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Research and Proposal a Solution to Mitigate Salinity Intrusion for Tam Ky River in Quang-Nam Province of Vietnam

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Abstract
TamKy river is one of three river systems in Quang Nam province. Being a small river, however it takes an important role in the economic development of TamKy city and Quang Nam province in general. Due to the impact of climate change, the flow of the river has been decreasing and partly influenced by the deterioration of PhuNinh reservoir. This makes the salinity intrusion of this river get worse. In this study, we use MIKE21 software to set up a 2D hydraulic model to simulate the flow in TamKy river. After calibrating by the real database, it is shown that the model is able to simulate the flow regime and salinity changes in TamKy river very well. Based on the model that has been set, we calculate many salinity washing options of Phu Ninh reservoir with different discharge flows then identify the required discharge rate of 26m3/s, 30m3/s and 37 m3/s corresponding to the flow in TamKy River at high, medium and low level compared to average flow in dry season.

Keywords: *TamKy River, MIKE21, Salinization, Estuary, Reservoirs Operating.*

1. Introduction

Quang Nam has three main river systems: Vu Gia, Thu Bon and Tam Ky. The Vu Gia and Thu Bon Rivers are connected to form a complex river system. This river system has also received special attention from both management agencies as well as scientists due to the increasing problems of landslide, erosion, accretion and flooding. Meanwhile, TamKy river is smaller but directly influences TamKy city, the capital of Quang Nam province. It has not encountered problems with sedimentation of estuaries, river bank slides but faced another problem which is salinity intrusion, especially since PhuNinh reservoir blocked the river to move water up north for irrigation. The location of TamKy city and PhuNinh reservoir in TamKy basin is clearly shown in Figure 1. So far, little research has been done on this river. The studies have still mainly focused on the flood season and the flooding problems of the river downstream. Representatively, a study by Nguyen Ngoc Quynh (2015) suggested a toolset for flood forecasting, reservoir management and flood management in TamKy river basin. There are also some studies on salinity intrusion such as "The summary report on the irrigation planning of Quang Nam province to 2020 with orientation towards 2050" and in "Project on adjustment of general planning of TamKy city to 2030 with a vision to 2030". However, these studies just simply used one dimensional model (1D) and there was no comparative evaluation with actual measurements. Therefore, the results are mainly qualitative and using for building plans rather than quantitative reliability. So, in this study, we set up a 2D model to study the flow regime and salinity intrusion of this river.

Fig. 1. TamKy River Network (source from Google)

Moreover, in this study we use the 2D model, which was established and verified, to determine the required discharge flow of PhuNinh reservoir to prevent salinization in downstream areas. This is an urgent problem in reality to solve because since PhuNinh reservoir was built, salinity intrusion has been more and more serious. Meanwhile, PhuNinh reservoir was designed to have function against salinity intrusion and in 2012, PhuNinh reservoir was tested the flushing to clean salty water for downstream but not effectively.

2. Inputs for the models

In the 2D model for flow simulation in dry season, the inputs consist of the following componants: riverbed terrain, upstream and lowerstream boundary data, real measured data and some other information.

In this work, we inherited the measured databases from the project invested by Quang Nam province which include all the data of TamKy river's riverbed terrain, part of TruongGiang river that connect to TamKy river and the estuary as shown in Fig.2 below.

Fig. 2. Riverbed tarrain and entuary data measured in 2017

The upperbound of the river system is the hourly real measured data at the required areas such as: Bau Ven, Truong Chi, Da Giang, Phu Ninh, Tam Tien. The lowerbound data is the hourly real measured water level at required areas including Cua Lo and Dong Thanh.

3. Set up and adjust the model

Based on the available data, our research group has set up two models which are 1D hydraulic model MIKE11 and 2D spreading model MIKE21. The 1D hydraulic model is used to mathematically simulate the flow on the river and calculate the inflow at the upper bound for the 2D spreading model MIKE21.

From the hydraulic diagram and the terrain maps of the basin, we processed the data and mapped into the network of rivers and streams in the MIKE11 model which consists of 88 cross sections. The upper bound includes Phu Ninh, Tam Tien, Truong Chi, Da Giang and Bau Ven. The lowerbound is Hoa An entuary and Cua Lo entuary as shown in Figure 3 below.

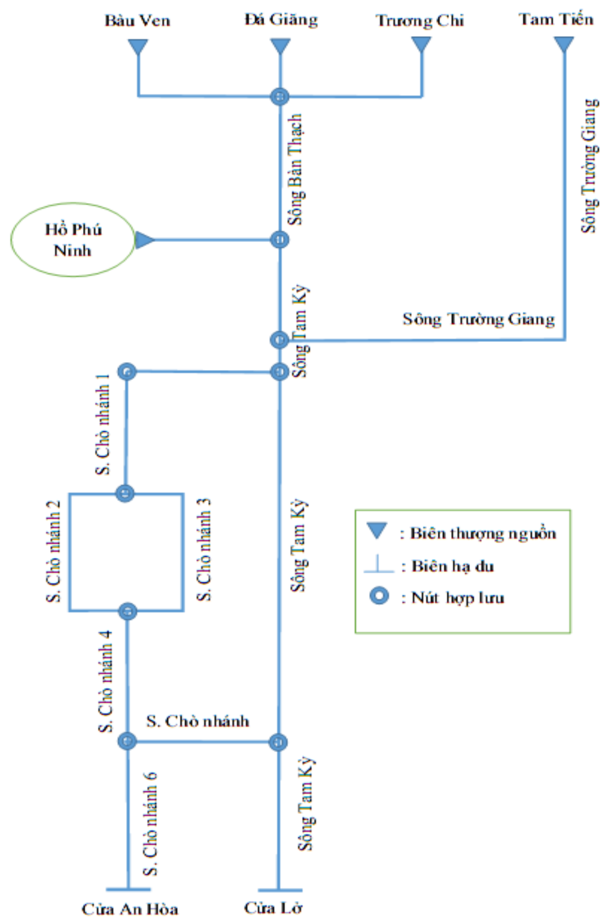

Fig. 3. 1D hydraulic diagram MIKE11 for TamKy river

Based on the riverbed terrain data, The 2D spreading model MIKE21 has been set as the Figure 4.

Because of the small terrain and the large depth of the study area, the simulating the hydraulic and pollution spreading processes is quite complex. The hydrodynamic model for TamKy basin uses an unstructured grid (as in Figure 5) with a total of 8088 triangles computed from 4889 nodes, the largest triangle has the area of 10000m2.

The dataset from 7/3/2001 to 18/3/2001 is used to adjust the model. Using the upper and lower bounds as real measured data, the model is calibrated by the water levels and the salnility at TamAnh station. In Fig.6 and Fig.7, the model calibration get the results closest to the water level and salinity that real measured at TamAnh station.

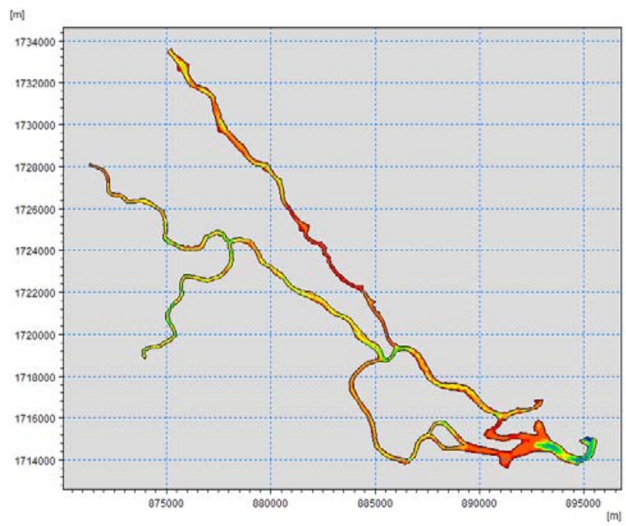

Fig. 4. Diagram using 2D spreading MIKE21

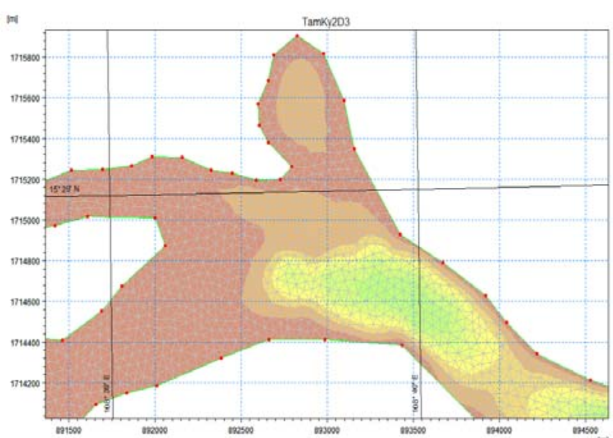

Fig. 5. Unstructured grid using in 2D model

In Fig.6, The water level at TamAnh station oscillates synchronously with the obserbed data which is shown that the 2D model calculates the water level quite well. The calculated peak and tidal values are lower than the real ones. However, the differences are small and acceptable.

The 2D model also give good calculated and adjusted results at salinization. The differences to TamAnh station data are quite small. This is clearly shown in Fig.7.

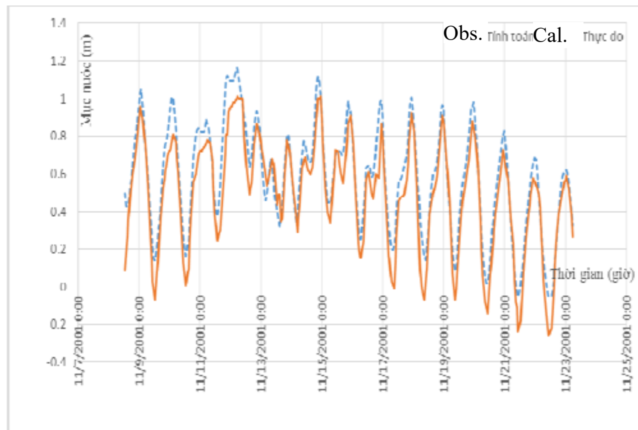

Fig. 6. The obserbed and calculaed water level at TamAnh Station from 11/8/2001 to 23/8/2001

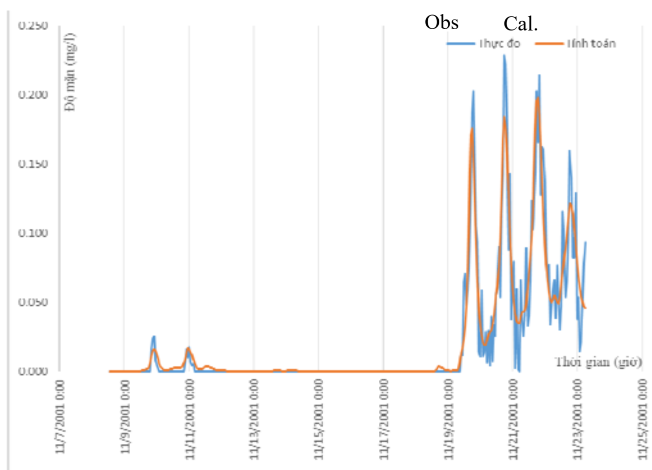

Fig. 7. Salinization at TamAnh station from 11/8/2001 to 23/8/200

4. Verification and application of numerical models to determine the effective discharge flow of PhuNinh reservoir to wash salinity

After calibrating the model, the research team obtained a set of parameters which is now sufficiently reliable to calculate the scenarios. To confirm the reliability of the model, we used this set of parameters including the flow and the water level at the corresponding boundary as the calibration plans from 8/3/2017 to 19/3/2017 to verify the real data in 2017.

The result of water levels at TamAnh station is shown on Fig.8. It have an NSE target of 0.75. This is a good result in the evaluation scale of this standard.

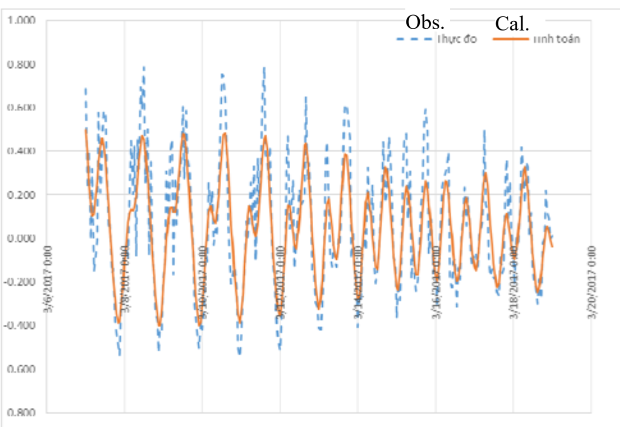

Fig. 8. Calculated and measured water levels at TamAnh station in 2017

The target for evaluating the calculated and measured results is the NSE (Nash-Sutcliffe Efficiency) which is calculated according to Function 1 below.

$$NSE = 1 - \frac{\sum_{i=1}^{N}(Q_{td,i} - Q_{tt,i})^2}{\sum_{i=1}^{N}(Q_{td,i} - \overline{Q}_d)^2} \qquad (1)$$

where:

Qtđ,i: Real measured value of the flow at time i,

Qtt,i: Calculated value of the flow at time i,

$\overline{Q_d}$: Average of real measured values of the flow,

N: The total number of the values in the string

Fig.9 and Fig.10 below are the calculated results of 2D model on all the river network.

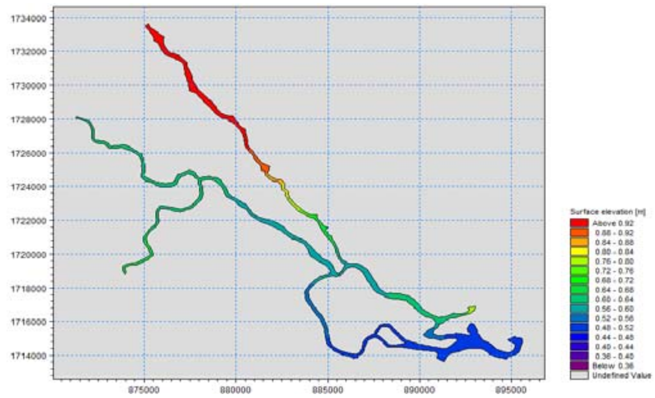

Fig. 9. Result at the water level in the whole region at 5pm on 11/11/2001

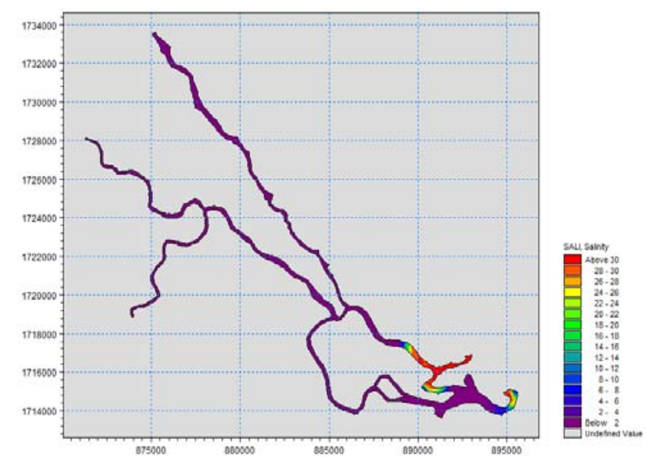

Fig. 10. Result of salinity sprea across the whole region at 2pm on 9/11/2001

The established and verified model is used to calculate three options of upperbounds of TamKy river as follow:

(4.1)

Option 1: the inflows into these upperbounds are stable and larger than the average flow in the dry season of many years.

Option 2: the inflows into these upperbounds are stable and equal to the average flow in the dry season of many years.

Option 3: the inflows into these upperbounds are stable and less than the average flow in the dry season of many years.

The boundary values (which is the discharge flows) of PhuNinh reservoir will be adjusted by these options to get the salinity at the junction near TruongGiang river less than 4 per thousand (which does not effect to the agricultural activities). With many calculation, the final option to get the minimum dischages is determined as in Table 1 below.

Table 1. Results of three options

No.	Upperbound compared to the average flow in dry season of many years	Required discharge flow of PhuNinh reservoir (m3/s)
1	Inflows are larger (than the average flow in the dry season of many years)	26 m3/s
2	Inflows are equal	30 m3/s
3	Inflows are less	37 m3/s

5. Conclusions

In this work, the 2D model MIKE21 is established to simulate the flow regime and the process of the salinity intrusion of TamKy river in the dry season. The riverbed terrain data and some other data are remeadsured and synchronized. The results of the model are quite consistent with the real data.
Using the result of the model to calculate the discharge plan for PhuNinh reservoir in oder to wash the salnility of TamKy river shows that: The required discharge flow of PhuNinh reservoir must be quite large to ensure that the Agricultural activities will not be effected by the salility of Tamky river (salinity less than 4 per thousand). They are 26m3/s, 30m3/s and 37 m3/s, corresponding to the high, medium and low level of the flow in TamKy river compared to the average anual flow. This also explains why PhuNinh reservoir discharged 20 milliions m3 in 2012 but salinity washing was not effective.

This result also show that the amount water for salinity washing takes a large volumme of the reservoir, which makes the ability of salinity washing of the reservoir is uneffective. Therefore, it is nescessary to continue researching to find other solution in exploiting and using the water amount of PhuNinh reservoir for salinity washing and irrigation of the downstream area in the most effective way, such as: allowing salinity intrusion deeperly into TamKy river, building a dam to prevent salinity at a appropriate area, or pumping fresh water on the surface into fields, etc.

Acknowledgments

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