CALCULATION OF FLOOD DISCHARGE AND STORAGE CAPACITY BY CLIMATE CHANGE SCENARIOS IN RACH BAU HA, TUY HOA CITY USING THE MIKE MODEL

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Abstract: *The climate and topography characteristics of Tuy Hoa city, Phu Yen province are quite complicated and being affected by most types of natural disasters, in which storms and floods frequently occur in the downstream of rivers. Huge amount of water from upstream in combination with local downpour have caused numerous flash floods. Rach Bau Ha, the main flood-discharge of the city, is a low-lying area and often being submerged during rainstorms. This article aims to apply MIKE model in forecasting the flood discharge and storage capacity of Rach Bau Ha response to climate change scenarios and proposing appropriate alternatives for the purpose of minimizing flood in the research area. Collected hydro-meteorological, topographical and geological data, previous research results, synthesis, analysis and calculation of designed hydro-meteorological characteristics will be used as input for the MIKE model. The results show that the cross-sectional area and lake area of Rach Bau Ha according to a scenario (lake surface area F = 12.50 ha) completely ensure the flood discharge and storage of Rach Bau Ha, without much increase of the maximum water level and inundation duration, ensure that the water levels of the canal shall not affect inhabitants and infrastructure of the vicinity.*
Keywords: *MIKE model, flood discharge, climate change.*

1. INTRODUCTION

Tuy Hoa city, Phu Yen province is becoming a dynamic economic center and an attractive destination of the region. The city is prioritizing the construction of comprehensive and sustainable infrastructure, of which the planning and construction of urban areas will significantly contribute to the development demand of the city. The climate and topography characteristics of Phu Yen province in general and Tuy Hoa city in particular are quite complex and being affected by most types of natural disasters with a frequent occurrence of storms and floods in the downstream of rivers. Huge amount of water from upstream in combination with heavy rain have caused numerous flash floods. There have been a number of historic floods causing extensive damages in 1993, 1999, 2007 and 2009. According to storm partition results, risk identification of storm and storm-surge of coastal areas, Tuy Hoa city is located in zone IV with rain-storm concentrated in November and December. The wind storm level was recorded at level 13, maximum daily rainfall was up to 470mm, sea level rose by

Receipt Date: July 30th, 2022
Review Approval Date: September 20th, 2022
Publish Approval Date: October 05th, 2022

1.5-2.0m, in case of flood tide combining with storm-surge, the water level could reach 3.2-3.4m. Climate change has also contributed to an increase in extreme weather that affects inundation. Rach Bau Ha, the main flood-discharge area for part of the city, is a low-lying area and often being submerged during soakers. Therefore, it is necessary to apply MIKE model to calculate and forecast flood discharge and storage of Rach Bau Ha for the purpose of formulating drainage planning and evaluating impacts of construction works on drainage capacity of Tuy Hoa city.

2. THEORETICAL BASIS AND CALCULATION METHODS

2.1. Basis for selection of calculation methods

In order to choose a reasonable calculation and anticipation method, factors affecting the capability of flood discharge and storage of Rach Bau Ha should be evaluated:

+ Width of fortified embankment canals along Rach Bau Ha.

+ System of bridges, road culverts and tide-lock in the downstream area of Rach Bau Ha before discharging into the sea.

+ Due to low terrain, the influence of tidal level at the estuary of Rach Bau Ha during the process of flood discharge and storage is quite significant.

+ Landscape construction and improvement of the canal area that affects the flood storage volume of Rach Bau Ha.

+ The accretion and dumping in the channel, damage of tide-lock and regulators greatly affect the ability of flood discharge and storage of the canal.

The problem of hydraulics and canals is quite complicated, requiring a large amount of data; research tools and methods must simulate the actual flow on the canal as closely as possible. On the basis of the problem requirements and collected survey data, the authors have chosen a mathematical modeling method to simulate the flood discharge and storage of Rach Bau Ha.

The mathematical modeling method is based on the system of mathematical equations describing the flow and sediment rule of the researched river section, determining reasonable boundary and initial conditions in order to find out analytic and algebraic solutions to research problems. In mathematical models of two-dimensional (2D) and three-dimensional (3D) flow simulations, river-bed development simulation, the MIKE model is preeminent and most reliable to calculate and forecast flood discharge of the research area.

The MIKE model, developed by DHI Water & Environment, is a software package used to simulate flow (flow discharge), water quality and sediment transport at estuaries, rivers, irrigation canals and other water bodies. The MIKE software consists of many application modules for different problems. Considering the calculation requirements of the research area, the authors have used hydraulic and sediment transport modules of MIKE11 and MIKE21. Hydrodynamic (HD) modeling module, the central part of the MIKE 11 modeling system, is the basis for most of the modules including: flood forecast, diffusion loads, water quality and sediment transport modules. The hydraulic module of MIKE 11 solves synthetic equations by flow direction to ensure the consecutiveness and conservation of momentum (Saint Venant system of equations).

2.2. Application of hydraulic calculation model for flood discharge and storage of Rach Bau Ha

2.2.1. Scope of hydraulic calculation research

The scope of the study is the flood discharge basin of Rach Bau Ha as shown in Figure 1:

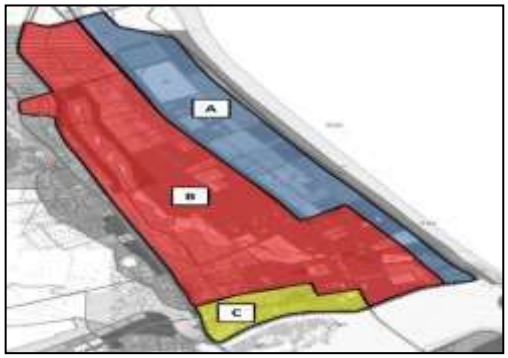

Figure 1: Research area for flood discharge and storage of Rach Bau Ha (zone B).

2.2.2. Hydraulic calculation diagram

Hydraulic calculation on flood discharge and storage of Rach Bau Ha is closely related to the tidal level of Da Rang estuary. Therefore, the hydraulic calculation diagram is set up for the canal section from the upstream of Rach Bau Ha to the tributary of Da Rang river with a simulation length of about 6.3km.

Figure 2: Diagram of river network and hydrological stations of research area

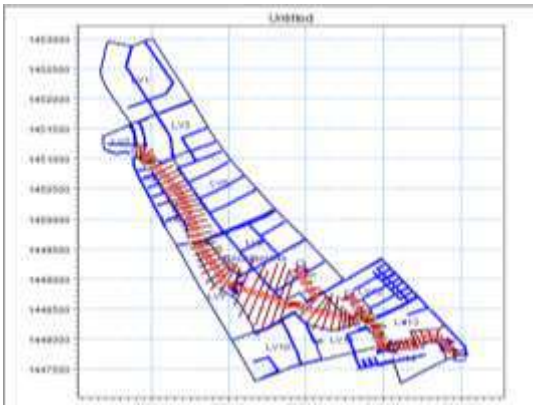

Figure 3: Diagram of simulated river network by hydraulic model

2.2.3. Set up MIKE 11 hydraulic model

Input data:

- Terrain data is the topographic cross-sections of construction projects along Rach Bau Ha. The cross-sections of remaining areas are based on the topographic map of Tuy Hoa city with the scale of 1:2000.
- Hydrological data is calculated based on actual measured data from the upstream of Rach Bau Ha to the Da Rang estuary with a total length of 6.3km. The upper boundary is the design rainfall graph of drainage areas, upstream of Rach Bau Ha; the lower boundary is the water level corresponding to the design frequencies; Middle tributary boundary is the design rainfall graph of the urban drainage areas to Rach Bau Ha.
- System of works on canal: Simulated canal system consists of works affecting the flow regime of research area such as traffic roads, bridges, culverts, channels, regulators...
- Model revision and calibration: The rainfall and inundation model selected to be verified and calibrated is the rainfall model in December 2016, which is the recent soaker causing severe flood in Rach Bau Ha.

Calculation scenarios

+ Hydrological calculation scenario: includes the design rainwater drainage scenario with a 5-year repetition cycle (Tuy Hoa is grade II urban area. Open canals and ditches will be calculated according to design rainfall with a 5-year repetition cycle).

+ Tidal level scenario: The tidal level is determined at Da Rang estuary with a 5-year repetition cycle.

+ Tide-lock operation scenario: The tide-lock is calculated for 2 cases: tide-lock completely closed at high tide; tide-lock operated when the sluice's water level is higher than the tidal level.

+ Climate change - sea level rise scenario: For coastal urban areas affected by tidal, climate

change - sea level rise is an important factor in terms of water drainage. Scenarios include:

- Scenario for design rainwater drainage increased by 3%

- Scenario for tidal level rose by 30cm.

Climate change scenarios are calculated for the proposed lake surface area that does not consist of extreme variables within the same scenario. Each scenario calculates one extreme factor due to climate change: increased design rainfall or sea level rise.

+ Scenarios of using lake surface area as detention basin:

***- SCE0:** The urban area has not yet been built (current status scenario).*

***- SCE1:** The lake surface area has been used as stipulated in the Decision approving the plan of previous period with the scale of 1:5000, F lake = 7.45ha.*

***- SCE2:** The proposed lake surface area has been used in this period: corresponding to 10.00 ha.*

***- SCE3:** The lake surface area: corresponding to 12.50 ha*

Calculation results:

- The calculation results of design rainwater drainage by actual rainfall model of Tuy Hoa meteorological station show that the water level is higher than in the rainwater drainage model as stipulated in TCVN 7957 (2008).

- The maximum water level according to the design rainwater drainage with a 5-year repetition cycle is of +2.22m without tide-lock, corresponding to the lake surface area of SCE1 (7.45 ha as approved in previous period) and +1.72m with operated tide-lock.

Among all the calculation scenarios, SCE1 has the maximum water level, with a rise of 0.06 - 0.20 m. SCE3 (F lake = 12.50 ha) has an increase of water level of 0.04 -0.16 m. The lake surface area varies from 7.45 ha to 12.50 ha, showing that the water level in research area remains stable, with the maximum variation of 0.06m.

- The inundation duration of Rach Bau Ha depends much on the estuary's water level as well as the opening and closing mode of flap valves. In case the flap valves operate when the tidal level is lower than the water level in the canal, the effect is negligible with an increase of about 30 minutes compared to current situation. In case flap valves are completely closed, the inundation time will last longer, but this scenario is less likely to happen.

The time to maintain the water level higher than +1.6m in case of having rainfall with a 5-year repetition cycle is of 6 hours 20 minutes. The scenario is calculated for actual flood model and the downstream flap valves are operated.

Table 1: Calculation results of water level along Rach Bau Ha, taking into account climate change and sea level rise scenarios

No.	Section	Distance (m)	Maximum water level (m)				Notes
			Design rainwater drainage by TCVN 7957		Design rainwater drainage by actual typical rainfall		
			Tidal level increases of 30 cm	Rainfall increases of 3%	Tidal level increases of 30 cm	Rainfall increases of 3%	

No.	Section	Distance (m)	Maximum water level (m)				Notes
			Design rainwater drainage by TCVN 7957		Design rainwater drainage by actual typical rainfall		
			Tidal level increases of 30 cm	Rainfall increases of 3%	Tidal level increases of 30 cm	Rainfall increases of 3%	
1	MC01	0	1.61	1.62	1.82	1.80	Upstream Rach Bau Ha
2	MC06	302	1.58	1.59	1.82	1.80	Mau Than road culvert
3	MC22	1803	1.58	1.59	1.81	1.79	Nguyen Huu Tho road
4	MC26	2187	1.58	1.59	1.77	1.75	Planned area
5	MC31	2725	1.58	1.59	1.77	1.75	Mau Than road
6	MC34	3067	1.58	1.59	1.77	1.75	Planned area
7	MC39	3542	1.58	1.59	1.77	1.75	Tran Phu road culvert
8	MC48	3799	1.58	1.59	1.74	1.72	Culvert to Son lake
9	MC56	4416	1.58	1.58	1.72	1.70	Mau Than culvert
10	MC57	4465	1.58	1.58	1.71	1.69	Youth park
11	MC59	4655	1.58	1.58	1.69	1.67	Dien Bien Phu road culvert
12	MC60	4750	1.58	1.58	1.68	1.67	Nguyen Hue road culvert
13	MC66	5119	1.58	1.58	1.67	1.65	Le Loi road culvert
14	MC68	5238	1.58	1.58	1.66	1.64	Hung Vuong road culvert
15	MC75	5594	1.58	1.58	1.62	1.60	Truong Chinh road culvert
16	MC79	5909	1.58	1.58	1.62	1.59	Van Kiep park
17	MC80	6010	1.58	1.58	1.62	1.59	Tide-lock
18	MC81	6092	1.73	1.42	1.55	1.25	Tran Hung Dao road culvert
19	MC85	6330	1.57	1.27	1.55	1.25	Tide-lock (Da Rang river)

Table 2: Peak water level duration of Rach Bau Ha-Calculation results of actual rainfall for the 5-year repetition cycle

Flap valves close completely.			
No.	Scenarios	Peak duration (hour)	Notes
1	PA0.2	55	Current status scenario
2	PA1.2	42	F lake =7.45 ha
3	PA2.2	42.3	F lake =10.00 ha
4	PA3.2	42.5	F lake =12.50 ha
Flap valves operate.			
No.	Scenarios	Peak duration (hour)	Notes

Flap valves close completely.			
No.	Scenarios	Peak duration (hour)	Notes
1	SCE0.3	44.2	Current status scenario
2	SCE1.3	43.5	F lake =7.45 ha
3	SCE2.3	43.6	F lake =10.00 ha
4	SCE3.3	43.7	F lake =12.50 ha

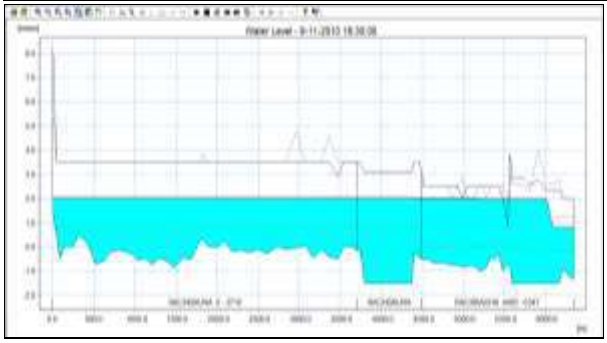

Figure 4: Water level along Rach Bau Ha – Current status scenario – Rainwater drainage model by actual rainfall model – Flap valves close completely.

Figure 5: Water level along Rach Bau Ha – Current status scenario – Rainwater drainage model by actual rainfall model – Flap valves operate

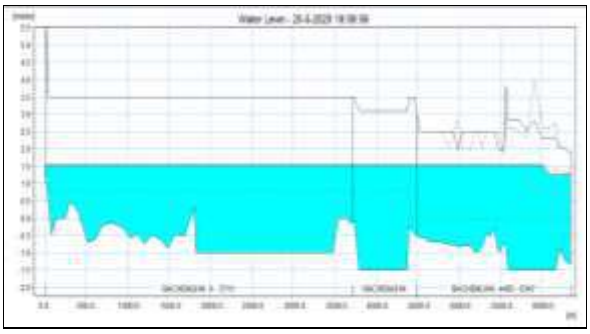

Figure 6: Water level along Rach Bau Ha – Lake surface area by SCE3 scenario – Rainwater drainage model by TCVN 7957 (2008)

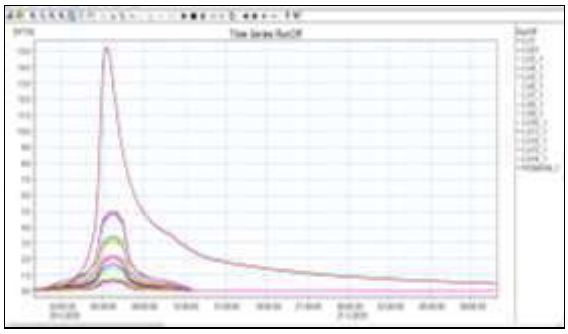

Figure 7: Discharge flow into Rach Bau Ha of all water concentration basins – Rainwater drainage model by TCVN 7957 (2008)

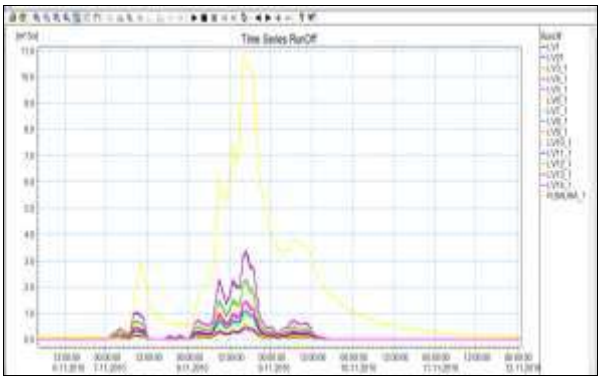

Figure 8: Discharge flow into Rach Bau Ha of all water concentration basins – Rainfall model scenario by actual rainfall model

3. CONCLUSIONS

From the above results, it could be seen that the cross-sectional area and lake area of Rach Bau Ha according to the SCE3 scenario completely ensure the flood discharge and storage of Rach Bau Ha, without much increase of the maximum water level and

inundation duration. The water levels of the canal do not affect inhabitants and infrastructure of the vicinity.

It is suggested to exploit and use lake surface of urban area in the North of Tran Phu street according to the SCE3 scenario, with a total surface area of 12.50 ha. Thus, the maximum water level corresponding to rainwater drainage of the 5-year repetition cycle is of 2.18 m, an increase of 0.04 -0.16cm compared to the current status of works on the basin.

ACKNOWLEDGMENT

The authors would like to express sincere thanks to the University of Mining and Geology for assistance and facilitation on the completion of this research.

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