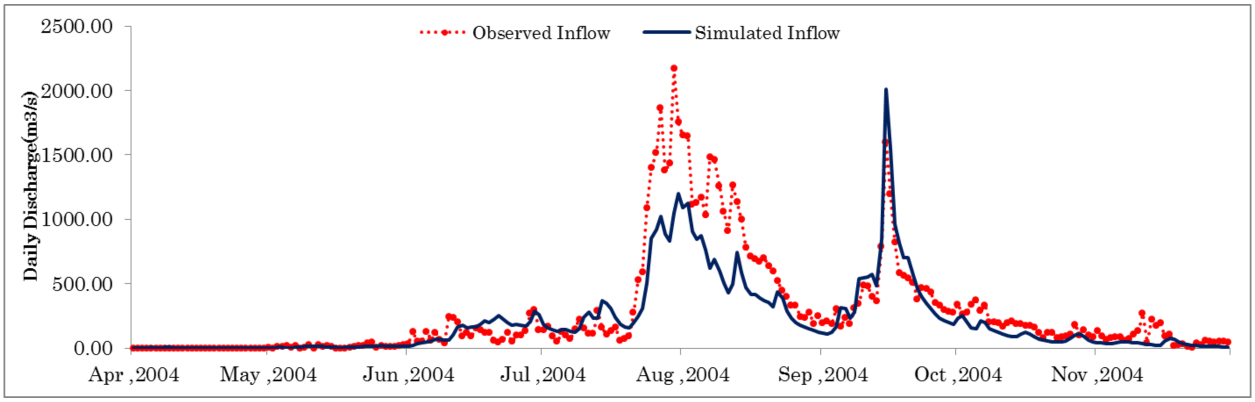


Fig. 2-10 Comparison of reservoir inflow at the Vajiralongkorn dam for the model validation, 2004.

Chapter 3

Analysis of hydrologic variable changes related to large scale reservoir operation in Thailand

Abstract *This chapter applies the Mann-Kendall (MK) statistical trend test to analyze increasing, decreasing or trendless characteristics of precipitation, temperature, inflow to dam reservoirs, release from dam reservoirs, and storage volume in dam reservoir in Thailand from historical operation recorded data. The five large scale dam reservoirs located in the northern and central parts of Thailand are selected to analyze the trend of the Ping River basin (Bhumibol Dam), the Nan River basin (Sirikit Dam), the Pasak River basin (Pasak Jolasid Dam) and the Mae Klong River basin (Srinagarind and Vajiralongkorn dams). Those reservoir operation time series which consist of daily inflow, release, rainfall and temperature were analyzed and examined in association with various aspects of dam reservoir operations.*

3.1 Introduction

Climate changes cause clear temperature increase for decades or even longer periods (IPCC, 2013), which significantly affects various hydrologic processes of time and space distribution pattern and quantity in such as precipitation and evapotranspiration. There are numerous earlier studies which focus on trend analysis of atmospheric and hydrologic variables in quantity and quality using historical data and GCM data. For example, Tao *et al.* (2011) analyzed the trends of streamflow in the Tarim River basin during the past 50 years using historical data, and Duong *et al.* (2014) examined the impact of river discharge changes by using a distributed river flow routing model and GCM datasets in the Indochina Peninsula region.

In the Southeast Asian countries such as Thailand, agriculture is the main source of the economy as well as ensures the well-being of the people. Thus, to sustain the water resource into the future is quite essential. Unless the water resources are utilized with a balance approach of supply and demand, its sustainability will become at risk. Therefore proper planning of water resource development as well as the utilization based on uncertainty in climate change impact is very necessary. The large scale multiple purposes dam reservoirs are one of countermeasures to manage and address water resources problems. Therefore, the appropriate operation of dam reservoir based on a proper understanding of a change of hydrologic variables is very important.

In this Chapter, the trend of various hydrologic variables related to dam reservoir operations such as inflow to dam reservoirs, release from dam reservoirs, dam storage as well as precipitation and temperature using long historical record were examined with the Mann-Kendall test (Manee *et al*, 2015). The trend analysis is one of the methods to support and confirm the change of hydrologic variables to propose an adaptive dam release operation rules and constraint in advance combining with GCM data analysis for the future.

3.2 Methodology

3.2.1 Study area and data collection

The study area is Thailand which is located in the Southeast Asia with an area 513,115 km^2. Its climate is tropical climate with clear dry and wet seasons. The seasons are defined as follow: the dry season starts from November until April and the wet season starts from May until October in the central and northern part of Thailand. In the western river basins dry season starts from January until June and wet season begins July until December.

The five large scale dam reservoir basins located in the northern, western and central parts of Thailand as shown in Fig. 1 are selected to analyze the historical trend of precipitation, temperature, dam inflow, dam release, and storage. The five basins are the Ping River basin with the Bhumibol Dam (BB), the Nan River basin with the Sirikit Dam (SK), the Pasak River basin with the Pasak Jolasid Dam (PS), and the Mae Klong River basin with the Srinagarind dam (SR) and Vajiralongkorn dam (VRK).

Daily temperature and precipitation data were collected from 25 meteorological stations for the period 1980-2011 and time series of monthly inflow, release and storage data were obtained from the Electricity Generating Authority of Thailand (EGAT) and Thai Royal Irrigation Department (RID) for the period of starting reservoir operation. The reservoir characteristics of reservoir description are given in Table 3-1. The spatial distribution of the selected meteorological stations in Thailand is shown in Fig. 3-1.

Table 3-1 Characteristic features of selected reservoirs.

Name	**BB**	**SK**	**SR**	**VRK**	**PS**
Location	17°14′33″N 98°58′20″E	17°45′50″N 100°33′48″E	14°24′31″N 99°07′42″E	14°47′58″N 98°35′49″E	14°51′41″N 101°03′58″E
Catchment Area (km^2)	26,386	13,130	10,880	3,720	12,292
Maximum Storage (MCM)	13,462	9,510	17,745	8,860	785
Minimum Storage (MCM)	3,800	2,850	10,265	3,012	3
Active Storage (MCM)	9,662	6,660	7,480	5,848	782
Mean Inflow (MCM)	5,783	5,780	4,790	5,585	2,725
Opening Year	1964	1974	1980	1984	1999

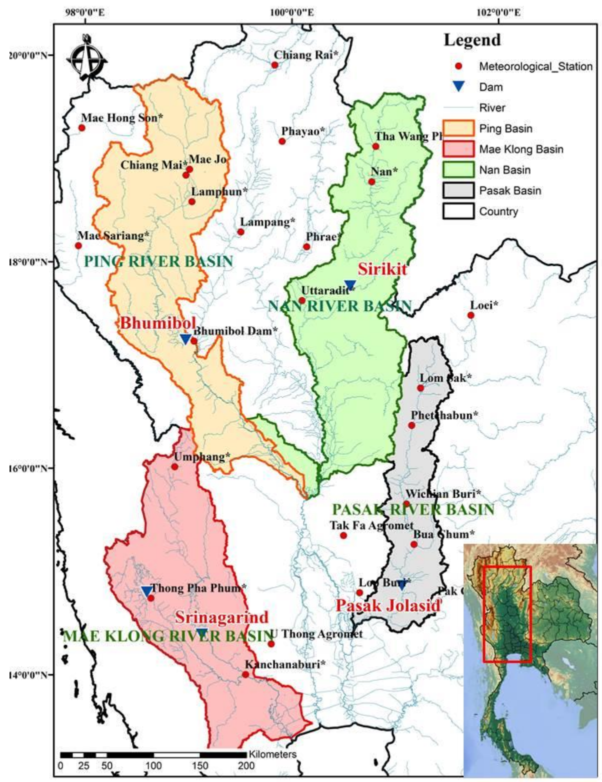


Fig. 3-1 Location map of large scale reservoirs and meteorological stations in Thailand.

3.2.2 Trend analysis method

Detecting trends in hydrologic, climatic, water quality and other natural time series has been an active topic for more than three decades now. Statistical tests for the detection of significant trends in hydrologic and climatologic time series can be classified as parametric and non-parametric methods. The parametric trend tests require sample data to be independent and normally distributed, while the non-parametric tests need only that the data be independent. The Mann-Kendall trend test is one of the widely used non-parametric tests to detect significant trends in time series. The Mann-Kendall trend test is based on the correlation between the ranks of a time series and their time order. For the statistics S is calculated as equation (3-1). This statistic represents the number of positive differences minus the number of negative differences for all the differences considered as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_j - x_i\right) \tag{3-1}$$

where n is the number of total data points, xi and xj are the data values in time series i and j ($j>i$), respectively, and sgn (x_j-x_i) is the sign function as:

$$\operatorname{sgn}\left(x_j - x_i\right) = \begin{cases} +1, & if \quad x_j - x_i > 0 \\ 0 & if \quad x_j - x_i = 0 \\ -1 & if \quad x_j - x_i < 0 \end{cases} \tag{3-2}$$

The variance of Mann-Kendall statistic is calculated by equation (3-3) as

$$Var\,(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i\,(t_i - 1)(2t_i + 5)}{18} \tag{3-3}$$

where n is the number of total data points, m is the number of tied groups. The tied group mean a simple data having a same value. The t_i indicates the number of ties of extent i. In case of the sample size n > 10, the standard normal test statistic ZS is estimated by equation (3-4) as

$$Z_S = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}}, if\ S > 0 \\ 0\ \ if\ S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}}, if\ S < 0 \end{cases} \tag{3-4}$$

The positive values of Z_S show increasing trends while negative Z_S values present decreasing trends. In this study 1% and 5 % significance level (α) were used. When, $|Z_S| > Z_{1-\alpha/2}$ the null hypothesis is rejected and significant trend exists in the time series. $Z_{1-\alpha/2}$ is obtained from the standard normal distribution table. Therefore, the null hypothesis of no trend is rejected if $|Z_S|$ > 1.96 and $|Z_S|$ > 2.576 at the 5% and 1 % significance level respectively.

3.2.3 Data analysis

The observation data used in this study consists of a daily observation of precipitation, temperature, daily inflow, release and volume storage. The daily precipitation, dam inflow and dam release flow data were summed up for monthly, seasonally, and yearly and developed monthly, seasonally and annual time series data for the trend analysis. The daily temperature data were averaged monthly, seasonally, and yearly and developed for each time series data. Similarly the dam storage volume time series were arranged at the end of each month. After compiling all-time series data on each parameter, the monthly time series in the designed month was selected to generate new time series for the Mann-Kendall trend analysis.

In addition, the seasonal analysis also calculate by dividing on dry season (November to April) and wet season (May to October) for the northern and central of study area. The climate for western of study area is delayed, so the calculation was chosen the dry season (January to June) and the wet season (July to December) based on each climate characteristics.

3.3 Results and discussion

3.3.1 Analysis of temperature and precipitation trend

Results of applying statistical tests for seasonal and annual temperature and precipitation trend over the period 1980-2011 are presented in Table 3-2 .The Z_S values in equation (3-4) are presented in Table 3-2. The positive values represent the increasing trend and the bold values shows statistically significant at the 5% or 1% significant level. Moreover, Fig. 3-2 and Fig. 3-3 showed the spatial distribution of trend on temperature and precipitation respectively by indicative red dot color for decreasing trend and blue dot color for increasing trend. Furthermore, the observed temperature and precipitation on the Asian Precipitation-Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) project were adopted to analysed the spatial distribution of trend for comparison with the direct observation station. A daily APHRODITE datasets for 0.25° x0.25 ° resolution from 1961 until 2007 (47 years) was used to calculated the same as the observation station dataset.

All of the entire stations show the little significant increasing trends except some stations near to the BB dam stations while the other stations trends present increasing trend in term of temperature and rainfall. For the results of temperature trend, the Wichianburi and Maejo stations in the Pasak River basin and the Ping River basin showed dramatically insignificant increasing trends at the 1% significance level of temperature in all season. The other stations have slightly increasing and decreasing trends in dry and wet seasons.

The temperature in the Pasak, Nan and Mae Klong River basins shows the increasing trends, which means the evapotranspiration trend in those river basins would increase because the temperature is a main factor of evapotranspiration components. According to the precipitation trend results, the precipitation trends of the Pasak, Nan and Mae Klong River basins also slightly increase as similar trends with the temperature.

For the annual spatial distribution of meteorological stations on temperature and precipitation between two datasets (observed station and APHRODITE data) showed a similar trend results. The advantage of APHRODITE dataset can be shown the obviously spatial pattern of meteorological variable.

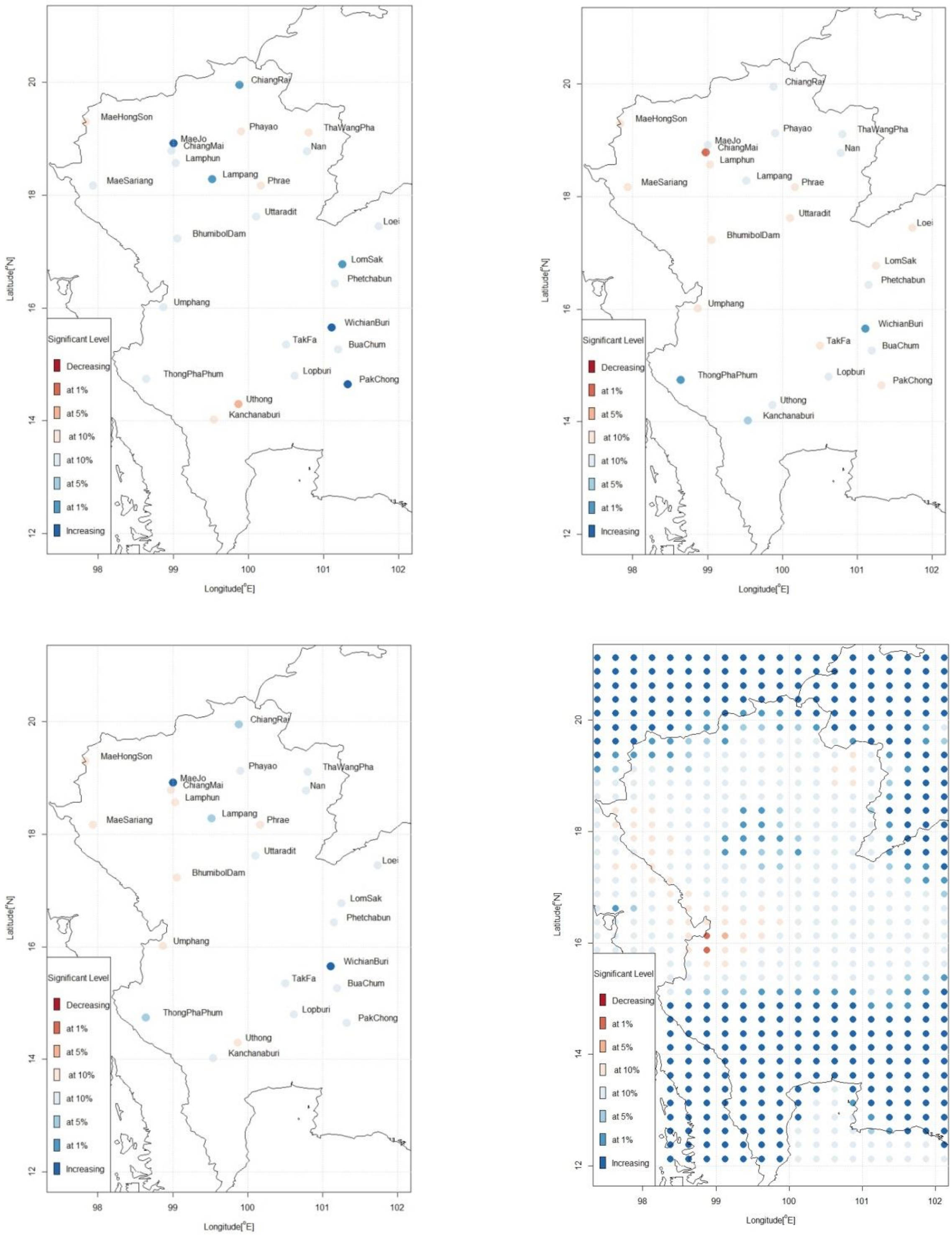


Fig. 3-2 Spatial distribution of meteorological stations on temperature for seasonal and annual data during the period 1980-2011. (upper left: dry season, upper right: wet season , lower left: annual and lower right : annual [APHRODITE])

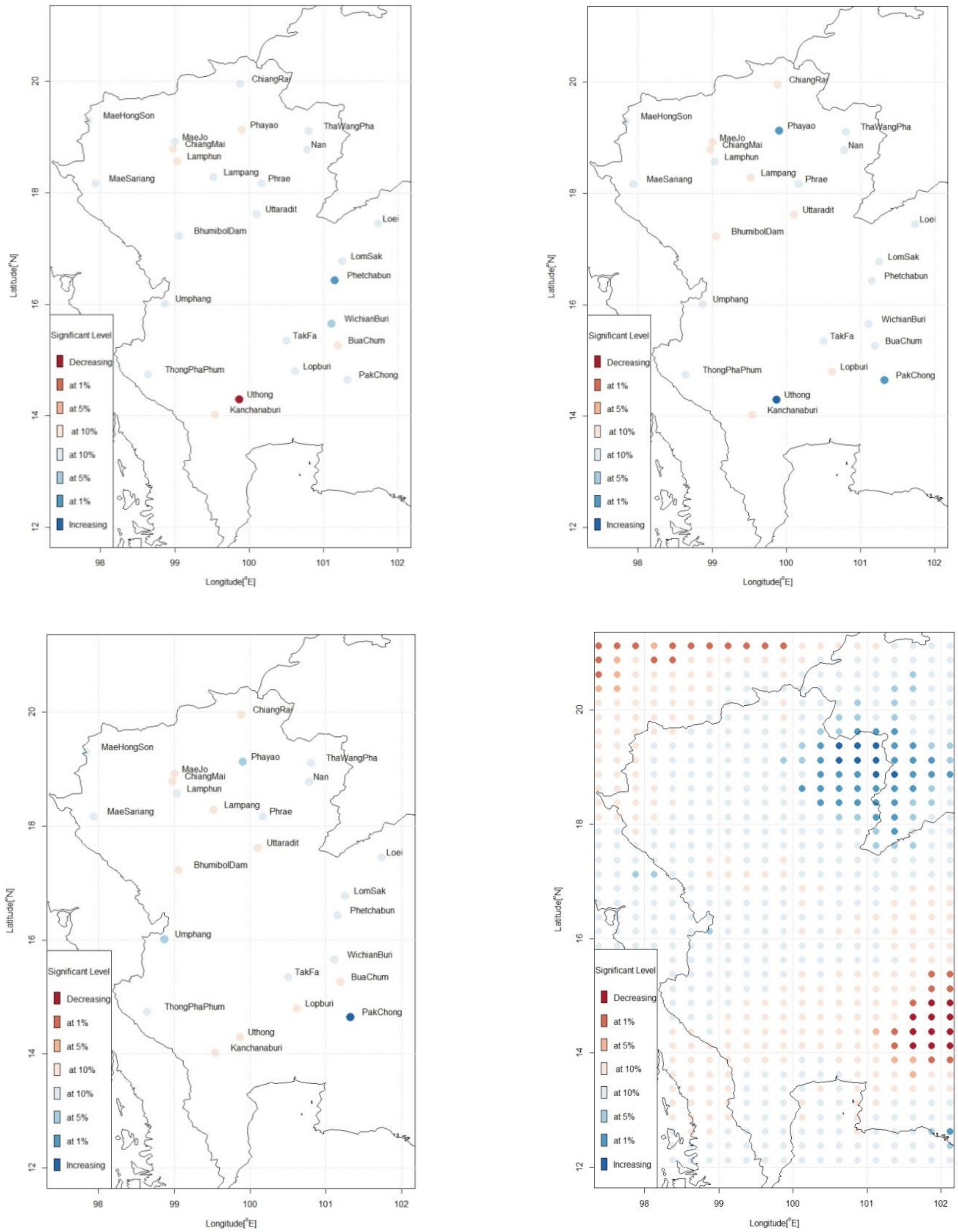


Fig. 3-3 Spatial distribution of meteorological stations on precipitation for seasonal and annual data during the period 1980-2011. (upper left: dry season, upper right: wet season , lower left: annual and lower right : annual [APHRODITE])

Table3-2 Results of the statistical tests for seasonal and annual temperature and precipitation over the period 1980-2011.

River Basin	Station	Average Temperature			Precipitation		
		Dry Season	Wet Season	Annual	Dry Season	Wet Season	Annual
Ping	Bhumibol Dam	0.214	-0.714	-0.018	0.712	-0.188	-0.021
	Chiang Mai	0.464	**-2.194***	-1.053	-0.335	-0.314	-0.649
	Chiang Rai	**1.963***	0.839	1.731	0.251	-0.565	-0.523
	Lampang	**2.569****	0.036	1.855	0.126	-0.628	-0.607
	Lamphun	0.788	-1.632	-0.263	-0.068	1.564	1.19
	Mae Hong Son	-0.244	-0.732	-0.619	0.555	0.795	0.795
	Mae Jo	**2.963****	0.691	**2.904****	0.34	-1.216	-1.112
	Phayao	-0.338	0.319	0.638	-0.187	**2.108***	1.836
	Mae Sariang	0.143	-1.07	-0.749	1.13	0	0.251
Nan	Nan	1.035	0.125	0.517	0.272	0.188	0.293
	Phrae	-0.393	-0.624	-0.232	1.193	0.649	0.733
	Tha Wang Pha	-0.892	1.035	0.91	0.054	0.715	0.412
	Uttaradit	1.427	-0.125	0.5	0	-1.047	-1.214
Pasak	Phetchabun	1.285	0.178	1.285	**2.156***	0.9	1.465
	Pak Chong	**2.623****	-0.963	1.267	0.921	**2.219***	**2.623****
	Lom Sak	**2.177***	-0.125	1.409	0.076	0.195	0.433
	Lop buri	0.178	0.071	0.107	0.23	-1.088	-0.481
	Loei	1.249	-0.624	0.892	0.586	1.005	1.235
	Bua Chum	0.393	0.225	0.161	-0.303	0.195	-0.206
	Wichian Buri	**2.814****	**2.176***	**2.701****	1.741	0.108	0.966
	Tak Fa	0.696	-0.731	0.232	0.954	1.047	1.17
MaeKlong	Kanchanaburi	-0.892	1.873	0.232	-0.147	-0.586	-0.356
	Thong Pha Phum	0.731	**2.301***	1.855	0.52	0.011	0.412
	Uthong	-1.82	0.464	-0.892	**-3.181****	**2.972****	-0.544
	Umphang	0.535	-1.356	-0.393	1.363	0.824	1.761

Bold Character represent trends identified with

*Statistically significant trends at 5% significance level (1.960)

**Statistically significant trends at 1% significance level (2.576)

Dashed line indicate the separation of gauging station on each basin

3.3.2 Analysis of inflow trend

The output of the analyzed inflow series was summarized in Table3-3. The inflow series of the SK dam at the Nan River basin and the SR dam at the Mae Klong River basin were found significant increasing trends throughout the year, which are corresponding with the increasing precipitation trends. Both increasing and decreasing trends were detected at the BB, PS and VRK dams. The VRK and BB dam have a strong significant decreasing trend at 1% significance levels in early dry season. The Pasak reservoir was found only two months of slightly increasing trends comparing with other ten month significant decreasing trends, even though, the precipitation trends in the Pasak River basin have been detected increasing trends in all stations that cover the basin. This suggests the higher evapotranspiration rate occurred, which made the reducing the amount of water resources in the basin.

Table 3-3 Results of the statistical tests for monthly, seasonal and annual inflow over the period from the operation to 2013.

Month/Season	Test statistic (Zs)				
	BB	SK	PS	SR	VRK
Jan	**-2.141***	1.27	0	0.415	**-2.12***
Feb	-1.824	**2.552***	-1.204	0.978	**-2.345***
Mar	-0.351	0.804	-0.985	1.038	-0.769
Apr	-0.97	0.781	0.109	0.326	**-2.157***
May	1.029	0.874	-0.495	0.83	0.732
Jun	0.151	0.408	-0.594	0.86	0.071
Jul	0.46	0.92	-1.188	**1.986***	**2.212***
Aug	-0.067	0.804	-0.891	**2.194***	1.249
Sep	-0.033	1.014	0.495	1.393	1.855
Oct	0.184	0.478	0.891	1.127	0.928
Nov	-1.422	0.384	-1.188	0.296	0.036
Dec	**2.894****	**2.598****	**-2.078***	0.385	0
Dry Season	-1.939	1.766	-1.642	1.334	0.319
Rainy Season	0.151	0.851	0.396	1.186	**2.07***
Annual	-0.233	0.702	0.495	1.512	**1.97***

Bold character represent trends identified with

*Statistically significant trends at 5% significance level (1.960)

**Statistically significant trends at 1% significance level (2.576)

Dashed line indicate the separation between dry and wet seasons

3.3.3 Analysis of release flow trend

The monthly, seasonal and annual trends of release flow obtained by the Mann-Kendall test are given in Table 3-4. According to these results, the significant increasing trend at 1% significance level of release flow during dry season were found except the Pasak dam, however the release flow of the Pasak dam has a little significance increasing trends especially on December and January at the 1% significance level. The inflow trends of the BB and SK dams during early wet season (May to July) found increasing trends as shown in Table 3-3. Therefore, the release of the BB, SK and PS dams in wet season have significant decreasing trend to store the flood flows in the Ping, Nan and Pasak Rivers. In brief, the results found generally increasing significant trends in dry season of release flow in all reservoirs for high water demand, and decrease trends in the BB, SK, and PS dams to store water in the rainy season.

Table 3-4 Results of the statistical tests for monthly, seasonal and annual release flow over the period starting from the operation to 2013.

Month/Season	Test statistic (Zs)				
	BB	SK	PS	SR	VRK
Jan	**3.543****	**4.928****	**3.266****	**3.579****	**2.72****
Feb	**4.215****	**3.944****	1.683	**4.092****	**4.858****
Mar	**2.595****	**2.179***	1.584	**3.765****	**3.395****
Apr	1.457	0.478	-0.792	**2.846****	**4.221****
May	-1.405	-0.711	0	**3.172****	**2.532***
Jun	-1.69	-0.151	0	2.046*	-0.469
Jul	**-2.476***	-1.456	-0.693	**2.075***	0.206
Aug	**-2.108***	-1.34	-0.693	1.66	1.069
Sep	**-3.279****	**-2.039***	-0.792	0.049	-0.019
Oct	-2.509*	-1.2	0.891	**3.143****	1.427
Nov	-0.569	-0.198	-0.891	**2.787***	**2.676****
Dec	1.941	**3.111****	**2.771****	**3.41****	**2.034***
Dry Season	**2.957****	**3.29****	0.766	**3****	**3.358****
Rainy Season	**-2.225***	-1.13	0.099	1.832	1.356
Annual	0.353	1.379	0.396	**3.13****	**2.72****

Bold character represent trends identified with

*Statistically significant trends at 5% significance level (1.960)

**Statistically significant trends at 1% significance level (2.576)

Dashed line indicate the separation between dry and wet seasons

3.3.4 Analysis of storage trend

Results of the Mann-Kendall test to the monthly storage volume at the end of each month are presented in Table 3-5. As shown, the majority of the monthly trends in the BB dam have a significant decreasing trend due to reservoir operation based on existing rule curve while the SR dam shows increasing trend throughout the year. The SK, PS and VRK dams remain the similar trends of increasing trends in wet season and of decreasing trends in dry season as a natural condition.

Table 3-5 Results of the statistical tests for monthly, seasonal and annual storage over the period starting from the operation to 2013.

Month	Test statistic (Zs)				
	BB	SK	PS	SR	VRK
Jan	-1.715	-0.431	**2.628****	1.127	1.144
Feb	**-2.405***	-1.2	**2.847****	0.949	0.732
Mar	**2.801****	-1.596	**-3.23****	0.771	0.131
Apr	-2.87	-1.596	**2.956****	0.534	-0.54
May	-2.577	-1.2	-1.534	0.474	-0.73
Jun	**-2.192***	-0.618	-2.177*	0.682	-0.32
Jul	-1.957	-0.431	**-2.573***	0.993	1.053
Aug	-1.656	0.198	**-2.078***	1.482	1.409
Sep	-1.455	0.431	0.891	1.779	1.499
Oct	-1.221	0.664	1.881	1.571	1.409
Nov	-1.171	0.885	0.594	1.245	1.481
Dec	-1.539	0.268	-1.188	0.949	1.463

Bold character represent trends identified with

*Statistically significant trends at 5% significance level (1.960)

**Statistically significant trends at 1% significance level (2.576)

Dashed line indicate the separation between dry and wet seasons

3.3.5 Analysis of insufficient and excess storage volume

Insufficient and excess storage volume below or exceeding the rule curves of all reservoirs were also evaluated from the beginning of each dam operation. The insufficient storage volume means the amount of volume below the lower rule curve while the excess volume represents the total of volume exceeding the upper rule curve. The explanation of insufficient and excess storage volume is illustrated as Fig. 3-3.

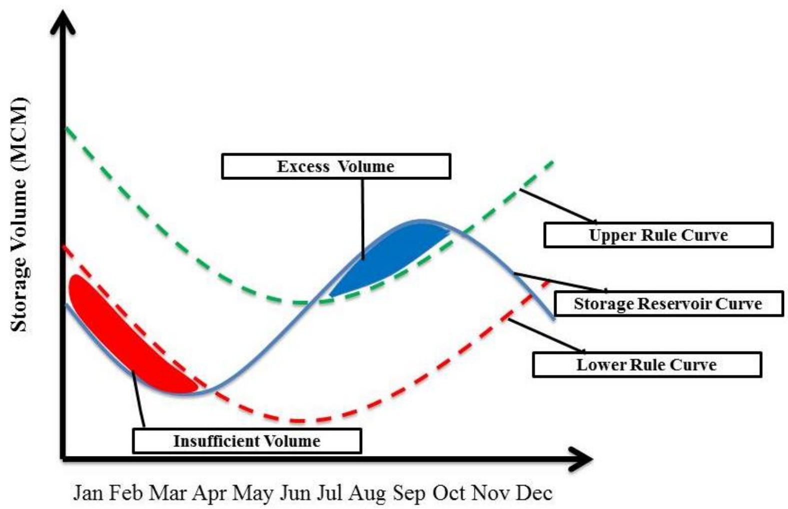


Fig. 3-4 Explanation of insufficient and excess storage volume.

The results of this analysis are summarized in Table 3-6. At the BB dam, increasing of insufficient storage volume trends was detected, which is corresponding on previous analysis of reduced in-flow and increasing outflow trends results. The PS Dam also had a similar significant inflow and outflow trends results with the BB dam nevertheless the results of insufficient and excess storage volume results of the PS dam have indistinct. The SK, SR and VRK dams show gradually a rising trends of excess storage volume same an inflow trends of preceding section that represent the water resources in those areas would be increased.

Table 3-6 Results of insufficient and excess storage volume.

Dam		Number of Event	Zs	
BB	Insufficient	24	1.15	Increasing
	Excess	4	-	-
SK	Insufficient	28	-0.01	Decreasing
	Excess	14	0.99	Increasing
PS	Insufficient	10	0.00	No Trend
	Excess	17	0.72	Increasing
SR	Insufficient	17	-0.03	Decreasing
	Excess	2	-	-
VRK	Insufficient	8	-1.86	Decreasing
	Excess	14	0.00	No Trend

The number of insufficient events in the BB, SK and SR reservoir found biannually on average. The PS dam has a small capacity comparing with other dams, so many insufficient and excess events detected within fifteen years. However, the VRK dam is also found the excess events with fourteen times to cope with flood. According to the dam characteristics in Table.1, the large scale reservoir such as the BB and SR dams have an advantage to address the flood for four and two events, respectively.

3.4 Conclusion

The trends of precipitation, temperature, dam inflow, and dam release flow and volume storage were analyzed statistically based on long term historical data by using the Mann-Kendall trend test. Our findings are summarized as follows:

- Through the analysis, we found that the temperature and precipitation trends were increasing trends nevertheless Ping River basin temperature and precipitation trends were decreasing trends.
- The water resources availability in term of inflow to BB dam and PS Dam were decreasing trend during dry season. The inflow of all reservoirs in rainy season has increasing trends.
- For dam release from the reservoirs, generally increasing significant trends in dry season of release flow in all reservoirs. Only BB and SK dam has decreasing trends during rainy season.
- As a result, dam storage for BB dam found dramatically decreasing trends throughout the year while the SR dam detected decreasing trends.
- These insufficient and excess storage results indicate the increasing trends of water shortage in BB dam (Ping River basin) and PS dam (Pasak River basin) and also raising the trend of flood in SK dam (Nan River Basin) and both dams in Mae Klong River Basin.

This chapter about trend analysis showed the climate change impacts have been already appeared in water resources in Thailand. The further study will be combined with the analysis of the historical data and GCM outputs. The analysis using a hydrologic model and GCM outputs are combined to predict future dam inflow under a changing climate and to evaluate a current rule curve for adaptive dam reservoir operation.

Chapter 4

Prediction of large scale reservoir water availability in Thailand

Abstract *In this chapter, the assessment of future water resources availability in term of inflow through large scale reservoirs in Thailand by using Atmospheric General Circulation Model (MRI-AGCM3.2S). The output of runoff generation data also used as input forcing based on land surface model inside the MRI-AGCM3.2S to simulate reservoir inflow of the five large scale dam reservoirs for two different climate experiments: the present climate (1979-2003) and future climate (2075-2099) with various future sea surface temperatures (SST) scenarios.*

4.1 Introduction

General circulation models (GCMs) have been commonly used in climate change impact studies. The several studies of application to use GCMs in Chao Phraya River Basin and surrounding River Basin were conducted. For instance, Hunukumbura and Tachikawa (2012) utilized the runoff projected by MRIAGCM3.1S, which showed the increasing of extreme discharge at the upper part of Chao Phraya River Basin and the decreasing of monthly discharge in October at the Pasak River basin. Kure and Tebakari (2012) showed the increased tendency of the mean annual river discharge and annual maximum daily flow at the Nakhon Sawan station located at the downstream of the four major rivers in the in upper Chao Phraya River Basin using the precipitation and temperature projected by MRI-AGCM3.1S and MRI-AGCM3.2S. Champathong *et al.* (2013) assessed the uncertainty of river flow projections using the outputs of MRIAGCM3.1S and MRI-AGCM3.1H. Kotsuki *et al.* (2014) found the increasing of runoff at the Nakhon Sawan area using a land surface model forced by outputs from six bias corrected CMIP5 GCMs. Watanabe *et al.* (2014) projected natural river flow using newly developed bias-corrected outputs of nine GCMs and presented the increasing of future river discharge in September to reference simulations.

Sato *et al.* (2012, 2013) used the raw super-high-resolution MRI-AGCM3.2S based on the sea surface temperature ensemble projected by the Coupled Model Intercomparison Project phase 3, assuming the A1B scenario of the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios to evaluate the impacts of climate change on river discharge and also applied a hydrological simulation to several major river basins in Japan.

The objective of this chapter is to assess future water resources availability in term of inflow through large scale reservoirs in Thailand by using recently General Circulation Model (MRI-AGCM3.2S, Mizuta *et al.*, 2012).

The location of reservoirs, reservoir catchment area and river basins which are used as dominant water resources for downstream water utilization are shown in Fig.4-1.For the reservoir characteristic features of targeted reservoirs can be referred as Table 3-1.

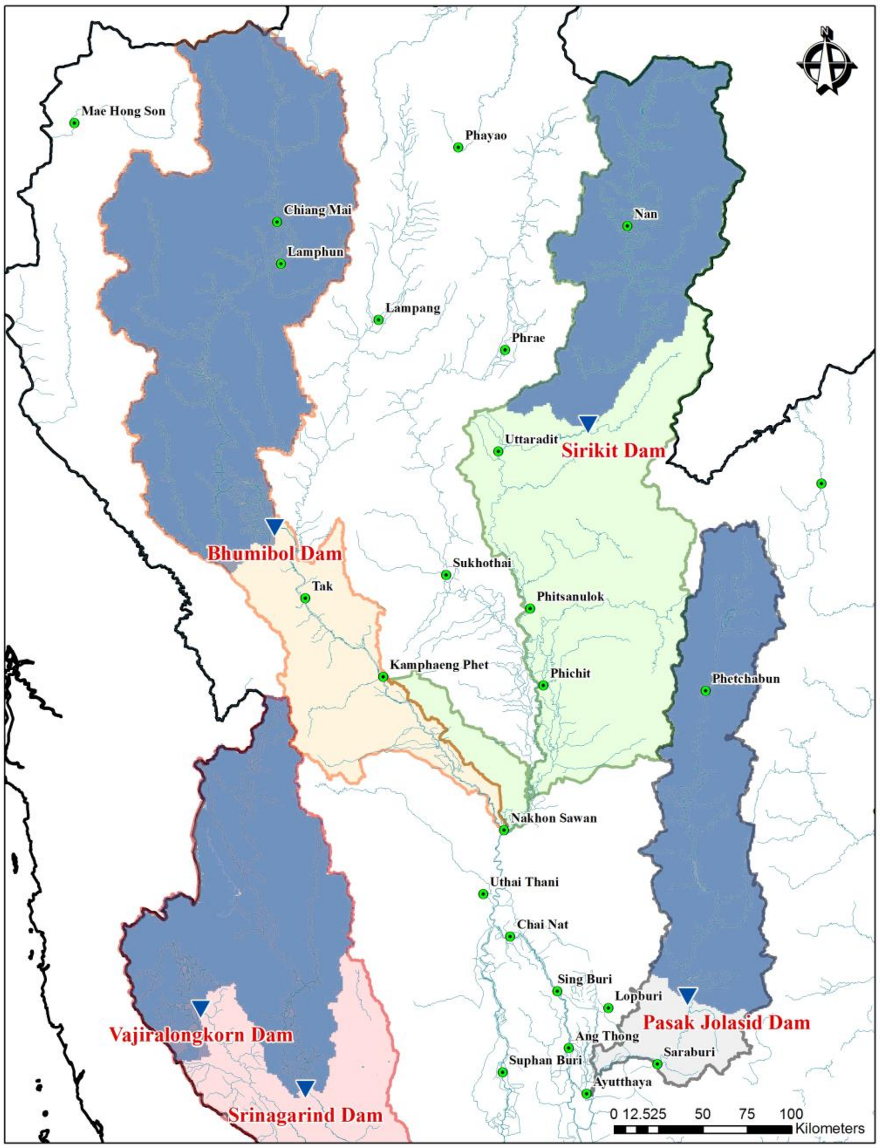


Fig. 4-1 Location of reservoirs, reservoir catchment area and river basins in Thailand selected as study area.

4.2 Atmospheric general circulation model (MRI-AGCM)

4.2.1 Model description

The climate models used for this research experiment were lately a model jointly developed by the Japan Meteorological Agency (JMA) and the Meteorological Research Institute (MRI) in versions of MRI-AGCM 3.2S (where 'S' refers to super-high resolution). To obtain the high resolution of climatic forcing data is to used downscaling technic by an atmospheric general circulation model (Kitoh *et al.*2009, 2015). Fig.4-1 show schematic figure of high-resolution that is obtain the observed or projected sea surface temperature (SST) as boundary condition. This type of mechanism simulations, which uses the observed present day interannually varying SST plus ensemble mean future SST changes obtained by CMIP-class models, can minimize the effects of climate model bias (Kitoh *et al.*, 2015). Based on the SST data of 28 CMIP5 model, the different SST spatial patterns are analyzed by a cluster analysis of these 28 CMIP5 model. Figure 4-3 shows a dendrogram that is classified into 3 clusters from 8, 14 and 6 models of cluster 1, cluster 2 and cluster 3, respectively.

That model has a horizontal resolution of triangular truncation 959 (TL959) and a vertical resolution of 64 levels (top at 0.01 hPa) to transform grid uses 1920* 960 grid cells with corresponding to approximately a 20 km grid interval. The 20-km mesh MRI-AGCM3.2 was employed in each 25-year time-slice experiment for the present-day climate (1979-2003) and late 21stcentury climate (2075-2099) scenarios with the Representative Concentration Pathway (RCP) 8.5 that refers to the final radiative forcing achieved by the year 2100 around 8.5 watts per square meter (W/m^2). Simulation of the present-day was performed the observed Sea Surface Temperature (SST) and sea-ice concentration and observed global-mean concentrations of CO2 and other greenhouse gas (GHGs) based on the HadISST1.1 data (Rayner *et al.*, 2003) as the lower boundary condition. For future climate projection, SST warming in the multiple-model ensemble (MME) of SST projected under the RCP8.5 scenario in the Couple Model Intercomparison Project Phase 5 (CMIP5) models was added to the observed SST as shown in Fig.4-4. Moreover, the cluster analysis also analyzed the ensemble SST to classify the characteristic pattern of SST into three groups as following 1) cluster 1: Uniform warming in the tropics zone pattern or in the both hemispheres, 2) Cluster 2: Larger warming over the central equatorial Pacific (so-called EI Nino-like pattern) and 3) Cluster 3: Larger warming in the north Indian Ocean and north-west Pacific pattern. Therefore, the future climate projection was combined of different SST (4 future SSTs) to assess the uncertainty of future water availability as illustrated in Fig.4-5.However, for 20 km grid output data provide a new cumulus convection scheme (Yoshimura *et al*, 2015), called the “Yoshimura scheme” only.

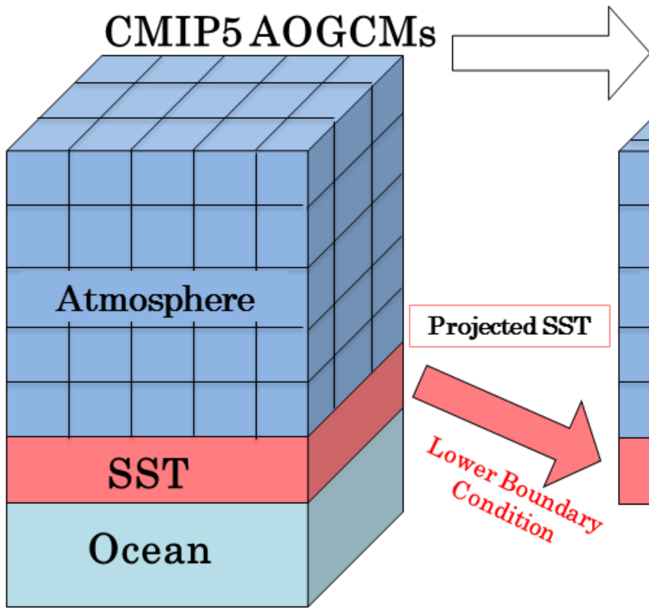


Fig. 4-2 Schematic figure of high-resolution time-slice experiments.

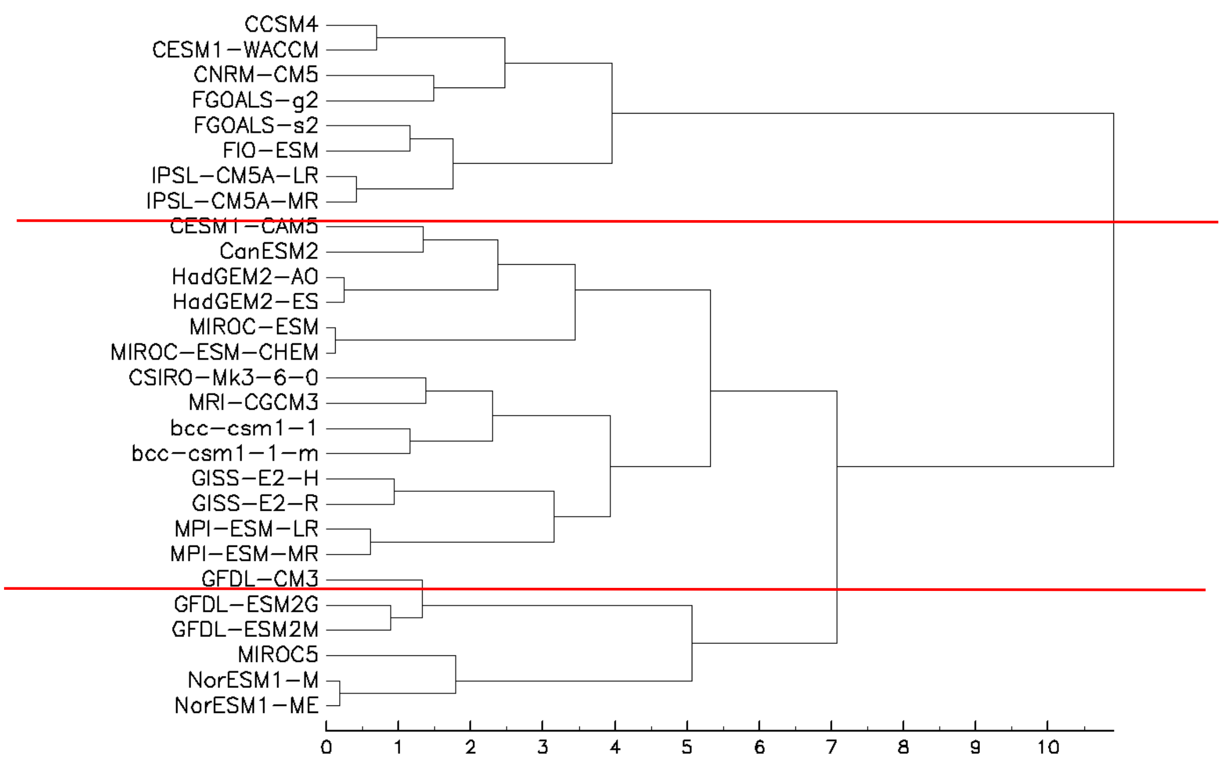


Fig. 4-3 Dendrogram for clustering of SSTs projected by the 28 CMIP5 models.

(source: MRI-SOUSEI program, 2014)

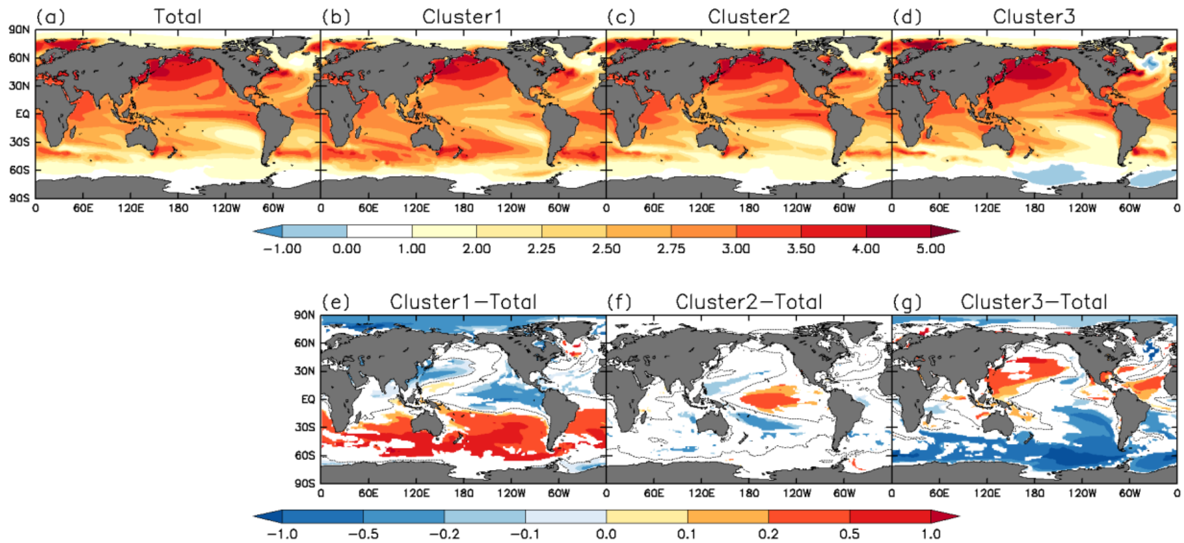


Fig. 4-4 Annual-Mean sea surface temperature change (K) between the present (1979-2003 average, historical experiment) and the end of the 21st century (2075-2099 average, RCP 8.5 experiment) [upper] and differences for each cluster compared with the total 28 models mean [Lower].

(source: MRI-SOUSEI program, 2014)

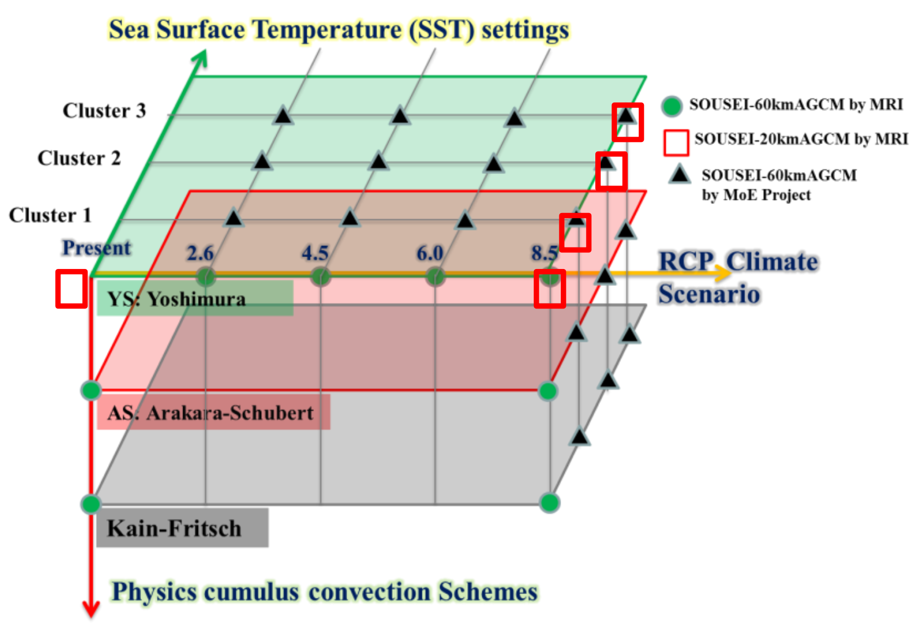


Fig. 4-5 Matrix of Ensemble Experiments

(source: MRI-SOUSEI program, 2014)

4.2.2 Super high-resolution forcing data model

For the each 20-km grid cell, the various hydrological components of the ACCM such precipitation, evaporation, transpiration and surface runoff generation were analyzed through the land-surface scheme of Simplified Biosphere (SiB) model, originally developed by Sellers (1986). Afterward, SiB was revised by MRI for calculation of soil water storage, total runoff which is combination of surface and sub-surface runoff generation (Yukimoto *et al.*, 2011) as shown in Fig.4-6. A distributed flow routing model (1K-FRM) based on kinematic wave theory (Tachikawa and Tanaka, 2013) developed by hydrology and water resources research laboratory, Kyoto University, was used to simulated and projected river discharge at selected reservoir. The runoff generation data of all slope units were flow through the 8-direction movement which assumes the flow direction one-dimensionally to the steepest gradient direction. The 30 arc-second (1 km) of Digital Elevation Model (DEM) and flow direction were stored in HydroSHEDS (Lehner *et al.*, 2006) that provides hydrographic information for region and global-scale based on NASA's Shuttle Radar Topography Mission (SRTM) and applied those data into 1K-FRM for river discharge calculation. All period of simulation have been performed at a spatial resolution of 30 arc-second (1 km) and temporal resolution of one day. For the validation data, the observed time series of daily inflow was obtained from the Electricity Generating Authority of Thailand (EGAT) and Thai Royal Irrigation Department (RID) for the period of starting reservoir operation.

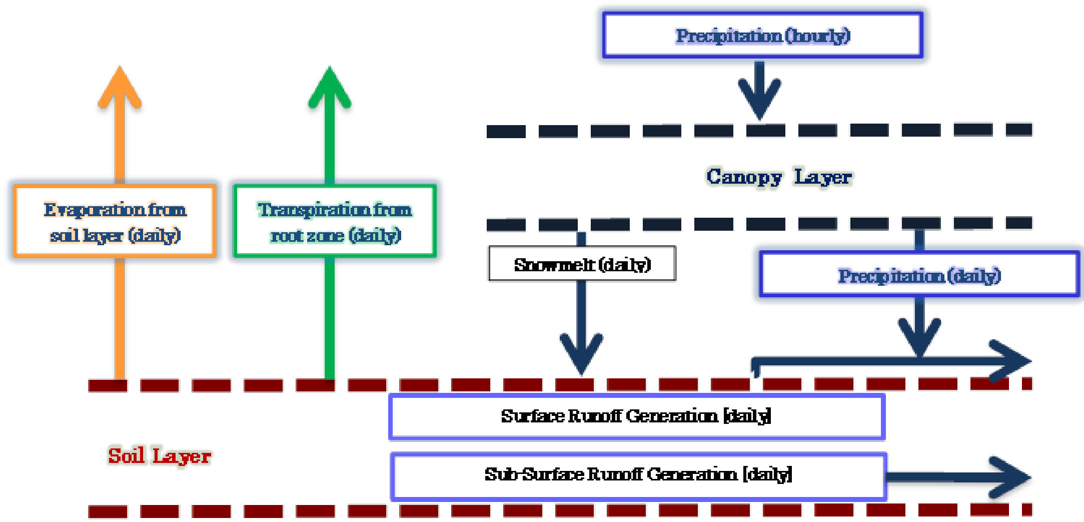


Fig. 4-6 Land surface generation data of MRI-AGCM3.2S fed into river discharge simulation.

4.3 Results and discussion

The daily reservoir inflow projection outputs for two different climate experiments as showed in Fig.4-7 were summed up to monthly data. The average monthly inflow and the flow duration curve were plotted to evaluate the climate change impact on reservoir inflow in term of water availability changes in large scale reservoir.

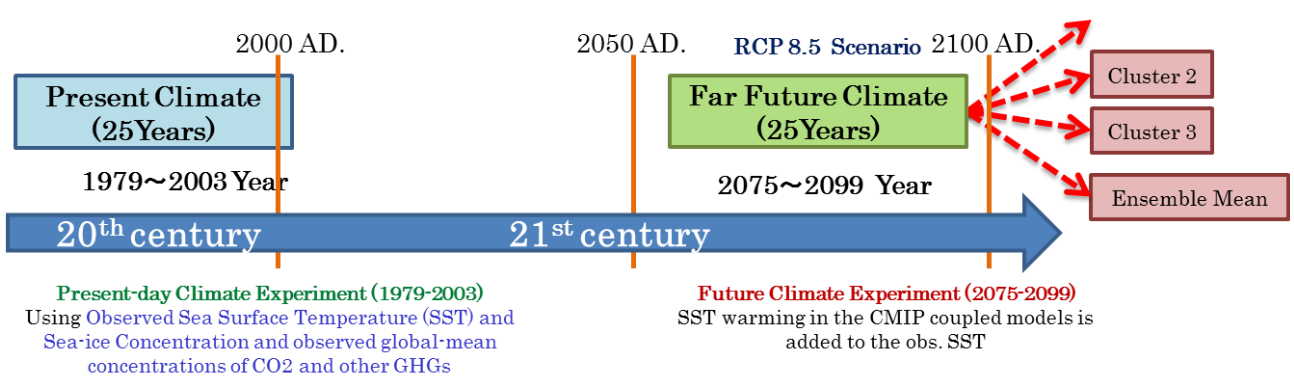


Fig. 4-7 Timeline of future reservoir inflow prediction.

4.3.1 Evaluation of the simulation results

Fig.4-7. shows the comparisons of total flow duration curve between the model simulation and observation of reservoir inflow for each location during the present-day climate simulation (1979-2003).The results found that the river discharge simulation of present climate at Bhumibol, Sirikit and Pasak reservoirs (in the Chao Phraya River Basin) had a good agreement with observed river discharge data. On the other hand, the river discharge output from MRI-AGCM3.2S still has underestimated at on the Mae Klong River basin with the Srinagarind dam (SR) and Vajiralongkorn dam (VRK). In this study, the raw runoff generation result of newest MRI-AGCM3.2S model has a well performance in the Chao Phraya River Basin.

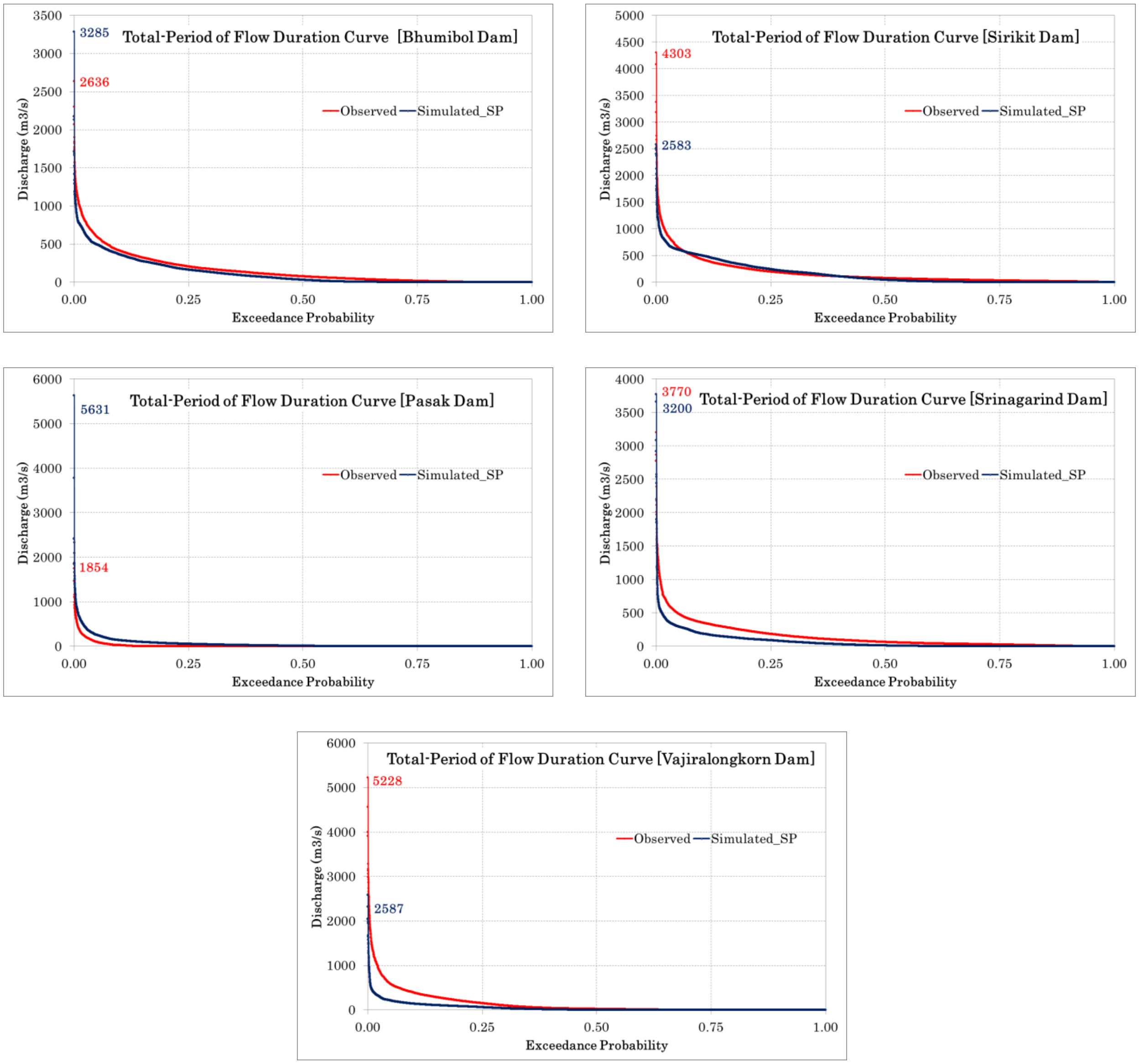
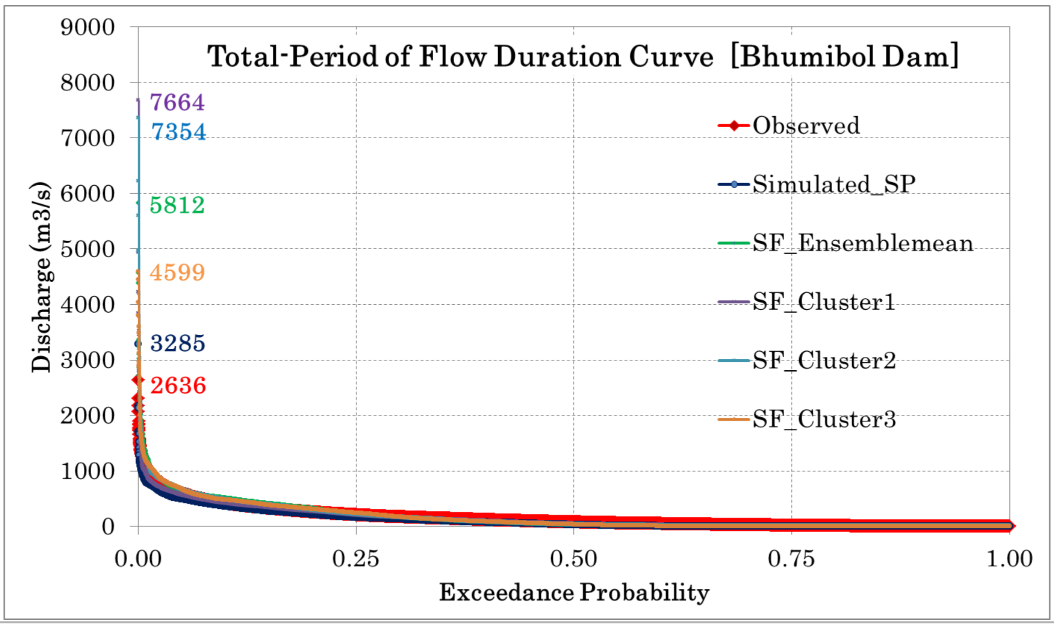
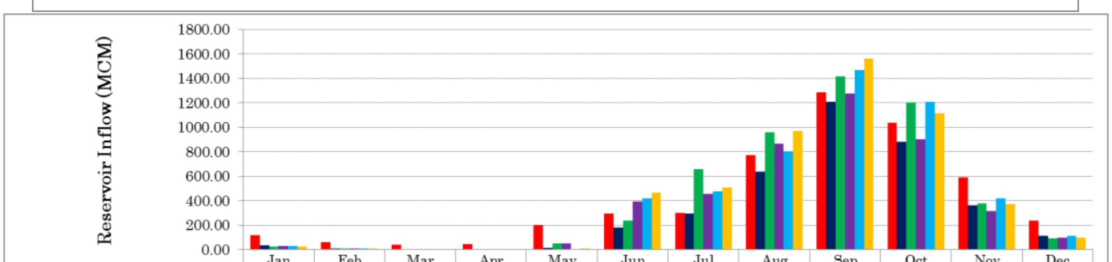


Fig. 4-8 The total-period of flow duration curve of each target reservoir.

4.3.2 Projection of annual and monthly mean inflow under a changing climate

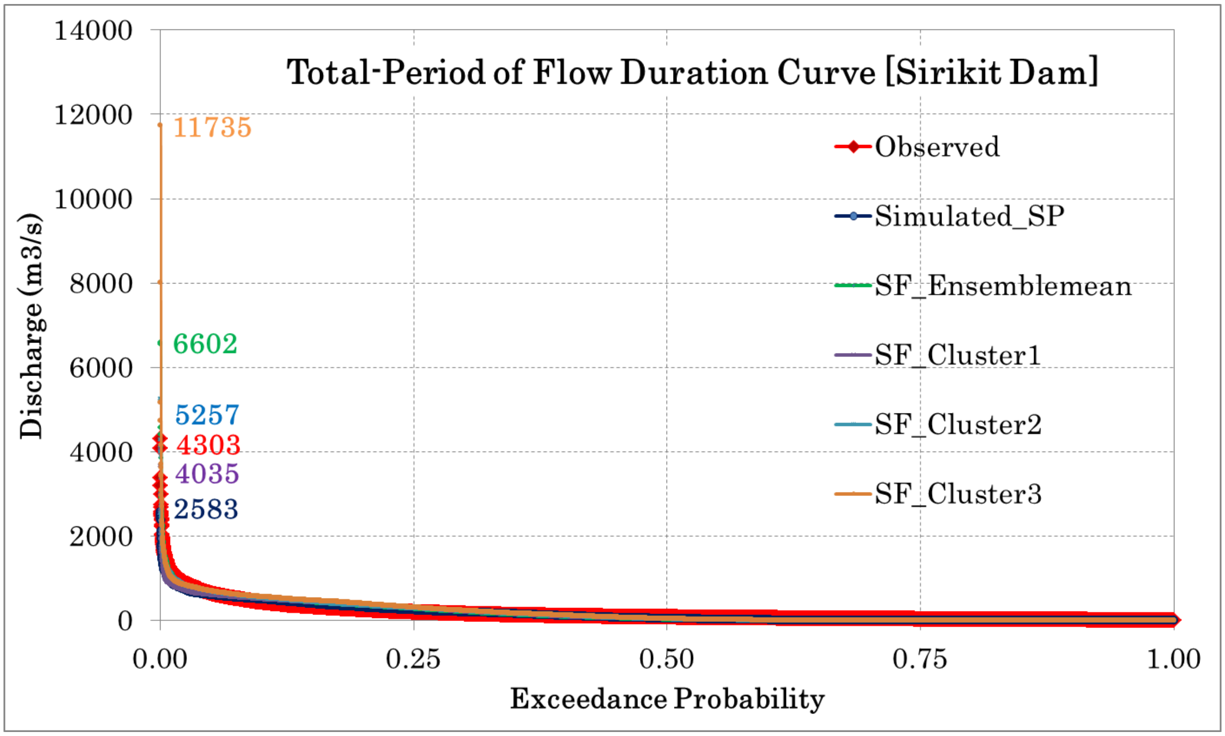
The effected of changing reservoir inflow during future climate experiment (2075-2099) under RCP 8.5 scenario were detected by 4 differences SST setting. The daily projected river discharge from 1K-FRM outputted were summarized to sum up monthly and annual in Fig. 4-8, Fig. 4-9, Fig. 4-10, Fig. 4-11 and Fig.4-12.

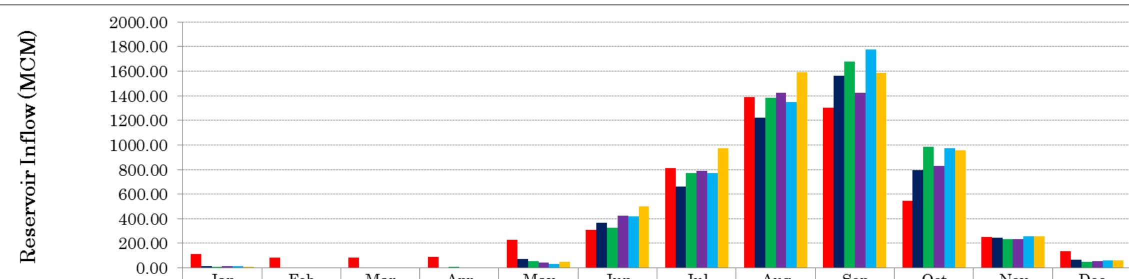




	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed	120.06	60.59	39.63	43.33	200.40	294.73	300.71	771.66	1287.73	1039.34	588.54	239.04
Simulated_SP	32.27	8.70	3.71	1.59	15.34	179.93	295.83	635.36	1206.95	881.20	361.26	112.98
Simulated_SF_Ensemblemean	24.01	8.28	4.01	2.03	50.45	236.21	656.80	958.26	1418.77	1205.72	376.43	93.70
Simulated_SF_Cluster1	30.96	10.38	4.11	1.98	47.72	394.76	453.64	866.98	1274.59	902.21	315.53	94.55
Simulated_SF_Cluster2	28.09	8.36	4.12	1.99	2.07	419.03	475.34	801.93	1467.10	1207.79	417.54	113.52
Simulated_SF_Cluster3	22.35	6.62	3.13	1.56	6.10	464.17	507.48	969.78	1561.58	1114.52	371.89	96.08

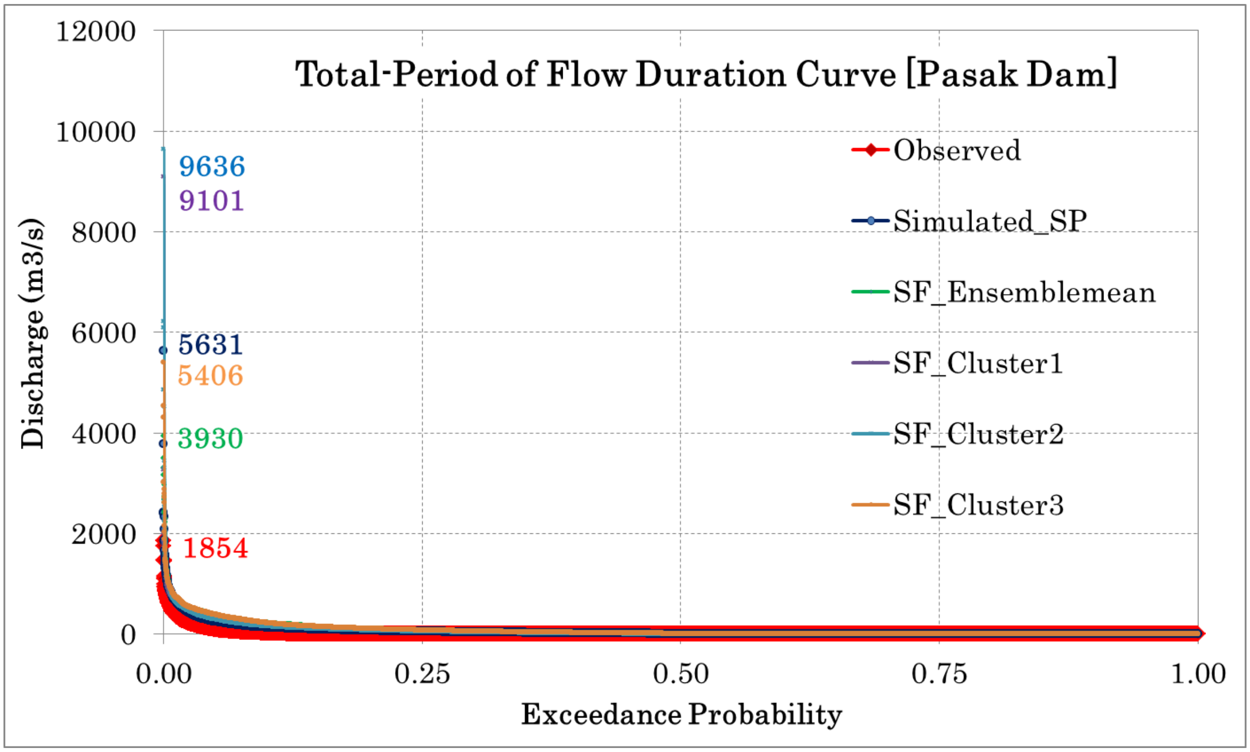
Fig. 4-9 The total-period of flow duration curve in Bhumibol dam between observed inflow, present and future simulation (upper). The monthly reservoir inflow (in MCM) in Bhumibol dam between observed inflow, present and future simulation (lower). (see Appendix A2-A7)

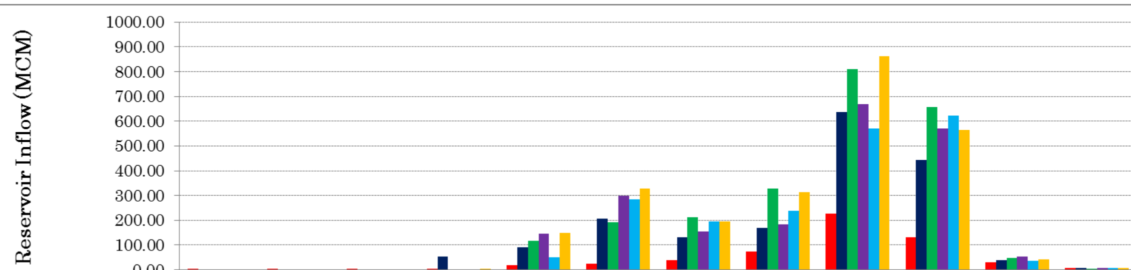




	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed	110.75	86.54	85.70	90.69	228.43	311.96	814.16	1389.61	1299.99	546.07	249.52	135.61
Simulated_SP	15.85	5.22	2.75	2.01	71.47	369.70	662.00	1220.66	1559.71	794.48	248.73	66.69
Simulated_SF_Ensemblemean	11.49	5.94	3.64	10.85	55.80	328.72	769.95	1383.74	1676.63	984.68	234.47	48.79
Simulated_SF_Cluster1	14.66	4.19	1.96	1.07	41.66	424.95	786.32	1423.79	1422.50	829.51	233.95	56.47
Simulated_SF_Cluster2	14.03	4.18	3.23	2.77	33.98	421.16	773.33	1350.44	1775.32	974.93	255.92	58.85
Simulated_SF_Cluster3	12.21	3.50	1.63	0.79	51.59	501.14	975.98	1590.03	1583.95	956.70	259.70	59.36

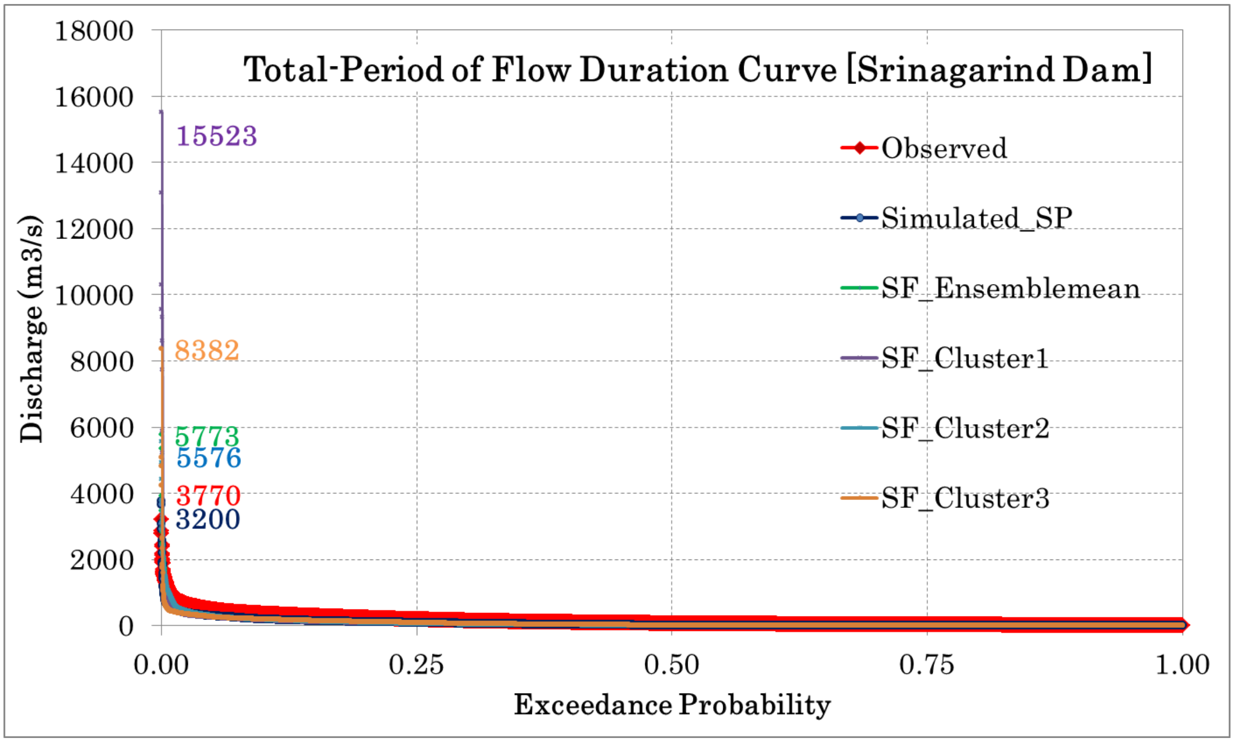
Fig. 4-10 The total-period of flow duration curve in Sirikit dam between observed inflow, present and future simulation (upper).The monthly reservoir inflow (in MCM) in Sirikit dam between observed inflow, present and future simulation (lower). (see Appendix A8-A13)

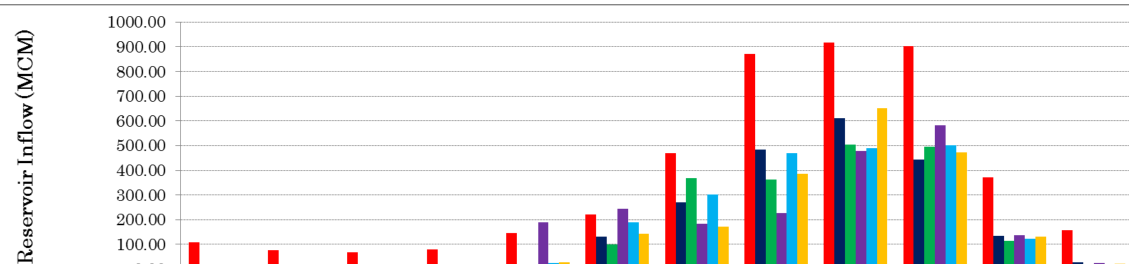




	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed	4.00	4.23	3.75	3.31	18.55	24.23	38.11	74.07	226.70	132.91	32.04	6.70
Simulated_SP	2.75	1.05	0.55	53.36	91.40	206.02	130.32	170.03	637.63	443.87	39.28	7.01
Simulated_SF_Ensemblemean	1.84	0.71	0.67	3.02	117.17	192.13	213.19	328.61	811.12	657.83	47.84	6.11
Simulated_SF_Cluster1	2.16	0.82	0.43	2.54	147.50	300.49	154.32	184.03	667.73	570.08	53.12	6.34
Simulated_SF_Cluster2	1.86	0.71	0.72	1.54	50.66	284.94	195.22	238.25	571.10	622.08	37.55	6.92
Simulated_SF_Cluster3	2.01	0.86	0.56	4.96	148.86	327.35	195.96	313.18	860.78	563.57	41.49	6.20

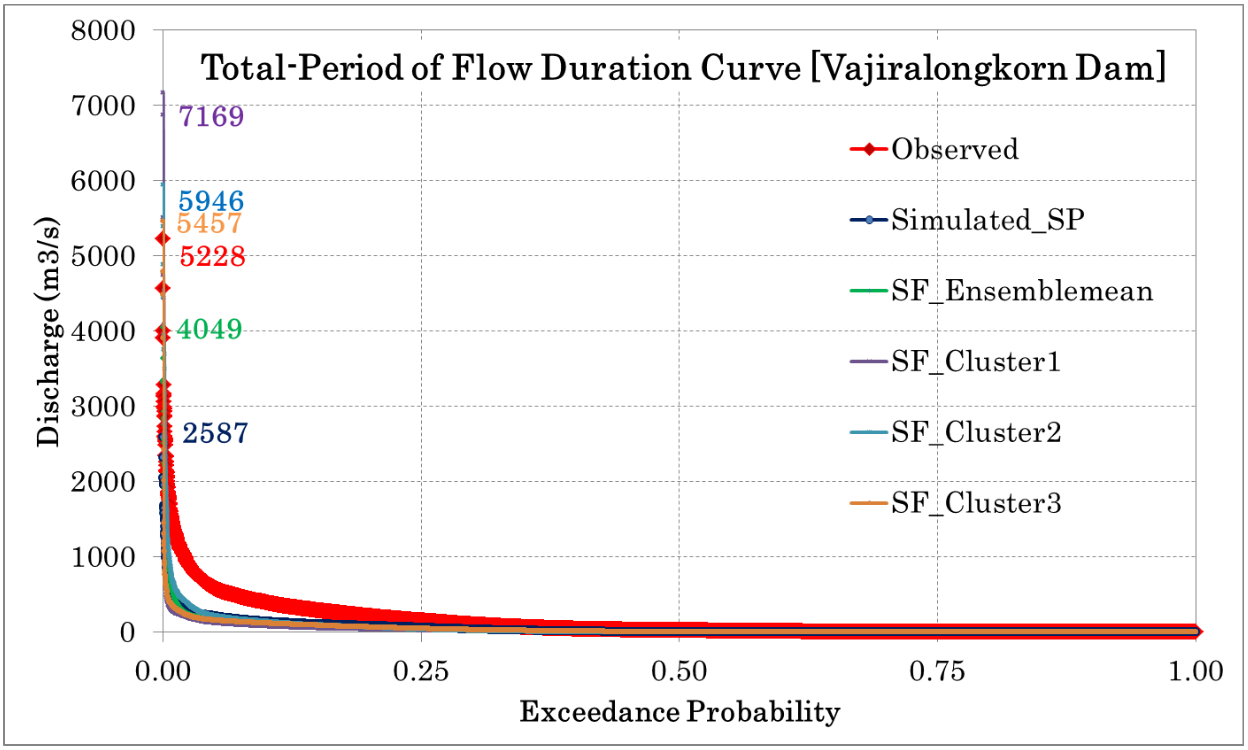
Fig. 4-11 The total-period of flow duration curve in Pasak dam between observed inflow, present and future simulation (upper).The monthly reservoir inflow (in MCM) in Pasak dam between observed inflow, present and future simulation (lower). (see Appendix A14-A19)

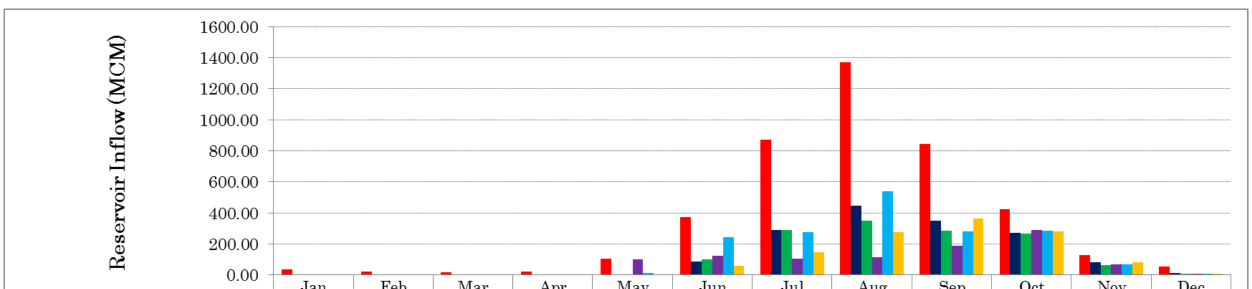




	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed	107.91	75.51	67.51	80.79	146.73	222.01	469.72	869.87	917.82	901.91	370.92	158.58
Simulated_SP	4.79	1.19	0.50	0.50	11.89	132.23	269.30	482.89	610.76	444.82	134.38	27.90
Simulated_SF_Ensemblemean	3.00	0.74	0.35	0.33	19.86	99.63	368.01	361.37	503.04	496.64	115.36	19.72
Simulated_SF_Cluster1	3.99	0.87	0.38	12.11	190.32	245.20	182.85	227.32	478.96	581.07	137.49	24.66
Simulated_SF_Cluster2	2.91	0.77	0.36	0.20	24.36	189.90	301.03	470.89	488.32	502.49	121.74	18.54
Simulated_SF_Cluster3	2.98	0.79	0.38	0.33	26.71	142.36	172.46	385.59	650.25	471.74	130.57	21.22

Fig. 4-12 The total-period of flow duration curve in Srinagarind dam between observed inflow, present and future simulation (upper).The monthly reservoir inflow (in MCM) in Srinagarind dam between observed inflow, present and future simulation (lower) (see Appendix A20-A25).





	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed	37.50	20.68	17.61	22.77	104.82	370.28	872.42	1370.30	844.09	425.03	126.49	54.26
Simulated_SP	0.57	0.09	0.04	0.04	1.89	85.14	290.12	446.22	348.53	269.04	79.23	10.10
Simulated_SF_Ensemblemean	0.38	0.07	0.03	0.02	2.12	98.83	287.91	351.05	283.91	266.83	60.73	5.62
Simulated_SF_Cluster1	0.41	0.07	0.03	0.02	99.21	122.01	102.87	114.76	187.83	290.64	68.63	7.29
Simulated_SF_Cluster2	0.37	0.07	0.03	0.02	14.16	242.01	275.20	538.97	278.80	283.89	68.43	5.52
Simulated_SF_Cluster3	0.39	0.08	0.03	0.02	3.39	59.74	147.40	276.30	365.30	281.22	82.65	7.19

Fig. 4-13 The total-period of flow duration curve in Vajiralongkorn dam between observed inflow, present and future simulation (upper).The monthly reservoir inflow (in MCM) in Vajiralongkorn dam between observed inflow, present and future simulation (lower). (see Appendix A26-A31)

As illustrated in Fig. 4-8, Fig. 4-9 and Fig. 4-10, the reservoir in the Chao Phraya River Basin (BB, SK and PS reservoirs) showed a similar pattern of increasing inflow compared with present climate simulation. Especially, the estimated river discharge during wet season (from May to October) found increase of all months for water resources amount.

Table 4-1 Mean monthly and annual reservoir inflow of each reservoir and relative change between present and future reservoir inflow on different scenarios.

Reservoir Inflow [MCM] at each Reservoir													
MRI-AGCM3.2S		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bhumibol Reservoir (BB)														
1979-2003 (SP)	Average	32.27	8.70	3.71	1.59	15.34	179.93	295.83	635.36	1206.95	881.20	361.26	112.98	3735.13
2075-2099 EN-SST	Relative Change	0.74	0.95	1.08	1.28	3.29	1.31	2.22	1.51	1.18	1.37	1.04	0.83	1.35
2075-2099 C1-SST		0.96	1.19	1.11	1.24	3.11	2.19	1.53	1.36	1.06	1.02	0.87	0.84	1.18
2075-2099 C2-SST		0.87	0.96	1.11	1.25	0.13	2.33	1.61	1.26	1.22	1.37	1.16	1	1.32
2075-2099 C3-SST		0.69	0.76	0.84	0.98	0.4	2.58	1.72	1.53	1.29	1.26	1.03	0.85	1.37
Sirikit Reservoir (SK)														
1979-2003 (SP)	Average	15.85	5.22	2.75	2.01	71.47	369.70	662.00	1220.66	1559.71	794.48	248.73	66.69	5019.25
2075-2099 EN-SST	Relative Change	0.72	1.14	1.32	5.40	0.78	0.89	1.16	1.13	1.07	1.24	0.94	0.73	1.10
2075-2099 C1-SST		0.92	0.80	0.72	0.53	0.58	1.15	1.19	1.17	0.91	1.04	0.94	0.85	1.04
2075-2099 C2-SST		0.89	0.80	1.18	1.38	0.48	1.14	1.17	1.11	1.14	1.23	1.03	0.88	1.13
2075-2099 C3-SST		0.77	0.67	0.59	0.39	0.72	1.36	1.47	1.30	1.02	1.20	1.04	0.89	1.19
Pasak Reservoir (PS)														
1979-2003 (SP)	Average	2.75	1.05	0.55	53.36	91.40	206.02	130.32	170.03	637.63	443.87	39.28	7.01	1783.26
2075-2099 EN-SST	Relative Change	0.67	0.67	1.22	0.06	1.28	0.93	1.64	1.93	1.27	1.48	1.22	0.87	1.33
2075-2099 C1-SST		0.78	0.78	0.79	0.05	1.61	1.46	1.18	1.08	1.05	1.28	1.35	0.90	1.17
2075-2099 C2-SST		0.68	0.67	1.31	0.03	0.55	1.38	1.50	1.40	0.90	1.40	0.96	0.99	1.13
2075-2099 C3-SST		0.73	0.82	1.01	0.09	1.63	1.59	1.50	1.84	1.35	1.27	1.06	0.89	1.38
Srinagarind Reservoir (SR)														
1979-2003 (SP)	Average	4.79	1.19	0.50	0.50	11.89	132.23	269.30	482.89	610.76	444.82	134.38	27.90	2121.14
2075-2099 EN-SST	Relative Change	0.63	0.62	0.70	0.66	1.67	0.75	1.37	0.75	0.82	1.12	0.86	0.71	0.94
2075-2099 C1-SST		0.83	0.73	0.77	24.43	16.01	1.85	0.68	0.47	0.78	1.31	1.02	0.88	0.98
2075-2099 C2-SST		0.61	0.64	0.72	0.41	2.05	1.44	1.12	0.98	0.80	1.13	0.91	0.66	1.00
2075-2099 C3-SST		0.62	0.67	0.76	0.66	2.25	1.08	0.64	0.80	1.06	1.06	0.97	0.76	0.95
Vajiralongkorn Reservoir (VRK)														
1979-2003 (SP)	Average	0.57	0.09	0.04	0.04	1.89	85.14	290.12	446.22	348.53	269.04	79.23	10.10	1531.01
2075-2099 EN-SST	Relative Change	0.67	0.76	0.81	0.66	1.12	1.16	0.99	0.79	0.81	0.99	0.77	0.56	0.89
2075-2099 C1-SST		0.72	0.77	0.83	0.58	52.36	1.43	0.35	0.26	0.54	1.08	0.87	0.72	0.65
2075-2099 C2-SST		0.65	0.76	0.83	0.52	7.47	2.84	0.95	1.21	0.80	1.06	0.86	0.55	1.12
2075-2099 C3-SST		0.69	0.87	0.89	0.58	1.79	0.70	0.51	0.62	1.05	1.05	1.04	0.71	0.80

Remark: Red shading area indicates decreasing inflow volume and Blue shading area indicates increasing inflow volume.

4.4 Conclusion

- For flow routing model parameter evaluation, the total-period of flow duration curve at each dam site were constructed to compare with flow duration curve of observation data. The results showed that the model curve were more close to observed data, although the simulation of west study area showed an underestimation of the simulated river discharge.

- Through the analysis of reservoir water availability in study area by flow duration curve and monthly average inflow analysis, the Bhumibol (BB) reservoir , Sirikit (SK) reservoir and Pasak (PS) reservoir inflow will increase in rainy season (May to October) and flow duration curve of BB, SK and PS reservoir in the future climate experiment will rise up from present climate; However, the reservoir water availability in western part of selected dam will decrease on the future flow duration curve and monthly inflow.

- The peak discharge will increase dramatically of all selected reservoirs.

- Our results of the relative change in reservoir inflow between present and future climate conditions indicate that the future inflow in BB, SK and PS reservoirs during rainy season will increase in all month and scenarios expect the Sirikit dam inflow in May. Although, the amount of water available in SK dam and VSK dam will also reduce in majority of months except May and October.

Chapter 5

Evaluation of bias correction methods for future river discharge projection

Abstract *The objective of this chapter is to apply the differential split-sample test (DSST) to evaluate appropriate bias correction methods for future river discharge projection using the present climate GCMs data for dry and wet years and observed data for validation. A distributed flow routing model (1K-FRM) is used to obtain the dry and wet years in the present climate experiment by inputting the runoff generation data output from MRI-AGCM3.2S, a 20 km spatial resolution general circulation model (GCMs) developed by the Meteorological Research Institute, Japan. The Nan River Basin in Thailand is selected and several kinds of bias corrected inflow to Sirikit reservoir located at midstream of Nan River Basin are evaluated for a time period of 1979-2003. An effective bias correction method is proposed with suitable statistical performance considering a non-stationary condition for applying the bias correction methods for future discharge estimation.*

5.1 Introduction

Bias correction methods are commonly used for corrections of model errors from general circulation models (GCMs) to properly estimate future river discharge assessment for hydrological impact studies (IPCC, 2013). Several bias correction with different techniques were applied to meteorological data such as precipitation and temperature for improvement of model errors before applying GCM outputs to hydrological models. However, research findings of direct application of bias correction methods on river discharge are limited.

Several impact studies by using GCM runoff generation output were conducted at the Chao Phraya River basin in Thailand. For example, Hunukumbura and Tachikawa (2012) used the runoff projected by MRI-AGCM3.1S, which showed the increasing of extreme discharge at the upper part of Chao Phraya River basin. Duong *et al.*, (2013) examined the impact of river discharge changes by using runoff generation data of MRI-AGCM3.2S in the Indochina Peninsula region. To analyze the projected river discharge data for future water resources evaluation, bias correction for river discharge is indispensable. In this study, the differential split-sample test (DSST) is used to evaluate appropriate bias correction methods for future river discharge projection and propose a suitable bias correction method for river discharge in a non-stationary condition.

5.2 Methodology

To evaluate the performance of bias correction techniques for a non-stationary condition in term of a changing climate condition, Teutschbein *et al.*, (2012) applied an operational testing to five different catchments in Sweden. Chong-yu Xu (1999) also used an operational testing of a water balance model on both stationary and non-stationary conditions. In this study, a post-bias correction method correcting estimated river discharge data, not correcting input data to a hydrological model such as precipitation and temperature is our interest for applying bias corrections for a practical way more than pre-bias correction to various hydrological parameters. In this paper, we accessed the differential split-sample test (DSST) to evaluate appropriate a post-bias correction method. The summary of each activity for evaluation of bias correction methods is shown in Fig. 5-1.

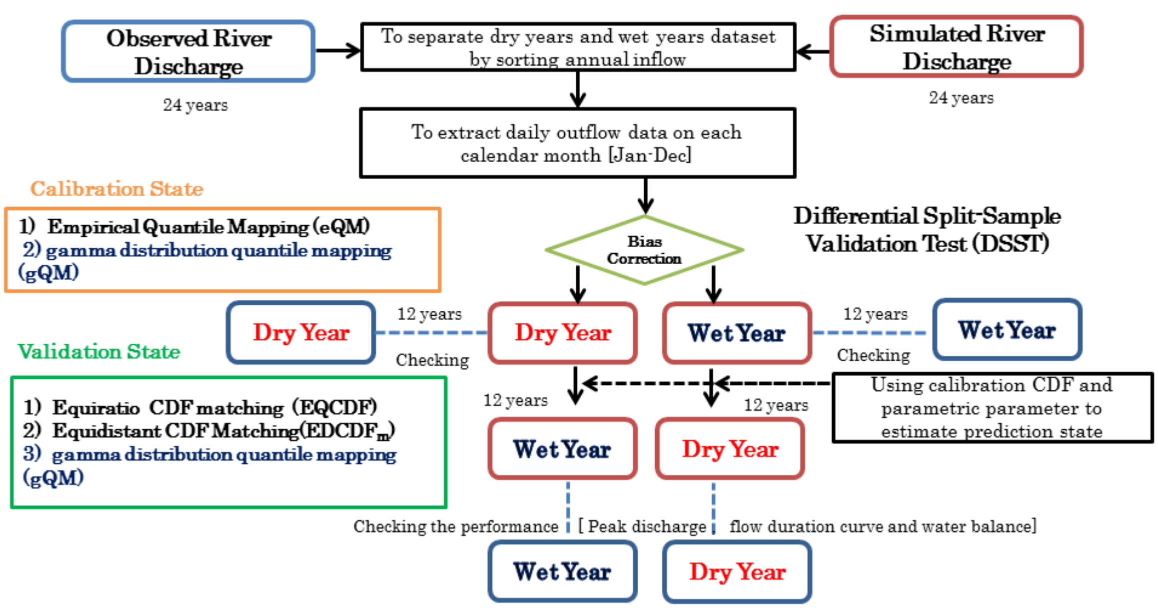


Fig. 5-1 Flowchart of bias correction methods evaluation.

5.2.1 Study area selection

The Sirikit reservoir with coverage catchment area of 13,130 km^2 is located of the midstream of Nan River basin in Thailand as shown in Fig.5-2. The upstream of the Sirikit reservoir is a mountainous area which is not affected by major flow regulations or any other direct human activities impacts. The continuous time series data of observed inflow into the reservoir is available for the period of 1979-2003. Its climate is tropical with distinctly clear dry and wet seasons. The seasons are defined as follows: the dry season starts from November until April and the wet season starts from May until October.

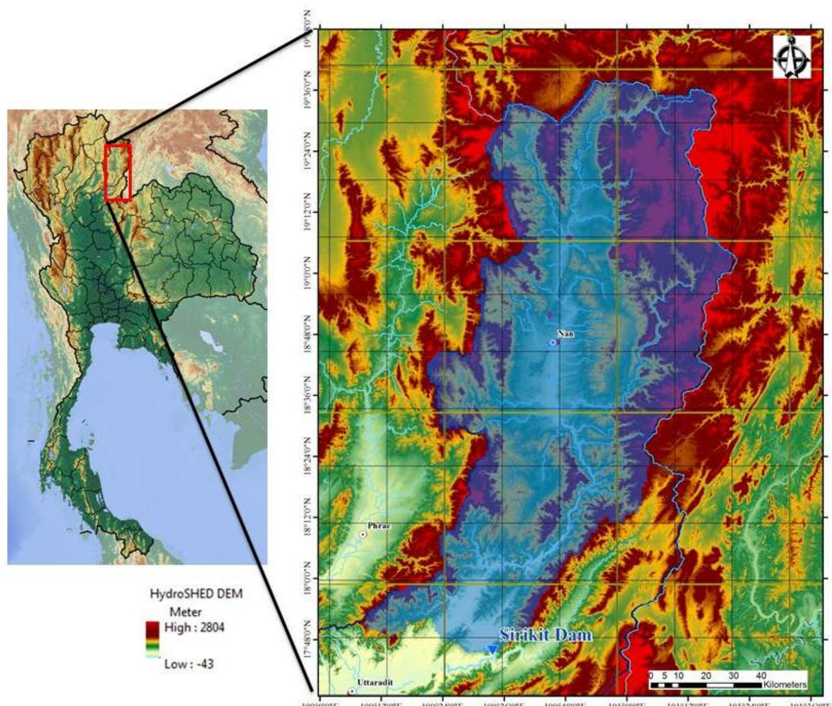


Fig. 5-2 Map showing the study area, reservoir location and spatial 20 km x 20 km square grid of MRI-AGCM3.2S.

5.2.2 River discharge data

The GCM outputs used for this research were gridded runoff generation data from MRI-AGCM 3.2S (Mizuta *et al.*, 2012), where 'S' refers to super-high resolution developed by Japan Meteorological Agency (JMA) and the Meteorological Research Institute (MRI). The AGCMs grids covering the Sirikit reservoir study area were total of 88 grids (8 columns and 11 rows) with the spatial resolution 0.1875 degree (approximately 20 km), located between the latitude of 17 degrees 42 minutes and 19 degrees 35 minutes north and the longitude of 100 degrees 7 minutes and 101 degrees 26 minutes east. For each 20-km grid cell, the various hydrological components of MRI-AGCM 3.2S such as precipitation, evaporation, transpiration and surface runoff generation were calculated through the land surface scheme of Simplified Biosphere (SiB) model (Sellers *et al.*, 1986), originally developed by Sellers. Afterward, the SiB model was revised by MRI for calculation of soil water storage, total runoff which consists of the combination of surface and sub-surface runoff generation. The schematic diagram of surface runoff generation data of each grid cell is illustrated in Fig. 5-3 a).

The runoff generation of MRI-AGCM3.2S was used to simulated river discharge at the Sirikit reservoir by a distributed flow routing model (1K-FRM) based on the kinematic wave theory, which was develop by the hydrology and water resources research laboratory, Kyoto University (Tachikawa and Tanaka, 2013). The runoff generation data of all slope units was given to the flow routing model using the 8-direction method which assumes the flow direction one-dimensionally to the steepest gradient direction as shown in Fig.5-3 b). The 30 arc-second (1km) Digital Elevation Model (DEM) and flow direction stored in HydroSHEDS (USGS, 2011) provides hydrographic information for regional and global scale based on NASA's Shuttle Radar Topography Mission (SRTM), which were used to develop the topography data of 1K-FRM. All period of simulation have been performed at a spatial resolution of 1 km and temporal resolution of one day. For the verification data, the observed time series of daily inflow was obtained from the Electricity Generating Authority of Thailand (EGAT).

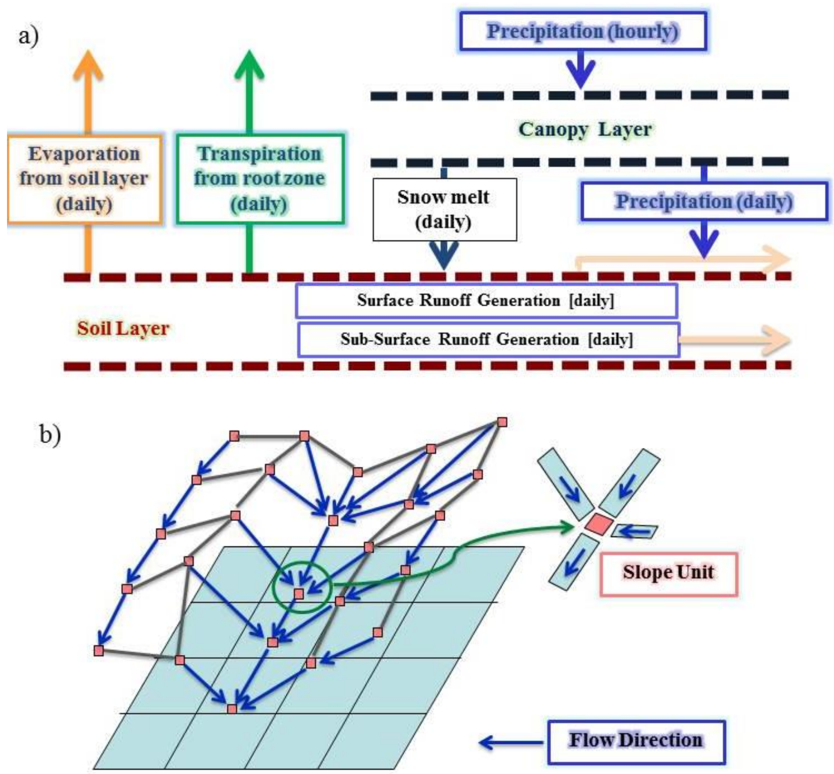


Fig. 5-3 The framework diagram river discharge simulation.

a) Land surface generation data of MRI-AGCM3.2S fed into river discharge simulation in a grid. b) Schematic drawing of a catchment and flow routing model using HydroSHEDS DEM.

5.2.3 Bias correction methods

A recent bias correction method based on a relationship of cumulative distributions (CDFs) of the GCMs and observation data has been commonly used for hydrologic simulations and climate change studies. In this study, two variant of distribution mapping methods are applied to raw daily river discharge data simulated by using GCMs runoff generation data. The distribution mapping technique adjusts all particles of the cumulative distribution function (CDF) of projected data with GCM outputs by using the CDF of observation and construct a transfer function to convert the projected data using GCMs to corrected data. All bias correction methods of quantile mapping have to initiate by 1) sorting long-term observation and simulation river discharge data to create CDFs for each calendar month (Jan-Dec); 2) correcting bias in the frequency and intensity distribution on each different method; and 3) rearranging corrected data back to the original time series. The exemplary procedure of the quantile mapping is illustrated in Fig.5-4.

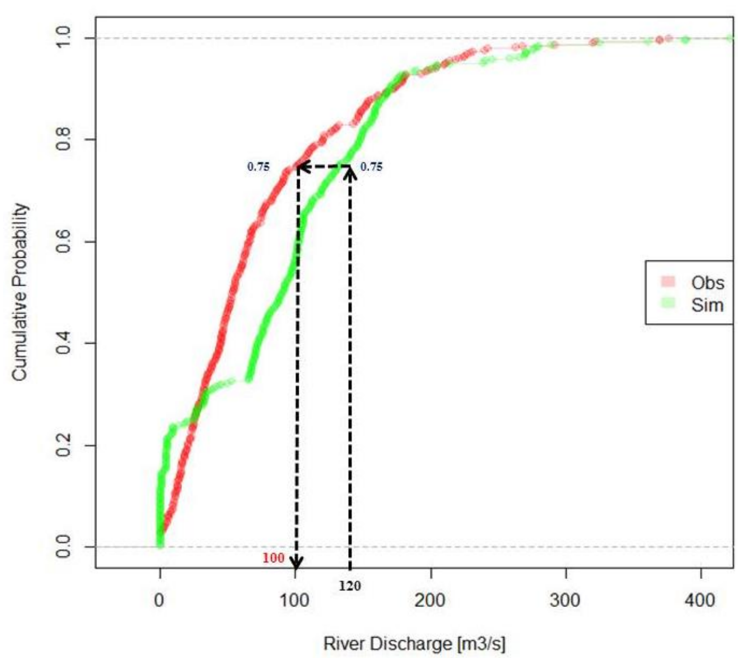


Fig. 5-4 Exemplary procedure of the quantile mapping.

Empirical quantile mapping (eQM)

The classical distribution quantile mapping is expressed by setting the pair with the same non-exceedance probability as follow

$$Q^{*}_{c} = F^{1}_{obs,C}(F_{raw,C}(Q_{raw,C})) \tag{5-1}$$

where Q^* is the corrected river discharge value, $Q_{raw,C}$ is the raw original river discharge value and $F^{-1}_{obs,C}$ stands for the inverse function of CDFs of the observed daily discharge, and accordingly $F_{raw,C}$ as the CDFs of the projected river discharge using MRI-AGCM3.2S. The probability of projected river discharge is thus transferred to the quantile of the observed CDF by matching exactly this probability. Hence, equation (1) is used to remove a bias for control period only.

However, for the application of eQM method to the future climate condition, if we assume that the transfer function is stable and follows the same current climate condition, the assumption would be violated for future periods especially maxi-mum peak discharge, so we proposed the other two methods by using the relationship between CDFs of GCM projection and observation river discharge Both methods proposed by Wang *et al.* and *Li et al.* First of all, the eQM with the ratio or referred to as equiratio CDF matching (EQCDF) is described as following equation:

$$Q^{*}_{P} = Q_{raw,P} \quad \frac{F^{1}_{obs,C}(F_{raw,P}(Q_{rawP}))}{F^{1}_{raw,C}(F_{raw,P}(Q_{rawP}))} \tag{5-2}$$

where, $Q_{raw,P}$ is the original river discharge value for the future projection period. The $F^{-1}_{obs,C}$ and $F^{-1}_{raw,C}$ stand for the inverse function of CDFs of the observations and raw GCMs during calibration period, respectively.

Second, the eQM with the difference of CDFs or referred to as equidistant CDF matching (EDCDFm; Li *et al.*) is calculated by adding the difference between CDFs of GCM and observation river discharge during calibration as following equation:

$$Q^*_P = Q_{raw,P} + [F^{-1}_{obs,C}(F_{raw,P}(Q_{raw,P})) - F^{-1}_{raw,C}(F_{raw,P}(Q_{raw,P}))] \tag{5-3}$$

So, equation (2) and (3) are used for validation in prediction period.

Empirical with gamma distribution quantile mapping (gQM)

The gamma distribution with shape parameter β and scale parameter α is defined as:

$$f(x) = x^{\alpha-1} \cdot \frac{1}{\beta^{\alpha} \cdot \Gamma(\alpha)} \cdot e^{\frac{-x}{\beta}} ; x, \alpha, \beta > 0 \tag{5-4}$$

where Γ is the gamma function. In this study, the shape and scale parameter were fitted with observation and GCMs projection on each calendar month. The gQM method is a parametric correction method which can be expressed as:

$$Q^*_c = F_Y^{\ 1}(F_Y(Q_{raw,C} \mid \alpha_{raw,C}, \beta_{raw,C}) \mid \alpha_{obs,C}, \beta_{obs,C}) \tag{5-5}$$

$$Q^*_p = F_Y^{\ 1}(F_Y(Q_{raw,P} \mid \alpha_{raw,C}, \beta_{raw,C}) \mid \alpha_{obs,C}, \beta_{obs,C}) \tag{5-6}$$

5.2.4 Operational testing of stationarity assumption

To evaluate each bias correction procedure on different climate condition, we employed the differential split-sample test (DSST) presented by Kleme (1986). In this study, the first step of this test comprises the classification of two equal periods with wet and dry years by sorting ascending according to their annual amount of observed and simulated inflow. The test starts to develop a bias correction relation calibration on the period of one condition and validates the relation on the period with another condition. Afterward, twofold cross-validations were switched. Therefore, the pair of available river discharge of 25 years (from 1979-2003) were separated into two 12 year subsets with different climate condition as illustrated in Fig.5-4.

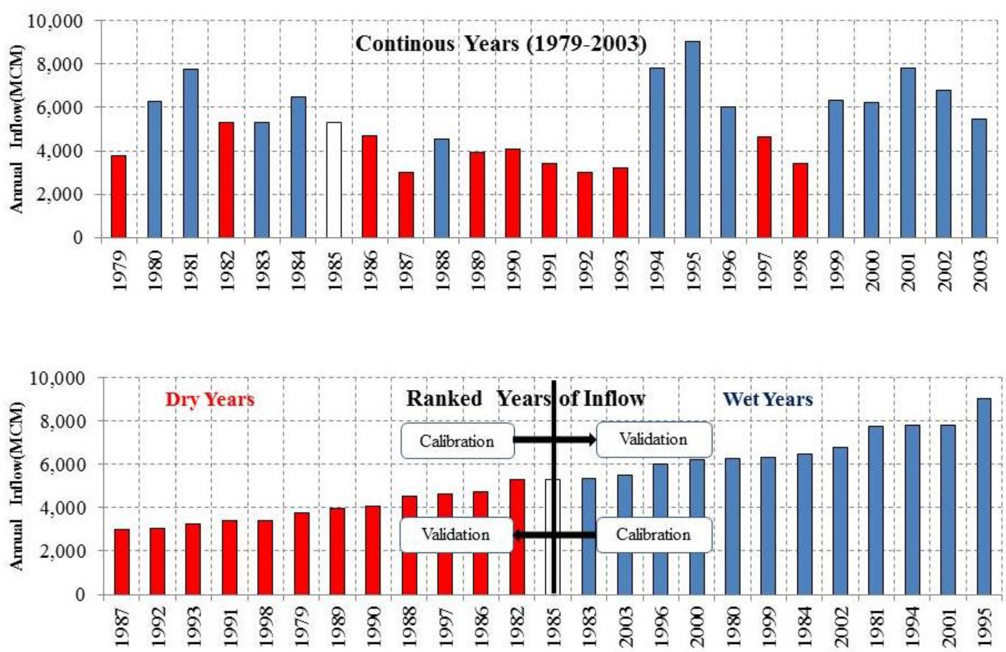


Fig. 5-5 procedure of the differential split-sample test (DSST).

5.3 Results and discussion

5.3.1 Bias correction for control period

Fig. 5-6 and Fig. 5-7 show the comparisons of total flow duration curves between the projected river discharge without bias correction, observed discharge and bias-corrected discharge during 12 dry years and wet years condition, respectively. The results found that the biases were found on projected river discharge especially in low flow. After applying both the distribution mapping (eQM and gQM), the results had a good matching with the dry years and wet years observation data. Furthermore, both bias corrections showed similar pattern of inflow with observed inflow. As illustrated in Fig. 5-8 and Fig. 5-9, the projected river discharge simulation obviously found underestimation in the dry season (50 % for dry year dataset and 51 % for wet year dataset) and overestimation in the late wet season. The percentage of water volume difference between eQM, gQM corrected and observed river discharge data are lower than 2% change (see Table. 5-1 and Table. 5-2)

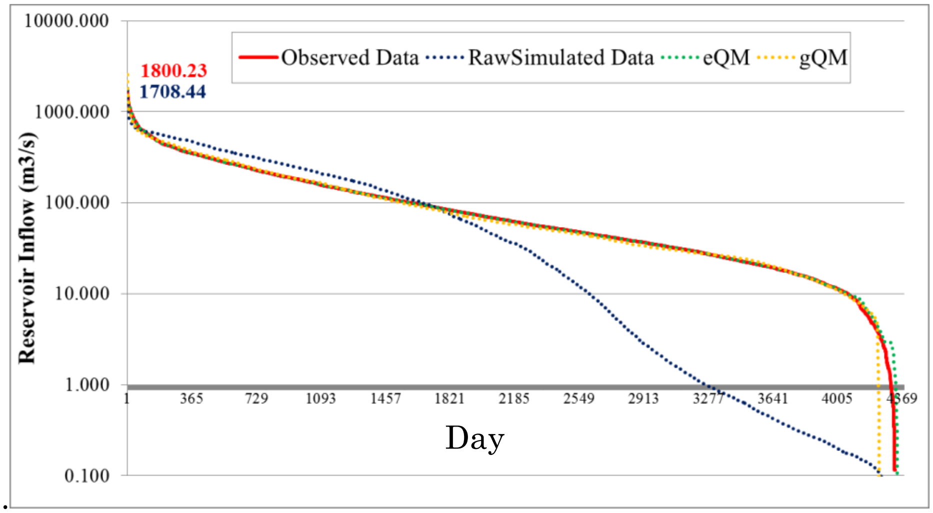


Fig. 5-6 The total flow duration curve of dry year dataset.

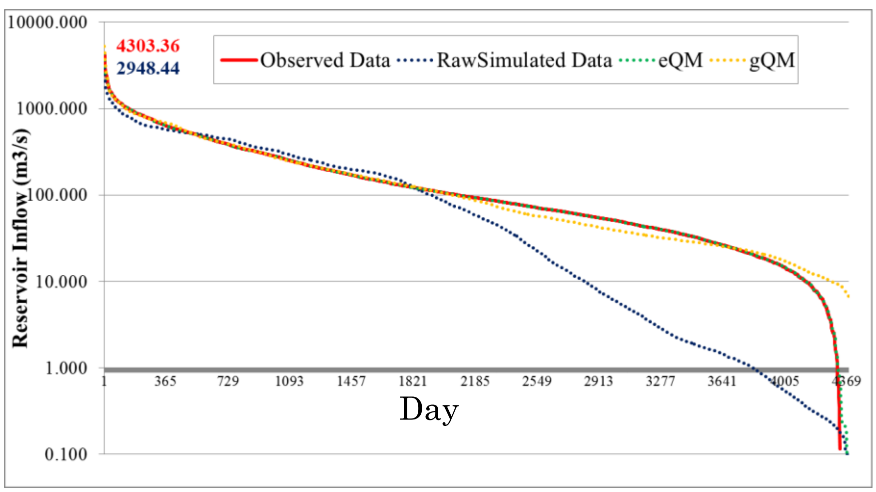


Fig. 5-7 The total flow duration curve of wet year dataset.

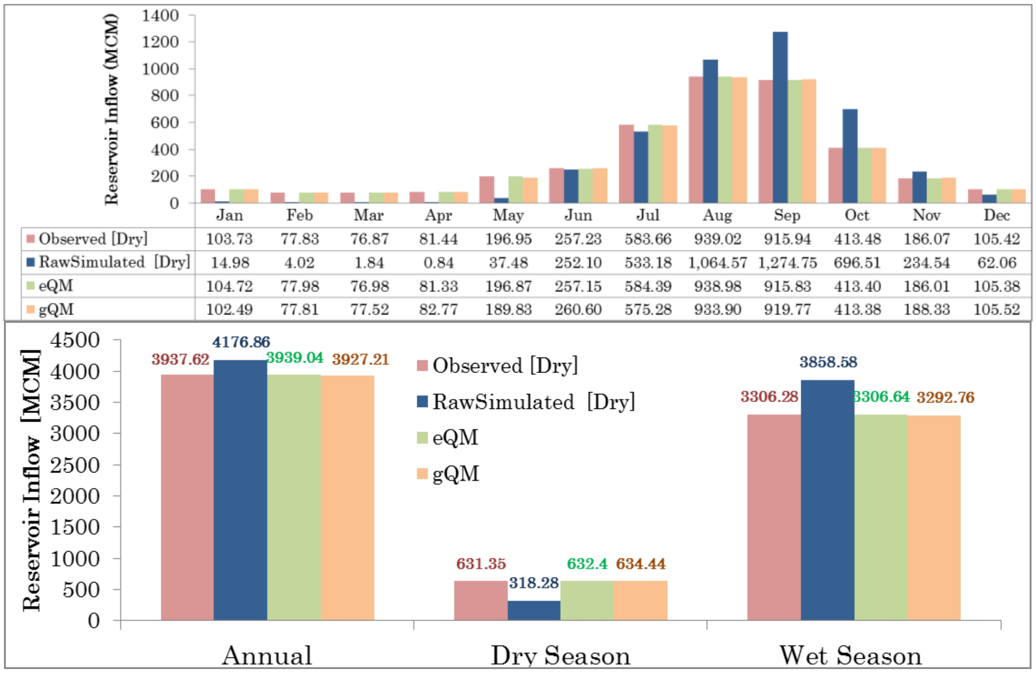


Fig. 5-8 Monthly, seasonal and annual reservoir inflow of various dataset in dry year dataset.

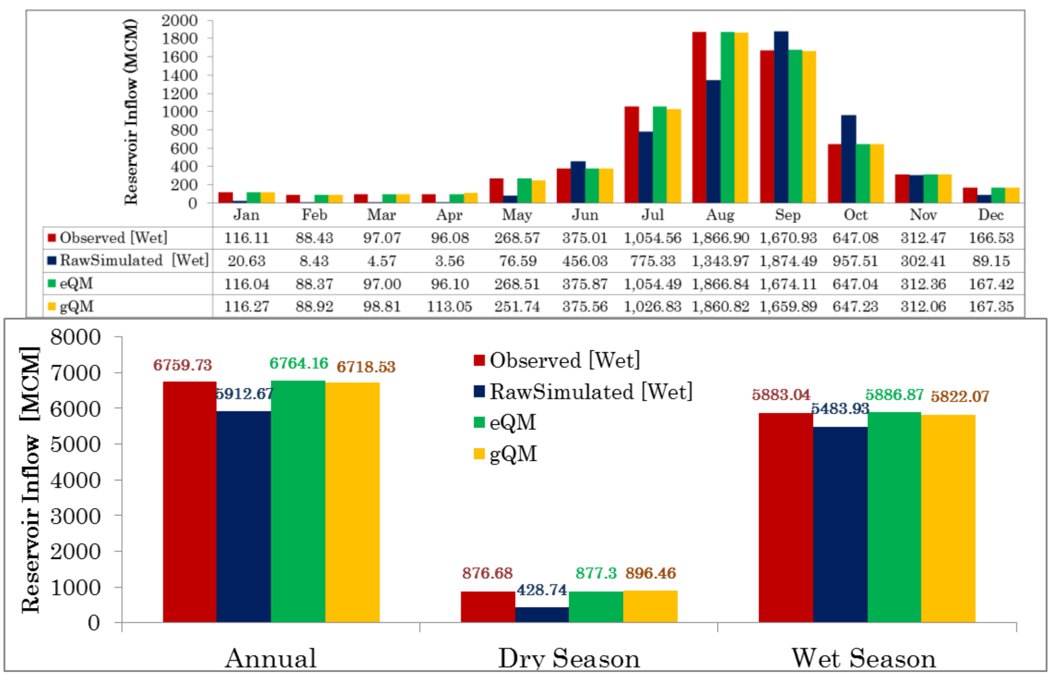


Fig. 5-9 Monthly, seasonal and annual reservoir inflow of various dataset in wet year dataset.

Table 5-1 Amount of average annual and seasonal reservoir inflow (unit: million cubic meters) and percentage of water balance between different dataset during dry year control period.

Unit : MCM	Annual	Dry Season	Wet Season	Percentage of water volume difference		
				Annual	Dry Season	Wet Season
Observed [Dry]	3937.62	631.35	3306.28			
RawSimulated [Dry]	4176.86	318.28	3858.58	6.08	-49.59	16.70
eQM	3939.04	632.4	3306.64	0.04	0.17	0.01
gQM	3927.21	634.44	3292.76	-0.26	0.49	-0.41

Table 5-2 Amount of average annual and seasonal reservoir inflow (unit: million cubic meters) and percentage of water balance between different dataset during wet year control period.

Unit : MCM	Annual	Dry Season	Wet Season	Percentage of water volume difference		
				Annual	Dry Season	Wet Season
Observed [Wet]	6759.73	876.68	5883.04			
RawSimulated [Wet]	5912.67	428.74	5483.93	-12.53	-51.10	-6.78
eQM	6764.16	877.3	5886.87	0.07	0.07	0.07
gQM	6718.53	896.46	5822.07	-0.61	2.26	-1.04

5.3.2 Bias correction for validation period

Validation in wet year condition

According to the calculation of the bias correction method by the EQCDF, the discharge of the high rank quantile produced innumerable value due to the little value of the inverse function from raw CDFs of MRI-AGCM3.2S derived from the dry years calibration as shown in Fig.5-10.

For the validation step into the wet year dataset, the seasonal and annual water volume balance were found that underestimation occurs of EQCDF and EDCDFm except the gQM method was found slightly overestimation as summarize in Table. 5-3 and Fig. 5-11 (16 % for EDCDFm and 4 % for gQM). However, the EDCDFm method was improved to close observed river discharge in the wet year dataset in the dry season nevertheless the gQM method was reproduced overestimation (42 %).

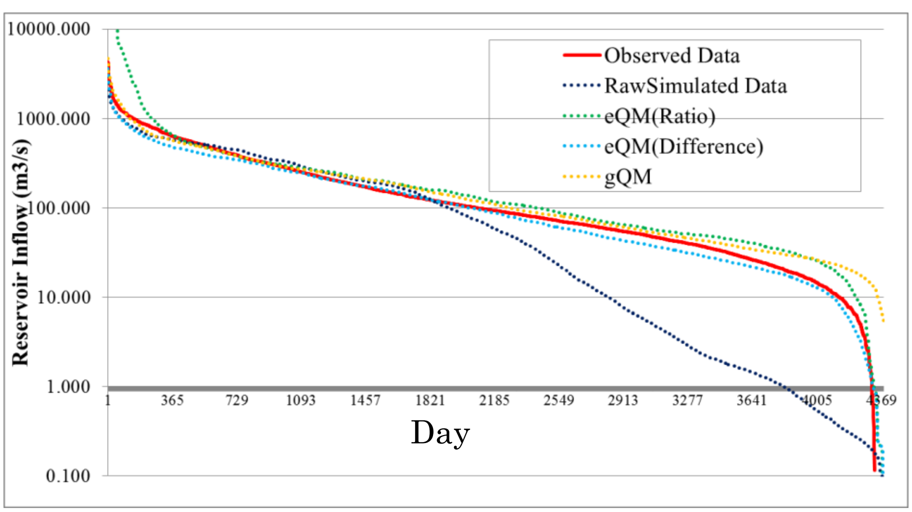


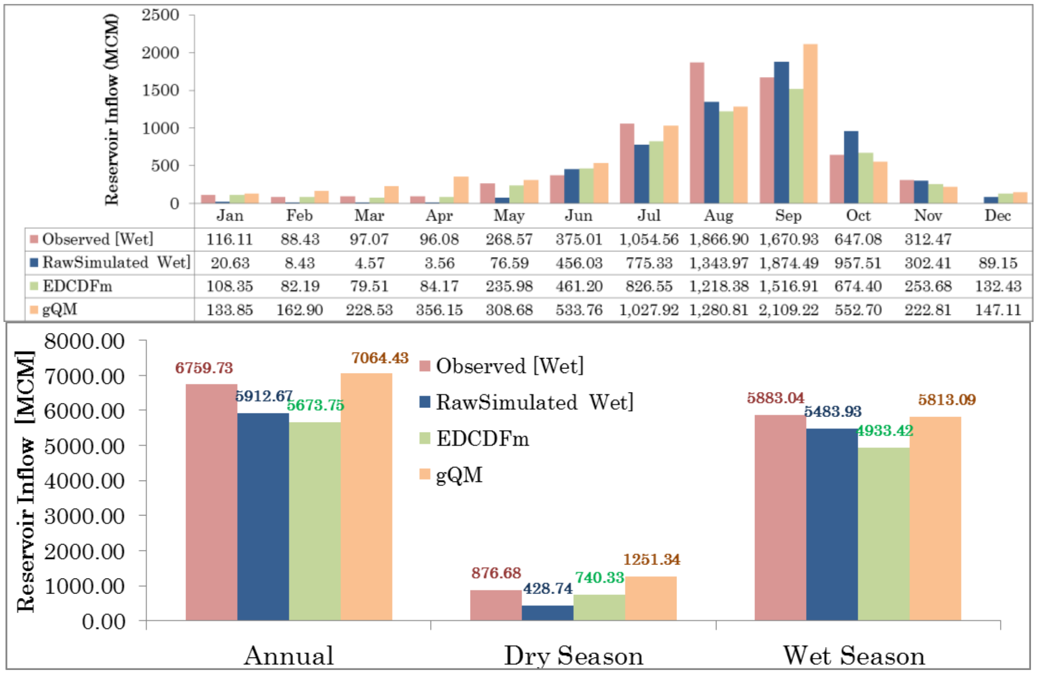
Fig. 5-10 The total flow duration curve of dry year dataset.

Table 5-3 Amount of average annual and seasonal reservoir inflow (unit: million cubic meters) and percentage of water balance between different dataset for wet year with dry years calibration.

Unit : MCM	Annual	Dry Season	Wet Season	Percentage of water volume difference		
				Annual	Dry Season	Wet Season
Observed [Wet]	6759.73	876.68	5883.04			
RawSimulated Wet]	5912.67	428.74	5483.93	-12.53	-51.09	-6.78
EQCDF	-	-	-	-	-	-
EDCDFm	5673.75	740.33	4933.42	-16.07	-15.55	-16.14
gQM	7064.43	1251.34	5813.09	4.51	42.74	-1.19

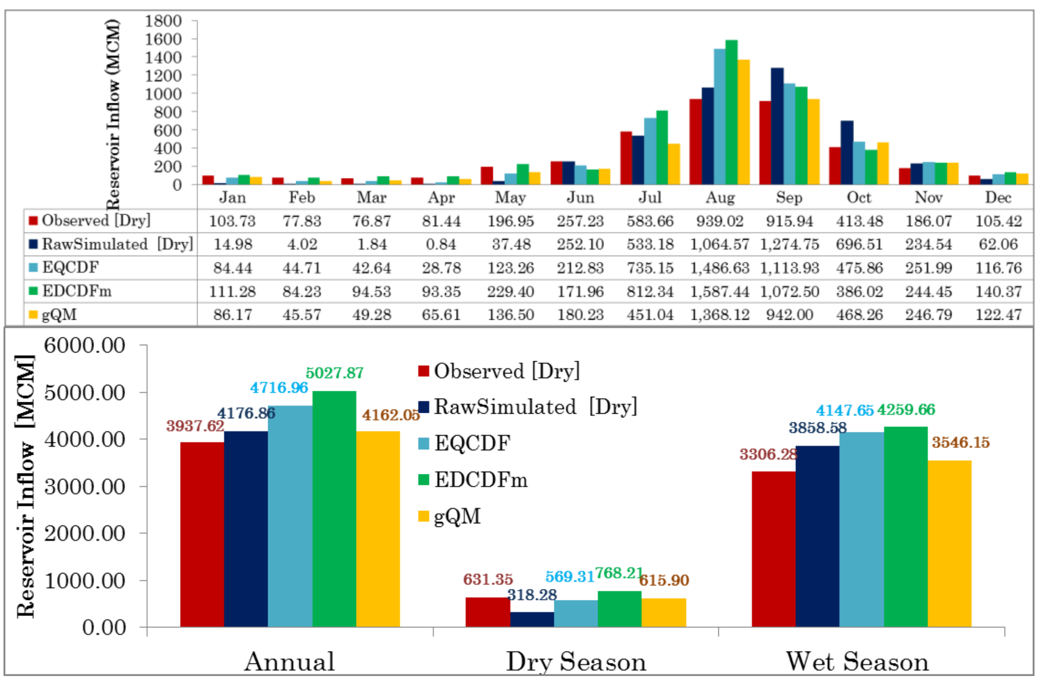
Validation in dry year condition

In the validation for the dry year dataset, the contrast results is similarly found that an overestimation throughout the dry year validation period when is used the transfer function of the wet year as summarize in Fig. 5-12 and Table. 5-4 (19 % for EQCDF, 28% for EDCDFm and 6 % for gQM of average annual amount of reservoir inflow).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed [Wet]	116.11	88.43	97.07	96.08	268.57	375.01	1,054.56	1,866.90	1,670.93	647.08	312.47	
RawSimulated Wet]	20.63	8.43	4.57	3.56	76.59	456.03	775.33	1,343.97	1,874.49	957.51	302.41	89.15
EDCDFm	108.35	82.19	79.51	84.17	235.98	461.20	826.55	1,218.38	1,516.91	674.40	253.68	132.43
gQM	133.85	162.90	228.53	356.15	308.68	533.76	1,027.92	1,280.81	2,109.22	552.70	222.81	147.11

Fig. 5-11 Monthly, seasonal and annual reservoir inflow of various dataset in wet year dataset with dry years calibration.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed [Dry]	103.73	77.83	76.87	81.44	196.95	257.23	583.66	939.02	915.94	413.48	186.07	105.42
RawSimulated [Dry]	14.98	4.02	1.84	0.84	37.48	252.10	533.18	1,064.57	1,274.75	696.51	234.54	62.06
EQCDF	84.44	44.71	42.64	28.78	123.26	212.83	735.15	1,486.63	1,113.93	475.86	251.99	116.76
EDCDFm	111.28	84.23	94.53	93.35	229.40	171.96	812.34	1,587.44	1,072.50	386.02	244.45	140.37
gQM	86.17	45.57	49.28	65.61	136.50	180.23	451.04	1,368.12	942.00	468.26	246.79	122.47

Fig. 5-12 Monthly, seasonal and annual reservoir inflow of various dataset in wet year dataset with wet years calibration.

Table 5-4 Amount of average annual and seasonal reservoir inflow (unit: million cubic meters) and percentage of water balance between different dataset for dry year with wet years calibration.

Unit : MCM	Annual	Dry Season	Wet Season	Percentage of water volume difference		
Observed [Dry]	3937.62	631.35	3306.28	Annual	Dry Season	Wet Season
RawSimulated [Dry]	4176.86	318.28	3858.58	6.08	-49.59	16.70
EQCDF	4716.96	569.31	4147.65	19.79	-9.83	25.45
EDCDFm	5027.87	768.21	4259.66	27.69	21.68	28.84
gQM	4162.05	615.90	3546.15	5.70	-2.45	7.26

However, the all river discharge corrected data results were also improved to close observed river discharge in wet year dataset in dry season same as another validation case before as shown in Fig.5-13.

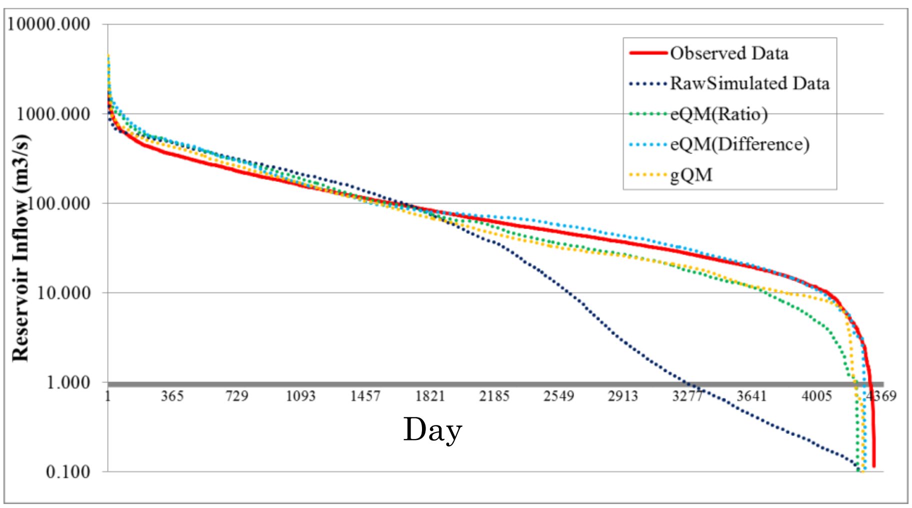


Fig. 5-13 The total flow duration curve of wet year dataset.

5.3.3 Overall performance of bias correction methods

The evaluation of average projected and corrected GCMs river discharge showed clearly improvement and reduces the bias in dry season of all experiment cases compared with twofold observation. This finding also found that when the climate condition change dramatically as the dummy time series of different climate, the corrected river discharge results would divergence change. Furthermore, all bias correction methods of distribution mapping can reduce the bias during low flow to the same frequency and intensity with observation river discharge of dry and wet year conditions (Fig. 5-10 and Fig. 5-13). However, the results can be showed that the classical quantile mapping algorithms corrupt relative trend in the river discharge extremes. The ECCDFm and EQCDF explicitly preserve relative changes in all quantiles of a distribution (Cannon *et al.*, 2016).

5.4 Conclusion

During calibration period, the both eQM and gQM bias correction techniques were improved in the raw twofold current climate condition (1979-2003) that were heavily biased from ob-served river discharge during dry season, to close in a good agreement with the observed river dis-charge.

For the validation of the bias correction method, the equidistant CDF matching (EDCDFm) and the empirical with gamma distribution quantile mapping (gQM) methods showed the good overall performance and applicable to potentially changed climate condition in term of less bias of water balance and proper for adjusted peak river discharge. However, the empirical with gamma distribution quantile mapping (gQM) also found the lowest performance of water balance volume compare with EDCDFm and EQCDF methods in validation process into wet year dataset with dry years calibration. The equiratio CDF matching (EQCDF) method still found the improper corrected results in validation process into wet year dataset due to less raw simulation discharge occurred in dry year dataset.

For the future climate condition, the choice seems difficult to select method with non-stationary condition. Though the differential split-sample test (DSST), EDCDFm and gQM methods showed good performance in non-stationary condition. For EQCDF method, we found that high flow rank river discharge was overestimated due to non-stationarity in dry and wet years. Based on the finding of Duong *et al.* (2013), the future river discharge in Chao Phraya River basin also showed increase tendency. Therefore, to consider about the change of future river discharge projection, the EDCDFm and gQM methods are appropriate bias correction technique to ensure the transferability of the correction approach to different climate condition.

Chapter 6

River inflow and reservoir operation assessment under a changing climate on large scale reservoir in Thailand

Abstract *This chapter applies the future reservoir inflow after removing the suitable bias correction method for reservoir operation assessment in term of future water storage and release flow under different scenarios. The effective bias-corrected input forcing data method in Sirikit reservoir as mentioned in previous chapter also uses for reservoir operation algorithms. The artificial neural network (ANN) technic is used to estimate the daily released flow based on a large number of historical reservoir inflow and water storage inputs for evaluation the changes of water storage and release in the various future climate scenario.*

6.1 Introduction

This chapter aims to estimate the future water storage and to evaluate the tendency of excess water use (flood risk) and insufficient water use (drought risk) by given the bias-corrected river discharge based on the methodology of previous chapter. The Flowchart of reservoir simulation procedure for calculated future reservoir outflow and storage is shown as Fig. 6-1. Kim *et.al* (2009) investigated the adaptability of current dam operation rules under climate change condition to a dam in the upper part of Tokyo, Japan based on AGCM20 input data.

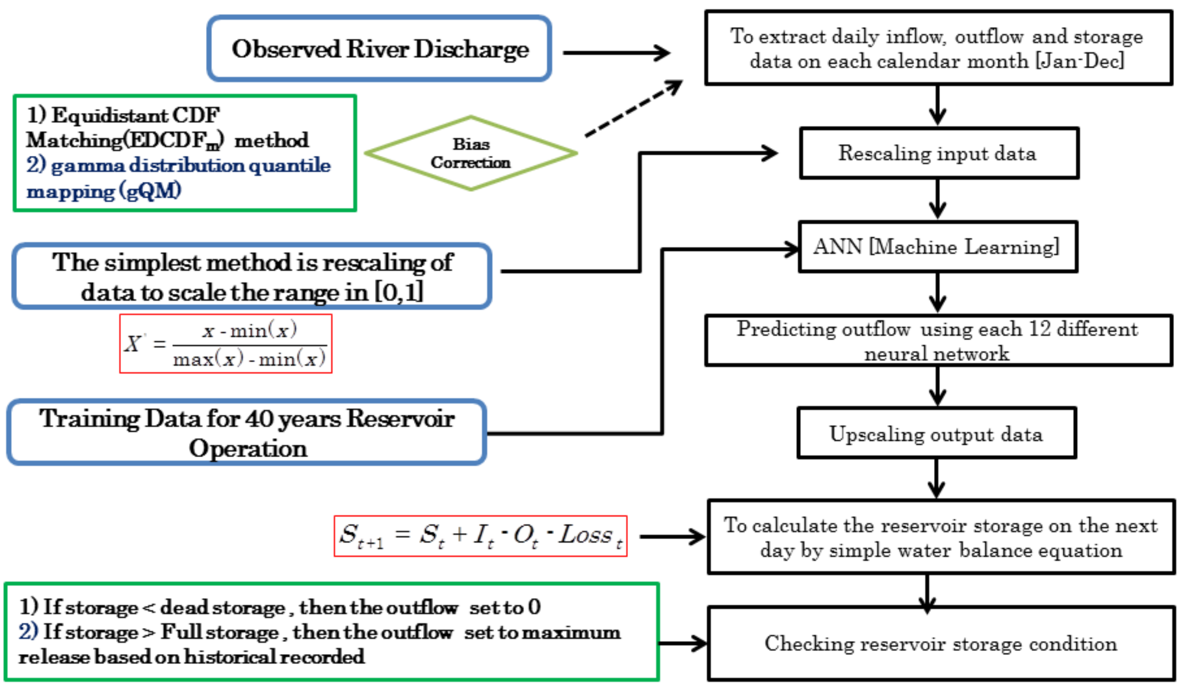


Fig. 6-1 Flowchart of reservoir simulation for future reservoir outflow and storage.

6.2 Methodology

6.2.1 Study area and input data

The raw original output of river discharge simulation results as showed in Chapter 4 has been processed to remove the bias by adopted the methodology of differential split-sample test (DSST) in Charter 5 to reduce the number of bias correction method. There are two bias correction methods to improve the four raw different future reservoir inflow data. The empirical distribution quantile mapping with difference between cumulative distribution functions (CDFs) of GCM and observation river discharge (eQM) and the empirical with gamma distribution quantile mapping (gQM) are used to correct river discharge results.Study area is also continuously to select the catchment area of upstream Sirikit reservoir dam in Thailand.

6.2.2 Reservoir operation modeling approach

The Artificial Neural Network (ANN) is selected to learn the past reservoir operation and transferred to the machine learning. The relationship of storage and reservoirs inflow is important to give through covariates (also known as input variables) and response variables (also known as output variables) is represented as release flow of reservoir. The ANN consists of the neurons are organized in layers, which are usually fully connected by synapses. A synapse can only connect to subsequent layers. The input layer consists of all covariates in separate neurons and the output layer consists of the response variables.

The layers in between input and output layers are referred to as hidden layers, as they are not directly observable. Input layer and hidden layers include a constant neuron relating to intercept synapses. The number of hidden layers and numbers of nodes in each hidden layer are usually determined by a trial-and-error procedure (Govindaraju, R. S., 2000); therefore, the output of a node in a layer is only a dependent on the inputs it receives from previous layers and the corresponding weight. Fig. 6-2 shows the example of a neural network with three hidden layer that consists of five, three and two hidden neurons, respectively. In this study, the number of hidden layer and neurons were selected by a trial-and-error after comparison the best fitted of simulated outflow and the observed outflow.

This neural network models the relationship between the two covariates (inflow and water storage) and the response variable outflow. This neural network model theoretically allows inclusion of arbitrary numbers of covariates and response variables. However, there can occur convergence difficulties using a huge number of both covariates and response variables.

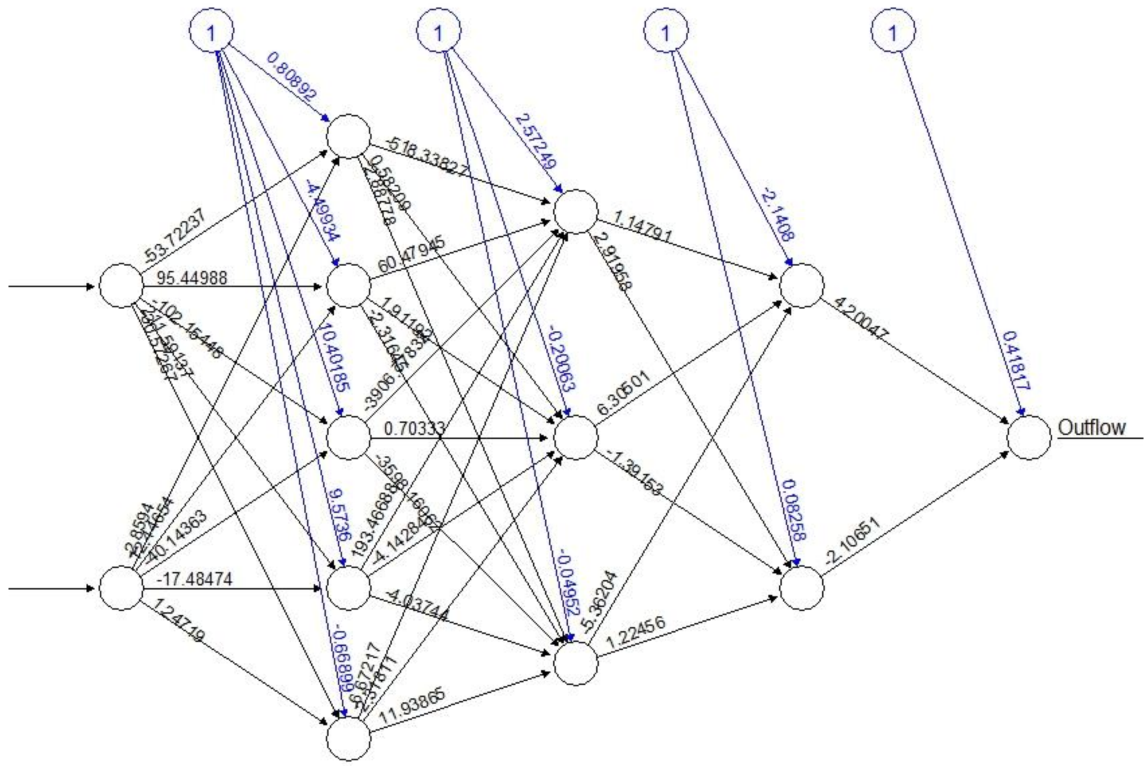


Fig. 6-2 Example of a neural network with two input neurons (inflow and water storage), one output neuron (outflow) and three hidden layer consisting of five, three and two hidden neurons, respectively.

There are twelve neural networks which are constructed by separating reservoir operation data (reservoir inflow, outflow and water storage) into on different each calendar month. According to Fig.6-2, the black lines show the link connections between each layer and the weight on each connection while the blue lines indicate the bias terms added in each step. So, the training of past reservoir operation has been processed for 40 years data recorded (1974-2013). For the future outflow estimation, the analysis was calculated by bias-corrected inflow as an input to reservoir and setting the daily loess in the reservoir based on 40 years historical reservoir operation. Lastly, the general water balance equation was used to calculate the future reservoir storage as

$$S_{t+1} = S_t + I_t - O_t - Loss_t$$

where t stands for the month, S_{t+1} stands for next day reservoir storage, S_t is current reservoir storage, I_t is daily inflow to reservoir, O_t is the daily outflow that is acquired from different model structure of ANN and $Loss_t$ is total daily losses from reservoir. In this study, the losses from reservoir were calculated by the different water storage from general water balance equation and the observed water storage.

6.2.3 Selecting of bias-corrected input forcing data and initial reservoir operation model

Based on the different future discharge projection in Sirikit reservoir, the two bias correction techniques provide a reasonable result of reservoir inflow at dam site. Table 6-1 shows the bias-corrected simulation discharge by two quantile mapping.

Table 6-1 Summary of ensemble simulation name for future experiment.

Bias Correction Method / Future SST setting	Empirical distribution quantile mapping	Gamma distribution quantile mapping
Ensemble Mean SST	Mean_EDCDF	Mean_gQM
Cluster1 SST	C1_ EDCDF	C1_gQM
Cluster2 SST	C2_ EDCDF	C2_gQM
Cluster3 SST	C3_ EDCDF	C3_gQM

According to the various the future river discharge projection was conducted before given to reservoir operation model, the initial reservoir storage setting is also important to control reservoir storage at the initial condition, So the initial reservoir storage condition is defined into three different level as follow, normal condition (at 8,250 MCM), upper rule curve condition on January, 1st (at 9,494 MCM) and lower rule curve condition on January, 1st (at 6,405 MCM). According to the calculated loss during present climate, the average daily losses can be calculated from 40 years data recored, So the Table 6-2 showed the amount of estimated daily losses from Sirikit reservoir for using future reservoir storage estimation.

Table 6-2 Estimated losses (in MCM) at Sirikit reservoir.

Month	MCM/day	MCM/Month
Jan	1.22	37.82
Feb	1.24	34.72
Mar	1.08	33.48
Apr	1.38	41.4
May	0.74	22.94
Jun	0.48	14.4
Jul	0.19	5.89
Aug	0.51	15.81
Sep	2.35	70.5
Oct	1.74	53.94
Nov	1.03	30.9
Dec	0.76	23.56
Annual (estimation)		385.36
Annual (EGAT's Report)		342.2

(Source: http://www.sirikitdam.egat.com/)

6.3 Results and discussion

6.3.1 Changes in river discharge through Sirikit reservoir

The results of average daily reservoir inflow of bias-corrected river discharge at Sirikit dam during present climate (1979-2003) were summarizes in the flow duration curve plot for comparison the characteristic of high and low flow between reservoir inflow observation and both bias-corrected river discharge as shown in Fig. 6-3.

For the changes in river discharge through Sirikit reservoir under a changing climate is shown in Table 6-3.The majority cases of the future annual reservoir inflow are higher than present observed Sirikit reservoir except the c1_gQM and c2_gQM. The amount of water resources availability in the future climate experiment showed that the reservoir inflow with SST of c3 pattern reproduce a highest values. However, after applying bias-corrected reservoir inflow data can cause the contrast of low flow occur in the case of reservoir inflow with SST of c2 pattern as shown in Fig.6-4 and Fig.6-5.

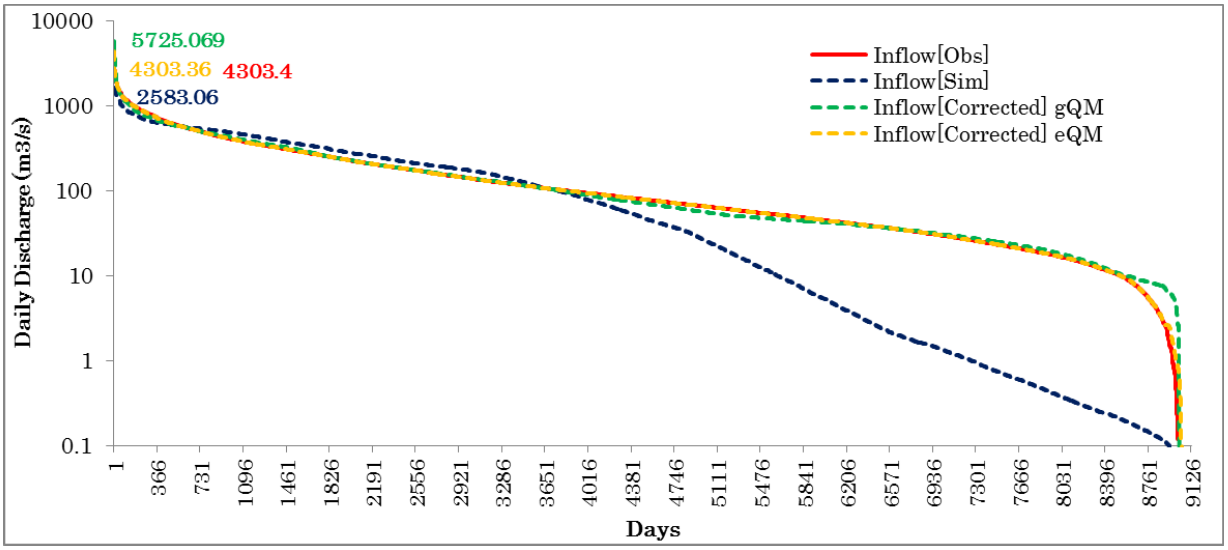


Fig. 6-3 The total-flow duration curve between observation, raw simulation and bias-corrected river discharge at Sirikit dam during present climate (1979-2003).

Table 6-3 Summary of average monthly and annual reservoir inflow of each 25 years period.

Avarage Inflow 25 years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Observed Inflow [PresentClimate]	110.75	86.54	85.7	90.69	228.43	311.96	814.16	1389.61	1299.99	546.07	249.52	135.61	5349.03
Future Climate Scenario [2075-2099]													
EnsembleMean_EDCDF$_m$	106.56	87.52	86.98	100.44	214.74	274.07	925.09	1552.63	1416.81	736.18	235.2	117.67	5853.89
EnsembleMean_gQM	110.77	103.85	100.25	127.38	239.32	309.6	798.06	1410.4	1287.78	545.98	249.53	135.64	5418.56
Cluster1_EDCDF$_m$	109.73	85.77	85.51	91.25	201.07	368.71	940.41	1592.66	1162.69	581.01	234.63	125.33	5578.77
Cluster1_gQM	113.71	86.89	85.67	90.48	209.82	311.54	786.84	1372.79	1294.75	546.95	249.55	136.79	5285.78
Cluster2_EDCDF$_m$	109.1	29.64	86.7	92.8	194.01	365.83	926.95	1519.34	1515.51	726.44	256.64	127.71	5950.67
Cluster2_gQM	112.74	86.84	98.47	105.98	221.07	311.21	781.98	1371.19	1287.15	546.34	249.89	137.85	5310.71
Cluster3_EDCDF$_m$	109.1	85.18	85.38	92.04	210.58	444.93	1128.72	1758.93	1324.12	708.2	260.43	128.24	6335.85
Cluster3_gQM	110.7	87.06	86.48	89.89	212.22	311.44	924.69	1383.38	1282.63	546.5	249.46	135.6	5420.05

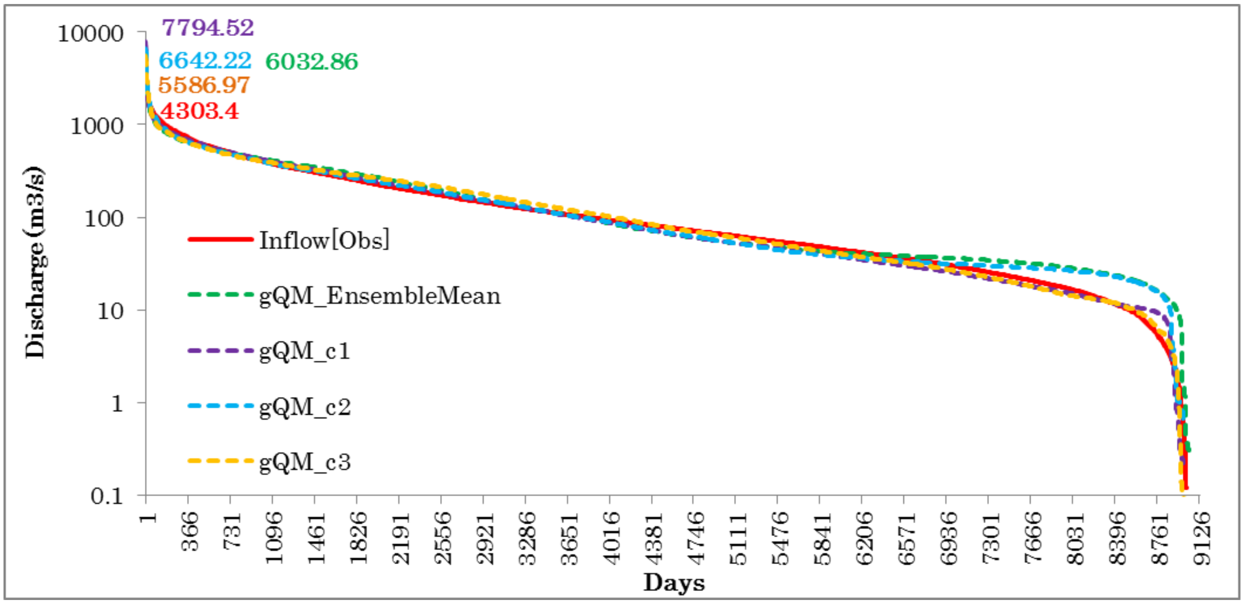


Fig. 6-4 The total-flow duration curve between observation, raw simulation and bias-corrected river discharge (gQM method) at Sirikit dam during future climate (2075-2099).

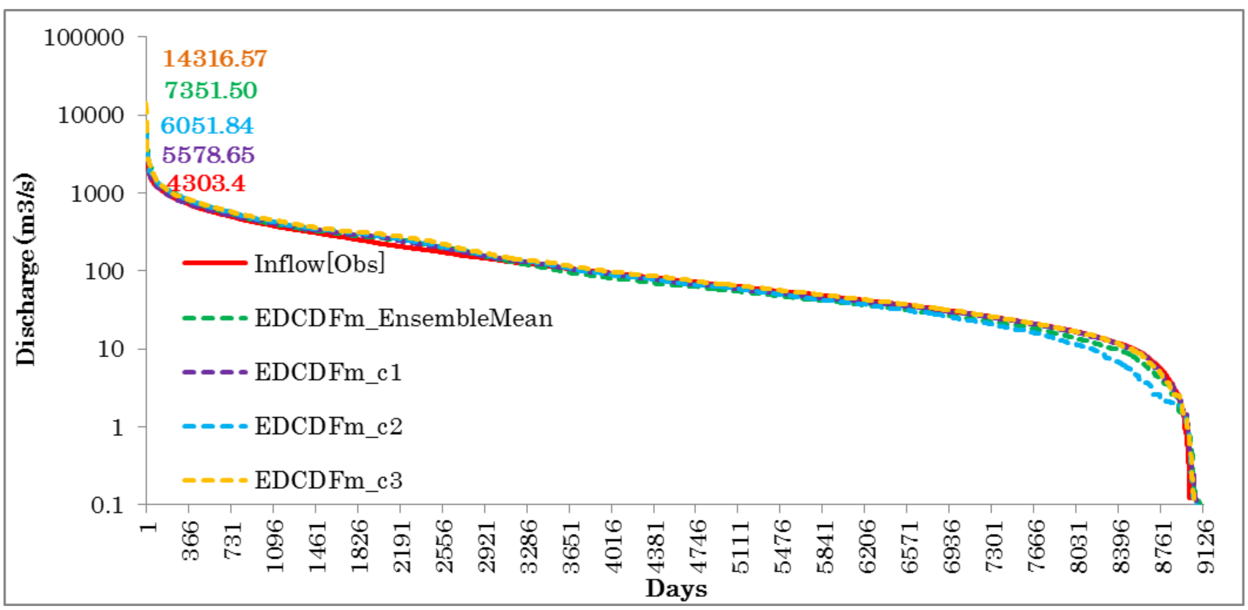


Fig. 6-5 The total-flow duration curve between observation, raw simulation and bias-corrected river discharge (EDCDFm method) at Sirikit dam during future climate (2075-2099).

6.3.2 Future reservoir storage and outflow simulation under different scenarios

Comparison release flow simulation and observation during 1974-2013

The output of reservoir operation based on the Artificial Neural Network (ANN) have been evaluate by compared with the observed outflow from 1974-2013. The best simulated results of average monthly outflow and water storage showed a good performance and reasonable to utilized for the future release flow assessment under the impacts of climate change. Table 6-4 and Fig.6-6 showed that the average outflow simulation performed well with the small difference between average outflow and water storage approximately lower than 6 % for water release and 9 % for water storage. However, the amount of outflow in particular month found some error for monthly outflow analysis as shown in Fig.6-9. Moreover, the time series plot of storage between simulated and observed outflow of each year compared with upper rule curve and lower rule curve were shown in Fig. 6-7 and Fig. 6-8.

Table 6-4 Comparison between average simulated and observed outflow and water storage during 1974-2013.

Outflow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Obs	485.53	596.62	690.06	640.18	486.94	354.48	391.21	451.90	341.74	271.78	357.03	366.90	5434.38
Sim	480.64	604.40	706.49	657.67	491.39	354.22	385.29	425.46	321.20	259.85	357.49	373.22	5417.32
% Difference	-1	1	2	3	1	0	-2	-6	-6	-4	0	2	0

Storage [Total Average]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed	6,742	6,406	5,900	5,316	4,847	4,675	4,780	5,466	6,406	6,918	6,931	6,776
Simulated ANN	6,457	6,016	5,452	4,864	4,435	4,294	4,423	5,174	6,212	6,771	6,805	6,616
Difference[Obs-Sim]	285	391	447	452	413	381	357	292	194	147	126	160
% Difference	4	6	8	9	9	8	7	5	3	2	2	2

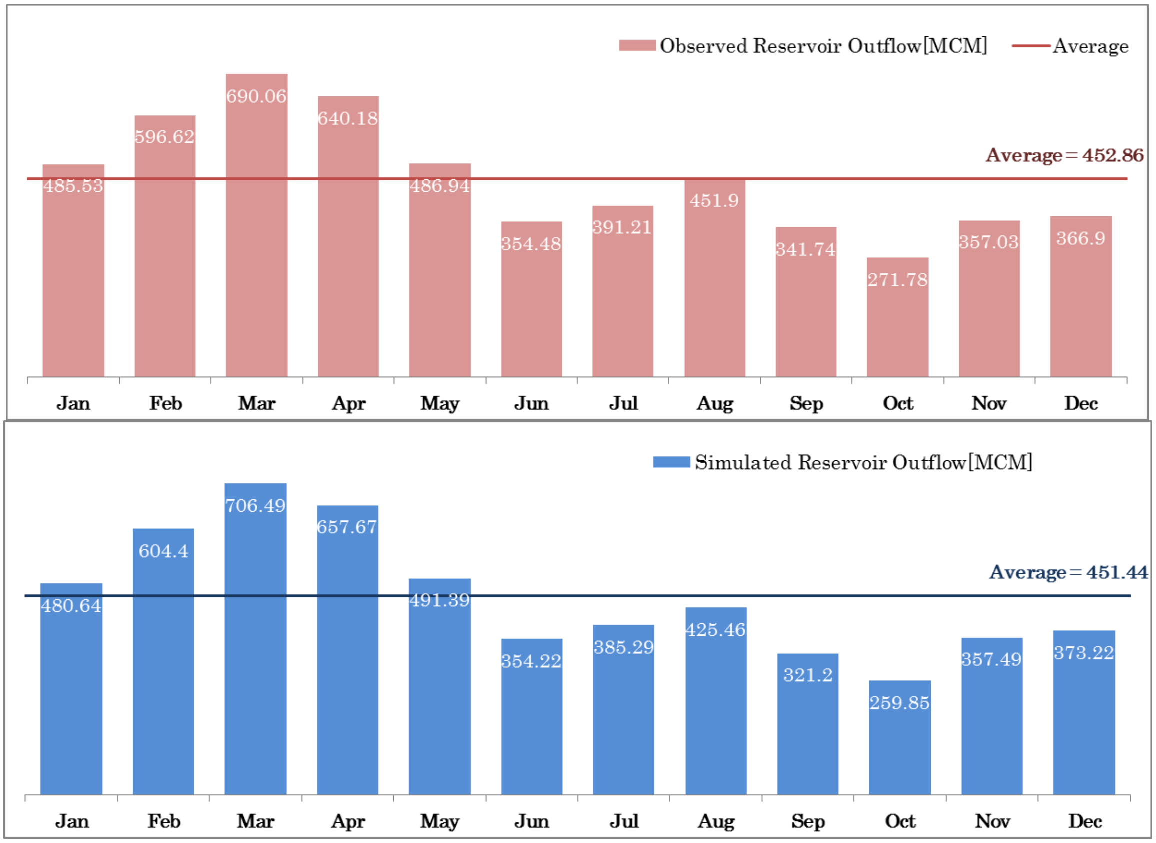


Fig. 6-6 The average monthly observed and simulated outflow during 1974-2013.

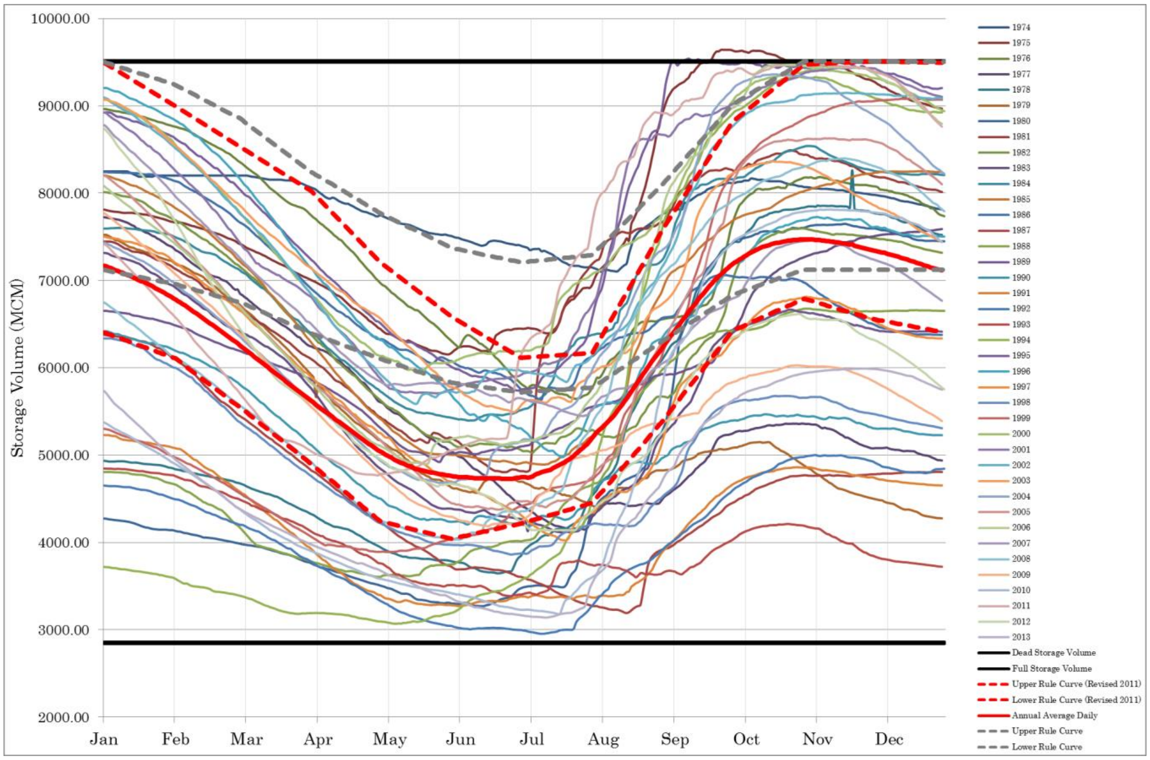


Fig. 6-7 The observed of water storage for 40 years operation.

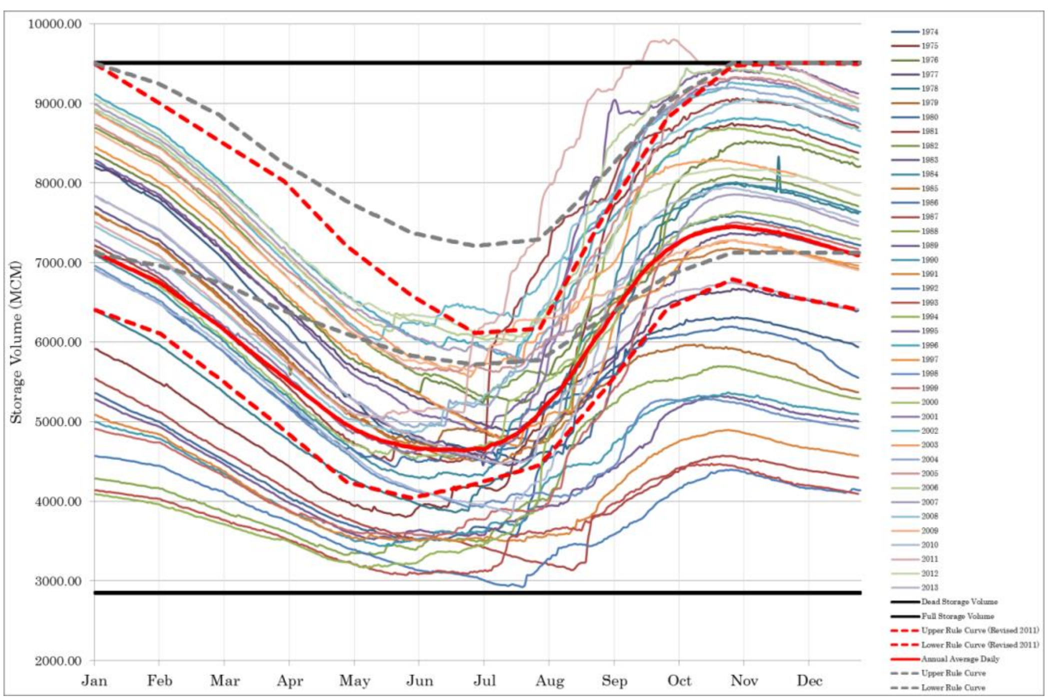


Fig. 6-8 The simulated of water storage for 40 years operation.

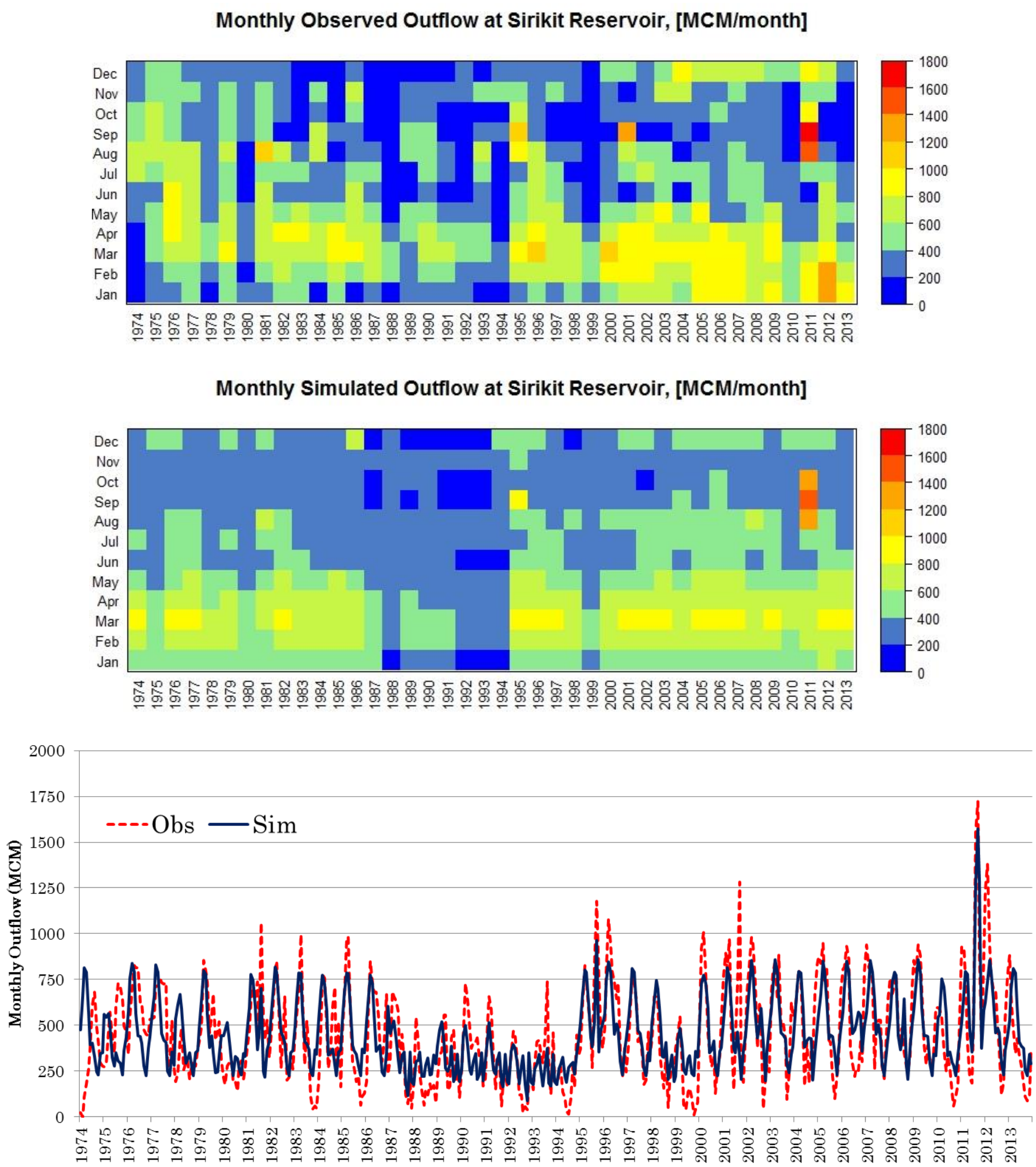


Fig. 6-9 Comparison of monthly outflow observation and simulation by ANN.

Lastly, the future reservoir storage and outflow simulation under different scenarios showed that in percentage of changes in Table 6-5 for water storage and Table 6-6 for water release of different reservoir inflow projection data. The limitation of this projection is to assume the same rate of downstream water requirement and reservoir loss during present climate condition. According to the Table 6-5, the tendency of future storage might be decreasing of all scenarios with bias-corrected gQM cases of reservoir inflow projection data.

Furthermore, the future storage water storage of bias-corrected Mean_EQCDFm and c1_ EQCDFm showed the decreasing water storage from January until July and increasing water storage from August until December. For c2_ EQCDFm and c3_ EQCDFm cases showed the increasing water storage trend throughout the year. The overall water release flow results showed the reasonable and matching with the relationship of water storage. For instance, the tendency of future water release might be decreasing of all scenarios with bias-corrected gQM cases.

Table 6-5 The percentage of water storage changes on each different reservoir inflow projection data.

Scenarios	Initial Storage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed	normal	6,742	6,406	5,900	5,316	4,847	4,675	4,780	5,466	6,406	6,918	6,931	6,776
EDCDFm_EnsembleMean	Upper	2.26	0.36	-0.68	-0.87	-0.28	-0.40	2.14	2.79	4.47	6.57	6.36	5.21
	Normal	0.28	-1.69	-3.02	-3.77	-3.80	-4.16	-1.43	0.15	2.83	5.24	5.10	3.93
	Lower	-1.39	-3.33	-4.64	-5.33	-5.22	-5.43	-2.58	-0.76	2.14	4.68	4.55	3.33
EDCDFm_c1	Upper	-0.15	-2.17	-3.32	-3.88	-4.22	-3.79	0.15	3.29	3.07	2.28	2.63	1.73
	Normal	-0.95	-3.01	-4.42	-5.62	-6.43	-6.11	-1.92	1.99	2.53	2.19	2.58	1.68
	Lower	-2.21	-4.29	-5.75	-7.00	-7.75	-7.32	-3.05	1.15	2.14	1.95	2.38	1.48
EDCDFm_c2	Upper	8.94	7.10	6.28	6.52	7.32	7.48	10.36	9.37	11.13	13.12	13.93	13.22
	Normal	6.25	4.33	3.17	2.91	3.24	3.30	6.52	6.37	8.91	11.21	12.02	11.24
	Lower	4.41	2.52	1.38	1.22	1.73	1.99	5.32	5.41	8.11	10.48	11.29	10.45
EDCDFm_c3	Upper	12.35	10.61	9.70	9.15	8.68	9.11	14.15	16.19	15.11	15.36	15.86	15.35
	Normal	10.47	8.60	7.27	6.14	5.09	5.30	10.69	13.80	13.51	14.21	14.70	14.18
	Lower	8.76	6.84	5.54	4.48	3.73	4.23	9.74	13.05	12.94	13.71	14.19	13.67
gQM_EnsembleMean	Upper	-3.15	-5.05	-6.10	-6.01	-4.79	-3.93	-1.93	-2.06	-1.09	0.39	0.13	-0.82
	Normal	-5.88	-7.91	-9.33	-9.85	-9.22	-8.50	-6.22	-5.33	-3.44	-1.68	-1.91	-2.87
	Lower	-8.00	-10.02	-11.42	-11.82	-11.04	-10.21	-7.76	-6.60	-4.47	-2.62	-2.83	-3.87
gQM_c1	Upper	-2.42	-4.24	-5.16	-5.18	-4.89	-3.53	-2.01	-1.39	-0.56	-0.43	-0.40	-1.05
	Normal	-3.21	-5.05	-6.27	-6.83	-7.02	-5.82	-4.15	-2.84	-1.14	-0.55	-0.46	-1.11
	Lower	-4.62	-6.51	-7.80	-8.39	-8.51	-7.19	-5.39	-3.81	-1.77	-0.95	-0.80	-1.45
gQM_c2	Upper	-3.95	-5.83	-7.29	-7.31	-7.23	-6.51	-4.71	-4.89	-2.21	-0.79	-0.71	-1.22
	Normal	-6.93	-8.88	-10.53	-11.06	-11.21	-10.60	-8.29	-7.77	-4.50	-2.84	-2.75	-3.38
	Lower	-8.39	-10.25	-11.93	-12.40	-12.45	-11.64	-9.26	-8.57	-5.16	-3.46	-3.39	-3.90
gQM_c3	Upper	1.13	-1.08	-2.51	-3.36	-3.77	-3.15	0.55	1.37	1.76	3.54	3.80	3.04
	Normal	-1.33	-3.65	-5.45	-6.85	-7.74	-7.19	-3.16	-1.42	-0.15	1.86	2.12	1.31
	Lower	-2.86	-5.10	-6.91	-8.27	-9.07	-8.40	-4.23	-2.34	-0.90	1.19	1.45	0.71

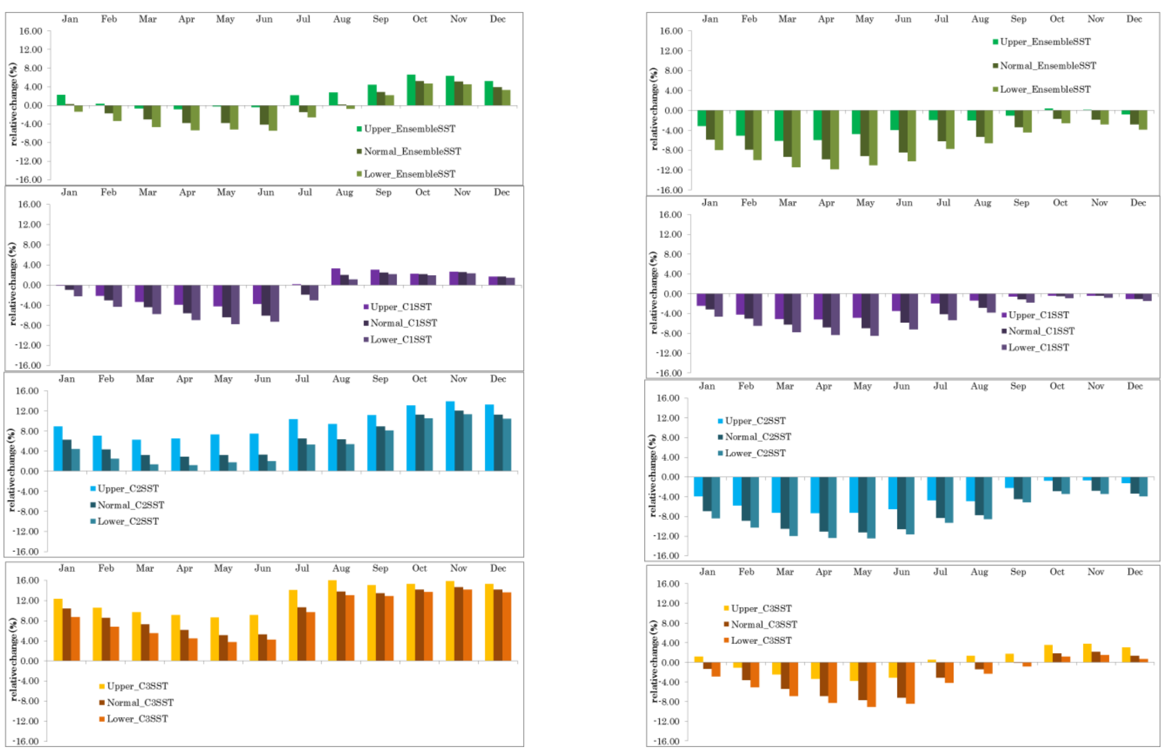


Fig. 6-10 The percentage change of water storage changes (left: EDCDF$_m$ and right: gQM inflow scanarios)

Table 6-6 The percentage of water release changes on each reservoir inflow projection data.

Scenarios	Initial Storage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DrySeason	WetSeason	Annaul
Observed	normal	486	597	690	640	487	354	391	452	342	272	357	367	3,136	2,298	5,434
EDCDFm_ Ensemble Mean	Upper	-0.77	-3.37	-3.73	-3.94	-5.36	-1.12	2.17	7.42	21.03	35.86	10.91	-0.38	-1.19	7.89	2.65
	Normal	-0.70	-4.14	-1.25	-1.25	-2.30	-2.38	0.10	-2.50	14.93	31.23	10.95	-1.47	-0.35	4.59	1.74
	Lower	-2.17	-5.36	-2.93	-3.33	-5.37	-3.59	-1.05	-3.62	12.42	30.92	11.04	-0.51	-1.48	2.92	0.38
EDCDFm_c1	Upper	-2.21	-4.17	-4.58	-2.96	-2.29	-3.05	-3.21	9.51	6.23	-1.51	-1.66	-2.30	-3.20	1.11	-1.38
	Normal	-2.00	-4.34	-0.70	0.79	-0.87	-4.11	-7.94	1.40	-5.09	-5.07	-1.67	-2.34	-1.59	-3.25	-2.29
	Lower	-3.96	-4.83	-1.42	0.77	-2.24	-5.14	-8.49	-1.51	-9.94	-8.57	-2.17	-2.95	-2.28	-5.50	-3.64
EDCDFm_c2	Upper	-0.40	-7.39	-1.69	-1.21	-2.55	4.92	4.88	15.40	24.99	6.21	2.82	1.81	-1.55	8.53	2.71
	Normal	-1.09	-8.17	0.56	-0.53	-1.19	1.49	2.19	8.65	20.50	5.95	2.86	2.05	-1.14	5.80	1.80
	Lower	-3.27	-9.29	-1.40	-3.41	-4.30	-0.63	1.24	8.01	20.44	5.82	2.89	3.55	-2.53	4.51	0.44
EDCDFm_c3	Upper	5.01	2.38	5.80	9.33	9.77	7.74	16.12	32.71	44.66	19.66	0.32	1.13	4.58	21.41	11.69
	Normal	5.07	2.84	9.41	10.79	13.28	5.44	11.22	22.72	36.42	19.57	0.24	0.28	5.66	17.76	10.78
	Lower	6.46	1.66	7.52	8.13	8.12	3.48	10.59	21.30	35.50	19.89	0.26	0.25	4.69	15.88	9.42
gQM_Ense mbleMean	Upper	-3.74	-4.05	-6.53	-8.56	-11.00	-5.80	-1.76	-3.71	-10.73	5.17	-0.37	-2.89	-4.91	-5.24	-5.05
	Normal	-4.04	-4.10	-4.55	-6.39	-9.76	-7.97	-4.59	-13.68	-13.69	4.34	-0.35	-4.36	-4.26	-8.29	-5.97
	Lower	-5.73	-5.34	-6.90	-9.63	-11.94	-9.91	-6.16	-14.29	-14.50	3.96	-0.28	-1.95	-5.65	-9.61	-7.32
gQM_c1	Upper	-6.85	-5.10	-9.90	-11.73	-11.77	-8.51	-4.73	1.71	-3.07	-2.72	-0.18	-11.74	-8.00	-5.05	-6.75
	Normal	-7.15	-5.07	-6.14	-8.77	-9.62	-9.10	-7.12	-6.66	-15.69	-6.85	-0.18	-11.78	-6.61	-9.11	-7.67
	Lower	-7.59	-5.37	-6.94	-10.26	-11.85	-10.52	-8.30	-8.59	-21.03	-9.15	-0.20	-12.05	-7.25	-11.45	-9.02
gQM_c2	Upper	-11.98	-1.64	-7.53	-9.33	-4.99	-10.41	-4.88	-10.47	-20.35	-8.07	-0.90	-15.52	-7.64	-9.53	-8.44
	Normal	-11.50	-4.04	-6.16	-9.24	-6.00	-12.28	-10.79	-13.16	-22.79	-8.41	-0.95	-13.21	-7.44	-11.97	-9.36
	Lower	-14.43	-4.37	-7.63	-11.00	-8.58	-14.52	-11.19	-13.34	-22.98	-7.64	-1.10	-17.03	-9.11	-12.91	-10.71
gQM_c3	Upper	0.36	1.36	-1.53	-1.70	-6.80	-2.24	-11.40	-7.13	-15.55	-12.53	0.26	-7.28	-1.19	-8.92	-4.46
	Normal	0.23	0.89	1.23	-0.20	-6.41	-5.04	-15.15	-15.71	-19.38	-12.62	0.30	-7.37	-0.39	-12.18	-5.38
	Lower	-2.97	0.05	-0.04	-2.25	-8.22	-7.04	-15.72	-16.39	-19.61	-12.91	0.14	-9.48	-2.01	-13.17	-6.73

Fig. 6-11 The percentage change of water release changes (left: $EDCDF_m$ and right: gQM inflow scanarios)

6.4 Conclusion

The tendency of future reservoir inflow after applying both the empirical distribution quantile mapping with difference between cumulative distribution functions (CDFs) of GCM and observation river discharge (eQM) and the empirical with gamma distribution quantile mapping (gQM) provides higher than present climate condition at Sirikit Reservoir dam.

The Artificial Neural Network (ANN) approach can be performed well with the small difference between average outflow and water storage approximately lower than 6 % for water release and 9 % for water storage.

Finally, the future reservoir storage and outflow simulation under different scenarios showed the tendency of future storage might be decreasing of all scenarios with bias-corrected gQM cases of reservoir inflow projection data. On the other hand, the scenarios with bias-corrected eQM cases of reservoir inflow projection data presented the increase storage due to high reservoir inflow on wet season as similarly with the water storage trend analysis in Chapter3.

The overall water release flow results showed the reasonable and matching with the relationship of water storage. The Mean_EDCDF, C1_EDCDF and C3_gQM inflow projection datasets are compatible with the trend analysis of Sirikit dam storage in Chapter 3.Nevertheless, the rising water storage throughout a year also was found in C2_EDCDF and C3_EDCDF inflow projection datasets and most of gQM inflow projection datasets except C3_gQM provided the decreasing water storage throughout a year. The results indicated that, The SK dam seems to reduce the release flow due to decreasing bias-corrected gQM reservoir inflow.

Chapter 7

Concluding remark

The main objectives of this dissertation were as follows:

- To develop a regional distributed hydrological model for estimation the amount of reservoir inflow to each large scale reservoirs in Thailand,
- To investigate the trend of hydrologic variable changes based on an observation data by applying the statistical trend analysis,
- To predict future reservoir water resources availability in term of inflow through each large scale reservoir by using atmospheric General Circulation Model (AGCM),
- To propose an appropriate bias correction methods for corrected daily river discharge projection by adoption the operational testing of hydrological simulation models method, and
- To project future river discharge and evaluate the reservoir water storage and water releases under various climate change scenarios.

Chapter 2 explains the development of a regional distributed hydrological model for water resources prediction based on a concept of the kinematic wave equation which is including topographic data, input forcing data and information about each reservoir and study area are described.

After that, the trends of precipitation, temperature, dam inflow, and dam release flow and volume storage were analyzed statistically based on long term historical data by using the Mann-Kendall trend test. Moreover, the trend analysis showed the climate change impacts have been already appeared in water resources in Thailand.

The assessment of future water resources availability in term of inflow through large scale reservoirs in Thailand by using Atmospheric General Circulation Model (MRI-AGCM3.2S) were analysed based on the basic information on Chapter 2. For flow routing model parameter evaluation, the total-period of flow duration curve at each dam site were constructed to compare with flow duration curve of observation data. The results showed that the model curve were more close to observed data, although the simulation of west study area showed an underestimation of the simulated river discharge .Through the analysis of reservoir water availability in study area by flow duration curve and monthly average inflow analysis, the Bhumibol (BB) reservoir , Sirikit (SK) reservoir and Pasak (PS) reservoir inflow will increase in rainy season (May to October) and flow duration curve of BB, SK and PS reservoir in the future climate experiment will rise up from present climate; However, the reservoir water availability in western part of selected dam will decrease on the future flow duration curve. The peak discharge will increase dramatically of all selected reservoirs. Our results of the relative change in reservoir inflow between present and future climate conditions indicate that the future inflow in BB , SK and PS reservoirs during rainy season will increase in all month and scenarios expect the Sirikit dam inflow in May. Although, the amount of water available in SK and VSK will also reduce in majority of months except May and October.

The all of proposed bias correction techniques were improved in the raw twofold current climate condition (1979-2003) that were heavily biased from observed river discharge during dry season, to close in a good agreement with the observed river discharge. The choice of bias correction algorithms plays an important role in assessing impacts of changing climate. For the current condition it would be reasonable to choose the one method that performed well-chosen case. For the future climate condition, the choice seems difficult to select method with non-stationary condition. Therefore, the differential split-sample test (DSST) would be used to consider and ensure the transferability of the correction approach to different climate conditions for future river discharge projection.

The tendency of future reservoir inflow after applying both the empirical distribution quantile mapping with difference between cumulative distribution functions (CDFs) of GCM and observation river discharge (eQM) and the empirical with gamma distribution quantile mapping (gQM) provides higher than present climate condition at Sirikit Reservoir dam. The Artificial Neural Network (ANN) approach can be performed well with the small difference between average outflow and water storage approximately lower than 6 % for water release and 9 % for water storage. Finally, the future reservoir storage and outflow simulation under different scenarios showed the tendency of future storage might be decreasing of all scenarios with bias-corrected gQM cases of reservoir inflow projection data. On the other hand, the scenarios with bias-corrected eQM cases of reservoir inflow projection data presented the increase storage due to high reservoir inflow on wet season. The overall water release flow results showed the reasonable and matching with the relationship of water storage. The results indicated that, the SK dam seems to reduce the release flow due to decreasing bias-corrected gQM reservoir inflow.

Remark was made at the results of future water storage in case of Mean_EDCDF, C1_EDCDF and C3_gQM inflow projection datasets are compatible with the trend analysis of Sirikit dam storage in Chapter 3.Therefore, the possibility of current storage trend also occur in the future. By the achievement of overall methodology to obtain the expected future storage and outflow, the uncertainty of future storage and outflow at Sirikit dam also found in this study, so the adaptive current operation rule curve for different inflow pattern is interesting to include in advance finding. Hopefully, this research finding would be helpful for people who have been decision maker to use as information for appropriate water sustainable development.

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Appendix

Table A1: List of climatological stations in study areas.

No	Code	Name	Latitude	Longitude
1	376203	Bhumibol Dam	17.233	99.050
2	327501	ChiangMai	18.790	98.977
3	303201	ChiangRai	19.961	99.881
4	328201	Lampang	18.283	99.517
5	329201	Lamphun	18.567	99.033
6	300201	MaeHongSon	19.300	97.833
7	327301	MaeJo	18.917	99.000
8	310201	Phayao	19.133	99.900
9	300202	MaeSariang	18.167	97.933
10	331201	Nan	18.780	100.778
11	330201	Phrae	18.167	100.167
12	331401	ThaWangPha	19.111	100.803
13	351201	Uttaradit	17.617	100.100
14	379201	Phetchabun	16.433	101.150
15	431301	PakChong	14.644	101.321
16	379401	LomSak	16.774	101.249
17	426201	Lopburi	14.800	100.617
18	353201	Loei	17.450	101.733
19	426401	BuaChum	15.264	101.192
20	379402	WichianBuri	15.657	101.108
21	400301	TakFa	15.350	100.500
22	450201	Kanchanaburi	14.023	99.536
23	450401	ThongPhaPhum	14.742	98.636
24	425301	Uthong	14.300	99.867
25	376401	Umphang	16.016	98.866

Table A2: Observed monthly inflow (unit: MCM) of Bhumibol reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	82.95	27.71	16.57	11.69	155.87	423.55	148.97	531.17	732.09	952.34	112.52	54.22	3249.65
1980	21.62	12.08	5.08	8.62	349.54	442.67	344.72	625.27	2000.91	1616.34	461.69	310.01	6198.55
1981	100.20	68.65	16.76	169.50	200.40	297.27	678.79	1109.29	955.39	699.76	923.74	384.06	5603.81
1982	173.25	34.04	27.36	72.36	236.59	633.94	306.95	677.41	1503.24	1175.31	425.47	205.40	5471.32
1983	108.17	45.79	14.09	0.00	35.99	67.71	37.44	401.80	1138.90	1484.74	1407.09	370.21	5111.93
1984	149.42	75.16	9.44	18.36	52.85	303.96	189.20	514.06	939.52	1311.34	398.05	190.80	4152.16
1985	69.97	33.52	12.60	23.82	111.90	271.65	413.71	522.98	1240.56	1156.18	1467.39	423.74	5748.02
1986	192.88	127.16	73.04	80.00	296.99	225.44	329.08	679.35	938.34	615.23	286.48	182.93	4026.92
1987	103.56	30.38	12.23	46.05	42.50	224.31	19.04	893.49	1246.46	978.68	793.27	268.26	4658.23
1988	110.35	39.65	1.19	7.64	340.24	769.09	532.81	752.49	848.20	1813.42	713.62	326.00	6254.70
1989	165.21	66.52	9.08	0.00	139.62	367.71	351.02	513.85	664.49	1457.60	448.23	216.24	4399.57
1990	77.80	23.13	2.65	12.41	266.97	292.27	205.32	439.99	1013.71	942.67	464.92	182.37	3924.21
1991	49.77	9.45	0.00	0.00	41.07	247.47	181.79	923.82	1227.07	862.78	504.95	167.60	4215.77
1992	102.32	24.96	5.02	0.00	1.00	30.78	143.19	610.64	1305.41	1207.60	353.31	350.93	4135.16
1993	151.47	31.78	30.71	0.24	48.50	67.85	73.40	174.30	925.37	611.80	163.79	102.38	2381.59
1994	32.26	11.67	61.87	84.27	253.22	509.68	717.81	1997.11	2380.55	988.14	440.86	333.82	7811.26
1995	168.16	87.63	90.80	46.17	234.12	170.22	337.13	1452.71	2191.15	1118.20	467.59	242.80	6606.68
1996	172.77	243.74	125.93	117.17	221.23	443.78	392.27	1003.24	2101.46	1226.81	734.42	246.69	7029.51
1997	165.76	93.03	104.87	119.21	39.69	32.77	296.37	915.94	1002.78	1164.23	333.80	145.73	4414.18
1998	80.02	50.98	27.26	1.68	12.73	4.18	98.54	261.94	690.34	137.31	68.84	35.74	1469.56
1999	4.33	0.00	1.97	5.10	485.83	369.55	147.57	871.47	1167.81	1232.08	1271.38	251.17	5808.26
2000	109.50	94.73	46.18	176.79	696.25	645.12	483.57	623.30	1095.67	949.82	518.39	194.37	5633.69
2001	98.98	29.39	134.48	0.00	233.98	149.99	408.85	1406.04	758.69	745.77	529.52	193.51	4689.20
2002	126.44	48.32	12.27	16.14	379.35	251.18	326.30	945.49	2990.21	1111.80	1286.92	589.41	8083.83
2003	384.33	205.31	149.18	65.93	133.65	126.19	354.03	444.41	1134.90	423.52	137.37	7.67	3566.49
Average	120.06	60.59	39.63	43.33	200.40	294.73	300.71	771.66	1287.73	1039.34	588.54	239.04	4985.77

Table A3: Raw simulated monthly inflow (unit: MCM) of Bhumibol reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	0.00	0.00	0.00	0.00	0.00	0.08	9.29	31.17	316.47	397.34	244.05	63.72	1062.12
1980	16.83	5.33	2.39	1.14	4.23	143.07	221.47	970.50	1295.78	1264.51	347.94	110.75	4383.94
1981	26.53	7.20	3.14	1.45	12.90	171.65	295.23	1394.01	2374.41	1555.37	468.51	127.93	6438.31
1982	38.95	13.26	5.34	2.12	1.24	164.52	253.91	377.99	713.13	1019.63	440.34	140.38	3170.81
1983	36.90	8.85	3.49	1.51	0.85	419.40	394.62	511.63	998.12	970.98	267.42	92.96	3706.72
1984	22.90	6.94	2.90	1.30	0.75	416.88	406.26	557.05	1196.78	620.44	218.89	109.52	3560.62
1985	33.76	9.76	5.07	2.84	1.40	126.32	111.03	265.47	1378.12	1082.47	651.33	197.72	3865.28
1986	61.51	15.43	6.78	2.47	1.25	213.81	381.53	467.62	865.52	383.98	165.61	37.46	2602.99
1987	8.62	2.82	1.50	0.80	0.51	53.06	479.60	321.63	919.05	1001.57	695.52	259.15	3743.81
1988	172.93	42.99	10.80	3.30	1.54	308.75	408.74	630.63	1661.23	816.58	189.00	39.98	4286.49
1989	9.12	3.02	1.73	0.90	0.58	115.37	276.28	299.64	928.05	1239.67	634.28	153.22	3661.85
1990	38.38	9.31	3.68	1.58	0.89	181.30	663.13	646.15	799.16	847.80	280.91	144.66	3616.95
1991	34.13	8.62	3.56	1.58	30.97	571.20	247.92	913.04	2502.84	1213.15	385.46	122.14	6034.60
1992	26.04	6.80	2.82	1.29	0.76	63.04	350.42	689.83	802.86	786.81	253.47	56.85	3040.99
1993	12.22	3.68	1.99	1.13	0.66	0.42	5.27	42.74	579.72	854.75	298.42	75.42	1876.43
1994	19.61	5.41	2.52	1.22	0.78	25.09	75.89	1694.02	1661.41	944.03	328.92	58.13	4817.02
1995	13.82	4.47	2.14	1.06	0.64	34.58	187.24	220.55	872.65	908.80	422.62	198.91	2867.47
1996	45.30	10.55	3.78	1.61	0.95	1.12	10.75	358.61	1330.59	1256.37	327.61	68.81	3416.05
1997	14.13	4.02	1.95	0.98	0.61	28.59	165.52	259.37	756.95	488.50	532.97	154.93	2408.53
1998	38.05	9.49	4.33	1.78	0.97	73.45	433.49	1214.09	1698.46	1083.70	344.30	61.21	4963.34
1999	11.95	3.48	1.74	0.90	0.57	234.14	567.95	846.73	1868.63	627.66	120.59	36.54	4320.87
2000	8.75	2.96	1.49	0.80	0.51	284.41	394.27	911.65	1326.62	946.02	288.78	137.69	4303.94
2001	33.16	7.99	3.29	1.45	316.99	636.25	537.19	1025.61	1837.17	272.70	100.76	55.26	4827.81
2002	17.49	5.24	2.76	1.47	0.88	91.83	322.33	1021.30	937.47	837.40	650.82	223.92	4112.91
2003	65.72	20.00	13.60	5.14	2.13	140.00	196.40	212.89	552.64	609.86	372.93	97.20	2288.49
Average	32.27	8.70	3.71	1.59	15.34	179.93	295.83	635.36	1206.95	881.20	361.26	112.98	3735.13

Table A4: Raw simulated monthly inflow (unit: MCM) of Bhumibol reservoir over future period [Ensemble mean SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	0.00	404.59	271.02	430.48	1155.51	1279.50	790.52	176.00	4507.62
2076	41.46	11.31	4.82	2.30	83.50	388.09	223.67	432.58	1010.41	839.43	172.83	34.92	3245.31
2077	9.92	3.53	1.98	1.10	7.49	333.32	1096.38	1646.33	1750.27	1251.91	201.68	37.16	6341.06
2078	9.52	3.47	1.97	1.10	0.72	64.01	224.40	507.44	2482.69	3397.28	788.62	167.38	7648.60
2079	32.93	8.48	3.84	1.86	1.12	0.71	43.41	173.67	630.89	716.78	228.75	96.75	1939.18
2080	26.82	7.74	3.46	1.69	1.02	56.91	610.67	917.93	1343.52	1032.77	337.41	117.13	4457.08
2081	31.89	8.70	4.06	1.98	4.60	671.71	1775.85	2035.74	2817.68	725.77	81.80	16.30	8176.08
2082	5.53	2.36	1.47	0.88	0.61	1108.64	1812.14	1124.46	1310.06	834.75	255.26	160.29	6616.45
2083	61.21	16.67	7.00	3.02	1.64	0.93	36.13	68.77	384.09	616.46	556.32	179.32	1931.56
2084	44.51	11.94	4.82	2.20	1.27	168.13	374.98	1472.95	1317.07	677.13	129.19	22.91	4227.10
2085	6.57	2.62	1.57	0.92	1109.74	766.71	599.89	1117.43	868.91	821.03	233.01	48.54	5576.94
2086	11.71	3.96	2.16	1.18	0.76	46.00	240.60	1036.00	1532.68	1151.58	316.68	78.70	4422.01
2087	27.44	7.92	3.67	1.78	30.13	1035.33	1071.37	1186.78	2085.40	1244.87	259.90	44.22	6998.82
2088	10.63	3.83	2.13	1.17	0.76	0.71	22.04	216.63	861.02	943.21	251.61	59.25	2373.00
2089	15.91	5.05	2.60	1.36	0.86	7.03	60.84	222.32	711.02	1145.69	330.95	74.07	2577.69
2090	17.86	5.45	2.76	1.43	0.92	291.93	3752.26	2317.31	2639.00	1462.37	348.41	61.80	10901.49
2091	15.21	38.05	22.23	11.55	6.57	21.07	106.65	240.96	913.96	786.08	160.83	33.01	2356.17
2092	8.76	3.28	1.80	1.01	0.67	52.40	322.30	1012.88	1394.40	1355.10	790.56	233.83	5176.98
2093	54.49	12.10	5.26	3.56	2.28	101.63	1441.50	3392.60	2934.60	1554.71	373.91	145.89	10022.54
2094	59.39	17.82	6.86	2.85	1.57	0.96	552.12	1083.45	1326.02	1265.10	552.18	116.37	4984.71
2095	23.30	6.78	3.30	1.66	1.02	45.95	447.60	940.74	1587.92	1967.70	525.27	82.37	5633.60
2096	16.32	5.08	2.51	1.33	0.85	16.44	367.11	702.69	1289.70	1121.19	300.32	75.53	3899.06
2097	17.82	5.35	2.71	1.41	0.88	75.42	399.83	683.48	1462.35	769.96	213.67	43.70	3676.59
2098	10.46	3.79	2.16	1.18	0.77	200.50	359.89	325.58	624.44	1454.82	825.07	174.02	3982.68
2099	40.52	11.72	5.08	2.36	1.50	46.20	207.33	667.36	1035.62	1727.72	385.92	62.97	4194.29
Average	24.01	8.28	4.01	2.03	50.45	236.21	656.80	958.26	1418.77	1205.72	376.43	93.70	5034.66

Table A5: Raw simulated monthly inflow (unit: MCM) of Bhumibol reservoir over future period [Cluster 1 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	31.49	264.10	498.44	1219.06	1953.46	1035.80	321.69	62.58	5386.62
2076	14.31	4.74	2.40	1.29	46.74	453.29	579.14	742.86	685.59	637.98	296.47	84.50	3549.31
2077	19.58	5.71	2.82	1.44	3.20	291.33	924.45	2144.76	2006.22	1117.55	301.67	51.50	6870.24
2078	11.87	4.10	2.25	1.22	0.79	2.37	56.11	169.57	800.54	559.38	254.59	86.19	1948.98
2079	22.41	6.41	3.07	1.54	0.95	0.60	56.83	541.42	1721.82	1082.03	393.51	139.48	3970.07
2080	41.37	10.99	4.37	1.99	1.16	40.63	129.74	254.01	1023.55	743.34	250.61	107.40	2609.18
2081	27.43	9.66	4.65	2.14	4.52	434.41	523.30	480.66	1014.71	713.89	328.75	74.23	3618.34
2082	16.87	5.14	2.62	1.37	1081.95	2634.30	1053.34	1055.37	1635.99	1186.37	256.91	42.85	8973.10
2083	11.85	4.29	2.32	1.25	0.82	149.03	278.62	788.66	971.14	1045.85	565.14	241.29	4060.26
2084	111.68	27.08	8.76	3.33	1.74	190.71	302.08	277.28	1121.13	782.56	248.52	44.77	3119.64
2085	10.48	3.61	2.00	1.10	0.72	298.23	459.85	780.04	1246.03	770.93	471.90	192.98	4237.88
2086	57.90	12.87	5.14	2.27	1.30	933.21	756.41	509.77	1155.26	701.63	155.98	31.74	4323.48
2087	8.42	3.11	1.80	1.02	0.68	254.31	415.89	448.80	1244.17	687.42	329.00	74.82	3469.43
2088	86.39	66.33	19.93	10.42	5.37	31.15	260.78	1107.56	1893.54	1009.15	201.79	37.05	4729.46
2089	9.18	3.33	1.89	1.06	0.70	2167.03	1661.10	750.30	1470.25	846.62	187.69	74.33	7173.48
2090	30.01	8.73	3.98	1.89	1.12	285.38	335.44	521.92	1045.24	591.57	199.16	39.42	3063.88
2091	24.67	12.77	5.38	2.39	1.34	211.73	287.87	2520.77	1229.18	1002.56	265.02	58.36	5622.03
2092	13.74	4.57	2.34	1.27	0.83	70.15	86.10	331.57	875.32	646.94	241.77	42.45	2317.05
2093	9.85	3.44	1.93	1.08	0.73	107.97	116.91	440.59	923.01	687.77	459.96	280.56	3033.79
2094	76.75	18.65	6.81	2.82	1.55	239.69	342.06	1248.29	1669.26	1272.92	277.33	47.22	5203.35
2095	11.07	3.75	2.07	1.14	0.75	351.13	798.26	1628.40	1350.11	1962.39	603.60	256.26	6968.92
2096	99.48	22.60	7.58	3.03	1.79	196.80	395.21	1781.70	1559.94	1037.47	372.82	82.83	5561.27
2097	17.30	5.21	2.67	1.39	0.90	69.25	169.24	951.46	1621.78	1568.15	578.76	123.76	5109.86
2098	28.43	8.03	3.71	1.80	1.08	172.30	468.01	650.60	866.52	356.56	158.50	49.94	2765.47
2099	13.00	4.25	2.26	1.21	0.78	19.90	385.83	329.03	781.06	508.37	167.02	37.23	2249.93
Average	30.96	10.38	4.11	1.98	47.72	394.76	453.64	866.98	1274.59	902.21	315.53	94.55	4397.40

Table A6: Raw simulated monthly inflow (unit: MCM) of Bhumibol reservoir over future period [Cluster 2 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	0.00	4831.28	1457.31	897.35	1405.99	1548.79	522.96	169.17	10832.86
2076	37.59	9.82	4.11	1.96	1.17	0.73	30.11	564.33	916.83	1058.08	492.41	96.62	3213.75
2077	20.61	5.91	2.91	1.49	0.93	380.30	475.60	1184.90	1857.10	1478.64	225.93	41.30	5675.62
2078	10.79	3.79	2.12	1.17	0.76	444.70	2299.44	1399.47	1423.71	941.90	373.44	135.09	7036.38
2079	53.61	15.58	5.92	2.51	1.39	18.01	359.76	944.16	1194.38	1054.86	511.51	143.86	4305.55
2080	34.99	9.81	4.10	1.94	1.15	0.71	37.67	94.39	713.00	764.67	162.81	31.54	1856.79
2081	8.27	3.08	1.78	1.01	0.68	132.86	143.32	522.00	1024.94	727.57	155.57	32.60	2753.67
2082	13.62	5.00	2.59	1.34	0.84	286.52	309.25	1275.03	3353.27	975.33	268.66	79.00	6570.46
2083	19.13	5.76	2.90	1.49	0.93	0.60	54.63	107.87	263.11	1074.35	476.56	139.24	2146.57
2084	32.36	9.01	3.94	1.89	1.14	174.37	513.93	1245.57	1313.51	1147.24	239.09	52.75	4734.80
2085	12.68	4.25	2.31	1.24	0.80	5.70	137.88	216.68	646.73	1735.68	408.30	76.80	3249.06
2086	21.33	7.09	3.39	1.68	1.02	14.07	111.42	550.00	3249.84	1737.67	434.41	92.41	6224.31
2087	19.98	6.08	3.09	1.59	0.99	23.30	350.09	691.52	1328.62	886.53	368.55	98.95	3779.29
2088	25.30	7.48	3.37	1.66	1.01	0.64	126.82	383.10	1152.17	1440.20	663.36	235.32	4040.43
2089	86.90	21.46	8.49	3.89	2.40	12.12	177.26	259.50	976.00	812.94	387.34	105.61	2853.92
2090	22.56	6.45	3.12	1.56	0.96	19.18	356.78	1239.09	1605.23	2777.21	537.78	170.73	6740.67
2091	43.95	12.62	5.25	4.70	19.71	465.03	541.79	485.64	767.64	451.44	97.66	19.50	2914.90
2092	8.64	4.01	2.14	1.16	0.74	584.08	565.41	895.75	1967.66	940.87	220.67	50.41	5241.52
2093	12.15	4.16	2.24	1.21	0.78	70.39	366.10	477.64	1246.55	806.70	1001.19	383.70	4372.81
2094	88.37	19.60	7.12	2.97	1.63	35.90	386.45	1054.95	2171.33	1674.01	493.90	169.80	6106.02
2095	41.58	19.05	17.83	5.90	2.68	54.14	195.49	804.00	1167.97	1043.16	409.21	102.02	3863.03
2096	22.69	6.70	3.14	1.57	0.97	427.22	286.35	580.22	1182.90	809.40	269.33	48.16	3638.65
2097	10.85	3.65	2.01	1.10	0.72	291.18	664.09	703.58	1874.99	1426.42	336.65	68.04	5383.28
2098	17.56	6.71	3.28	1.61	0.98	235.80	494.00	659.70	1858.02	1299.19	831.04	165.88	5573.77
2099	36.76	12.06	5.76	3.03	7.32	1966.98	1442.48	2811.81	2016.05	1581.96	550.29	129.54	10564.04
Average	28.09	8.36	4.12	1.99	2.07	419.03	475.34	801.93	1467.10	1207.79	417.54	113.52	4946.89

Table A7: Raw simulated monthly inflow (unit: MCM) of Bhumibol reservoir over future period [Cluster 3 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.01	0.01	6.64	242.78	535.11	758.08	1028.31	746.47	165.89	3483.30
2076	34.41	8.90	3.80	1.84	12.91	514.99	1183.81	2566.09	1540.01	449.48	210.24	49.61	6576.09
2077	14.37	5.47	3.17	1.67	1.02	111.16	500.90	870.37	1191.49	1064.70	387.90	75.33	4227.54
2078	18.18	6.13	3.12	1.56	10.89	495.95	386.84	637.35	1357.97	1078.59	520.18	134.99	4651.75
2079	29.33	8.49	3.85	1.84	1.10	0.70	192.68	1406.14	2493.38	746.37	179.78	69.34	5133.00
2080	23.66	8.68	3.81	1.83	1.10	574.78	552.21	1004.82	1834.46	564.32	70.37	14.98	4655.02
2081	5.04	2.16	1.35	0.81	0.56	0.39	117.67	508.51	1366.32	739.73	306.50	79.84	3128.88
2082	19.70	6.13	3.01	1.52	0.94	95.63	177.97	397.38	920.35	899.56	232.78	97.50	2852.48
2083	28.20	8.72	3.90	1.86	1.11	2550.84	2063.79	1664.80	2516.41	1834.91	639.20	111.48	11425.22
2084	28.48	8.79	3.99	1.94	1.16	242.11	414.97	1122.01	1271.63	918.49	237.82	56.47	4307.86
2085	12.43	4.06	2.19	1.19	0.77	0.50	36.98	907.29	1341.92	1093.35	323.34	56.65	3780.66
2086	12.19	4.04	2.20	1.20	0.78	163.55	371.76	867.27	2309.33	974.75	214.45	41.31	4962.83
2087	10.66	3.78	2.11	1.16	0.77	434.06	327.95	349.00	763.24	935.08	456.10	116.61	3400.51
2088	30.71	8.41	3.64	1.77	1.06	72.63	817.08	1154.03	1717.32	1633.80	556.73	128.82	6125.99
2089	29.31	7.94	3.67	1.79	10.28	1802.59	1022.53	903.41	1301.94	1122.02	397.28	97.16	6699.92
2090	23.16	6.69	3.24	1.63	1.00	308.33	315.69	604.17	1453.74	1353.43	510.96	113.76	4695.82
2091	23.91	6.88	3.32	1.65	1.01	216.14	356.14	942.95	1444.56	917.78	342.88	103.43	4360.66
2092	21.91	6.33	2.97	1.51	21.23	1154.72	874.53	1350.71	1858.26	890.81	229.25	92.28	6504.53
2093	28.28	8.17	3.73	1.80	57.05	260.88	100.57	228.99	1662.95	1148.36	267.04	122.36	3890.17
2094	29.93	8.28	3.79	1.83	1.12	1078.79	926.24	3207.86	3163.34	2510.61	546.28	151.35	11629.43
2095	28.25	7.56	3.56	1.76	1.07	80.63	130.46	356.81	2436.51	2434.11	685.98	123.18	6289.87
2096	23.99	6.71	3.10	1.58	0.98	63.81	587.86	1065.89	1538.46	824.01	345.29	117.56	4579.23
2097	26.45	7.50	3.49	1.71	22.41	569.43	301.71	359.41	732.04	671.31	291.63	89.82	3076.92
2098	20.62	5.92	2.88	1.46	0.91	248.27	142.95	772.00	1178.73	1369.91	416.50	130.40	4290.55
2099	35.67	9.84	4.27	1.97	1.16	556.67	540.91	462.13	887.09	659.29	182.43	61.97	3403.40
Average	22.35	6.62	3.13	1.56	6.10	464.17	507.48	969.78	1561.58	1114.52	371.89	96.08	5125.27

Table A8: Observed monthly inflow (unit: MCM) of Sirikit reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	123.37	60.95	96.36	88.29	237.24	531.99	306.19	1084.75	687.78	311.47	145.88	92.02	3766.29
1980	95.70	43.49	78.10	69.01	130.11	382.23	1069.08	1129.65	2427.26	503.63	223.10	134.66	6286.02
1981	100.14	33.98	99.18	79.13	435.32	379.89	2792.43	1583.42	1171.19	618.43	312.99	155.44	7761.54
1982	130.69	113.79	55.21	136.98	124.55	212.18	695.43	1069.15	1457.37	924.88	255.47	115.03	5290.73
1983	101.63	69.26	74.61	112.66	221.44	196.33	572.15	1251.30	1347.43	896.16	328.83	159.16	5330.96
1984	129.85	120.19	106.13	121.62	220.96	375.50	1230.29	1500.35	1637.41	626.74	270.62	136.43	6476.09
1985	126.78	104.68	95.02	128.81	179.09	219.86	589.70	1868.00	1053.62	439.43	346.80	168.39	5320.18
1986	124.28	115.06	131.43	164.07	466.21	410.18	912.74	865.67	812.11	384.32	208.02	121.36	4715.45
1987	75.85	66.35	72.13	61.57	88.03	160.64	142.07	951.56	661.09	414.90	221.65	89.78	3005.62
1988	78.82	65.99	50.04	89.20	310.81	346.47	817.75	1464.25	635.63	413.64	165.26	103.51	4541.37
1989	74.04	76.11	63.10	47.20	279.43	237.16	642.80	828.47	941.22	492.31	173.71	92.99	3948.54
1990	83.97	80.39	59.38	48.60	239.92	360.69	730.53	884.00	885.62	395.50	219.83	97.17	4085.60
1991	86.39	44.56	29.31	68.46	226.62	260.75	347.85	826.93	846.40	413.09	167.39	85.65	3403.40
1992	81.94	66.53	64.18	45.02	58.45	91.11	417.97	693.05	741.49	440.15	176.51	150.90	3027.30
1993	93.66	49.93	75.24	69.75	125.51	205.59	787.25	643.01	649.74	322.22	130.59	80.93	3233.42
1994	65.58	58.24	91.77	67.21	218.30	411.32	875.10	3272.35	1665.43	631.53	254.62	183.90	7795.35
1995	119.28	84.83	55.89	51.72	133.51	211.26	1019.29	3300.10	2614.23	744.39	510.35	210.68	9055.53
1996	156.63	149.11	95.80	151.15	194.56	387.61	886.28	1592.54	1196.93	744.53	316.04	161.02	6032.20
1997	124.23	99.27	50.63	96.82	107.43	69.80	460.91	1125.32	1367.78	738.75	248.73	134.05	4623.72
1998	111.73	73.35	71.82	96.06	103.43	144.34	503.92	657.56	1155.42	265.22	159.51	83.97	3426.33
1999	71.26	67.05	74.35	115.90	237.82	431.95	458.79	1578.61	2193.74	685.61	285.20	128.09	6328.37
2000	141.74	146.31	101.18	111.09	421.00	517.43	1181.01	1054.76	1433.02	643.20	287.49	175.81	6214.04
2001	138.28	107.80	201.82	83.31	283.57	333.31	1202.84	2740.68	1642.43	609.82	286.09	176.73	7806.68
2002	146.44	123.34	91.03	61.41	547.12	653.40	777.71	1531.07	1668.47	621.50	327.46	219.85	6768.80
2003	186.46	142.96	158.80	102.22	120.28	267.98	934.00	1243.62	1607.04	370.21	215.74	132.66	5481.97
Average	110.75	86.54	85.70	90.69	228.43	311.96	814.16	1389.61	1299.99	546.07	249.52	135.61	5349.02

Table A9: Raw simulated monthly inflow (unit: MCM) of Sirikit reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	0.00	0.00	0.00	0.00	1.25	92.22	714.93	860.65	1050.27	388.24	220.66	53.09	3381.32
1980	11.56	3.76	1.70	0.79	35.63	308.89	840.13	1342.69	1484.02	962.81	208.31	58.04	5258.34
1981	14.76	5.41	4.58	4.46	151.28	532.92	1545.30	2112.11	3136.29	1305.41	309.21	72.50	9194.22
1982	18.81	7.02	3.64	5.12	192.15	571.12	618.35	1211.71	2001.79	1382.59	381.53	142.18	6536.01
1983	37.68	8.51	3.41	1.41	41.13	430.57	650.07	1216.97	1691.12	836.34	187.39	74.14	5178.73
1984	20.01	5.91	2.54	1.06	47.73	463.17	670.79	1195.41	1508.34	476.25	141.02	76.06	4608.28
1985	29.66	24.08	17.32	4.88	32.15	269.52	454.11	1033.12	1558.80	966.93	578.80	159.37	5128.75
1986	41.69	9.91	4.16	1.95	268.54	519.59	519.84	1728.60	1183.94	268.75	70.54	16.58	4634.08
1987	4.23	1.43	0.77	0.42	16.84	294.54	408.44	549.06	1303.19	1053.99	301.21	67.49	4001.62
1988	25.41	9.32	3.65	1.39	2.53	393.05	1110.67	1494.62	1631.01	730.46	152.18	39.12	5593.41
1989	9.16	3.00	1.53	0.72	21.91	287.89	529.05	944.77	2019.73	1335.07	485.32	109.82	5747.98
1990	28.00	7.06	2.86	1.17	47.67	257.00	440.55	930.25	987.48	659.91	129.54	61.97	3553.46
1991	15.93	4.70	2.16	0.96	130.89	486.86	426.51	1280.39	1608.33	707.30	284.20	88.05	5036.29
1992	20.22	5.70	2.27	0.96	0.52	18.02	518.78	935.93	855.91	756.13	197.74	40.59	3352.78
1993	8.16	2.49	1.70	0.81	0.48	148.76	243.12	713.48	1112.13	892.29	262.22	63.23	3448.86
1994	15.78	4.23	2.22	1.16	1.35	133.44	488.72	1449.15	1324.94	807.66	268.62	51.99	4549.24
1995	12.57	3.78	1.77	0.81	91.00	525.94	991.29	816.64	1803.37	906.63	300.56	106.28	5560.63
1996	23.67	6.10	2.57	1.06	0.57	72.91	453.95	974.03	1763.44	990.24	210.07	44.03	4542.63
1997	9.47	2.76	1.31	0.67	28.00	278.97	626.13	792.28	1229.05	717.53	686.59	159.49	4532.25
1998	36.10	8.67	3.28	1.26	18.42	381.24	703.77	2132.07	2345.52	811.28	157.04	24.13	6622.79
1999	4.76	1.67	0.92	0.49	20.71	454.78	812.52	1176.82	1489.85	483.02	70.71	15.41	4531.66
2000	3.79	1.36	0.72	0.40	16.10	291.81	500.38	1469.11	1488.47	864.07	255.56	94.74	4986.49
2001	22.70	5.85	2.61	1.12	137.43	551.73	779.97	1585.47	2052.55	219.52	42.92	32.87	5434.74
2002	13.33	5.45	3.70	1.66	35.14	181.74	647.39	1442.24	1084.47	1062.08	430.50	164.16	5071.86
2003	49.74	16.63	10.30	15.87	185.29	942.51	583.58	543.05	1469.29	943.31	317.15	66.07	5142.80
Average	19.09	6.19	3.27	2.02	60.99	355.57	651.13	1197.23	1567.33	821.11	265.98	75.26	5025.17

Table A10: Raw simulated monthly inflow (unit: MCM) of Sirikit reservoir over future period [Ensemble mean SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.37	1.08	110.85	692.34	523.74	743.79	1061.65	965.94	375.34	81.77	4556.88
2076	19.06	7.24	10.98	171.49	475.21	852.89	788.32	1834.28	1883.46	1161.01	158.69	24.97	7387.59
2077	5.17	1.91	1.37	0.66	0.46	268.82	1233.08	1556.40	1454.87	1247.01	138.21	21.20	5929.17
2078	4.64	1.54	0.82	0.44	43.28	182.55	203.86	637.80	1731.09	1608.67	444.19	91.41	4950.29
2079	16.54	4.10	1.78	0.80	0.47	17.80	187.13	1532.00	1460.76	934.08	205.15	64.87	4425.48
2080	15.18	4.22	1.81	0.81	1.01	305.19	791.46	869.87	1334.60	650.24	195.24	44.59	4214.22
2081	10.33	3.45	1.69	0.79	8.36	416.68	1626.98	2012.41	2946.67	439.91	47.34	7.17	7521.80
2082	2.12	0.89	0.55	0.32	4.01	533.35	1686.01	1536.27	1531.39	746.38	187.70	106.68	6335.69
2083	35.27	8.94	6.45	3.02	10.66	114.20	245.14	625.09	958.26	928.57	494.18	98.26	3528.02
2084	20.60	5.84	2.38	0.98	34.41	370.58	1113.66	1934.09	1454.16	534.12	64.61	9.21	5544.63
2085	2.48	1.07	0.73	0.39	264.74	943.41	1475.63	1583.61	1163.50	537.82	114.36	17.83	6105.57
2086	4.01	1.37	0.75	0.41	36.08	378.78	765.42	1993.69	1895.81	1096.00	235.44	63.31	6471.08
2087	18.20	5.39	5.89	50.61	199.45	831.66	816.09	778.46	3302.55	1298.76	214.42	30.11	7551.59
2088	5.61	2.66	1.46	0.71	0.41	17.84	370.25	988.60	1741.43	1073.45	239.57	44.97	4486.97
2089	9.10	2.94	1.65	1.21	25.76	219.10	247.59	1702.99	1061.50	935.85	250.22	48.74	4506.64
2090	10.27	3.24	1.51	0.69	36.48	364.76	376.03	697.13	1145.20	1125.94	193.25	31.69	3986.20
2091	11.37	63.64	30.24	12.39	5.18	144.07	262.08	1087.86	1857.85	680.66	91.51	13.13	4259.98
2092	3.27	1.22	0.66	0.37	0.41	136.02	425.96	1842.83	1536.56	896.14	405.30	97.89	5346.63
2093	18.03	4.50	3.33	13.90	84.81	247.29	1783.07	3781.45	3846.43	959.69	187.72	45.77	10975.97
2094	31.42	9.52	4.14	3.35	3.42	22.92	637.70	1071.38	1288.46	1003.77	237.43	40.09	4353.58
2095	7.27	2.87	2.47	1.65	0.84	28.52	1256.61	1123.74	1477.95	1274.88	284.88	38.72	5500.40
2096	6.14	1.87	0.92	0.48	0.31	192.34	767.53	1049.60	1435.67	805.24	220.37	48.73	4529.20
2097	9.35	2.56	1.20	0.59	0.36	227.90	717.36	1111.76	1749.45	904.44	180.53	24.36	4929.84
2098	5.46	2.50	1.71	0.78	21.42	507.61	392.77	678.28	1240.73	1361.65	453.08	88.47	4754.46
2099	16.45	4.95	6.04	3.41	26.66	201.40	555.38	1820.15	1355.68	1446.87	243.06	35.78	5715.84
Average	11.49	5.94	3.64	10.85	55.80	328.72	769.95	1383.74	1676.63	984.68	234.47	48.79	5514.71

Table A11: Raw simulated monthly inflow (unit: MCM) of Sirikit reservoir over future period [Cluster 1 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	48.24	668.48	1322.96	1692.24	1775.46	1038.81	262.90	42.21	6851.31
2076	7.94	2.72	1.38	1.07	85.72	524.32	897.77	1394.45	1278.04	636.75	262.85	59.32	5152.33
2077	11.57	3.11	1.39	0.65	143.99	820.19	1293.44	1823.64	1640.86	907.30	188.29	25.52	6859.96
2078	8.56	3.16	1.68	0.77	42.00	133.71	178.72	496.57	1291.88	503.76	181.03	49.26	2891.10
2079	10.51	3.13	1.44	0.67	0.39	0.52	640.51	1715.35	1195.70	814.38	309.46	85.33	4777.40
2080	18.19	4.53	2.09	0.93	96.55	193.24	522.93	1917.03	1748.98	853.12	213.24	61.62	5632.45
2081	15.30	6.66	3.40	1.51	71.34	439.27	753.99	1106.87	1174.55	820.35	236.03	43.75	4673.03
2082	8.62	2.36	1.13	0.56	25.01	804.40	1455.64	1240.52	1238.09	1143.53	186.32	30.54	6136.71
2083	9.39	2.87	1.97	1.30	38.73	403.35	576.50	1264.35	1529.56	1330.09	405.45	144.54	5708.10
2084	62.87	15.51	5.83	2.25	104.28	524.32	623.85	1007.63	1542.93	1121.68	338.37	53.01	5402.53
2085	8.42	2.24	1.08	0.55	31.88	966.87	807.81	1072.89	1052.48	700.41	227.15	57.52	4929.29
2086	16.45	5.36	2.63	1.26	55.14	879.70	1285.87	1130.16	1868.13	468.11	86.00	13.59	5812.40
2087	3.30	1.19	0.67	0.38	12.35	334.54	904.79	920.77	1502.95	569.69	265.24	47.09	4562.97
2088	9.20	5.94	3.20	3.17	52.72	303.23	819.02	2048.80	1543.22	834.18	138.16	19.67	5780.49
2089	4.11	1.38	0.76	0.42	8.11	461.62	726.75	1049.27	1128.27	746.12	151.18	48.91	4326.88
2090	13.06	3.60	1.60	0.73	0.42	72.22	335.36	923.30	1247.11	489.58	106.52	15.68	3209.19
2091	24.83	8.00	4.32	1.77	0.83	136.45	292.71	2199.74	1724.17	1016.42	170.40	26.28	5605.93
2092	5.39	1.77	0.88	0.47	0.30	114.06	364.72	917.11	1046.98	687.65	162.33	22.20	3323.87
2093	4.31	1.41	0.76	0.41	19.76	216.64	400.77	2608.54	1548.71	791.30	335.45	175.29	6103.34
2094	35.87	8.40	3.83	1.92	51.40	540.93	938.63	2105.88	1684.13	994.83	180.83	24.64	6571.30
2095	4.79	1.71	0.89	0.47	66.60	1032.56	1725.57	2280.26	1403.83	987.55	448.80	181.49	8134.52
2096	54.61	11.62	3.92	1.66	34.98	498.05	835.41	1136.27	1328.70	895.45	231.43	42.17	5074.26
2097	7.47	2.13	1.05	0.53	0.35	71.11	457.33	1289.19	1916.91	1446.82	501.02	89.52	5783.44
2098	17.00	4.26	2.39	2.87	27.13	263.97	655.77	1035.46	715.86	179.84	62.42	16.21	2983.18
2099	4.73	1.59	0.83	0.44	23.30	220.11	841.21	1218.41	1434.95	760.03	197.82	36.46	4739.90
Average	14.66	4.19	1.96	1.07	41.66	424.95	786.32	1423.79	1422.50	829.51	233.95	56.47	5241.04

Table A12: Raw simulated monthly inflow (unit: MCM) of Sirikit reservoir over future period [Cluster 2 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	0.05	860.45	731.95	1003.70	1237.29	802.15	221.07	57.25	4913.92
2076	11.96	3.59	1.54	0.71	36.68	266.29	675.80	1309.59	1175.85	957.10	306.12	51.62	4796.86
2077	9.03	2.43	1.16	0.57	0.35	975.08	1257.58	1724.56	1836.55	1018.45	136.55	21.59	6983.91
2078	4.50	1.48	0.80	0.43	0.29	237.42	373.80	585.92	839.63	396.85	128.13	40.67	2609.92
2079	18.42	5.98	2.77	1.58	4.51	305.81	1030.46	1129.59	1050.15	1364.61	381.76	75.07	5370.73
2080	15.81	4.34	1.88	0.82	0.52	161.55	781.88	1014.14	1685.38	709.56	113.50	15.50	4504.87
2081	3.77	1.45	0.78	0.42	0.27	118.69	412.57	1351.16	1484.58	687.38	126.38	26.58	4214.05
2082	10.74	3.32	1.53	0.71	8.80	296.37	582.68	2223.05	3058.12	606.74	147.29	29.41	6968.76
2083	6.75	2.11	1.05	0.93	57.57	262.22	634.87	707.40	790.37	661.33	265.53	65.92	3456.06
2084	13.06	3.89	1.68	0.76	0.44	163.03	1124.02	1594.73	2181.86	1133.15	173.31	28.82	6418.76
2085	5.73	1.78	0.92	0.48	0.31	39.57	359.67	624.67	1169.73	1605.43	261.26	47.54	4117.09
2086	14.98	4.56	2.02	0.89	0.74	54.50	192.19	1580.07	3661.72	1573.27	374.21	62.12	7521.28
2087	11.80	3.62	1.71	0.79	36.85	369.14	739.36	1861.73	1775.80	839.13	295.36	68.90	6004.17
2088	14.91	4.21	1.80	0.80	0.46	48.73	714.49	1103.76	1919.01	1320.41	351.99	143.81	5624.38
2089	58.17	15.80	13.53	18.12	162.68	641.39	885.63	1511.81	1555.08	929.06	322.88	65.85	6180.00
2090	12.10	3.38	1.51	0.70	0.41	266.60	681.03	1174.92	2119.03	1059.15	249.65	78.92	5647.41
2091	24.66	9.50	26.99	26.31	203.03	876.47	948.94	1218.37	1669.59	448.88	64.90	11.21	5528.86
2092	6.88	2.48	1.16	0.57	115.43	1425.82	2240.08	1411.80	2058.95	1077.89	176.62	30.12	8547.79
2093	6.39	2.02	1.01	0.52	0.32	371.61	872.02	1470.58	1627.48	527.97	534.70	229.56	5644.18
2094	47.59	10.68	4.20	3.94	52.38	247.55	670.59	1749.58	2122.81	1232.89	259.98	51.53	6453.70
2095	10.71	3.01	2.49	1.45	10.88	310.05	684.09	1467.60	1153.10	782.92	243.86	49.42	4719.59
2096	8.85	2.50	1.19	0.60	7.94	621.28	393.81	1124.59	1336.34	683.93	132.42	18.30	4331.73
2097	3.83	1.32	0.73	0.40	41.41	588.36	807.82	1313.05	1909.13	1691.33	237.18	35.65	6630.20
2098	11.02	4.16	2.23	3.03	31.33	486.75	738.85	1193.05	3499.99	1370.49	658.54	108.92	8108.34
2099	19.16	7.00	6.03	3.72	75.84	534.32	799.11	2311.56	1465.43	893.19	234.92	56.93	6407.20
Average	14.03	4.18	3.23	2.77	33.98	421.16	773.33	1350.44	1775.32	974.93	255.92	58.85	5668.15

Table A13: Raw simulated monthly inflow (unit: MCM) of Sirikit reservoir over future period [Cluster 3 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.04	0.15	449.37	1017.19	1041.56	999.66	937.91	435.83	81.71	4963.42
2076	15.47	4.23	1.91	1.05	48.56	959.45	1845.54	2867.34	1352.10	383.08	233.09	53.35	7765.18
2077	12.28	4.70	2.68	1.22	13.53	171.86	3897.58	2143.20	1816.97	1020.80	277.43	45.28	9407.53
2078	11.57	5.15	2.72	1.21	64.23	607.34	380.39	974.42	1221.66	842.01	314.27	74.56	4499.53
2079	14.86	3.97	1.77	0.89	0.49	81.49	1061.19	2627.30	1846.35	591.14	141.68	38.58	6409.69
2080	10.53	4.23	1.96	0.95	65.54	488.56	936.87	1802.58	1737.97	441.31	52.50	8.54	5551.54
2081	2.40	0.95	0.57	0.33	0.23	187.94	570.37	1012.39	1251.96	665.62	293.71	65.43	4051.90
2082	13.07	3.22	1.41	0.67	14.25	331.03	649.93	1379.59	1879.92	1030.28	171.20	47.08	5521.64
2083	11.55	3.60	1.63	0.74	18.32	834.47	2686.69	1939.87	2058.94	1388.37	399.23	59.92	9403.34
2084	12.79	3.76	1.77	0.81	7.91	1035.81	1271.43	1421.33	1701.46	875.52	166.03	30.92	6529.54
2085	5.66	1.73	0.90	0.48	0.30	17.91	655.62	2280.31	1384.71	910.05	175.86	23.96	5457.48
2086	4.65	1.51	0.81	0.44	39.68	582.33	726.19	1574.79	1923.34	739.29	119.10	18.87	5731.02
2087	4.80	1.65	0.91	0.49	90.24	727.98	490.57	696.12	1301.87	932.47	342.48	78.84	4668.43
2088	18.14	4.81	2.38	1.00	168.72	708.05	740.99	1055.57	2276.22	1558.28	484.10	96.45	7114.72
2089	19.45	5.27	2.32	0.96	146.01	1264.84	899.33	1150.97	1613.65	956.30	196.02	40.50	6295.62
2090	9.07	2.85	1.33	0.64	85.64	581.71	789.09	1164.94	1773.88	1149.47	376.48	70.35	6005.44
2091	11.98	3.42	1.63	0.75	36.72	311.09	669.17	1633.93	1505.56	950.30	330.73	82.79	5538.07
2092	14.42	3.52	1.46	0.69	107.24	800.16	1138.68	2689.81	1438.58	832.00	226.18	90.90	7343.63
2093	19.29	4.64	1.96	0.89	186.36	422.49	263.19	742.96	2207.69	985.07	228.66	80.13	5143.32
2094	16.65	3.95	1.66	0.76	18.05	63.92	396.26	1491.48	1601.34	1944.90	247.51	62.38	5848.86
2095	9.87	2.81	1.56	0.71	0.41	150.89	499.71	1965.00	1432.78	1536.18	424.52	71.45	6095.88
2096	12.19	3.12	1.34	0.65	0.40	304.82	936.04	1862.84	1298.13	472.07	155.16	45.57	5092.33
2097	10.89	3.47	1.63	0.74	39.18	426.06	457.50	1248.79	1229.06	816.16	224.19	45.76	4503.42
2098	10.14	2.96	1.36	1.44	86.47	363.72	548.41	1710.22	1447.41	1180.60	316.32	127.41	5796.44
2099	33.50	7.85	3.19	1.31	51.05	655.27	871.48	1273.49	1297.46	778.22	160.22	43.31	5176.34
Average	12.21	3.50	1.63	0.79	51.59	501.14	975.98	1590.03	1583.95	956.70	259.70	59.36	5996.57

Table A14: Observed monthly inflow (unit: MCM) of Pasak reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1999	0.00	0.00	0.00	0.00	0.00	0.00	50.79	154.92	635.98	955.17	300.76	23.99	2121.61
2000	0.00	18.68	21.64	26.50	241.18	318.10	596.63	741.48	1731.89	843.97	141.35	35.85	4717.27
2001	29.95	31.24	4.60	9.26	102.43	93.82	121.10	470.68	436.80	349.07	135.62	44.39	1828.96
2002	49.40	35.12	52.05	40.05	69.91	120.20	55.30	164.76	2239.74	724.66	190.68	22.64	3764.52
2003	20.74	20.74	15.55	6.91	50.20	73.66	128.93	319.85	623.10	449.87	32.68	40.61	1782.84
Average	4.00	4.23	3.75	3.31	18.55	24.23	38.11	74.07	226.70	132.91	32.04	6.70	568.61

Table A15: Raw simulated monthly inflow (unit: MCM) of Pasak reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	7.90	3.25	1.47	0.64	0.70	42.80	8.01	7.92	439.97	257.20	44.36	7.28	821.50
1980	2.64	1.03	0.52	0.28	109.53	60.10	121.23	266.19	641.30	662.80	20.14	4.91	1890.66
1981	1.88	0.74	0.40	0.24	84.43	263.63	242.47	834.89	1982.61	1187.98	36.29	9.97	4645.52
1982	2.90	1.18	0.60	0.44	170.25	173.93	92.70	179.83	228.92	326.39	30.02	7.62	1214.77
1983	3.57	1.44	0.73	0.35	55.25	141.75	84.17	100.43	241.32	1210.07	46.85	10.99	1896.92
1984	4.23	1.63	0.78	0.37	63.32	165.26	86.20	89.93	311.94	63.71	8.84	4.79	801.00
1985	2.00	0.85	0.52	0.55	37.44	102.55	32.95	41.69	274.68	147.58	164.18	11.62	816.61
1986	3.43	1.38	0.70	0.34	127.32	134.13	60.35	25.21	152.18	22.83	4.85	1.86	534.58
1987	0.76	0.36	0.24	15.29	34.62	194.59	339.74	67.12	419.01	869.21	37.81	7.31	1986.06
1988	2.38	0.93	0.59	0.46	170.33	203.40	129.52	35.07	1210.01	1111.56	49.19	8.17	2921.60
1989	2.97	0.96	0.51	0.29	148.35	104.03	53.49	45.22	466.68	456.19	44.70	8.36	1331.77
1990	2.56	0.94	0.49	0.31	150.51	980.24	448.09	248.75	582.54	83.18	7.23	2.48	2507.31
1991	0.99	0.45	0.27	3.37	147.69	253.05	73.48	285.72	1104.00	347.87	17.71	5.92	2240.53
1992	2.38	0.94	0.48	0.25	32.62	120.37	251.57	216.12	1150.98	517.96	26.90	5.51	2326.09
1993	2.00	0.76	0.42	3.73	44.36	54.15	33.75	50.94	174.70	223.70	34.11	6.95	629.57
1994	2.33	1.12	0.65	0.32	57.05	107.49	153.82	151.82	313.40	121.80	29.94	5.91	945.64
1995	2.10	0.81	0.45	0.23	39.76	74.24	100.63	120.46	1315.08	440.77	40.21	6.49	2141.25
1996	2.12	0.83	0.44	0.23	6.79	31.82	49.18	413.46	1164.77	884.34	79.19	10.59	2643.78
1997	2.82	1.00	0.52	0.27	63.07	77.60	60.88	78.97	215.90	163.08	71.87	9.52	745.48
1998	2.88	1.08	0.55	0.27	24.57	113.16	86.07	221.09	235.20	243.41	20.33	4.58	953.19
1999	1.61	0.61	0.35	0.19	208.99	225.88	149.75	177.06	610.45	84.28	8.85	2.96	1470.99
2000	1.18	0.50	0.28	0.16	8.23	66.05	69.84	187.47	677.90	242.23	16.92	4.13	1274.89
2001	1.96	0.77	0.44	0.30	106.40	131.14	79.20	172.13	395.21	32.73	8.10	4.74	933.11
2002	1.68	0.72	0.41	0.22	49.01	898.95	289.68	175.26	1049.41	855.95	87.96	15.81	3425.05
2003	7.53	1.98	0.93	1304.98	344.42	430.22	161.20	58.07	582.53	539.84	45.33	6.72	3483.75
Average	2.75	1.05	0.55	53.36	91.40	206.02	130.32	170.03	637.63	443.87	39.28	7.01	1783.26

Table A16: Raw simulated monthly inflow (unit: MCM) of Pasak reservoir over future period [Ensemble mean SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	420.37	446.49	248.88	144.28	341.54	630.16	20.12	5.50	2257.34
2076	1.98	0.75	6.83	43.99	147.41	261.88	118.27	114.14	567.54	509.56	11.25	3.11	1786.72
2077	1.12	0.47	0.28	0.16	10.94	261.90	529.58	688.25	1102.68	269.66	12.44	3.45	2880.93
2078	1.43	0.59	0.36	0.41	128.07	107.61	59.76	191.97	605.56	840.35	122.63	7.14	2065.88
2079	2.13	0.80	0.43	0.28	12.43	40.22	18.98	124.08	571.91	499.85	20.19	5.76	1297.05
2080	2.29	0.91	0.46	0.28	746.13	264.01	367.88	246.00	408.37	407.73	21.32	4.93	2470.30
2081	1.64	0.63	0.36	0.22	97.74	500.65	1146.06	1199.52	1107.66	71.22	7.80	2.14	4135.65
2082	0.84	0.38	0.24	0.16	4.30	183.71	179.20	240.96	1006.88	195.93	12.74	5.85	1831.20
2083	1.79	0.77	0.47	0.29	28.08	60.43	22.53	7.34	319.32	565.63	67.03	8.62	1082.30
2084	2.73	1.05	0.52	0.28	61.77	96.44	60.74	119.48	555.65	417.53	12.47	3.22	1331.86
2085	1.13	0.46	0.27	0.16	567.88	551.05	350.85	340.89	647.57	614.84	24.24	5.16	3104.51
2086	1.79	0.68	0.37	0.24	109.49	161.49	129.48	889.07	1476.79	1471.50	24.70	4.71	4270.31
2087	1.65	0.62	0.34	1.76	76.39	364.73	164.78	201.68	533.50	355.89	33.33	5.96	1740.64
2088	2.03	0.77	0.40	0.21	116.09	90.43	32.14	514.83	341.84	296.42	22.52	5.17	1422.84
2089	1.77	0.68	0.37	0.21	15.14	118.22	59.18	119.09	249.87	388.66	31.85	5.63	990.67
2090	1.91	0.72	0.39	0.22	178.21	245.66	388.56	314.73	1529.35	998.94	31.21	6.10	3696.02
2091	1.90	0.72	0.39	0.21	0.45	88.82	71.07	413.29	1836.15	233.82	12.79	6.17	2665.78
2092	2.01	0.76	0.41	0.24	0.38	93.23	118.63	100.79	577.59	1310.18	400.55	24.17	2628.93
2093	4.48	1.57	0.76	24.43	137.84	108.97	133.35	558.56	1120.58	283.21	16.67	3.97	2394.39
2094	1.41	0.55	0.71	0.55	6.92	44.59	348.65	487.68	1669.50	949.85	26.03	4.71	3541.14
2095	1.83	0.72	0.40	0.23	0.39	159.11	223.40	420.79	958.13	797.00	43.69	5.48	2611.17
2096	1.72	0.66	0.35	0.20	14.70	113.40	160.13	266.00	1133.82	1469.39	63.36	6.62	3230.36
2097	2.23	0.83	0.44	0.23	0.41	32.81	34.34	53.57	817.64	666.20	23.24	4.65	1636.60
2098	1.52	0.58	0.33	0.19	32.39	203.71	235.90	180.02	566.06	1389.30	104.34	9.22	2723.56
2099	2.61	1.00	0.81	0.46	15.36	203.71	127.31	278.25	232.42	812.87	29.48	5.19	1709.48
Average	1.84	0.71	0.67	3.02	117.17	192.13	213.19	328.61	811.12	657.83	47.84	6.11	2380.23

Table A17: Raw simulated monthly inflow (unit: MCM) of Pasak reservoir over future period [Cluster 1 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	88.34	168.05	294.61	194.13	807.74	500.30	35.35	5.52	2094.04
2076	1.80	0.68	0.36	0.86	168.44	197.50	21.76	23.93	504.72	213.58	13.56	4.49	1151.69
2077	1.76	0.71	0.39	30.00	299.84	266.88	234.82	869.16	1273.27	531.07	20.09	4.46	3532.45
2078	1.56	0.61	0.36	0.21	0.14	102.96	161.56	29.78	128.20	58.82	8.77	3.33	496.29
2079	1.32	0.54	0.32	0.18	0.14	7.54	41.75	59.46	2028.97	519.68	151.59	8.82	2820.31
2080	2.81	1.06	0.53	0.28	524.60	766.44	164.83	124.08	575.50	1231.43	72.94	8.54	3473.04
2081	2.60	0.95	0.49	3.15	619.78	639.31	210.49	57.25	294.52	391.91	35.51	6.36	2262.33
2082	2.09	0.79	0.43	0.23	454.41	1117.12	233.29	180.48	778.10	1114.69	24.19	4.55	3910.36
2083	1.54	0.59	0.42	0.27	15.93	95.47	111.23	90.35	389.70	1103.99	58.55	6.88	1874.91
2084	2.63	1.85	0.83	0.48	250.57	334.42	204.10	225.99	1436.49	763.12	21.86	5.36	3247.70
2085	1.82	0.68	0.38	0.21	85.38	239.46	219.41	329.03	859.37	771.03	108.19	13.83	2628.77
2086	4.92	1.52	0.73	0.38	304.10	333.70	192.87	264.81	566.19	66.09	6.90	2.40	1744.61
2087	0.92	0.39	0.24	0.39	60.80	172.04	122.84	43.47	143.97	230.17	29.38	6.77	811.37
2088	2.13	0.79	0.42	0.22	20.27	100.22	50.99	79.41	217.18	163.37	11.87	3.47	650.34
2089	1.24	0.48	0.29	0.20	27.61	337.90	482.44	58.42	114.09	141.31	14.52	5.99	1184.49
2090	2.60	1.02	0.53	0.40	12.07	807.62	165.18	76.88	276.54	118.22	28.98	4.98	1495.02
2091	1.69	0.64	0.36	0.20	1.70	88.27	25.94	23.62	217.23	124.06	10.07	3.17	496.94
2092	1.56	0.64	0.34	0.19	138.86	255.81	45.43	139.81	985.75	793.89	25.20	4.36	2391.83
2093	1.43	0.55	0.32	0.31	140.84	60.88	28.58	291.90	822.91	288.09	33.36	13.41	1682.58
2094	3.58	1.25	0.62	0.42	71.15	355.23	101.51	491.31	953.83	595.26	16.38	3.50	2594.02
2095	1.25	0.52	0.30	0.19	78.17	233.15	149.03	176.72	1124.62	1987.39	351.13	13.54	4116.00
2096	6.13	1.82	0.80	0.44	122.05	161.62	134.57	479.70	1136.08	562.30	30.45	5.68	2641.64
2097	1.92	0.72	0.40	0.22	55.08	125.12	54.00	79.86	726.11	1516.72	188.64	8.84	2757.62
2098	2.58	0.95	0.49	0.25	17.31	86.82	124.05	124.63	87.64	36.66	12.01	6.20	499.60
2099	2.06	0.79	0.50	23.77	129.82	458.75	282.75	86.54	244.59	428.91	18.39	4.00	1680.89
Average	2.16	0.82	0.43	2.54	147.50	300.49	154.32	184.03	667.73	570.08	53.12	6.34	2089.55

Table A18: Raw simulated monthly inflow (unit: MCM) of Pasak reservoir over future period [Cluster 2 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	50.08	418.89	154.79	59.07	2024.34	790.22	22.39	4.99	3524.78
2076	1.71	0.67	0.36	0.20	45.71	64.07	49.00	159.96	292.20	492.70	23.15	5.60	1135.34
2077	1.99	0.74	0.40	0.21	84.89	527.47	325.92	212.58	1277.63	738.18	27.28	5.29	3202.60
2078	1.67	0.63	0.35	0.22	6.58	430.86	830.77	187.88	238.60	40.44	12.55	30.75	1781.32
2079	2.14	0.65	0.36	11.77	11.41	54.82	50.45	115.85	846.08	1759.98	69.84	9.33	2932.67
2080	2.39	0.87	0.44	0.33	19.77	89.14	36.80	14.18	217.61	157.69	10.38	3.11	552.71
2081	1.16	0.47	0.28	0.16	23.10	171.01	85.41	108.04	350.30	162.15	11.51	3.25	916.84
2082	1.16	0.63	0.49	0.26	78.26	280.87	103.91	59.46	298.49	95.74	22.76	6.00	948.01
2083	2.06	0.78	0.42	0.26	19.33	35.50	9.12	3.55	42.96	173.72	58.40	7.71	353.80
2084	2.57	0.94	0.46	0.29	34.45	178.18	868.21	454.62	1205.22	764.57	20.49	4.59	3534.58
2085	1.59	0.61	0.35	0.35	45.69	159.58	82.76	162.88	415.97	662.13	22.44	4.77	1559.12
2086	1.64	0.62	0.34	0.19	62.75	102.52	89.48	263.35	697.85	702.43	29.46	5.50	1956.12
2087	1.83	0.69	0.38	0.21	120.03	168.66	121.98	77.39	205.92	166.37	24.05	6.52	894.04
2088	2.34	0.90	0.45	0.24	0.15	28.60	77.88	65.06	604.65	2738.03	53.41	6.42	3578.12
2089	2.15	0.93	8.74	21.32	17.60	47.47	36.24	14.24	437.69	202.09	23.66	5.80	817.94
2090	1.98	0.73	0.39	0.21	0.24	2410.73	397.85	541.85	353.42	522.30	65.32	8.42	4303.45
2091	2.48	0.89	0.47	0.33	81.38	195.56	153.22	179.43	373.80	91.43	8.14	2.48	1089.62
2092	0.90	0.39	0.23	0.15	98.59	321.67	659.17	2066.63	904.34	601.61	25.86	4.84	4684.40
2093	1.46	0.56	0.32	0.18	37.91	136.67	120.61	78.91	120.43	38.79	12.41	4.84	553.10
2094	2.07	0.81	0.46	0.25	0.16	51.92	43.40	150.23	701.69	1177.54	49.81	6.18	2184.53
2095	2.03	0.78	0.43	0.26	31.06	140.84	98.97	201.69	397.48	1184.44	128.93	11.74	2198.64
2096	3.19	1.15	0.56	0.29	156.56	308.89	40.99	245.70	762.43	579.87	24.09	5.21	2128.93
2097	1.71	0.65	0.37	0.21	89.16	249.92	143.44	41.82	354.06	391.19	17.48	4.19	1294.19
2098	1.41	0.54	0.31	0.18	70.90	358.35	176.08	171.78	477.19	1043.54	152.18	9.84	2462.28
2099	2.84	1.06	0.55	0.34	80.80	191.38	123.92	320.15	677.13	274.98	22.66	5.63	1701.45
Average	1.86	0.71	0.72	1.54	50.66	284.94	195.22	238.25	571.10	622.08	37.55	6.92	2011.54

Table A19: Raw simulated monthly inflow (unit: MCM) of Pasak reservoir over future period [Cluster 3 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	2.54	3.40	1.05	7.98	552.41	269.95	98.00	727.20	407.15	70.44	8.14	2148.25
2076	2.55	0.95	0.48	0.56	99.47	192.46	429.42	647.95	642.73	263.18	51.66	7.52	2338.92
2077	2.56	0.88	0.85	0.64	118.77	190.96	170.64	633.10	1326.35	1174.16	47.49	8.00	3674.40
2078	2.35	0.87	0.47	0.27	113.02	621.20	305.07	182.43	566.67	287.40	43.23	5.23	2128.21
2079	1.73	0.65	0.36	0.20	0.13	95.92	75.60	182.59	521.56	141.26	36.21	6.82	1063.01
2080	2.43	0.98	0.49	7.47	295.33	538.16	164.63	832.12	926.83	78.01	7.22	2.33	2856.00
2081	0.99	0.41	0.25	0.15	9.52	93.05	56.39	74.33	839.59	328.34	105.79	7.27	1516.08
2082	2.25	0.82	0.45	0.24	42.99	277.97	65.86	112.18	2050.75	413.96	18.63	4.43	2990.53
2083	1.70	0.64	0.36	0.20	32.53	398.12	406.12	1876.81	1253.88	1117.86	88.14	9.61	5185.97
2084	2.35	0.83	0.42	0.23	120.52	189.04	940.63	617.90	1606.96	328.87	23.89	5.72	3837.35
2085	1.75	0.65	0.36	0.20	0.19	12.14	166.00	205.80	580.53	604.53	27.96	4.23	1604.33
2086	1.47	0.56	0.32	0.19	122.33	144.21	56.85	216.59	1569.69	296.61	12.49	3.46	2424.77
2087	1.23	0.49	0.29	0.25	98.50	299.46	58.90	24.28	228.18	649.27	52.39	6.33	1419.58
2088	2.09	0.79	0.42	0.22	62.47	94.00	85.94	95.43	541.63	644.71	38.39	5.96	1572.06
2089	2.08	0.78	0.42	0.26	133.95	441.25	125.90	126.95	735.48	520.41	22.29	4.72	2114.47
2090	1.59	0.61	0.35	0.28	138.72	260.22	174.80	109.49	299.16	497.58	89.25	8.56	1580.60
2091	2.57	0.95	0.50	0.25	61.98	199.29	79.28	188.48	703.88	425.95	29.95	5.94	1699.01
2092	2.12	0.80	0.42	0.52	305.02	392.18	177.23	234.57	561.22	214.66	19.66	6.33	1914.72
2093	2.37	1.00	0.53	21.38	209.47	200.51	21.21	44.10	438.85	211.70	20.83	6.44	1178.40
2094	2.03	0.79	0.43	0.26	32.64	755.77	272.56	286.50	1418.10	1731.50	51.91	7.79	4560.25
2095	2.46	0.85	0.45	0.25	30.93	187.93	60.46	40.53	1466.52	1657.78	85.48	7.71	3541.36
2096	2.46	0.91	0.46	0.24	61.62	202.42	370.00	551.43	359.63	158.03	10.85	3.17	1721.22
2097	1.39	0.57	0.33	6.59	563.10	828.93	159.72	94.03	361.94	697.60	37.66	8.64	2760.51
2098	2.91	1.03	0.54	0.27	103.52	160.37	16.73	189.64	637.84	748.76	24.55	5.31	1891.48
2099	2.79	1.12	0.56	81.86	956.82	855.68	189.11	164.39	1154.31	490.01	20.82	5.49	3922.97
Average	2.01	0.86	0.56	4.96	148.86	327.35	195.96	313.18	860.78	563.57	41.49	6.20	2465.78

Table A20: Observed monthly inflow (unit: MCM) of Srinagarind reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	104.66	50.66	65.97	73.03	158.16	183.38	240.55	413.01	720.04	751.05	253.51	121.74	3135.76
1981	76.13	71.70	69.94	64.62	125.52	385.29	529.94	1430.83	1087.20	859.43	1235.07	340.73	6276.40
1982	171.16	101.97	70.55	96.50	92.67	255.91	624.40	1599.11	1008.42	705.30	275.20	149.13	5150.32
1983	106.84	56.48	46.97	51.55	77.69	96.35	121.47	300.94	500.15	1839.13	656.78	209.67	4064.02
1984	139.11	100.86	81.29	124.91	82.34	322.18	365.51	677.53	842.00	864.96	287.97	159.40	4048.06
1985	117.50	89.91	65.83	95.13	93.58	289.02	790.31	861.10	1609.67	908.85	404.04	206.74	5531.68
1986	141.40	83.25	68.04	103.71	472.28	191.35	436.41	668.04	586.06	573.10	218.57	139.87	3682.08
1987	85.24	71.09	85.66	100.55	67.90	168.96	236.31	423.65	833.67	612.98	368.96	134.27	3189.24
1988	111.90	93.09	64.39	103.20	346.10	489.89	422.56	621.71	1306.03	2097.53	450.93	246.33	6353.66
1989	172.88	109.36	71.91	39.50	128.31	124.37	165.16	503.89	442.28	409.05	128.96	84.16	2379.83
1990	76.92	94.18	56.36	48.97	103.77	164.91	407.09	397.77	650.18	798.24	230.89	113.03	3142.31
1991	81.45	56.94	33.26	44.16	80.86	340.39	429.18	1754.82	812.26	1125.08	299.98	134.45	5192.83
1992	135.74	59.35	48.83	75.17	67.66	76.62	279.91	744.38	465.84	709.40	263.42	120.80	3047.12
1993	90.15	41.43	61.85	53.62	48.97	78.93	206.23	616.32	750.24	350.22	135.57	60.34	2493.87
1994	61.40	93.91	48.97	45.84	186.19	294.89	1445.34	2037.39	1279.27	741.44	231.47	122.64	6588.75
1995	100.86	58.23	50.98	56.21	82.01	126.99	261.89	866.73	1881.19	929.26	334.13	152.78	4901.26
1996	105.42	96.22	64.08	86.81	173.63	218.74	787.46	1112.67	1372.18	2069.33	603.51	226.72	6916.77
1997	141.16	82.12	85.22	74.86	55.34	71.42	724.38	1624.43	997.79	821.05	435.00	234.66	5347.43
1998	77.25	58.93	47.82	37.87	67.86	90.47	161.04	295.72	437.10	396.72	121.88	75.30	1867.96
1999	63.71	37.89	42.85	129.39	213.65	234.94	374.77	969.77	571.08	1310.71	939.94	232.34	5121.04
2000	159.38	122.53	89.50	256.41	399.81	566.34	714.34	695.46	1161.68	1149.00	416.50	193.92	5924.87
2001	146.00	83.09	128.28	101.47	199.89	283.21	609.15	887.23	626.14	622.49	247.99	141.43	4076.37
2002	106.23	82.73	58.99	65.78	260.56	236.34	612.27	1440.87	2050.74	1028.64	486.63	243.80	6673.58
2003	125.23	91.93	180.11	90.38	83.38	259.37	797.30	803.29	954.25	874.87	246.01	120.17	4626.29
Average	107.91	75.51	67.51	80.79	146.73	222.01	469.72	869.87	917.82	901.91	370.92	158.58	4389.26

Table A21: Raw simulated monthly inflow (unit: MCM) of Srinagarind reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	0.00	0.00	0.00	0.00	0.24	4.91	19.49	158.29	268.07	266.36	123.42	24.28	865.07
1980	3.79	0.97	0.47	0.26	14.11	44.52	146.23	220.47	481.74	639.90	93.65	14.57	1660.67
1981	2.50	0.70	0.35	0.19	4.56	153.19	536.28	503.70	1398.92	956.73	243.07	56.92	3857.10
1982	9.50	1.89	0.75	0.47	2.44	28.25	252.94	332.30	352.68	448.20	122.98	41.08	1593.48
1983	6.80	1.48	0.60	0.44	11.02	55.83	148.57	174.03	595.36	467.93	125.57	42.25	1629.88
1984	7.04	1.50	0.58	0.35	23.90	646.22	321.41	480.94	558.00	307.97	218.41	41.75	2608.07
1985	6.82	1.55	0.63	0.49	29.50	169.76	268.84	327.45	592.83	401.67	215.83	51.21	2066.57
1986	8.37	1.74	0.68	0.85	47.69	177.07	167.16	107.32	346.65	137.64	20.83	3.71	1019.71
1987	1.03	0.38	0.22	0.18	0.44	133.63	419.58	397.38	394.16	583.67	174.90	33.41	2138.99
1988	12.36	3.98	1.22	0.48	2.34	32.49	124.23	165.56	641.18	585.33	136.25	23.04	1728.45
1989	3.02	0.81	0.39	0.21	4.22	14.03	35.05	57.94	275.54	378.99	165.47	29.40	965.07
1990	4.38	1.13	0.49	0.31	9.98	724.47	1322.54	1181.97	771.91	341.41	49.79	10.74	4419.14
1991	2.08	0.62	0.41	0.32	15.60	210.05	585.36	916.16	1142.26	869.10	155.07	25.43	3922.47
1992	3.47	0.92	0.41	0.21	1.21	103.02	442.68	500.88	798.98	791.85	151.95	19.73	2815.31
1993	2.82	0.76	0.37	0.19	0.18	0.23	19.87	99.14	155.59	285.92	117.45	18.11	700.63
1994	3.46	1.24	0.53	0.24	3.18	82.15	153.40	3763.12	1366.29	417.78	107.89	11.41	5910.70
1995	2.05	0.62	0.32	0.17	0.23	1.45	6.74	47.59	185.16	223.66	98.97	34.77	601.74
1996	6.84	1.54	0.59	0.27	3.81	16.43	53.30	351.15	807.94	713.77	230.06	34.60	2220.29
1997	4.74	1.14	0.50	0.24	0.89	42.24	408.97	480.05	311.21	229.91	141.56	29.26	1650.71
1998	4.50	1.06	0.47	0.22	0.15	0.41	1.57	23.14	120.69	158.36	53.22	9.33	373.13
1999	1.73	0.53	0.28	0.20	17.10	148.26	257.89	364.14	789.10	232.07	40.71	6.96	1858.98
2000	1.54	0.51	0.27	0.15	1.85	152.96	270.77	513.34	797.32	412.19	131.85	38.88	2321.64
2001	5.97	1.37	0.57	0.65	47.33	151.93	276.23	349.12	472.98	162.48	53.92	16.44	1538.99
2002	2.96	0.80	0.38	0.20	2.46	143.82	371.70	319.35	1113.49	612.11	205.92	52.85	2826.05
2003	12.01	2.54	0.95	5.10	52.82	68.40	121.57	237.73	530.86	495.41	180.80	27.47	1735.66
Average	4.79	1.19	0.50	0.50	11.89	132.23	269.30	482.89	610.76	444.82	134.38	27.90	2121.14

Table A22: Raw simulated monthly inflow (unit: MCM) of Srinagarind reservoir over future period [Ensemble mean SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.01	83.92	300.73	267.07	275.77	552.87	427.01	143.68	33.00	2084.07
2076	4.03	1.03	0.45	2.86	71.56	169.74	269.04	925.32	695.13	423.57	48.30	6.48	2617.49
2077	1.44	0.48	0.26	0.14	0.20	2.43	79.34	155.58	421.22	268.68	29.35	7.83	966.94
2078	1.67	0.53	0.28	0.22	0.92	27.38	480.29	373.17	910.76	806.05	246.71	28.98	2876.96
2079	3.34	0.87	0.41	0.21	0.18	0.21	0.92	100.88	348.58	390.70	83.92	16.70	946.92
2080	2.69	0.75	0.35	0.27	154.00	83.28	128.18	163.18	308.47	509.85	118.60	21.66	1491.29
2081	2.82	0.76	0.37	0.21	2.75	100.66	271.88	664.80	671.78	189.47	20.18	4.85	1930.52
2082	1.08	0.38	0.25	0.16	6.88	54.19	133.41	393.62	587.34	293.03	67.46	20.51	1558.32
2083	4.07	1.04	0.47	0.23	0.14	0.21	5.72	157.18	321.08	427.24	166.09	28.53	1111.98
2084	3.95	0.96	0.42	0.27	31.96	128.37	120.03	335.55	558.27	423.54	44.33	4.26	1651.89
2085	1.00	0.37	0.22	0.14	16.26	460.94	276.62	281.52	440.99	696.85	111.34	11.47	2297.74
2086	1.91	0.58	0.30	0.18	3.06	26.10	46.61	294.70	440.06	1143.18	137.22	16.04	2109.92
2087	2.26	0.67	0.34	0.28	13.64	172.52	166.48	170.72	229.84	183.31	49.71	6.58	996.36
2088	1.65	0.53	0.27	0.15	0.20	0.59	2.18	18.99	61.73	129.30	56.57	8.70	280.86
2089	1.71	0.53	0.28	0.15	0.10	0.28	0.44	768.41	507.95	997.57	159.08	20.31	2456.83
2090	2.94	0.77	0.38	0.26	63.62	695.98	5695.33	1615.39	666.96	644.88	108.20	10.75	9505.46
2091	1.87	0.59	0.31	0.16	0.12	0.19	0.42	54.65	301.01	240.52	45.62	7.22	652.68
2092	1.42	0.48	0.25	0.17	1.00	15.63	47.37	143.49	339.30	659.82	373.11	125.59	1707.64
2093	19.34	2.83	0.98	0.81	5.07	60.31	706.02	941.24	1967.56	625.60	85.55	9.81	4425.13
2094	1.95	0.61	0.34	0.27	0.18	0.14	1.75	28.21	248.51	658.65	140.59	17.27	1098.47
2095	2.52	0.69	0.34	0.22	1.18	43.86	148.91	399.49	765.43	598.82	131.92	12.64	2106.02
2096	1.96	0.61	0.30	0.17	1.39	47.17	70.25	277.21	613.47	530.29	195.76	29.94	1768.51
2097	3.58	0.88	0.41	0.21	0.56	2.37	4.81	64.79	161.70	323.48	60.99	6.28	630.06
2098	1.25	0.43	0.24	0.16	37.17	88.94	227.55	236.94	254.23	425.18	181.93	28.51	1482.53
2099	4.45	1.10	0.48	0.23	0.41	8.44	49.58	193.40	201.73	399.45	77.88	9.17	946.34
Average	3.00	0.74	0.35	0.33	19.86	99.63	368.01	361.37	503.04	496.64	115.36	19.72	1988.04

Table A23: Raw simulated monthly inflow (unit: MCM) of Srinagarind reservoir over future period [Cluster 1 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.03	38.10	126.63	227.32	185.69	597.83	460.63	103.22	11.72	1751.18
2076	1.97	0.61	0.31	0.70	87.21	227.81	88.41	43.15	99.62	187.66	52.44	11.68	801.56
2077	2.20	0.64	0.32	1.65	70.23	115.94	124.63	377.67	624.19	460.62	92.56	8.33	1878.97
2078	1.51	0.50	0.27	0.15	0.28	46.68	106.58	77.86	177.85	148.96	48.29	9.02	617.96
2079	1.89	0.57	0.30	0.16	0.11	0.22	7.66	55.82	380.18	325.35	118.78	30.24	921.27
2080	5.28	1.28	0.53	0.25	11.08	296.38	158.14	105.11	226.59	425.95	149.09	31.26	1410.93
2081	4.29	1.25	0.54	0.49	87.38	374.25	184.69	99.44	284.00	329.22	70.61	8.67	1444.83
2082	1.72	0.53	0.28	0.15	4077.25	2139.84	313.78	277.83	554.30	504.51	79.72	7.08	7957.02
2083	1.40	0.47	0.26	0.15	19.47	34.48	44.79	406.93	486.44	833.52	369.62	89.28	2286.80
2084	20.51	2.91	0.93	0.48	12.21	74.63	90.31	185.60	534.01	529.15	88.33	8.89	1547.97
2085	1.61	0.52	0.28	0.15	2.22	61.51	255.63	373.12	700.93	1166.55	326.33	85.13	2973.97
2086	13.73	2.45	0.88	0.40	0.58	86.52	192.86	142.98	309.01	188.03	29.99	4.05	971.47
2087	0.99	0.37	0.22	0.16	0.31	28.09	51.37	258.95	189.32	225.62	77.76	10.14	843.32
2088	2.05	0.62	0.30	0.16	0.15	9.29	25.10	83.47	252.49	187.37	33.58	4.70	599.27
2089	1.15	0.41	0.23	0.15	5.55	254.46	473.26	226.75	241.40	234.46	48.26	9.94	1496.04
2090	2.62	0.73	0.36	0.19	1.62	1042.94	426.62	230.71	340.34	224.09	43.79	5.58	2319.59
2091	1.32	0.45	0.25	0.14	0.09	1.44	8.76	72.30	172.70	138.86	21.92	5.16	423.41
2092	1.32	0.46	0.24	0.14	17.01	262.49	121.55	229.12	708.24	696.49	137.16	12.04	2186.27
2093	1.74	0.54	0.29	0.32	11.71	41.57	361.30	716.37	1032.28	588.09	225.26	63.81	3043.29
2094	8.12	1.55	0.64	0.40	2.23	28.10	34.97	87.41	437.86	450.65	61.45	6.43	1119.82
2095	1.37	0.47	0.26	295.05	194.80	141.80	158.17	228.69	1686.17	4938.17	794.14	128.04	8567.12
2096	14.53	2.08	0.73	0.60	46.18	98.85	100.84	316.11	1255.81	574.11	187.18	22.16	2619.18
2097	2.68	0.72	0.36	0.18	4.61	12.66	33.23	65.12	86.08	328.46	172.10	22.63	728.84
2098	3.32	0.87	0.41	0.20	49.41	318.67	788.26	684.31	413.84	153.41	49.15	12.04	2473.89
2099	2.39	0.67	0.34	0.36	18.11	304.65	192.98	152.49	182.54	226.82	56.45	8.57	1146.36
Average	3.99	0.87	0.38	12.11	190.32	245.20	182.85	227.32	478.96	581.07	137.49	24.66	2085.21

Table A24: Raw simulated monthly inflow (unit: MCM) of Srinagarind reservoir over future period [Cluster 2 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	0.33	650.71	344.93	364.07	676.32	908.36	188.64	21.54	3154.90
2076	3.00	0.83	0.38	0.20	0.17	8.70	19.14	38.13	242.78	344.21	87.26	12.86	757.67
2077	2.17	0.63	0.32	0.17	479.18	794.79	309.84	210.28	617.10	537.20	75.98	8.46	3036.12
2078	1.56	0.51	0.27	0.16	0.45	1813.86	2905.78	2140.16	1172.38	326.41	102.22	21.90	8485.66
2079	4.77	1.33	0.56	0.29	0.35	150.68	64.41	134.68	371.39	539.36	167.69	25.78	1461.30
2080	3.85	0.96	0.42	0.40	0.60	2.52	3.91	22.83	121.60	142.04	24.70	4.03	327.86
2081	1.03	0.37	0.22	0.12	0.69	27.03	68.14	82.95	155.45	187.45	43.87	5.72	573.03
2082	1.40	0.65	0.33	0.17	4.32	135.99	115.31	641.13	1526.28	417.73	148.55	19.58	3011.45
2083	2.74	0.73	0.36	0.19	0.13	0.24	0.58	8.39	272.23	241.12	108.84	20.01	655.55
2084	3.14	0.83	0.38	0.21	1.67	31.86	95.13	139.06	267.50	382.63	69.06	8.69	1000.16
2085	1.67	0.53	0.28	0.18	13.37	53.50	66.79	234.04	394.61	610.08	77.61	7.97	1460.63
2086	1.53	0.50	0.27	0.15	48.82	52.44	44.46	146.35	600.09	553.33	117.18	12.67	1577.79
2087	2.21	0.64	0.33	0.17	0.19	5.56	100.66	242.78	454.18	337.53	135.53	26.23	1306.00
2088	3.68	0.95	0.41	0.20	0.12	0.08	24.82	232.73	630.18	913.82	248.17	47.93	2103.09
2089	8.13	1.74	0.69	0.30	0.17	0.12	2.42	75.74	119.17	201.33	72.17	10.39	492.38
2090	1.96	0.58	0.30	0.16	0.16	709.38	1862.42	3258.25	996.33	2142.51	250.21	30.44	9252.70
2091	3.78	0.93	0.43	0.38	32.08	51.90	54.51	103.28	266.91	154.62	17.37	2.91	689.09
2092	1.07	0.33	0.19	0.20	11.82	43.93	111.50	720.25	649.83	467.39	85.87	9.00	2101.37
2093	1.58	0.51	0.28	0.15	0.65	13.40	144.76	1228.90	346.90	374.13	212.49	45.09	2368.84
2094	7.97	1.64	0.63	0.28	0.19	0.79	4.34	50.71	393.60	748.50	172.00	31.29	1411.94
2095	4.83	1.06	0.47	0.23	0.38	7.92	32.30	212.29	367.37	458.82	162.73	28.24	1276.63
2096	3.95	1.00	0.43	0.21	9.94	118.39	77.35	90.96	315.93	309.97	93.80	10.67	1032.59
2097	1.77	0.55	0.29	0.17	0.96	8.38	35.34	51.00	260.08	394.07	87.74	10.03	850.37
2098	1.67	0.53	0.28	0.15	1.75	47.67	373.97	525.79	503.16	430.77	198.99	25.21	2109.93
2099	3.29	0.86	0.41	0.24	0.46	17.69	663.02	817.37	486.72	438.86	94.91	16.91	2540.73
Average	2.91	0.77	0.36	0.20	24.36	189.90	301.03	470.89	488.32	502.49	121.74	18.54	2121.51

Table A25: Raw simulated monthly inflow (unit: MCM) of Srinagarind reservoir over future period [Cluster 3 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.02	0.12	0.19	0.15	0.38	0.72	10.24	85.96	800.63	603.39	236.28	35.27	1773.36
2076	4.28	1.02	0.45	0.40	20.21	170.17	329.87	309.91	519.80	276.57	119.26	14.34	1766.27
2077	2.26	0.66	0.33	0.24	25.20	92.53	90.36	1334.52	1049.15	951.23	241.52	30.52	3818.51
2078	4.26	1.14	0.53	1.01	141.72	414.55	471.35	453.31	705.13	542.80	108.97	13.81	2858.56
2079	2.18	0.64	0.33	0.17	0.14	0.19	0.25	64.44	338.24	180.05	90.02	25.70	702.35
2080	4.99	1.25	0.52	1.60	159.01	644.56	269.51	255.36	426.08	172.03	20.41	3.29	1958.61
2081	0.88	0.34	0.20	0.12	0.27	7.12	154.92	217.98	415.41	294.74	87.06	16.78	1195.82
2082	2.82	0.78	0.38	0.20	2.31	26.08	33.13	46.01	364.40	303.06	102.56	16.81	898.53
2083	2.53	0.67	0.33	0.17	0.34	128.93	469.01	356.05	681.81	722.80	186.17	19.13	2567.93
2084	2.54	0.73	0.35	0.18	7.58	128.52	107.12	246.22	682.26	635.16	156.94	21.97	1989.58
2085	2.44	0.67	0.34	0.18	0.63	5.96	13.60	138.87	598.57	497.41	195.66	20.55	1474.88
2086	2.83	0.78	0.38	0.20	23.78	87.06	318.82	897.87	826.98	386.98	47.79	5.01	2598.48
2087	1.12	0.41	0.23	0.18	1.42	72.42	115.46	588.13	396.10	493.37	151.26	21.52	1841.63
2088	3.50	0.93	0.41	0.22	0.36	4.03	48.96	190.25	497.38	396.46	121.11	16.34	1279.95
2089	2.55	0.72	0.36	0.23	19.97	331.53	267.87	192.87	421.59	383.92	74.17	8.65	1704.42
2090	1.79	0.58	0.30	0.17	5.12	89.98	354.48	2081.24	2849.87	580.85	192.68	26.78	6183.84
2091	3.20	0.82	0.39	0.20	2.29	64.18	75.28	221.71	534.94	425.36	126.81	22.80	1477.98
2092	3.05	0.82	0.38	0.43	16.52	443.06	258.69	454.34	485.94	299.91	72.90	20.97	2057.00
2093	3.52	0.93	0.43	0.49	3.92	41.99	81.33	221.87	916.89	469.91	130.29	33.86	1905.44
2094	4.32	0.96	0.44	0.22	0.32	141.16	293.16	364.58	940.20	1104.75	222.17	35.30	3107.58
2095	3.47	0.85	0.40	0.21	21.19	39.67	57.13	126.98	251.44	513.62	183.36	24.10	1222.42
2096	3.19	0.85	0.39	0.20	1.40	33.81	197.19	358.95	398.28	240.03	67.11	15.49	1316.89
2097	2.58	0.74	0.36	0.55	199.18	426.99	170.06	172.45	410.30	530.04	156.07	38.16	2107.49
2098	5.48	1.28	0.54	0.25	11.99	146.43	62.19	106.33	384.85	505.31	109.78	28.77	1363.21
2099	4.69	1.16	0.52	0.25	2.62	17.40	61.55	153.68	360.11	283.75	63.90	14.66	964.28
Average	2.98	0.79	0.38	0.33	26.71	142.36	172.46	385.59	650.25	471.74	130.57	21.22	2005.40

Table A26: Observed monthly inflow (unit: MCM) of Vajiralongkorn reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1984	0.00	0.00	0.00	0.00	0.00	864.65	569.32	1598.54	985.42	604.17	195.55	94.41	4912.06
1985	75.80	40.70	41.77	66.65	96.86	1043.03	1559.68	1935.29	1402.73	466.88	192.34	59.91	6981.64
1986	48.07	41.62	25.91	36.27	180.56	270.10	702.19	1057.02	562.81	364.88	135.81	63.55	3488.79
1987	46.22	19.07	71.59	21.91	25.27	286.92	449.61	831.81	1000.42	587.56	207.40	76.86	3624.64
1988	64.47	35.63	5.49	56.02	266.06	723.41	561.70	1121.29	580.44	949.63	239.44	98.83	4702.40
1989	78.65	38.56	30.95	17.51	80.40	188.92	365.03	1140.41	683.40	362.74	108.20	40.89	3135.66
1990	41.59	19.02	4.84	23.95	67.75	447.46	763.61	871.00	1028.71	737.51	157.57	73.35	4236.36
1991	40.39	29.54	13.99	15.37	33.13	980.44	1327.82	3180.91	719.13	460.97	90.08	42.76	6934.53
1992	48.47	20.02	1.50	8.42	34.05	154.97	506.87	1729.76	774.68	430.76	129.11	96.22	3934.83
1993	54.74	29.31	26.10	18.83	51.36	151.77	586.68	1890.91	943.39	327.46	87.97	42.90	4211.42
1994	40.36	14.05	21.63	6.40	132.25	494.78	3043.56	3361.36	1062.87	442.06	81.65	33.49	8734.46
1995	41.48	23.00	23.57	15.08	139.22	575.36	590.41	1531.10	2031.65	539.46	117.68	70.53	5698.54
1996	39.52	32.95	12.11	34.77	78.87	211.72	1393.28	1598.21	1419.50	777.44	195.01	74.20	5867.58
1997	51.97	27.11	12.61	10.81	45.89	187.71	2587.18	3489.75	870.73	470.73	154.38	60.42	7969.29
1998	39.45	11.55	4.11	0.00	67.32	106.32	186.66	276.79	509.65	350.96	85.47	20.99	1659.27
1999	27.05	13.27	22.27	96.41	208.81	658.86	1160.23	2053.07	932.62	599.51	366.72	97.77	6236.59
2000	62.16	56.54	39.34	107.50	366.61	638.22	1122.00	1018.61	1523.47	692.69	186.03	88.02	5901.19
2001	57.55	22.02	35.21	9.88	181.40	418.05	1380.70	1787.62	947.87	532.65	132.20	68.19	5573.34
2002	46.36	18.89	7.07	17.76	465.57	496.37	1734.73	2428.44	1980.51	461.06	187.11	112.44	7956.31
2003	33.22	24.06	40.08	5.77	99.13	357.90	1219.24	1355.52	1142.35	466.54	112.49	40.71	4897.01
Average	37.50	20.68	17.61	22.77	104.82	370.28	872.42	1370.30	844.09	425.03	126.49	54.26	4266.24

Table A27: Raw simulated monthly inflow (unit: MCM) of Vajiralongkorn reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	0.00	0.00	0.00	0.00	0.00	0.80	37.38	257.97	246.49	244.20	75.64	12.52	875.00
1980	0.77	0.12	0.05	0.02	0.02	1.86	9.93	27.05	85.15	115.29	20.27	1.19	261.72
1981	0.15	0.04	0.02	0.01	0.43	246.99	403.41	626.03	750.93	682.37	151.41	25.89	2887.69
1982	1.28	0.14	0.05	0.02	0.02	0.82	394.19	429.70	320.28	269.43	90.92	31.29	1538.15
1983	1.76	0.16	0.06	0.03	0.73	6.16	80.28	183.12	407.46	205.05	42.25	10.16	937.21
1984	0.55	0.10	0.04	0.02	1.87	508.01	232.58	546.86	438.71	391.23	135.40	16.79	2272.18
1985	1.13	0.14	0.05	0.02	3.01	56.51	401.50	373.23	287.63	308.80	227.20	27.63	1686.85
1986	1.39	0.15	0.06	0.14	2.76	37.71	108.14	144.63	243.44	117.95	19.22	1.06	676.65
1987	0.13	0.04	0.02	0.02	0.08	117.75	599.59	445.31	224.55	301.98	82.28	4.99	1776.74
1988	0.33	0.08	0.04	0.02	0.78	2.08	47.78	114.11	226.39	241.54	44.18	2.24	679.57
1989	0.20	0.05	0.03	0.01	0.02	1.76	6.30	264.16	306.07	252.31	111.54	8.19	950.64
1990	0.41	0.08	0.04	0.02	0.07	598.24	1431.20	814.49	566.01	241.32	38.49	3.11	3693.48
1991	0.25	0.06	0.03	0.04	23.05	154.66	699.12	595.18	487.80	451.86	82.09	6.97	2501.10
1992	0.34	0.08	0.03	0.02	0.05	13.12	192.78	236.83	264.47	265.43	45.17	1.77	1020.08
1993	0.17	0.05	0.03	0.01	0.01	0.01	102.44	93.06	88.63	172.59	61.30	4.96	523.25
1994	0.72	0.11	0.04	0.02	0.05	4.45	382.89	2886.46	540.13	283.75	51.66	1.85	4152.14
1995	0.18	0.05	0.03	0.01	0.01	0.04	12.38	110.82	229.65	146.47	66.20	18.14	583.96
1996	0.91	0.12	0.05	0.02	5.95	22.06	98.51	582.58	480.72	348.12	93.07	5.30	1637.41
1997	0.30	0.07	0.03	0.02	0.02	24.42	903.23	929.49	347.07	193.03	113.51	9.80	2520.99
1998	0.43	0.08	0.04	0.02	0.01	0.01	0.04	1.13	11.92	42.93	18.81	0.92	76.34
1999	0.13	0.04	0.02	0.01	0.02	7.10	139.35	216.20	155.28	82.96	26.15	4.25	631.50
2000	0.30	0.07	0.03	0.02	0.25	226.30	251.46	470.00	444.12	376.55	77.23	11.03	1857.36
2001	0.56	0.10	0.04	0.02	2.82	13.37	172.19	137.17	251.91	93.47	48.93	10.74	731.32
2002	0.50	0.09	0.04	0.02	0.07	76.74	278.50	370.84	1026.73	544.83	165.37	26.24	2489.97
2003	1.33	0.15	0.06	0.30	5.27	7.63	267.88	299.04	281.63	352.53	92.53	5.59	1313.95
Average	0.57	0.09	0.04	0.04	1.89	85.14	290.12	446.22	348.53	269.04	79.23	10.10	1531.01

Table A28: Raw simulated monthly inflow (unit: MCM) of Vajiralongkorn reservoir over future period [Ensemble mean SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	2.23	35.36	181.09	103.65	160.27	116.08	57.19	5.51	661.37
2076	0.29	0.07	0.03	0.21	3.87	69.16	151.37	327.46	358.02	335.04	28.82	2.12	1276.45
2077	0.19	0.05	0.03	0.01	0.01	21.36	41.78	95.11	208.36	140.85	13.35	2.00	523.10
2078	0.19	0.05	0.03	0.01	0.06	20.33	381.96	190.82	261.97	437.16	165.84	7.17	1465.60
2079	0.33	0.07	0.03	0.02	0.01	0.02	0.01	178.64	319.94	356.27	60.65	5.61	921.60
2080	0.31	0.07	0.03	0.02	23.99	2.57	7.59	35.23	160.98	216.43	46.46	3.40	497.07
2081	0.24	0.06	0.03	0.02	0.10	45.27	117.72	1530.06	590.14	104.88	3.52	0.38	2392.41
2082	0.09	0.03	0.02	0.01	0.43	30.75	162.54	991.66	439.97	246.75	101.82	21.92	1995.98
2083	1.23	0.14	0.05	0.02	0.01	0.01	14.25	225.12	276.61	317.97	110.18	9.03	954.62
2084	0.39	0.08	0.04	0.02	6.32	19.37	100.14	274.12	150.33	136.29	9.47	0.36	696.91
2085	0.08	0.03	0.02	0.01	9.66	756.09	266.34	183.08	273.12	363.51	54.88	1.36	1908.18
2086	0.15	0.05	0.03	0.01	0.09	1.95	8.99	64.16	137.66	308.27	38.37	1.52	561.24
2087	0.16	0.05	0.02	0.01	0.17	33.96	130.97	358.45	251.60	124.91	25.54	1.04	926.88
2088	0.13	0.04	0.02	0.01	0.01	0.02	0.02	0.10	11.16	50.80	19.86	1.17	83.35
2089	0.14	0.04	0.02	0.01	0.01	0.01	0.01	146.07	133.74	269.76	36.62	1.82	588.25
2090	0.17	0.05	0.03	0.01	2.76	1260.32	4251.49	1045.56	433.59	209.68	25.91	0.76	7230.34
2091	0.12	0.04	0.02	0.01	0.01	0.01	3.12	262.56	206.79	151.63	42.47	2.62	669.41
2092	0.20	0.06	0.03	0.01	0.18	10.03	69.74	393.28	271.48	503.85	162.18	43.61	1454.65
2093	2.58	0.20	0.07	0.04	0.15	28.92	851.66	1425.15	995.52	384.28	65.06	4.47	3758.09
2094	1.15	0.16	0.05	0.02	0.01	0.01	1.90	18.49	325.95	337.02	55.20	2.04	742.02
2095	0.18	0.05	0.03	0.01	0.03	119.13	233.23	225.45	342.04	401.56	75.44	2.05	1399.22
2096	0.18	0.05	0.03	0.01	0.12	3.97	6.35	74.77	205.94	392.92	138.49	11.07	833.89
2097	0.41	0.08	0.04	0.02	0.10	0.16	0.60	12.11	78.81	206.15	29.47	0.88	328.83
2098	0.13	0.04	0.02	0.01	2.56	11.88	213.53	259.81	307.30	333.16	118.90	7.75	1255.09
2099	0.41	0.08	0.04	0.02	0.01	0.18	1.33	355.32	196.51	225.66	32.46	0.90	812.93
Average	0.38	0.07	0.03	0.02	2.12	98.83	287.91	351.05	283.91	266.83	60.73	5.62	1357.50

Table A29: Raw simulated monthly inflow (unit: MCM) of Vajiralongkorn reservoir over future period [Cluster 1 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	3.50	11.04	48.96	44.38	170.94	230.55	45.26	1.77	556.40
2076	0.17	0.05	0.03	0.10	4.85	15.08	9.04	5.14	51.70	76.75	31.44	2.48	196.84
2077	0.20	0.05	0.03	0.02	5.58	39.67	29.93	35.46	94.68	180.48	33.48	1.09	420.67
2078	0.17	0.05	0.03	0.01	0.01	2.14	35.09	54.16	121.71	109.29	34.48	1.89	359.04
2079	0.17	0.05	0.03	0.01	0.01	0.01	0.00	0.01	7.81	85.98	52.81	4.87	151.76
2080	0.28	0.07	0.03	0.02	0.09	128.73	98.96	94.02	98.32	215.95	91.17	9.02	736.67
2081	0.40	0.08	0.04	0.02	28.76	382.72	115.96	77.13	135.99	245.88	36.85	1.26	1025.08
2082	0.15	0.05	0.02	0.01	2427.57	991.03	126.64	74.59	139.58	396.56	40.12	0.94	4197.27
2083	0.13	0.04	0.03	0.01	1.32	5.54	16.09	102.05	281.75	512.66	199.40	35.32	1154.33
2084	2.68	0.21	0.07	0.03	1.23	19.46	33.27	61.19	108.04	226.95	31.18	0.93	485.25
2085	0.13	0.04	0.02	0.01	0.01	0.38	127.63	113.65	249.49	422.98	111.40	8.62	1034.36
2086	0.42	0.08	0.04	0.02	0.01	3.09	18.12	83.98	119.46	63.87	13.17	0.57	302.84
2087	0.10	0.03	0.02	0.01	0.05	20.57	67.53	316.43	109.51	127.05	36.88	1.27	679.45
2088	0.15	0.05	0.02	0.01	0.01	0.45	3.26	3.31	6.20	34.22	5.93	0.33	53.95
2089	0.08	0.03	0.02	0.01	0.23	191.69	315.10	163.78	112.35	125.99	18.80	7.63	935.69
2090	0.44	0.08	0.04	0.02	0.01	869.46	500.10	187.84	420.56	230.62	21.18	0.71	2231.07
2091	0.11	0.04	0.02	0.01	0.01	0.01	1.18	158.19	274.78	149.62	18.30	1.45	603.73
2092	0.16	0.05	0.02	0.01	0.19	161.89	58.16	73.32	272.56	451.20	70.08	1.80	1089.43
2093	0.17	0.05	0.03	0.02	1.21	2.37	321.11	525.86	522.13	366.10	147.39	26.99	1913.41
2094	1.15	0.13	0.05	0.02	0.07	1.33	3.21	19.53	125.67	168.98	17.93	0.71	338.79
2095	0.11	0.04	0.02	0.01	1.80	6.93	81.46	157.21	707.85	1977.11	332.40	42.28	3307.22
2096	1.59	0.16	0.06	0.05	2.60	8.75	14.33	20.76	253.20	276.43	97.57	4.50	680.00
2097	0.26	0.06	0.03	0.02	0.02	0.53	1.21	1.32	10.19	144.83	86.71	4.86	250.05
2098	0.27	0.06	0.03	0.02	0.01	32.85	462.10	396.65	204.19	222.73	100.54	18.54	1438.00
2099	0.74	0.11	0.04	0.02	1.08	154.59	83.28	98.93	97.17	223.25	41.37	2.49	703.07
Average	0.41	0.07	0.03	0.02	99.21	122.01	102.87	114.76	187.83	290.64	68.63	7.29	993.77

Table A30: Raw simulated monthly inflow (unit: MCM) of Vajiralongkorn reservoir over future period [Cluster 2 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	0.04	1565.30	335.87	1405.85	570.36	448.89	75.79	2.22	4404.32
2076	0.19	0.05	0.03	0.01	0.01	0.37	1.12	1.50	10.15	93.28	34.20	1.99	142.92
2077	0.18	0.05	0.03	0.01	326.26	861.93	292.45	338.02	398.23	256.84	24.37	0.79	2499.16
2078	0.12	0.04	0.02	0.01	0.01	2552.77	2174.19	1615.98	498.94	227.45	63.35	12.79	7145.69
2079	1.17	0.14	0.05	0.02	0.04	10.05	6.86	6.16	23.27	176.08	64.66	5.78	294.29
2080	0.34	0.08	0.03	0.02	0.01	0.08	0.26	254.55	313.96	176.83	18.75	0.83	765.74
2081	0.12	0.04	0.02	0.01	0.01	1.43	6.36	48.15	90.17	130.96	23.47	1.78	302.52
2082	0.25	0.06	0.03	0.02	0.07	4.42	14.83	478.55	604.78	219.15	73.92	4.08	1400.16
2083	0.24	0.06	0.03	0.02	0.01	0.01	0.02	19.30	174.94	204.03	112.21	10.06	520.93
2084	0.43	0.09	0.04	0.02	0.23	7.69	19.95	25.74	83.27	140.87	25.37	1.57	305.24
2085	0.16	0.05	0.02	0.01	19.80	18.51	17.90	185.40	178.85	336.77	28.03	0.84	786.35
2086	0.14	0.04	0.02	0.01	3.19	7.02	12.20	387.27	508.79	388.65	63.67	2.22	1373.24
2087	0.19	0.05	0.03	0.01	0.01	24.14	203.39	435.24	300.26	304.35	119.04	10.13	1396.86
2088	0.39	0.08	0.04	0.02	0.01	0.01	53.08	182.29	183.41	937.35	142.82	16.16	1515.64
2089	0.83	0.12	0.05	0.02	0.01	0.01	0.39	33.76	98.44	182.60	38.87	2.00	357.10
2090	0.18	0.05	0.03	0.01	0.01	719.51	1630.04	3012.02	590.09	448.71	88.19	3.56	6492.40
2091	0.24	0.06	0.03	0.04	2.72	5.20	11.99	47.30	173.58	117.45	6.34	1.67	366.62
2092	0.30	0.07	0.03	0.06	0.88	4.68	465.95	1174.87	557.36	328.88	46.82	1.31	2581.21
2093	0.15	0.05	0.02	0.01	0.01	0.36	225.11	2142.02	314.08	473.90	252.42	34.56	3442.69
2094	2.44	0.19	0.06	0.03	0.02	0.06	0.26	1.55	83.26	142.28	38.50	4.61	273.27
2095	0.34	0.07	0.03	0.02	0.01	0.64	3.62	18.48	86.31	296.29	82.79	4.85	493.45
2096	0.28	0.07	0.03	0.02	0.60	5.17	11.22	106.41	147.22	234.00	46.24	1.77	553.04
2097	0.17	0.05	0.03	0.01	0.01	0.09	2.06	173.39	210.73	224.25	38.91	1.51	651.20
2098	0.16	0.05	0.03	0.01	0.02	260.33	877.38	527.68	349.93	357.23	130.03	4.97	2507.81
2099	0.26	0.06	0.03	0.02	0.01	0.49	513.54	852.88	419.50	250.10	72.05	5.96	2114.89
Average	0.37	0.07	0.03	0.02	14.16	242.01	275.20	538.97	278.80	283.89	68.43	5.52	1707.47

Table A31: Raw simulated monthly inflow (unit: MCM) of Vajiralongkorn reservoir over future period [Cluster 3 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.03	0.11	0.01	0.00	0.09	0.76	11.57	41.98	363.07	367.48	126.84	7.39	919.35
2076	0.34	0.08	0.03	0.02	0.37	23.35	184.67	143.04	253.09	276.41	86.66	4.09	972.14
2077	0.25	0.06	0.03	0.02	1.01	9.71	28.51	322.49	341.22	363.00	88.63	3.63	1158.55
2078	0.24	0.06	0.03	0.08	23.10	157.83	308.97	183.23	260.26	239.96	83.39	5.34	1262.48
2079	0.29	0.07	0.03	0.02	0.01	0.01	0.02	392.67	346.07	243.98	158.43	24.02	1165.60
2080	1.78	0.17	0.06	0.04	6.69	286.84	135.80	156.54	181.50	61.50	4.68	0.29	835.88
2081	0.07	0.03	0.02	0.01	0.02	2.94	48.26	60.52	90.87	115.92	66.38	8.46	393.50
2082	0.42	0.08	0.04	0.02	0.13	2.70	4.97	12.30	230.70	139.87	36.40	4.00	431.63
2083	0.41	0.08	0.04	0.02	0.01	109.05	496.89	320.14	328.37	429.66	114.55	4.30	1803.52
2084	0.26	0.07	0.03	0.02	0.68	14.83	23.83	36.93	136.66	121.86	28.41	1.50	365.07
2085	0.16	0.05	0.02	0.01	0.08	1.63	3.82	101.20	227.23	308.08	78.46	2.69	723.43
2086	0.20	0.06	0.03	0.02	2.22	68.78	523.30	542.47	369.16	230.66	19.99	0.63	1757.50
2087	0.11	0.04	0.02	0.01	0.07	10.30	262.40	588.21	649.79	605.86	152.09	9.05	2277.95
2088	0.44	0.09	0.04	0.02	0.01	110.58	223.00	138.88	172.71	316.55	93.02	5.06	1060.39
2089	0.27	0.07	0.03	0.02	1.33	47.35	51.34	50.29	180.13	280.99	30.39	0.96	643.17
2090	0.13	0.04	0.02	0.01	32.47	216.35	562.84	1790.94	1994.67	407.30	138.05	5.76	5148.58
2091	0.27	0.07	0.03	0.02	0.15	4.85	21.22	135.28	346.22	351.18	86.25	5.39	950.93
2092	0.28	0.07	0.03	0.02	1.02	112.99	118.31	286.52	251.72	208.86	55.47	17.06	1052.34
2093	1.12	0.13	0.05	0.02	0.17	0.76	26.39	265.11	1019.59	291.07	136.91	17.51	1758.84
2094	0.64	0.10	0.04	0.02	0.01	137.60	282.71	759.78	604.39	559.55	132.32	12.68	2489.84
2095	0.41	0.08	0.04	0.02	0.07	0.87	43.46	80.64	79.22	323.70	106.51	6.76	641.77
2096	0.33	0.07	0.03	0.02	0.16	1.66	182.77	178.47	111.73	127.37	68.77	9.61	680.99
2097	0.54	0.09	0.04	0.04	14.65	119.95	55.79	115.09	239.64	260.87	80.29	6.94	893.93
2098	0.33	0.07	0.03	0.02	0.06	37.73	50.43	170.50	229.33	241.36	47.45	8.38	785.70
2099	0.41	0.08	0.04	0.02	0.12	14.07	33.69	34.29	125.09	157.49	45.89	8.20	419.40
Average	0.39	0.08	0.03	0.02	3.39	59.74	147.40	276.30	365.30	281.22	82.65	7.19	1223.70

Table A32: Corrected simulated monthly inflow (unit: MCM) by eQM method of Sirikit reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	0.00	0.00	0.00	35.80	33.89	43.85	1117.12	813.95	623.58	241.10	214.04	98.95	3222.29
1980	73.72	66.31	59.50	109.85	155.70	268.06	1109.57	1521.28	1121.67	647.36	204.63	108.22	5445.87
1981	93.63	86.46	130.19	184.99	462.43	511.26	3335.32	2972.27	3610.18	896.25	290.10	128.46	12701.54
1982	110.65	100.39	103.86	195.49	545.79	521.95	703.25	1338.34	1964.67	964.36	345.21	251.62	7145.57
1983	196.92	109.34	92.20	123.82	187.52	389.40	743.92	1329.23	1409.90	548.05	185.91	137.29	5453.51
1984	115.38	88.38	77.97	117.86	199.87	436.10	659.00	1306.13	1155.49	289.07	149.90	142.73	4737.89
1985	171.87	289.56	336.20	180.85	163.38	219.97	279.97	1137.03	1199.83	659.15	516.59	271.67	5426.08
1986	217.86	124.94	110.12	140.73	678.40	468.86	375.61	2277.28	767.75	149.53	79.87	36.36	5427.30
1987	34.65	34.83	33.84	93.87	103.66	240.33	213.57	402.57	939.64	716.57	281.45	121.10	3216.08
1988	155.78	122.64	100.19	126.27	55.82	361.23	1851.17	1790.23	1317.67	470.69	153.70	74.73	6580.13
1989	60.17	55.86	55.27	107.54	118.88	240.95	410.65	954.60	1953.42	916.61	432.53	191.70	5498.16
1990	153.04	96.98	82.27	119.67	203.19	198.68	274.56	908.27	565.05	419.79	138.31	117.41	3277.23
1991	99.76	77.30	70.75	120.06	429.53	431.37	284.74	1527.63	1282.89	463.50	272.54	155.28	5215.35
1992	118.36	87.48	71.80	114.36	22.10	8.12	534.54	937.16	412.70	507.31	193.78	76.11	3083.82
1993	54.54	47.13	60.99	111.29	22.20	102.99	56.11	614.30	705.35	593.83	249.50	116.55	2734.80
1994	97.93	69.74	70.26	122.00	38.66	80.60	471.21	1811.70	905.40	539.95	249.18	95.94	4552.57
1995	79.48	65.58	61.09	109.64	294.60	486.47	1493.20	780.50	1552.40	601.83	286.12	187.23	5998.15
1996	132.41	89.97	78.73	117.87	23.13	34.75	485.23	998.23	1505.12	658.00	205.18	80.86	4409.48
1997	61.44	51.40	47.59	103.06	150.69	213.08	602.04	727.77	821.35	503.67	587.02	271.79	4140.91
1998	188.94	112.91	90.76	121.96	111.17	334.17	812.01	3033.07	2297.07	523.76	155.19	45.07	7826.07
1999	33.97	36.86	36.89	95.06	105.41	417.89	1093.87	1261.32	1128.92	288.99	78.47	33.03	4610.68
2000	30.55	33.21	31.53	91.10	87.95	227.74	434.37	1759.34	1116.39	577.48	245.14	170.01	4804.80
2001	130.66	86.85	78.49	119.91	404.37	514.45	961.88	2157.84	1966.34	116.08	52.95	73.02	6662.84
2002	88.81	90.32	110.25	135.29	158.95	119.06	826.81	1673.51	654.14	734.50	387.54	286.97	5266.15
2003	259.53	193.26	227.92	305.02	528.95	978.03	482.25	388.41	1147.31	636.25	290.78	118.81	5556.52
Average	110.40	88.71	88.75	128.13	211.45	313.97	784.48	1376.88	1284.97	546.55	249.83	135.64	5319.75

Table A33: Corrected simulated monthly inflow (unit: MCM) by gQM method of Sirikit reservoir over present period

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	6.98	2.35	0.00	4.21	80.11	65.76	1071.89	806.57	664.87	305.47	224.81	102.26	3335.27
1980	73.15	52.33	43.78	42.72	156.99	288.56	1159.19	1413.12	1106.50	610.58	216.55	112.71	5276.17
1981	94.58	86.58	171.10	220.27	395.47	493.13	3032.23	3064.01	3476.71	992.65	286.35	130.95	12444.03
1982	113.41	111.47	123.02	207.87	501.46	485.86	754.31	1384.06	1871.58	946.72	324.72	242.41	7066.91
1983	195.76	122.59	102.10	93.25	217.02	367.51	788.80	1327.05	1398.70	529.57	202.08	141.04	5485.45
1984	118.17	87.67	76.79	70.25	222.28	395.30	719.95	1222.70	1194.15	333.93	167.24	146.26	4754.69
1985	175.14	256.76	290.62	214.74	212.22	212.94	337.13	1195.90	1213.29	595.86	455.59	278.01	5438.19
1986	215.25	146.79	133.91	146.91	622.00	445.77	434.51	2206.64	805.30	227.07	82.32	27.88	5494.36
1987	30.93	17.24	11.00	9.46	177.47	233.98	266.48	432.44	915.29	681.54	279.51	124.12	3179.46
1988	160.47	142.38	116.31	102.32	155.32	359.48	1847.70	1888.57	1327.25	467.28	166.01	75.27	6808.37
1989	58.87	40.70	37.36	36.83	123.80	232.13	468.71	957.78	1959.29	937.77	390.75	188.92	5432.91
1990	156.68	104.49	84.30	77.10	212.77	197.18	330.43	854.44	629.56	432.03	155.10	122.51	3356.60
1991	101.02	70.83	63.56	71.81	396.45	394.94	334.40	1722.84	1361.02	452.51	272.14	156.27	5397.78
1992	121.32	86.77	65.57	56.83	63.50	21.78	591.98	932.36	518.46	488.66	204.32	76.92	3228.48
1993	52.93	31.57	46.32	45.68	65.08	123.93	111.45	636.85	738.62	578.79	254.70	120.80	2806.72
1994	99.12	59.77	61.69	85.88	135.25	108.24	523.77	1934.16	855.53	503.79	251.15	98.82	4717.17
1995	79.28	52.36	46.70	42.40	265.08	467.34	1544.90	800.23	1633.30	585.06	283.69	184.51	5984.84
1996	135.88	91.13	78.36	70.30	77.05	54.71	524.91	1020.18	1565.66	654.17	215.62	82.06	4570.03
1997	60.40	36.00	27.48	26.38	162.93	211.51	664.58	700.28	844.86	495.01	619.71	268.44	4117.57
1998	188.67	128.70	98.71	86.29	156.24	330.60	859.37	3117.98	2378.84	533.96	166.73	39.51	8085.59
1999	30.10	20.15	15.09	11.43	91.94	414.83	1136.46	1187.39	1124.28	329.49	80.13	23.84	4465.11
2000	25.34	13.74	7.66	5.03	69.83	222.72	492.04	1855.46	1124.75	535.75	252.78	169.84	4774.96
2001	134.51	87.80	77.91	78.36	390.47	501.05	1018.45	1983.66	1920.22	180.20	42.17	76.21	6491.01
2002	89.19	93.87	133.85	130.78	209.54	145.94	805.24	1680.17	687.71	656.96	356.22	277.33	5266.80
2003	253.52	218.73	226.94	328.26	548.86	1022.29	549.83	413.78	1181.76	594.77	284.72	121.58	5745.04
Average	110.83	86.51	85.61	90.61	228.37	311.90	814.75	1389.54	1299.90	545.98	249.40	135.54	5348.94

Table A34: Corrected simulated monthly inflow (unit: MCM) by $EDCDF_m$ method of Sirikit reservoir over future period [Ensemble mean SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	6.98	3.51	15.02	85.79	328.34	635.62	470.30	646.25	706.97	682.62	322.72	180.24	4084.37
2076	165.95	157.21	195.80	516.31	954.12	817.74	924.55	2321.64	1782.96	861.03	181.43	72.25	8950.98
2077	62.66	43.26	54.63	48.86	97.04	202.33	1589.13	1768.30	1056.70	1082.71	163.94	63.20	6232.77
2078	56.87	33.93	26.10	22.36	195.07	98.10	78.64	524.55	1415.74	1290.99	362.78	198.36	4303.47
2079	149.67	96.51	73.96	63.67	105.12	8.81	110.25	1690.95	1036.52	678.52	227.02	151.86	4392.83
2080	141.47	99.70	74.96	65.09	147.83	245.98	866.24	784.62	908.67	507.51	217.09	115.63	4174.80
2081	108.36	82.42	70.40	62.13	136.27	332.22	2488.98	2454.00	3078.57	364.92	58.47	17.04	9253.79
2082	22.73	12.82	7.29	4.18	36.98	478.40	2536.27	1737.91	1149.91	564.04	213.63	221.81	6985.97
2083	249.44	177.07	185.61	136.32	184.75	57.63	107.21	517.73	659.28	645.65	486.21	215.91	3622.80
2084	174.23	132.04	94.95	79.00	198.37	274.23	1439.14	2423.65	1195.79	429.97	83.24	24.61	6549.22
2085	28.66	20.15	19.60	14.55	589.25	1076.35	2101.35	1801.44	747.36	442.85	142.95	53.99	7038.49
2086	49.45	29.33	21.41	17.57	141.54	288.62	823.24	2642.80	1745.19	765.69	245.39	149.81	6920.04
2087	160.69	122.94	158.34	278.32	449.41	780.92	899.41	681.45	3548.13	1070.45	223.39	83.83	8457.28
2088	67.15	62.28	59.14	54.69	88.16	13.16	287.27	949.01	1537.86	771.19	245.85	115.57	4251.32
2089	98.23	70.26	68.06	83.48	207.03	135.58	96.41	2165.05	696.12	654.81	251.41	122.90	4649.33
2090	107.98	77.25	61.79	52.32	180.92	248.84	250.33	564.58	775.55	821.21	211.11	88.56	3440.45
2091	109.77	314.41	279.87	193.89	175.06	77.73	109.34	1198.14	1644.24	521.16	117.34	39.57	4780.52
2092	39.88	24.10	15.07	11.38	34.31	73.50	329.46	2310.62	1182.09	637.20	341.20	216.78	5215.59
2093	157.84	105.45	124.18	195.44	284.91	134.79	2732.03	4632.67	4058.43	704.59	207.85	118.90	13457.07
2094	236.42	179.80	140.31	142.91	173.62	11.67	735.81	1013.23	818.18	700.61	243.91	104.93	4501.38
2095	82.64	68.28	100.32	107.47	155.60	16.52	1771.11	1077.71	1236.03	938.10	270.40	101.11	5925.30
2096	71.74	42.50	32.11	28.10	55.45	128.60	831.97	984.27	1089.28	592.90	235.64	122.56	4215.13
2097	99.80	60.08	46.23	40.79	72.91	189.43	758.84	1127.34	1550.86	666.88	199.08	70.49	4882.72
2098	66.26	58.20	71.59	61.78	165.17	418.06	272.20	560.30	907.84	953.40	385.96	193.26	4114.03
2099	149.16	114.56	177.87	144.61	211.27	106.89	517.75	2237.60	892.06	1055.57	241.92	98.69	5947.95
Average	106.56	87.52	86.98	100.44	214.74	274.07	925.09	1552.63	1416.81	736.18	235.20	117.67	5853.91

Table A35: Corrected simulated monthly inflow (unit: MCM) by gQM method of Sirikit reservoir over future period [Ensemble mean SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	22.82	109.58	404.19	628.88	436.05	861.91	755.69	530.96	388.69	212.29	4351.06
2076	168.14	128.00	168.04	373.28	892.66	762.99	796.88	1820.18	1453.21	653.86	175.24	80.79	7473.27
2077	67.02	85.19	79.96	102.00	98.15	256.92	1356.64	1585.51	1086.14	711.65	154.55	71.14	5654.87
2078	62.43	80.41	67.78	96.51	275.99	188.73	119.54	758.60	1333.17	929.39	455.01	232.94	4600.51
2079	150.61	104.61	87.55	104.83	99.01	21.27	114.00	1518.46	1089.57	513.81	222.71	175.47	4201.90
2080	141.54	108.18	88.01	105.10	113.40	290.98	764.70	979.41	983.82	341.67	212.70	128.71	4258.24
2081	107.55	99.65	86.04	104.54	137.76	392.96	1934.07	1944.59	2405.34	224.49	58.87	31.52	7527.39
2082	38.08	70.58	60.04	92.42	105.91	489.58	2053.54	1568.07	1149.65	401.60	205.78	267.38	6502.64
2083	269.11	134.24	145.17	128.77	174.13	124.30	154.63	748.28	672.62	506.93	501.95	247.95	3808.10
2084	177.74	119.30	96.94	107.93	228.29	353.68	1204.12	1897.23	1087.98	277.82	77.67	37.88	5666.59
2085	41.89	73.74	65.23	94.94	527.84	837.32	1703.71	1608.75	839.92	277.70	130.25	62.26	6263.55
2086	56.80	78.17	65.92	95.53	208.64	360.43	741.21	1954.58	1466.05	610.36	252.21	172.41	6062.31
2087	162.33	113.61	135.77	238.38	582.28	744.80	794.16	894.83	2743.58	740.12	230.75	93.43	7474.02
2088	70.88	95.25	81.84	103.14	96.26	23.24	292.48	1083.75	1330.28	598.37	256.08	129.38	4160.95
2089	98.36	95.43	85.11	110.61	243.65	220.06	153.20	1673.03	755.76	511.69	266.41	138.25	4351.56
2090	107.11	97.84	82.66	102.69	235.78	350.38	275.10	808.16	826.07	631.12	210.17	97.64	3824.70
2091	112.93	314.43	321.00	168.84	173.87	153.40	166.23	1139.65	1435.21	364.01	106.29	49.34	4505.22
2092	49.80	78.02	63.38	94.29	89.33	142.76	341.00	1790.99	1154.48	488.03	417.78	247.11	4956.98
2093	160.33	107.63	110.30	168.37	405.52	247.54	2241.48	3336.93	3252.18	529.09	204.68	131.98	10896.04
2094	246.94	136.70	120.23	131.35	157.80	29.73	638.47	1162.91	943.95	553.73	253.97	117.50	4493.28
2095	84.38	94.69	98.72	116.85	112.43	36.01	1464.42	1209.56	1114.58	721.39	300.11	113.92	5467.05
2096	75.03	86.68	70.22	97.70	90.55	190.01	739.91	1143.00	1070.37	435.50	237.48	138.14	4374.58
2097	100.08	91.60	76.43	100.31	93.48	216.73	674.12	1193.52	1337.06	496.17	197.09	79.10	4655.70
2098	69.96	91.36	86.46	104.47	195.52	471.95	292.43	794.25	907.07	772.82	462.91	226.67	4475.86
2099	150.27	110.84	140.57	132.03	240.48	205.37	499.36	1783.77	1000.71	827.28	258.96	107.83	5457.47
Average	110.77	103.85	100.25	127.38	239.32	309.60	798.06	1410.40	1287.78	545.98	249.53	135.64	5418.55

Table A36: Corrected simulated monthly inflow (unit: MCM) by $EDCDF_m$ method of Sirikit reservoir over future period [Cluster 1 scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	6.98	3.51	0.00	0.00	173.79	581.67	2142.03	2038.42	1715.00	673.37	252.10	107.31	7694.16
2076	81.42	64.19	62.26	92.72	314.26	425.33	997.01	1431.23	893.64	457.58	266.06	137.98	5223.68
2077	110.51	73.56	62.80	57.39	427.81	807.70	2004.69	2282.03	1456.17	602.02	203.52	71.10	8159.30
2078	88.53	75.70	76.33	68.14	194.94	97.96	78.86	301.08	935.06	390.01	208.11	122.48	2637.18
2079	102.86	74.19	65.19	59.17	91.42	4.46	649.81	2053.11	820.39	549.43	287.27	178.80	4936.10
2080	148.86	103.64	94.85	81.48	309.00	132.80	397.25	2556.03	1690.82	576.46	233.85	142.21	6467.26
2081	137.00	142.12	152.67	135.60	299.61	319.86	739.49	1112.89	763.63	543.34	244.40	111.07	4701.69
2082	86.95	54.56	48.57	47.14	141.27	755.12	2497.71	1197.23	773.98	811.24	202.62	87.49	6703.90
2083	93.77	68.39	89.91	113.90	217.13	346.42	460.24	1232.58	1259.09	909.72	341.55	259.70	5392.40
2084	290.24	255.10	265.74	205.28	481.95	420.22	535.61	941.04	1344.81	861.35	304.71	125.97	6032.02
2085	84.89	51.19	45.85	45.22	154.62	987.43	838.13	983.00	687.67	487.26	239.75	137.54	4742.54
2086	141.29	119.11	118.62	110.24	232.50	822.23	1934.09	1052.53	1994.66	367.95	107.37	34.09	7034.69
2087	29.38	17.23	14.19	14.30	97.67	246.87	1032.32	821.04	1248.15	429.87	256.87	117.01	4324.90
2088	92.95	129.52	143.42	256.44	233.33	207.80	918.80	2516.03	1271.00	563.75	162.62	53.78	6549.43
2089	40.50	24.20	21.61	22.02	115.78	367.02	692.37	983.12	738.66	512.28	177.27	124.04	3818.86
2090	120.96	84.38	72.70	64.56	98.58	48.77	178.93	822.30	788.69	385.27	131.39	41.11	2837.64
2091	183.08	161.53	190.65	159.55	143.40	100.79	189.74	2924.52	1652.67	726.85	191.88	72.62	6697.30
2092	57.00	36.57	31.75	31.93	46.07	78.88	223.34	820.22	681.10	482.76	183.19	60.95	2733.76
2093	43.39	25.30	22.07	22.02	122.86	152.94	250.97	3202.54	1282.85	542.81	297.94	327.12	6292.81
2094	215.55	164.34	170.80	177.61	255.36	456.26	1068.71	2801.29	1560.52	654.98	197.26	67.59	7790.27
2095	49.93	35.36	32.62	31.93	247.33	1000.16	2864.74	3116.68	968.79	628.60	350.78	321.89	9648.81
2096	268.22	203.23	174.07	151.89	213.10	468.36	932.21	1058.85	921.65	602.11	242.89	106.79	5343.38
2097	77.05	47.74	43.59	43.21	74.21	50.02	377.92	1290.80	1973.92	1069.08	491.61	183.81	5722.95
2098	142.74	98.18	109.13	262.47	205.25	181.54	610.16	957.40	459.87	182.32	75.14	45.12	3329.31
2099	49.12	31.56	28.24	26.97	135.51	157.21	895.08	1320.47	1184.50	514.79	215.57	95.76	4654.78
Average	109.73	85.77	85.51	91.25	201.07	368.71	940.41	1592.66	1162.69	581.01	234.63	125.33	5578.77

Table A37: Corrected simulated monthly inflow (unit: MCM) by gQM method of Sirikit reservoir over future period [Cluster 1 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	206.03	479.82	1711.73	1676.92	2158.23	709.91	279.82	115.57	7338.02
2076	89.74	63.16	54.54	89.79	392.25	386.02	854.03	1299.90	887.83	389.30	280.22	146.32	4933.10
2077	108.25	69.97	55.05	53.42	592.59	575.35	1639.98	1838.11	1721.16	603.62	202.38	83.17	7543.04
2078	93.68	71.00	68.84	63.65	226.35	115.36	28.75	332.97	931.21	290.92	195.32	129.19	2547.23
2079	103.24	70.29	57.31	54.91	30.02	1.09	551.34	1696.12	762.84	528.59	328.32	190.95	4375.01
2080	137.44	96.01	88.95	77.63	422.76	159.09	302.38	1985.62	2143.63	561.83	228.82	150.64	6354.79
2081	126.62	132.36	156.17	128.06	324.27	329.30	606.51	978.56	676.21	529.85	252.25	118.63	4358.79
2082	93.28	55.82	42.80	45.56	138.98	569.18	1986.57	1116.75	772.36	803.30	200.34	94.36	5919.30
2083	97.53	65.58	83.14	109.90	228.78	299.98	355.87	1144.95	1453.66	954.74	427.07	284.24	5505.43
2084	293.07	277.54	286.82	194.33	387.20	385.97	419.37	859.33	1511.02	786.58	357.76	134.76	5893.75
2085	92.05	53.57	40.74	44.30	166.65	666.65	698.18	922.48	463.36	434.97	243.10	144.48	3970.52
2086	130.80	109.92	116.46	106.27	305.93	616.43	1620.21	988.47	2510.45	266.70	95.06	56.03	6922.75
2087	59.99	32.44	22.84	29.80	102.55	256.18	891.10	759.30	1431.70	336.42	282.40	124.72	4329.42
2088	96.73	120.80	145.82	277.41	311.16	235.91	785.03	2162.17	1465.05	548.15	150.07	70.17	6368.47
2089	66.03	36.45	26.40	33.00	80.46	342.90	561.87	900.49	602.40	473.79	163.85	129.47	3417.11
2090	115.44	78.89	64.94	59.90	30.84	61.35	113.62	756.79	792.98	278.19	116.80	61.17	2530.93
2091	165.09	154.79	205.13	151.16	41.25	116.89	131.99	2368.15	1998.41	698.19	183.83	84.45	6299.34
2092	74.76	44.65	31.55	37.39	26.71	95.98	154.76	748.69	495.12	424.50	175.31	75.63	2385.04
2093	67.44	37.06	26.59	33.00	119.34	175.04	167.07	2959.22	1474.58	509.65	355.14	326.96	6251.08
2094	204.18	161.21	178.99	164.91	254.40	396.60	926.29	2215.33	1846.79	675.94	194.57	80.83	7300.04
2095	70.82	43.13	32.08	37.39	327.35	715.98	2841.08	2435.35	1118.60	664.51	471.82	338.21	9096.32
2096	266.51	214.69	183.88	141.78	187.39	360.20	787.84	994.56	976.79	597.06	247.54	115.36	5073.59
2097	87.03	51.29	39.13	43.05	28.62	60.90	294.44	1176.32	2740.33	1054.33	524.52	196.73	6296.68
2098	132.49	90.71	104.02	250.26	186.51	208.90	489.22	882.88	152.45	71.64	69.99	62.95	2702.02
2099	70.49	40.82	29.66	35.12	127.24	177.46	751.79	1120.42	1281.72	481.13	212.50	104.78	4433.13
Average	113.71	86.89	85.67	90.48	209.82	311.54	786.84	1372.79	1294.75	546.95	249.55	136.79	5285.80

Table A38: Corrected simulated monthly inflow (unit: MCM) by $EDCDF_m$ method of Sirikit reservoir over future period [Cluster 2 scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	6.98	3.39	0.00	0.00	12.70	820.06	748.46	917.37	802.08	572.38	242.03	132.39	4257.83
2076	109.13	23.12	70.56	63.06	226.39	186.86	624.25	1346.04	767.51	663.01	289.73	120.54	4490.22
2077	84.15	11.53	46.34	43.06	89.56	964.78	1883.92	2223.84	1560.76	733.35	161.33	55.60	7858.21
2078	39.46	4.88	19.77	19.14	56.74	165.52	214.06	416.39	552.78	360.31	156.40	107.88	2113.33
2079	156.62	47.44	128.08	140.35	179.07	236.07	1399.63	1057.71	687.34	944.00	342.94	162.19	5481.44
2080	136.81	30.90	89.57	78.93	149.49	110.28	903.08	927.41	1356.58	534.06	136.57	36.81	4490.49
2081	31.65	4.84	18.15	16.54	48.57	76.97	297.55	1505.21	1052.86	521.44	151.69	72.95	3798.40
2082	99.20	20.82	70.39	63.75	145.76	203.14	587.13	2887.54	3119.97	473.24	176.84	76.77	7924.56
2083	64.23	8.74	38.66	92.16	267.79	174.58	571.72	589.06	522.42	493.04	274.10	146.59	3243.09
2084	117.34	26.39	78.96	70.66	125.50	110.41	1664.26	1855.74	2091.14	820.44	196.34	74.49	7231.66
2085	53.51	6.22	29.01	27.46	70.34	25.30	236.52	477.27	795.42	1264.79	260.84	117.25	3363.94
2086	132.51	33.53	97.35	88.05	176.79	28.14	73.10	1905.25	3890.85	1173.80	336.96	139.85	8076.19
2087	107.69	24.14	80.33	75.20	229.02	271.91	776.45	2529.65	1473.86	590.31	292.86	152.23	6603.64
2088	130.96	29.60	85.42	75.95	132.28	31.52	786.14	1064.69	1685.48	1009.06	318.79	266.42	5616.31
2089	292.16	132.13	233.42	258.55	492.77	561.77	1109.46	1688.38	1136.89	636.80	301.26	145.87	6989.47
2090	109.61	21.32	68.89	62.05	115.08	191.99	667.10	1213.50	1915.46	759.62	262.78	168.36	5555.75
2091	192.90	81.26	300.41	364.28	646.31	838.20	1241.82	1220.94	1384.60	370.12	76.69	23.76	6741.29
2092	65.86	11.53	46.57	41.98	359.34	1509.57	4115.74	1648.07	1871.34	820.98	199.90	77.57	10768.44
2093	60.65	8.04	35.77	33.48	75.71	340.72	1057.32	1806.98	1300.70	427.08	436.33	395.45	5978.26
2094	262.09	90.72	156.60	177.29	249.50	166.32	677.31	2252.35	1982.42	887.86	265.95	121.44	7289.84
2095	98.80	17.35	120.15	136.77	189.02	231.66	692.34	1669.74	768.03	554.76	255.70	116.61	4850.93
2096	82.64	11.67	48.52	46.71	120.84	556.67	243.80	1099.11	868.97	512.86	156.38	45.10	3793.26
2097	31.27	4.70	14.28	13.47	168.88	500.26	910.99	1426.77	1658.51	1462.60	245.20	89.10	6526.04
2098	103.75	29.54	108.59	156.06	220.07	403.85	774.52	1309.68	3630.90	937.31	626.14	215.58	8515.99
2099	157.46	57.32	181.75	175.02	302.69	439.12	917.06	2944.69	1010.98	637.76	252.26	131.84	7207.96
Average	109.10	29.64	86.70	92.80	194.01	365.83	926.95	1519.34	1515.51	726.44	256.64	127.71	5950.66

Table A39: Corrected simulated monthly inflow (unit: MCM) by gQM method of Sirikit reservoir over future period [Cluster 2 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.00	19.58	564.00	590.27	848.65	821.31	453.47	221.40	139.88	3658.57
2076	108.26	77.97	83.88	82.46	301.14	233.06	500.85	1265.32	772.07	538.07	295.40	129.86	4388.33
2077	91.37	55.44	75.76	77.60	81.20	627.56	1700.83	1872.96	1317.98	570.17	143.64	74.80	6689.31
2078	62.09	36.58	66.74	71.69	77.09	200.78	132.66	407.32	510.35	230.67	136.18	113.49	2045.66
2079	142.06	121.22	105.36	106.18	144.10	245.16	1229.09	1011.36	673.41	758.66	360.93	168.59	5066.11
2080	128.12	91.80	90.41	86.11	89.99	153.98	732.50	863.40	1193.59	402.18	121.99	61.33	4015.38
2081	56.87	36.07	66.14	71.00	75.99	124.85	213.78	1348.24	1023.07	389.77	134.26	86.73	3626.78
2082	101.53	72.61	83.80	82.60	139.23	250.62	435.65	2787.92	2420.07	345.98	154.22	90.90	6965.12
2083	77.68	49.32	73.21	89.44	327.40	230.83	450.42	495.90	474.88	376.61	261.00	153.61	3060.28
2084	114.01	83.61	86.73	84.20	86.06	155.14	1479.67	1668.60	1614.48	632.49	177.55	89.31	6271.85
2085	70.79	42.65	69.90	73.92	78.79	52.42	149.23	420.19	768.84	887.59	255.96	124.17	2994.46
2086	124.44	95.46	92.99	88.35	98.85	70.00	29.86	1672.40	2954.54	870.64	354.23	147.36	6599.13
2087	107.30	78.28	87.22	85.20	251.07	298.27	619.61	2083.42	1267.43	473.81	287.13	158.72	5797.46
2088	123.59	89.46	88.93	85.41	87.20	52.67	606.97	988.08	1401.12	733.86	336.24	270.88	4864.42
2089	310.43	290.85	221.63	296.01	650.80	459.87	901.86	1548.73	1081.08	523.04	310.53	153.24	6748.07
2090	108.82	73.64	83.32	82.19	84.58	217.50	518.26	1088.25	1579.88	592.52	247.24	174.89	4851.09
2091	171.70	183.39	325.71	363.94	745.55	592.59	989.06	1142.90	1184.56	259.01	74.99	51.68	6085.08
2092	78.81	56.75	75.83	77.35	511.37	869.75	4188.93	1427.36	1511.22	602.17	180.64	91.88	9672.06
2093	75.34	47.57	72.24	75.35	79.49	267.57	836.99	1526.42	1144.44	303.19	493.28	382.01	5303.88
2094	267.81	203.41	125.11	146.39	386.06	219.10	516.45	1931.78	1580.28	686.77	255.50	130.06	6448.72
2095	101.20	66.78	101.08	103.42	162.29	255.54	532.47	1518.04	756.42	443.27	241.28	126.28	4408.08
2096	90.31	57.17	76.48	78.43	121.31	444.35	157.87	1033.40	900.46	388.40	139.79	67.55	3555.52
2097	57.02	33.22	64.75	70.13	264.59	427.64	718.65	1281.04	1382.65	931.59	234.84	101.92	5568.05
2098	104.02	88.11	96.63	128.43	275.12	367.99	608.22	1126.03	2838.04	762.15	594.98	217.91	7207.62
2099	144.88	139.57	147.94	143.66	387.93	398.92	709.33	2922.10	1006.53	502.53	234.07	139.24	6876.70
Average	112.74	86.84	98.47	105.98	221.07	311.21	781.98	1371.19	1287.15	546.34	249.89	137.85	5310.71

Table A40: Corrected simulated monthly inflow (unit: MCM) by EDCDF$_m$ method of Sirikit reservoir over future period [Cluster 3 scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	6.98	3.51	0.00	0.04	11.58	398.48	1222.03	942.22	707.36	659.05	380.73	171.95	4503.92
2076	134.73	106.77	103.71	122.99	228.32	979.26	2638.60	3547.55	1146.63	343.69	246.77	119.56	9718.58
2077	108.75	128.40	176.28	193.39	184.85	129.77	5128.53	2776.86	1639.73	708.03	270.62	102.15	11547.35
2078	99.31	146.40	181.25	191.81	249.13	543.12	240.85	856.94	840.07	605.98	308.30	157.64	4420.81
2079	137.48	99.29	90.72	105.53	118.09	56.06	1318.09	3431.70	1692.11	459.25	178.34	89.42	7776.08
2080	100.36	106.93	108.07	121.35	251.98	395.85	1083.18	2077.41	1513.42	357.46	56.79	13.28	6186.08
2081	19.45	10.26	5.52	4.91	30.35	141.31	468.55	917.73	848.20	504.53	292.94	141.31	3385.07
2082	115.36	70.91	60.26	54.16	126.16	248.41	600.09	1331.60	1741.91	782.31	196.02	107.16	5434.37
2083	99.75	84.53	79.02	72.18	147.55	779.78	3761.67	2334.65	2060.38	951.62	351.81	131.37	10854.31
2084	115.68	88.29	91.01	87.45	123.45	1030.47	1679.38	1387.60	1457.85	623.93	191.24	72.22	6948.56
2085	48.72	26.60	22.57	21.73	50.47	15.96	618.13	2717.85	925.65	644.98	193.84	55.47	5341.98
2086	48.95	21.76	17.26	16.56	144.03	478.27	716.88	1679.04	1813.71	544.50	140.28	42.44	5663.70
2087	47.06	24.94	23.60	23.22	291.65	656.36	349.38	542.00	851.32	656.86	308.88	165.84	3941.10
2088	156.92	129.57	147.09	133.00	419.73	642.13	743.84	990.26	2339.69	1182.94	462.37	205.85	7553.41
2089	209.62	149.31	141.07	123.79	535.65	1234.45	1016.36	1076.78	1284.10	676.47	217.89	93.57	6759.06
2090	83.21	57.28	53.00	47.64	267.00	469.70	831.19	1088.00	1643.11	810.18	327.90	148.92	5827.12
2091	120.30	77.55	78.86	73.00	184.59	238.85	696.49	1959.40	1146.65	668.53	316.73	179.13	5740.08
2092	121.40	80.33	63.73	58.37	321.49	737.61	1410.51	3333.64	1242.28	594.85	251.40	186.76	8402.36
2093	156.40	125.50	107.69	105.96	509.32	326.80	139.72	601.80	2276.05	737.87	251.66	167.26	5506.04
2094	179.30	99.21	81.64	74.45	169.68	32.04	283.69	1579.13	1271.39	1753.97	259.95	133.69	5918.13
2095	88.70	55.24	72.64	63.17	88.20	115.44	386.08	2197.21	1028.27	1071.44	392.97	151.80	5711.15
2096	106.20	65.64	54.02	49.79	82.10	234.92	1099.00	2174.37	886.82	390.26	189.33	105.01	5437.46
2097	90.92	79.36	79.08	70.74	200.63	345.27	315.91	1277.34	808.05	590.29	240.19	104.61	4202.41
2098	91.58	61.11	55.32	254.26	291.19	282.53	500.41	1951.98	995.46	809.56	298.48	259.97	5851.85
2099	240.32	230.83	241.01	231.43	237.39	610.42	969.51	1200.06	942.80	576.57	185.35	99.57	5765.25
Average	109.10	85.18	85.38	92.04	210.58	444.93	1128.72	1758.93	1324.12	708.20	260.43	128.24	6335.85

Table A41: Corrected simulated monthly inflow (unit: MCM) by gQM method of Sirikit reservoir over future period [Cluster 3 SST scenario]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2075	0.00	0.00	0.00	0.37	23.98	280.56	998.54	870.49	383.64	538.29	424.83	185.84	3706.55
2076	139.39	107.32	104.40	153.41	261.44	585.10	1491.21	2590.41	993.16	229.23	222.56	122.27	6999.91
2077	112.09	125.89	183.03	181.49	123.19	113.16	2388.94	1890.17	1594.84	583.24	266.67	104.07	7666.77
2078	105.98	143.44	187.19	179.04	281.89	377.14	534.11	813.10	655.07	484.53	302.83	169.86	4234.18
2079	134.17	99.77	90.44	99.11	37.79	53.84	1015.70	2359.40	1676.94	345.09	132.44	89.00	6133.68
2080	96.93	107.24	108.56	112.92	298.72	306.64	932.23	1571.33	1460.74	260.66	47.10	20.46	5323.55
2081	24.40	10.21	8.16	10.27	28.17	120.91	688.69	845.17	689.71	386.83	282.49	149.39	3244.41
2082	118.72	73.95	60.00	55.71	99.98	210.74	746.93	1179.38	1799.75	586.67	161.54	108.16	5201.53
2083	105.72	86.65	78.36	70.52	119.75	512.31	1925.00	1698.90	2067.46	784.29	388.31	137.03	7974.31
2084	116.35	90.62	90.80	83.56	64.37	632.00	1151.39	1217.47	1447.18	502.74	156.52	71.62	5624.64
2085	54.03	28.12	23.47	25.86	31.37	12.34	746.50	2035.58	866.06	522.11	166.48	55.81	4567.75
2086	44.93	22.43	18.89	21.21	166.17	363.51	802.64	1361.15	1821.57	427.41	110.94	44.26	5205.12
2087	46.31	26.04	24.37	27.20	349.92	450.25	627.83	565.00	747.79	534.59	331.22	179.52	3910.04
2088	162.20	128.53	151.52	126.74	572.96	437.63	812.04	885.37	2821.03	876.19	473.36	218.84	7666.39
2089	173.39	148.30	145.37	117.20	413.06	768.53	923.53	970.89	1228.69	547.27	186.03	93.33	5715.58
2090	84.10	61.30	52.92	50.09	293.68	363.19	843.68	983.47	1605.78	653.25	365.23	160.35	5517.05
2091	109.34	80.27	78.36	71.19	184.62	198.99	740.62	1419.26	1077.79	544.56	319.19	188.24	5012.43
2092	130.31	82.78	63.42	59.29	396.88	493.60	1059.08	2419.34	1089.88	479.22	215.44	206.48	6695.72
2093	172.05	124.93	108.24	99.77	564.33	267.11	430.92	607.79	2742.09	562.18	217.85	182.33	6079.60
2094	149.51	99.58	81.24	72.24	134.15	44.66	540.46	1284.79	1213.21	1081.07	236.67	142.49	5080.06
2095	90.98	59.64	72.11	63.12	35.18	95.83	630.64	1757.11	947.90	864.72	413.54	162.86	5193.63
2096	111.11	69.35	53.91	51.98	34.75	192.70	929.49	1627.09	766.92	279.18	145.64	104.78	4366.89
2097	100.01	82.01	78.42	69.26	188.88	268.70	599.78	1062.70	646.54	470.45	213.78	105.20	3885.73
2098	93.41	64.90	55.31	240.36	347.24	231.57	656.48	1487.47	958.67	670.60	305.08	288.03	5399.13
2099	292.18	253.23	243.46	205.24	253.02	404.94	900.89	1081.62	763.34	448.26	150.82	99.67	5096.67
Average	110.70	87.06	86.48	89.89	212.22	311.44	924.69	1383.38	1282.63	546.50	249.46	135.60	5420.05

Table A42: Observed monthly storage (unit: MCM) of Sirikit reservoir over 1974-2013 periods (40 years)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	8217.09	8201.99	8150.79	7874.75	7603.21	7437.85	7258.42	7371.83	7967.07	8127.95	8029.09	7895.91
1975	7747.97	7559.89	7205.38	6736.08	6268.04	6303.45	6612.22	7732.02	9423.29	9577.53	9414.51	9089.68
1976	8870.22	8566.58	8001.00	7343.32	6616.31	6138.75	5728.18	6313.12	6858.40	8045.72	8131.36	7921.94
1977	7567.71	7089.03	6533.26	5973.49	5305.65	4736.27	4233.87	4434.76	4897.05	5325.58	5232.87	5027.64
1978	4900.81	4757.19	4503.87	4131.01	3831.47	3708.69	4155.72	5340.42	6848.13	7704.96	7848.24	7648.63
1979	7349.06	6968.82	6321.43	5477.43	4866.77	4668.27	4564.05	4639.41	4982.72	5069.04	4648.30	4373.14
1980	4196.73	4052.22	3879.01	3615.10	3369.27	3333.94	3676.61	4812.84	6802.46	7551.96	7626.23	7499.23
1981	7307.16	6898.48	6379.20	5760.24	5240.84	4929.72	6327.74	7522.91	8122.14	8397.71	8338.05	8102.31
1982	7876.86	7425.42	6750.53	5981.28	5334.66	5107.80	5175.88	5373.86	6209.04	7452.81	7534.40	7404.63
1983	7144.21	6639.72	6131.72	5251.27	4560.54	4328.04	4180.96	4693.18	5866.26	6977.21	7400.97	7551.79
1984	7570.73	7298.97	6733.07	6024.12	5516.19	5448.94	6001.65	6846.67	7987.79	8369.13	8386.65	8222.41
1985	8037.03	7536.71	6761.04	5808.09	5126.14	4951.61	4995.42	5971.90	7355.82	7855.58	8137.73	8245.90
1986	8211.93	7914.44	7287.54	6584.01	6161.11	5937.45	5810.54	6368.78	6880.87	7022.94	6711.59	6407.97
1987	6280.95	5760.60	5130.69	4514.32	3951.80	3680.79	3431.16	3414.52	4180.21	4654.85	4767.36	4798.58
1988	4757.61	4419.99	3902.49	3673.79	3675.26	3939.05	4360.22	5410.36	6304.97	6542.59	6650.80	6653.73
1989	6581.16	6330.60	6027.43	5611.15	5062.29	5045.11	5305.30	5736.09	6068.55	6569.02	6542.25	6417.00
1990	6309.71	6018.30	5452.22	4779.78	4315.94	4247.53	4307.90	4840.99	5232.60	5444.76	5402.33	5266.61
1991	5152.90	4834.23	4244.60	3610.45	3310.62	3320.17	3377.15	3524.29	4319.81	4800.01	4801.95	4683.84
1992	4593.43	4338.22	3984.88	3535.98	3140.24	3012.71	3040.76	3672.25	4282.76	4838.10	4977.18	4829.05
1993	4812.30	4621.87	4307.85	3946.68	3574.49	3455.07	3613.16	3675.96	3800.71	4171.89	4029.72	3768.75
1994	3659.97	3466.44	3253.13	3155.32	3113.44	3402.40	3930.74	6189.89	8375.97	9180.63	9239.41	8978.17
1995	8791.82	8337.11	7630.26	6847.02	6238.87	5866.29	6031.14	7943.77	9490.87	9465.12	9443.29	9290.88
1996	9029.74	8501.00	7603.36	6654.74	5992.71	5427.45	5177.05	5876.04	6769.71	7510.56	7691.81	7535.10
1997	7384.88	6922.08	6258.63	5546.09	4941.97	4513.11	4171.98	4670.69	5939.75	6653.24	6714.07	6396.31
1998	6199.46	5696.41	5055.46	4475.07	4062.36	3924.53	4042.88	4273.43	5176.48	5652.96	5579.01	5381.08
1999	5144.92	4770.98	4305.54	3948.30	3943.34	4177.75	4602.02	5467.08	7210.51	8606.14	8984.60	9073.35
2000	8845.02	8141.87	7266.88	6423.03	6036.96	6162.72	6649.82	7433.14	8511.72	9302.93	9381.48	9132.56
2001	8605.01	7859.90	7073.66	6332.99	5734.55	5851.20	6194.76	8035.34	8864.75	9214.69	9421.05	9242.62
2002	8815.34	8143.38	7313.37	6338.57	5708.63	5869.71	5955.50	6611.04	8112.31	8999.23	9139.98	9108.75
2003	8847.88	8186.68	7469.33	6826.21	6146.72	5596.71	5691.46	6295.30	7599.42	8327.73	8096.38	7648.58
2004	7213.37	6642.20	5949.81	5244.16	4752.30	4923.25	5486.32	6748.78	8416.65	9330.95	9125.25	8543.73
2005	7840.10	7070.61	6251.04	5500.83	4784.82	4415.31	4510.45	5484.47	7122.39	8507.30	8617.70	8366.05
2006	7733.64	7050.95	6246.43	5418.04	5021.51	5167.52	5313.07	6517.94	8503.20	9357.47	9436.74	9089.23
2007	8368.35	7594.44	6856.28	6129.35	5814.51	5714.98	5537.94	5807.21	6486.98	7227.49	7381.85	7018.57
2008	6419.30	5834.51	5217.57	4526.78	4116.98	4224.02	4752.36	6393.04	7562.71	8155.84	8364.45	8070.31
2009	7418.12	6722.36	5949.75	5150.54	4474.15	4219.05	4719.98	5209.39	5573.72	5955.06	5970.23	5611.11
2010	5132.03	4639.96	4108.27	3730.76	3492.13	3318.95	3320.00	4565.71	6770.30	7645.27	7801.75	7648.99
2011	6991.63	6125.52	5287.29	4870.32	4895.07	5276.83	6826.73	8442.36	9149.96	9439.66	9454.61	9117.41
2012	8214.62	6997.01	5903.89	5231.66	4747.27	4486.26	4185.76	4852.49	5986.32	6532.51	6482.16	6035.42
2013	5313.56	4651.38	4166.50	3816.89	3504.14	3238.24	3204.84	4174.50	5251.64	5807.72	5975.71	5891.22
Average	6742.06	6406.25	5899.55	5316.42	4847.21	4674.60	4780.43	5466.00	6405.74	6918.48	6931.17	6775.61

Table A42: Simulated monthly storage (unit: MCM) of Sirikit reservoir over 1974-2013 periods (40 years)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	7991.26	7412.98	6642.54	5782.46	4998.16	4695.28	4574.08	5027.61	5942.58	6265.73	6247.95	6049.02
1975	5698.83	5242.22	4732.81	4199.91	3878.04	4029.46	4434.96	5933.04	8070.22	8652.47	8702.58	8503.59
1976	8142.81	7603.71	6905.36	6170.20	5594.13	5429.52	5297.81	6047.15	6877.62	8244.07	8493.13	8317.52
1977	8011.66	7486.50	6794.98	6088.95	5521.28	5164.13	4952.49	5489.36	6110.07	6587.04	6611.93	6471.15
1978	6172.58	5678.81	5095.08	4539.95	4132.00	3922.68	4363.60	5477.58	6931.35	7832.85	7941.41	7724.42
1979	7406.58	6892.36	6208.39	5445.30	4905.16	4820.48	4807.76	5121.88	5752.38	5938.64	5822.75	5497.95
1980	5158.64	4749.93	4299.25	3871.43	3598.08	3558.53	3781.77	4773.92	6699.15	7497.39	7510.18	7314.81
1981	7002.08	6487.82	5832.32	5107.64	4625.95	4545.11	6057.77	7547.85	8414.82	8896.97	9017.31	8821.15
1982	8470.71	7959.84	7238.56	6500.53	5880.17	5522.54	5482.65	5843.09	6796.31	7944.51	8041.67	7832.43
1983	7473.54	6955.54	6286.14	5536.08	5004.51	4715.36	4543.36	5179.78	6234.37	7168.05	7345.44	7190.88
1984	6866.44	6327.06	5664.12	4982.59	4442.90	4326.13	4814.34	5720.55	7276.07	7855.71	7945.68	7754.42
1985	7406.61	6867.27	6173.25	5451.64	4885.80	4585.78	4577.05	5393.48	6740.57	7093.12	7145.12	7013.46
1986	6687.78	6185.06	5563.87	4927.05	4545.48	4541.71	4699.42	5319.98	5878.79	6133.18	6116.57	5784.98
1987	5316.75	4871.00	4414.02	3954.62	3644.22	3504.84	3330.17	3359.76	4071.73	4488.53	4494.58	4350.81
1988	4222.13	4015.97	3747.69	3450.90	3384.59	3502.94	3788.09	4675.53	5414.64	5627.82	5585.69	5368.45
1989	5088.94	4704.07	4249.87	3808.32	3553.01	3606.36	3736.11	4095.22	4672.65	5259.79	5209.79	5053.51
1990	4878.89	4570.50	4134.73	3720.18	3483.65	3582.82	3752.84	4405.55	4967.29	5307.47	5282.45	5142.34
1991	4941.90	4608.06	4142.71	3716.35	3536.59	3519.46	3527.36	3713.70	4406.11	4821.68	4793.10	4629.87
1992	4507.75	4267.82	3924.88	3577.67	3274.64	3096.93	3003.33	3418.13	3798.66	4285.20	4293.02	4144.22
1993	4082.42	3899.35	3660.64	3376.90	3136.00	3105.39	3389.94	3695.76	4144.14	4441.79	4328.86	4158.60
1994	4025.70	3837.37	3604.12	3351.59	3198.92	3346.22	3661.63	5709.90	7814.00	8568.49	8621.59	8412.53
1995	8056.81	7518.24	6807.68	6032.19	5396.73	5022.06	5149.94	7144.13	8924.04	9325.75	9433.43	9262.61
1996	8876.50	8330.80	7614.68	6869.17	6299.32	6002.42	5972.39	6847.48	7918.93	8644.63	8782.40	8584.70
1997	8222.47	7712.02	7003.70	6248.76	5629.03	5170.15	4843.43	5264.43	6489.39	7135.23	7212.01	7038.51
1998	6722.24	6205.06	5563.02	4888.35	4319.27	4031.91	4033.63	4150.07	4942.09	5268.91	5143.13	4977.51
1999	4813.07	4531.28	4117.33	3773.21	3601.40	3624.01	3862.70	4572.51	6151.65	7363.70	7462.27	7270.02
2000	6926.29	6376.39	5712.65	5025.60	4632.92	4600.69	5096.92	5791.76	6786.26	7506.77	7591.66	7392.60
2001	7057.40	6541.07	5946.05	5243.23	4742.98	4609.02	4852.20	6800.34	8442.33	9159.14	9271.49	9034.81
2002	8663.40	8126.98	7411.16	6629.63	6154.01	6355.87	6441.63	7192.55	8418.62	9095.89	9221.97	9024.97
2003	8650.32	8123.27	7446.17	6726.23	6074.95	5691.69	5820.74	6467.36	7665.87	8260.43	8189.36	7967.26
2004	7610.04	7057.34	6359.48	5645.51	5089.54	5086.55	5557.50	6640.10	8217.56	9126.30	9126.13	8890.46
2005	8508.32	7993.40	7307.68	6587.68	5929.77	5663.18	5719.77	6565.64	7996.39	9194.86	9302.15	9071.10
2006	8707.10	8177.11	7472.25	6733.66	6281.77	6164.24	6092.91	7084.40	8791.29	9355.44	9380.70	9135.83
2007	8756.14	8236.22	7536.47	6793.27	6263.43	5960.82	5855.21	6196.76	6935.94	7635.64	7807.48	7586.40
2008	7230.59	6706.90	6031.94	5324.67	4928.83	5091.49	5717.39	7278.58	8239.85	8837.22	9022.98	8797.17
2009	8420.50	7903.49	7211.74	6492.84	5925.07	5697.93	6076.11	6441.69	6811.23	7194.38	7203.49	7004.35
2010	6684.86	6235.03	5629.88	4945.32	4355.60	4052.88	4004.13	5146.24	7147.01	7856.60	7856.85	7636.38
2011	7282.65	6756.66	6104.70	5424.34	5095.74	5256.93	6690.80	8534.09	9525.56	9581.58	9474.97	9233.27
2012	8821.08	8274.33	7598.64	6881.90	6405.31	6254.28	6121.35	6719.01	7712.16	8126.76	8136.79	7960.20
2013	7612.45	7092.82	6419.97	5684.53	5050.28	4678.26	4528.84	5373.44	6277.83	6681.45	6664.62	6489.53
Average	6457.28	6015.57	5452.18	4863.95	4434.70	4293.93	4423.04	5174.20	6211.52	6771.40	6804.87	6615.98

Table A42: Observed monthly water release (unit: MCM) of Sirikit reservoir over 1974-2013 periods (40 years)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1974	23.50	0.00	121.09	180.98	261.15	373.55	620.00	670.26	485.33	424.45	281.53	276.53	3718.37
1975	275.19	307.05	464.37	572.86	435.53	352.92	612.98	725.92	709.98	635.99	495.96	455.48	6044.23
1976	343.05	556.57	707.48	825.75	820.24	804.51	614.49	644.75	455.41	455.73	440.72	525.47	7194.17
1977	548.09	542.85	705.28	712.30	754.09	744.39	716.56	727.09	267.35	308.29	518.52	263.55	6808.36
1978	198.39	240.73	418.90	476.90	252.79	301.36	311.11	209.68	276.29	296.72	282.57	367.52	3632.96
1979	427.27	496.05	857.63	784.95	737.21	441.36	568.03	681.06	400.82	482.68	505.27	300.27	6682.60
1980	219.91	172.36	285.22	292.41	300.66	191.27	192.88	139.96	287.14	303.09	214.11	249.08	2848.09
1981	390.22	468.66	632.52	712.76	653.77	724.28	457.71	1048.25	537.65	404.78	524.07	319.30	6873.97
1982	433.03	606.43	795.11	846.05	586.69	258.36	455.02	680.96	178.28	222.33	335.53	262.36	5660.15
1983	469.30	547.25	692.76	991.78	649.47	293.79	532.47	312.50	109.67	38.87	60.03	50.74	4748.63
1984	198.97	482.03	770.60	759.99	485.27	251.65	356.48	618.31	699.54	217.50	521.71	157.56	5519.61
1985	469.45	672.91	979.98	971.33	560.33	301.56	261.14	194.50	222.98	60.48	117.98	127.25	4939.89
1986	199.41	556.75	853.50	717.73	672.14	703.59	536.18	400.82	305.51	431.54	652.64	224.09	6253.90
1987	333.99	683.73	664.73	626.93	569.20	266.92	451.91	294.92	117.58	70.29	187.98	44.72	4312.90
1988	205.71	558.80	391.48	230.21	141.16	66.19	145.31	117.91	185.83	138.81	168.45	75.41	2425.27
1989	219.25	338.27	360.64	566.15	548.38	130.23	177.45	445.90	449.66	211.32	343.48	97.69	3888.42
1990	282.29	435.59	719.65	627.48	487.33	366.74	422.44	417.41	423.95	319.11	327.87	157.61	4987.47
1991	214.75	518.21	660.27	569.75	318.69	151.50	339.70	298.05	61.49	190.38	254.69	161.07	3738.55
1992	219.20	336.73	480.40	460.14	316.39	112.29	114.84	25.96	59.99	35.46	223.54	199.05	2583.99
1993	153.55	296.32	413.62	406.40	353.55	295.61	435.24	740.74	237.64	137.51	458.08	185.96	4114.22
1994	186.31	229.34	270.04	138.97	99.02	29.89	15.13	111.69	294.75	170.88	450.82	324.45	2321.29
1995	388.84	637.22	820.52	736.35	598.85	464.63	268.00	856.16	1155.11	750.88	528.20	357.16	7561.92
1996	502.06	814.86	1083.02	913.32	823.66	724.50	644.65	710.48	366.44	205.05	372.91	245.69	7406.64
1997	399.76	616.50	780.03	701.92	633.61	430.10	427.55	328.30	183.90	189.10	485.26	318.48	5494.51
1998	426.40	666.66	663.54	601.92	326.31	229.81	152.91	332.74	47.23	187.51	324.90	232.32	4192.25
1999	383.48	451.14	544.13	263.89	63.82	41.00	136.44	157.38	99.45	11.38	43.27	82.06	2277.44
2000	630.35	919.07	999.60	757.77	448.92	380.59	271.47	324.42	125.88	286.21	334.83	532.02	6011.13
2001	777.87	904.39	782.74	979.87	388.48	143.45	424.11	761.37	1234.28	226.96	185.35	484.72	7293.59
2002	700.39	838.33	979.88	937.85	727.13	381.73	631.63	453.79	44.59	221.75	283.23	246.24	6446.54
2003	697.88	790.05	843.86	635.17	882.50	492.37	521.23	413.80	94.84	247.18	630.80	544.57	6794.25
2004	580.36	706.36	802.40	758.74	427.26	163.02	403.10	205.31	356.65	347.00	676.91	828.39	6255.50
2005	889.89	836.02	947.27	741.50	803.21	405.87	404.33	225.02	84.45	237.21	304.39	697.94	6577.10
2006	800.06	823.65	930.10	854.95	361.23	286.81	225.71	255.85	259.85	423.67	320.16	776.62	6318.66
2007	949.17	811.22	842.23	731.11	258.32	507.34	523.30	526.33	272.02	211.82	453.00	650.79	6736.65
2008	759.44	669.55	727.44	771.82	482.51	433.33	475.00	348.95	271.94	248.84	336.39	729.64	6254.85
2009	856.01	792.15	939.14	881.49	670.65	387.11	284.86	401.06	288.26	247.53	366.32	594.62	6709.20
2010	592.55	591.47	536.59	361.20	250.66	331.43	261.68	124.97	63.02	111.38	184.04	528.50	3937.49
2011	934.58	932.05	752.56	383.50	213.48	180.51	512.59	1605.47	1727.12	861.76	420.79	878.13	9402.54
2012	1254.13	1369.92	909.08	772.55	688.46	696.67	466.76	358.97	117.10	211.28	542.36	758.86	8146.14
2013	887.20	647.63	473.19	350.32	425.31	337.14	276.18	178.79	110.72	88.63	122.70	364.00	4261.81
Average	485.53	596.62	690.06	640.18	486.94	354.48	391.21	451.90	341.74	271.78	357.03	366.90	5434.38

Table A43: Simulated monthly water release (unit: MCM) of Sirikit reservoir over 1974-2013 periods (40 years)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1974	484.69	659.14	813.92	779.88	564.71	396.50	400.37	324.92	246.35	235.76	341.20	361.79	5609.22
1975	565.31	541.17	563.91	487.50	320.79	279.51	349.38	305.36	291.32	233.11	371.18	433.54	4742.09
1976	586.88	758.12	837.36	784.58	557.31	446.24	434.77	399.65	276.31	233.43	375.40	434.82	6124.90
1977	563.70	666.80	827.75	784.95	594.98	455.78	410.10	404.55	248.20	232.38	350.14	286.08	5825.42
1978	541.40	616.65	667.12	589.95	414.07	292.41	317.72	347.90	269.60	231.17	351.20	365.11	5004.30
1979	490.71	642.37	797.01	768.23	556.71	379.04	431.14	350.87	241.98	248.52	346.98	430.08	5683.64
1980	451.15	470.30	513.16	406.10	288.24	227.23	330.67	315.90	264.53	232.61	347.72	325.96	4173.56
1981	482.67	599.08	778.86	740.01	590.20	368.99	445.45	698.88	246.77	221.52	366.84	415.16	5954.43
1982	536.59	670.45	818.91	786.29	621.65	464.08	429.60	403.57	270.87	231.56	349.36	372.43	5955.36
1983	498.97	642.92	784.98	779.27	573.78	409.16	397.47	362.57	247.83	231.86	362.41	349.15	5640.37
1984	541.51	683.43	776.36	722.05	569.84	338.77	352.55	365.85	282.60	232.77	350.76	374.48	5590.97
1985	521.67	690.99	786.49	776.73	593.45	389.93	361.26	338.74	277.14	230.83	373.16	355.26	5695.67
1986	529.31	624.96	770.77	717.30	563.83	360.81	376.21	388.19	244.94	232.21	347.71	607.13	5763.36
1987	457.26	495.41	523.14	422.71	308.28	240.87	340.75	346.49	176.90	127.93	349.97	193.73	3983.43
1988	180.83	302.92	309.39	348.54	223.69	223.34	287.67	315.06	228.73	237.34	339.43	289.98	3286.91
1989	393.30	472.85	517.14	398.21	262.57	252.05	287.72	378.57	195.40	239.28	337.28	199.17	3933.53
1990	264.18	440.57	494.08	386.16	253.47	237.27	300.04	344.52	205.04	239.70	344.80	204.10	3713.94
1991	309.66	428.44	511.30	383.52	256.00	232.95	310.10	343.55	187.63	172.59	337.65	193.87	3667.26
1992	188.74	358.94	393.42	375.63	297.25	182.93	276.81	332.11	173.24	99.69	342.78	188.61	3210.16
1993	178.12	263.45	290.98	340.48	254.94	173.45	276.61	367.74	179.92	180.46	334.62	193.71	3034.49
1994	182.91	264.94	287.33	320.89	217.68	190.00	268.18	288.82	296.20	237.23	359.73	428.58	3342.48
1995	523.97	677.59	799.59	784.38	614.28	427.99	374.85	554.27	923.75	364.51	470.49	503.86	7019.54
1996	570.38	739.18	849.25	788.05	656.51	451.54	503.77	479.37	300.34	231.91	370.94	421.48	6362.73
1997	528.90	662.71	806.87	785.42	591.83	471.97	447.57	368.03	266.07	231.30	352.23	310.44	5823.33
1998	524.70	623.28	745.70	697.46	533.31	328.85	330.89	397.05	206.14	269.91	334.65	196.71	5188.64
1999	231.06	418.56	482.20	380.57	257.13	235.75	320.64	325.17	237.06	232.39	357.69	329.88	3808.09
2000	555.37	731.81	772.78	718.36	588.12	347.27	369.82	408.44	268.83	234.06	358.08	377.96	5730.90
2001	531.37	669.05	811.38	754.97	566.70	374.25	350.48	462.10	317.38	210.97	358.08	451.20	5857.93
2002	557.51	709.64	851.75	786.64	556.01	435.90	497.84	589.80	395.12	201.97	373.82	487.93	6443.94
2003	601.67	707.46	858.74	787.20	639.57	461.22	447.12	421.98	287.48	244.78	342.70	391.22	6191.13
2004	550.35	720.53	795.80	781.14	581.70	380.12	414.42	430.21	422.54	204.12	355.63	484.29	6120.87
2005	576.43	672.56	850.73	786.14	631.39	427.17	445.43	434.31	344.73	233.90	365.96	488.90	6257.66
2006	573.57	709.80	851.63	784.59	623.87	460.89	471.42	505.98	558.97	562.84	365.62	492.95	6962.11
2007	570.81	716.78	854.86	787.70	624.73	451.33	500.39	420.66	283.02	232.36	359.12	432.82	6234.58
2008	553.15	733.67	791.96	761.69	442.47	366.24	413.91	643.03	276.94	212.81	379.86	510.97	6086.68
2009	587.77	724.91	855.24	785.83	586.24	441.68	444.70	433.53	285.95	230.94	345.69	335.63	6058.10
2010	549.10	558.64	755.35	707.67	554.45	333.25	352.45	292.62	281.09	231.12	340.66	416.93	5373.33
2011	525.60	671.64	797.03	763.19	478.11	355.71	481.31	1304.44	1593.73	1239.31	382.30	580.86	9173.22
2012	629.27	736.83	856.38	786.52	633.56	463.96	480.12	452.96	290.34	231.71	366.95	433.44	6362.06
2013	535.20	697.62	808.79	780.12	612.04	412.40	380.07	370.48	257.03	231.24	339.00	278.47	5702.45
Average	480.64	604.40	706.49	657.67	491.39	354.22	385.29	425.46	321.20	259.85	357.49	373.22	5417.32