

## CLIMATE CHANGE AND ADAPTIVE WATER MANAGEMENT IN BANGPAKONG RIVER, THAILAND

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### ABSTRACT

Climate change is one of the most pressing threats to sustainable development across the globe. There are expected to have significant effects on water resources planning and management, especially in estuary areas. The objective of this study is to evaluate of the vulnerability and adaptability for water management in eastern Thailand. The model is developed using Mike11 software, and calibrated and validated by historical matching utilizing data for the period 2013-2014. The study covered the area from Kgt.3 station, Prachinburi Province to the river estuary at the Gulf of Thailand. The model was divided into two parts, hydrodynamic (HD) module and advection-dispersion (AD) module. Calibration of each part was done by adjusting its important coefficients. It was observed that the Manning's coefficient ( $n$ ) and coefficient dispersion of mass were in the range of 0.025-0.035 and 100-1,400  $m^2/s$ , respectively. The results of comparison between models and observation data revealed order of forecasting error ( $R^2$ ) in the range of 0.88-0.99 for water level and 0.81-0.99 for salinity. For model application, the RCP2.6 and 8.5 scenarios from IPCC report were simulated, sea water level rising in the year of 2100 were 1.04 and 1.34 m, respectively. Maximum salinity at Bangkhanag regulator, Chachoengsao Province was 13.48-13.66 g/l, exceeding standard for raw, tap and agriculture water. The increased of salinity also affects the growth of plants in the estuaries areas. These studies note the importance of water demand management through formal or informal institutions, regulations, and other approaches to adapt to the impacts of climate change. Results of this study can be used as guidelines for the management of water resources and agriculture of the Bang Pakong River and Eastern Economic Corridor (EEC) areas, Thailand.

*Keywords:* Climate change, adaptation, Bang Pakong River, Eastern Economic Corridor, mike11 model

### 1. INTRODUCTION

Climate change has been observed local and global effects. Most of the effects were negative. The notable phenomena effected by extreme weather events, are heavy rains, heat waves, and draught. Climate change causes serious risks to the well-being of nature and people all over the world. Within the estuaries, sea water can be the important controls of water level, salinity and coastal erosion. Although the precise effect of climate change on estuaries dynamics and its processes in the alluvial river system is still not clear, there seems to be no doubt that it influences sea water level and salinity intrusion. Recently, numerical modelling has been shown to answer some of these problems. A number of works have used numerical models attempting to simulate river catchment hydrological processes of rainfall-runoff, sediment transport, salinity intrusion and coastal erosion processes as well as to study the impact of climate change. In addition, many numerical models have been applied to predict hill slopes and river channels DHI (2000), Kirby (1987), MWA (2011), Wicks and Bathurst (1996). Thus, it is clear that the numerical models appear to have considerable potential as tools for investigating hydrodynamic, sediment transport and water quality over long period simulation. Wassmann et al. (2004) have predicted that sea water level affected rice production in Mekong Delta, Vietnam, during the wet season. However, there are a few application studies in Thailand. Wongsas (2004), Wongsas and Ekkawatpanit (2009), Wongsas et al. (2010a), Wongsas et al. (2010b) and Wongsas (2015) have exploited MIKE11 model to predict sea level affecting salinity intrusion and agricultural production in Tha Chin, Mae Klong and Chao Phraya rivers. Metropolitan Waterworks Authority (MWA) and Royal Irrigation Department (RID) reported that salinity intrusion, raw water supply and agricultural productivity in Chao Phraya and Ta Chin Rivers were affected by climate change.

This paper addresses these issues by using a proposed MIKE11 numerical modelling to simulate the effects on sea water level change and salinity intrusion. Performance of the numerical model was applied to simulate flow events in 2100, which are water level change and salinity intrusion on agricultural and raw water supply in the Bang Pakong River, Thailand.

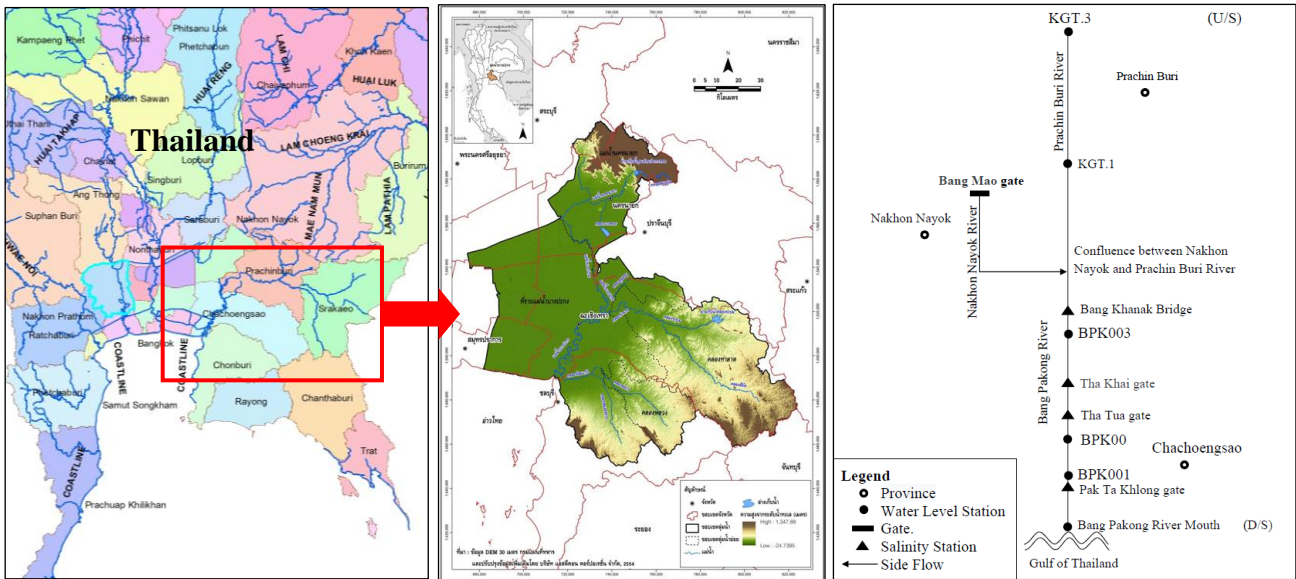


Figure 1. Study area of the Bang Pakong River.

## 2. DESCRIPTION OF THE SYSTEM

The Bang Pakong River Basin is located in the eastern region of Thailand (Figure 1) just east of Bangkok. It is part of the country's eastern economic corridor (EEC) which, has been a target of considerable economic development and, due to its location along the gulf of Thailand and border with Cambodia, represents an area of strategic national importance. The catchment area is about 10,707 km<sup>2</sup> covering the 11 provinces. The monsoon season is usually from May until late September, with averagely 1-2 tropical depressions occur over much of the area. The average annual rainfall is 1,387 mm, depending on monsoon direction and elevation with the maximum average in September. The basin is characterized by rapid industrialization and having one of the most pressing water problems in Thailand. In fact, the demand for water has already eclipsed its storage capacity. The Bang Pakong River also imports water from Chao Phraya and Pasak Rivers to boost water supply in EEC area. The water resources related problems in the basin are in fact more developed making its situation relatively worse than the country's other basins. Issues in the basin include water shortages, salinity intrusion and saline water flooding, land salinization, water quality deterioration, loss of forests, degradation of mangroves and water use conflicts between rice farmers and shrimp/fish farmers.

## 3. MIKE11 SOFTWARE AND MODEL SETUP

### 3.1 MIKE11 software

To assess the influence of the water flow and salinity impacts on climate change of the Lower Chao Phraya and Tha Chin Rivers, the MIKE11 model has been used. This numerical model simulates water flow and salinity as a consequence of low flow conditions, dry season. The shallow-water equations for one-dimensional unsteady flow can be expressed as following,

Continuity equation:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \quad (1)$$

Momentum equation:

$$\frac{\partial Q}{\partial t} + \frac{\partial \left( \alpha \frac{Q^2}{A} \right)}{\partial x} + gA \frac{\partial h}{\partial x} + \frac{gQ|Q|}{M^2 AR^{4/3}} = 0 \quad (2)$$

where,  $Q$  = flow discharge (m<sup>3</sup>/s),  $A$  = flow section area (m<sup>2</sup>),  $q$  = side flow discharge (m<sup>3</sup>/s),  $h$  = flow depth (m),  $R$  = hydraulic radius (m),  $g$  = acceleration (m/s<sup>2</sup>),  $\alpha$  = momentum correction factor,  $M$  = Strickler's Number ( $M = 1/n$ ;  $n$  = Manning's roughness coefficient),  $x$  and  $t$  = flow direction and time, respectively. For transportation of mass, such as, salinity can be obtained from,

Advection-Dispersion equation:

$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \frac{\partial}{\partial x} \left( AD \frac{\partial C}{\partial x} \right) = -AKC + qC_2 \quad (3)$$

where,  $C$  = salinity concentration (mass/volume),  $D$  = dispersion coefficient ( $m^2/s$ ),  $K$  = consumption rate ( $s^{-1}$ ) and  $C_2$  = Source/Sink Concentration (mass/volume).

### 3.2 Model setup

To modelling the river network of the Bang Pakong River, a digital elevation model has been used. The model input data were cross-section, flow discharge, water level, side flow and salinity. The MIKE11 program, 6-points Abbott's finite difference scheme was used to solve governing equations, consisting of separate modules each representing a different procedure in calculation process. A first module calculated hydrodynamics of river flow (HD module), and the next module of transportation of mass (AD module). The model setup of plan view and longitudinal profile of the Bang Pakong River is shown in Figure 2.

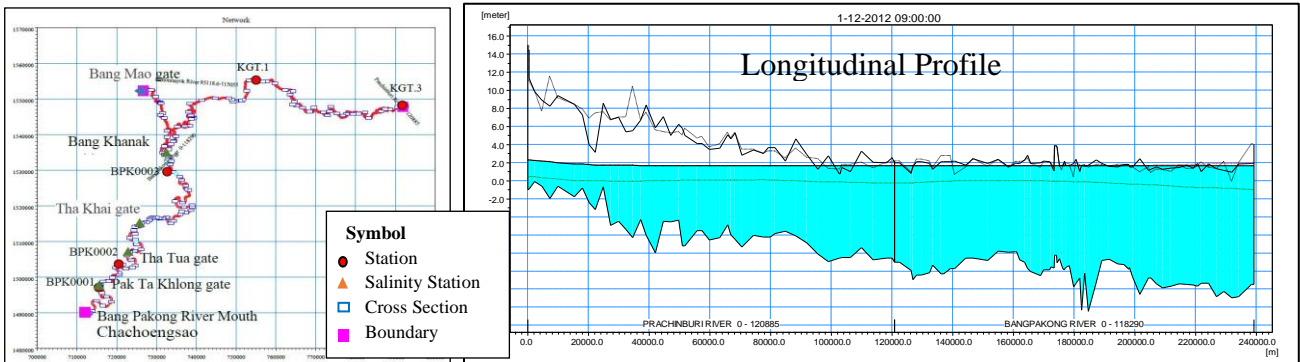


Figure 2. Model setup of the Bang Pakong River.

## 4. RESULT AND DISCUSSION

The Bang Pakong River was used for calibration and verification of the proposed model. The calibration and validation have focused on the applicability of water flow and salinity intrusion by using flow conditions in the year of 2013 and 2014, respectively. Performance of the foregoing numerical model were applied to simulate scenarios from IPCC SRES, consisting of RCP2.6 and RCP8.5, the predicted global average sea level rising from 1990 to 2100 for the SRES scenarios by using GCMs. RCP2.6 and RCP8.5 are consistent with a wide range of possible changes in future anthropogenic greenhouse gas emissions, and aim to represent their atmospheric concentrations (IPCC, 2013). For model simulation, flow discharge at station Kgt.3 (Prachinburi River) and Bang Mao Regulator (Nakhon Nayok River), water level at the Gulf of Thailand (Hydro Informatics Institute) were adopted for upstream and downstream boundaries. Before the water flow and salinity calculation was carried out, the model was run to provide the steady state of necessary flow variables.

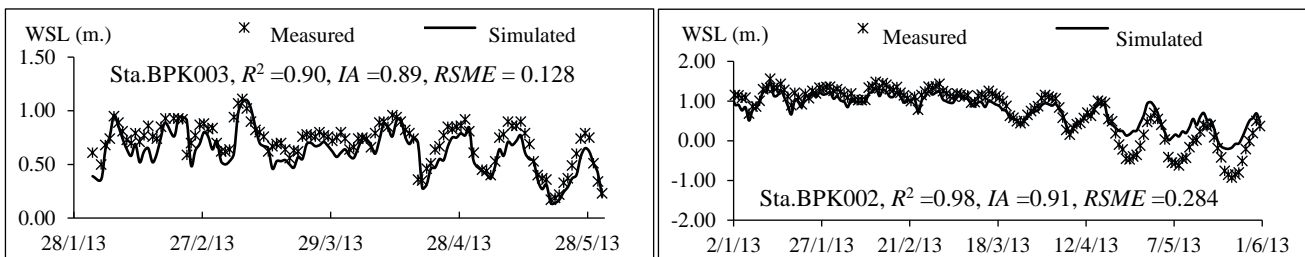


Figure 3. Comparison of time series of water surface level between simulated results (smoothed-line) and measured data (dotted) at the major gauge stations (for calibration).

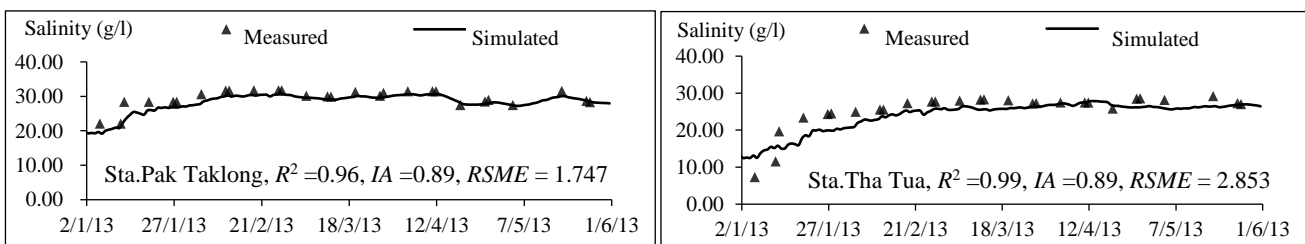


Figure 4. Comparison of time series of salinity between simulated results (smoothed-line) and measured data (dotted) at the major gauge stations (for calibration).

#### 4.1 Model calibration

The comparison of time series of measured and simulated water surface level and salinity at two major gauge stations and Manning's roughness coefficient ( $n$ ) are shown in Figures 3-4. Good agreement between the simulated and measured hydrographs for the low flow events were achieved by considering side flow, gate operation and pumps in the study area. The coefficient of determinant ( $R^2$ ) and index of agreement ( $IA$ ) have been used as the main criteria to judge whether the data fitted between measurement and simulation.

The study results, manning ( $n$ ), global dispersion factor, global exponent and  $K_{mix}$  were in the range of 0.025-0.035, 100-1,400  $m^2/s$ , 0.1-0.4 and 100-1,400, respectively. The results of comparison between models and observation data revealed order of forecasting errors,  $R^2$  and  $IA$  were in the range of 0.90-0.99, 0.71-0.98 for water level and 0.81-0.99, 0.84-0.99 for salinity. These indicate well fitted between measured data and the proposed model.

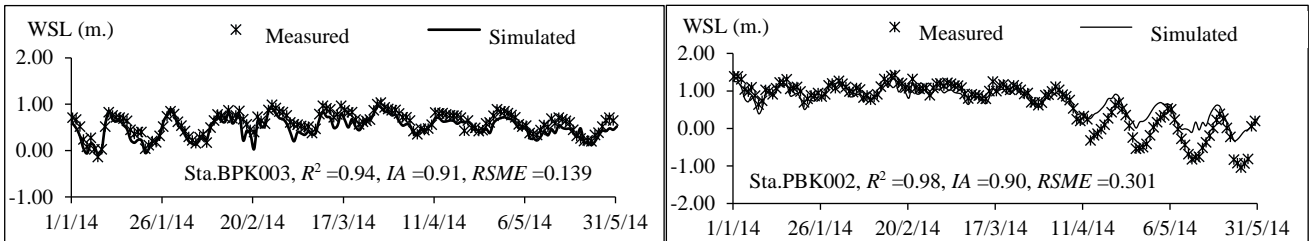


Figure 5. Comparison of time series of water surface level between simulated results (smoothed-line) and measured data (dotted) at the major gauge stations (for validation).

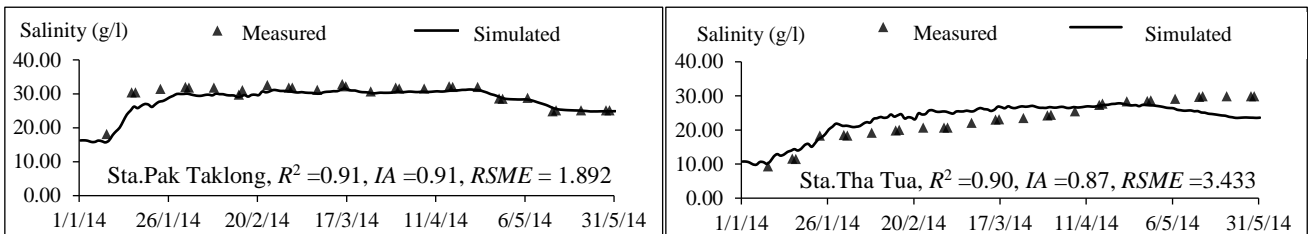


Figure 6. Comparison of time series of salinity between simulated results (smoothed-line) and measured data (dotted) at the major gauge stations (for validation).

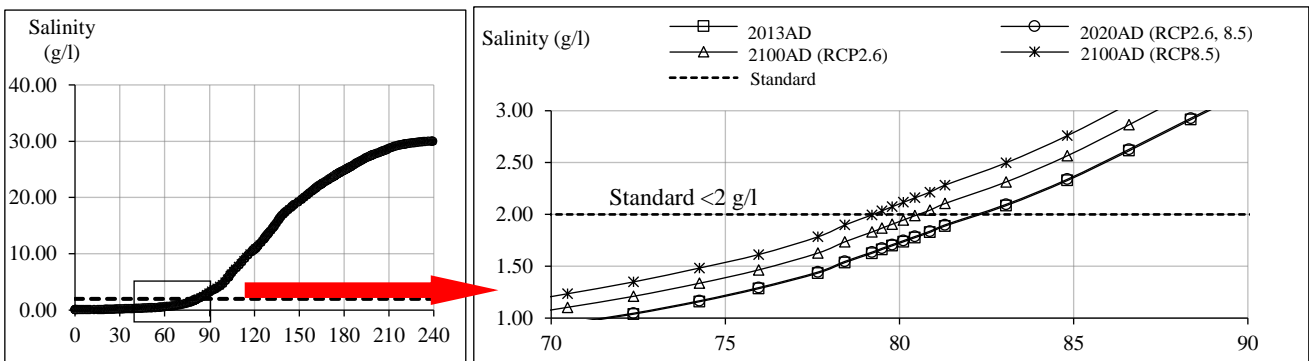


Figure 7. Salinity intrusion from river estuary in the year of 2100 (IPCC SRES), with 0.38 m and 0.68 m sea water level rising in RCP2.6 and RCP8.5 scenario and salinity 30 g/l at downstream (Gulf of Thailand).

#### 4.2 Model verification

The comparison of time series of measured and simulated water surface level and salinity at four major gauge stations are shown in Figures 5-6. Good agreement between the simulated and measured. There were observed that the values of  $R^2$  and  $IA$  for two major gauge stations in verification period were between 0.94-0.99, 0.91-0.98 for water level and 0.89-0.98, 0.86-0.93 for salinity, indicating well fitted between measured data and this proposed model. Good performance of simulated results was observed in both water flow and salinity intrusion characteristics, therefore, indicating that model simulation is reasonable. (Figures 5-6).

#### 4.3 Climate change projection

For model application, scenarios RCP2.6 and RCP8.5 from IPCC report were simulated, sea water level rising was 0.38 and 0.68 m in the year of 2100. The comparison of time series of measured and simulated flow discharge at the major gauge stations are shown in Figures 7. It was found that sea water level at the Bang Pakong estuarie had rising and be taking tendency to intrusion of sea water level. Salinity were shown to be in

the same tendency. For IPCC SRES in the year of 2100, sea water level rising in RCP2.6 and RCP8.5 scenario was 0.38 and 0.68 m, and salinity maximum values and intrusion distant were in the range of 13.48 and 13.66 g/l and 158.0-159.0 km from the Gulf of Thailand. The worst case scenario, a constant value of salinity of 30 g/l was adopted at the Gulf of Thailand. It was found that salinity at Bang Khanak Bridge increase were 0.23-0.41 g/l. For agriculture water, the value of 2.0 g/l exceeding standard and the pointed tip of salinity was at Bang Decha sub-District, Mueang District, Prachinburi Province shown in Figures 8. We could also observe these effects gained a more conspicuous large against higher sea water level rising.

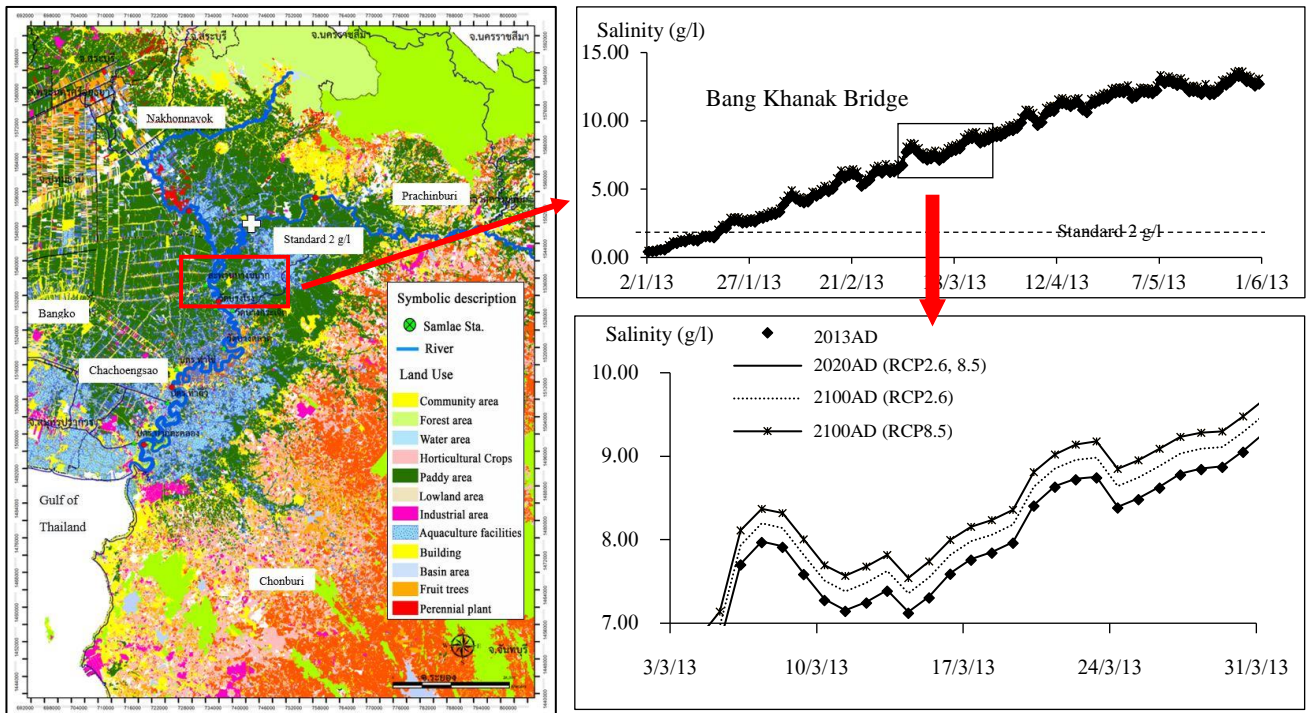


Figure 8. Salinity profile in the year of 2013 and 2100 (IPCC SRES).

#### 4.4 Adaptation measured for Bang Pakong River

The risk of water scarcity is looming in the East, mainly to industrial development in the EEC. The rising demand for water in the three EEC provinces - Chon Buri, Rayong and Chachoengsao - will lead to conflicts and confrontations over limited resources. Without rapid investment in EEC, core provinces such as Chon Buri and Rayong are already suffering shortages, as water consumption stands at 739 MCM versus the allocated 941 MCM, and with industrial expansion and population growth from EEC projects, water demand in this area will rise to around 1.21 MCM, surpassing the amount allocated, so more water resources need to be sought from outside areas. However, diverting water from these provinces will give rise to fiercer competition and other problems such as unjust land expropriation and deforestation to make way for new reservoirs. According to long-term climate projection, these areas will get lesser rains in the future. The authorities should carefully plan industrial expansion to suit the use of local land and water resources to minimize the risk of igniting water conflicts, while business operators should apply efficient policies to cut down on water demand, such as recycling or desalinating water for industrial use. The climate change, sea water rise was also affecting the growth and productivity of rice and mango in Bang Pakong River. Developing salt-tolerant crop varieties and farming methods, and funding infrastructure projects to prevent saltwater flooding, groundwater contamination by seawater intrusion can help coastal farms remain viable as sea levels rise. It will also be important to regulate brackish aquaculture to avoid conflicts between rice farmers and shrimp/fish farmers.

## 5. CONCLUSIONS

In this study, the MIKE11 model was exploited to simulate the effects of climate and sea level changes on the raw water supply and agricultural areas in the Bang Pakong River in the year 2100. The study covered the area from Prachinburi River (Kgt.3), Prachinburi Province and Bang Moa Regulator, Nakhon Nayok Province and to the river estuary at the Gulf of Thailand. IPCC SRES predicted that in the year 2100, sea water level rising in RCP8.5 scenario was 0.68 m. Based on this information, the simulation showed that salinity at Bang Khanak Bridge will be exceeded 0.25 g/l. This will help to balance level of salinity in river not over 0.25 g/l. For agricultural sectors, the value of 2.0 g/l exceeding standard and the pointed tip of salinity in Bang Pakong

River was at Bang Decha sub-District, Mueang District, Prachinburi Province. Results obtained from this study will give guideline in raw water resources management for water supply and agricultural Bang Pakong River.

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