AGU International Journal of Sciences – 2024, Vol. 11 (5), 55 – 62

AGU INTERNATIONAL JOURNAL OF SCIENCES

ISSN 0866 - 8086

SIMULATION OF WATER ELEVATION IN MANGROVE-SHRIMP SYSTEM IN AN MINH DISTRICT, KIEN GIANG PROVINCE

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Information:
Received: 27/06/2024
Accepted: 24/10/2024
Published: 12/2024

Keywords:
TELEMAC 3D, shrimp farming, water of depth, water elevation.

ABSTRACT

Mangrove-shrimp farming can bring economic and environmental benefits to livelihood and mangrove protection, which water control is a key of success. To aid assessing this farming, this study was conducted in a mangrove-shrimp in Minh Giong hamlet, Van Khanh Dong commune, An Minh district, Kien Giang province. Water elevation and depth were simulated using the Navier-Stokes equation (TELEMAC 3D). Model assessment for water elevation resulted in NSE= 0.77 – 0.87; RSR= 0.11 – 0.18; PBIAS= -4.6% – 7.22%; R2= 0.81 – 0.99 and S = 0.7 – 0.95, which indicated a good model performance. Results show water level varied spatio-temporally in the range of -0.27 – 0.55 m (water depth of 0.73-1.55 m). The water level in pond increased due to opening water gates allowing water inflow and declined due to water loss. This farming achieved both ecological shrimp farming and mangrove protection in terms of water control.

1. INTRODUCTION

In recent years, climate change and sea level rise, saltwater intrusion, deep into the mainland. In coastal areas, mangrove forests are considered valuable to limit saltwater intrusion and regulate the local climate. In buffer zones of the forests, an integrated mangrove-shrimp system (MSS) is applied to achieve mangrove protection and local livelihood enhancement from shrimp, particularly in the Mekong Delta in Vietnam. This MSS regulates water level regarding tides. With the development of technological information, simulation can potentially help assess MSS with popular candidates such as TELEMAC, MIKE, and DELFT3D. However, the exploration using modeling application has been limitedly for MSS. In regards to the competency of available modeling and simulation techniques, this research was conducted with the title "Simulation of water elevation in mangrove-shrimp system in An Minh District, Kien Giang Province" to reveal spatio-temporal water elevation variation to inform MSS management.

2. METHODS

2.1 Location selection

The selected study location is in Minh Giong hamlet, Van Khanh Dong commune, An Minh district, Kien Giang province (Figure 1). This area applies MSS which has been stable for years.

Figure 1. Research location

2.2 Water monitoring

This research periodically monitors water input and water level at 4 locations (named B, C, D and E) in each shrimp farm for model input and assessment (Figure 1).

2.3 Modeling using Navier-Stokes equations

The study uses the Navier-Stokes equations in the package of TELEMAC 3D (Laboratoire National d'Hydraulique et Environment of the Research and Development Division of EDF, 2023; Moriasi et al., 2007; Silva, E. et al., 2010; Trần Bá Hoằng et al., 2019) to simulate water elevation variation in MSS systems for the farming period of more than 3 months (more than 97 days). The model applicability is assessed regarding the values of results with NSE, RSR, PBIAS, R2 and S.

3. RESULTS AND DISCUSSIONS

3.1 Model assessment

In this research, TELEMAC 3D model run used a semi-structured mesh of 4m. Results of simulated water elevation were shown in Figure 2. Results also show the well model performance in terms of RMSE, RSR, PBIAS, R2, and S (Table 1) regarding the goodness-of-fit categories of Moriasi et al. (2007).

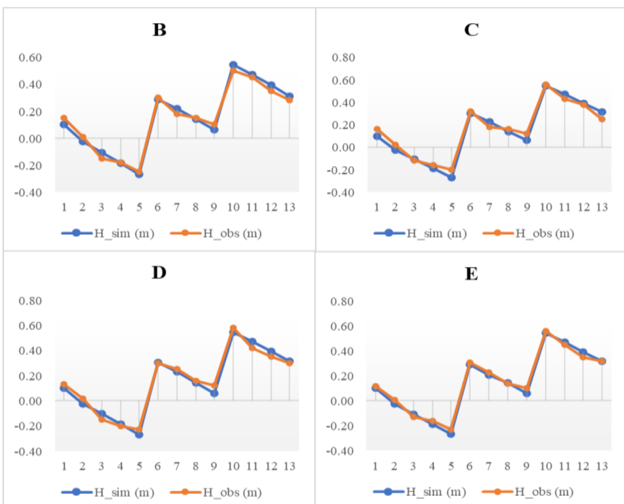

Figure 2. Simulated (sim) and observed (obs) water elevation at the four sampling sites B, C, D, E

Table 2. Model assessment

	B	C	D	E
NSE	0.979	0.969	0.978	0.987
	Very Good	**Very Good**	**Very Good**	**Very Good**
RSR	0.146	0.176	0.150	0.114
	Very Good	**Very Good**	**Very Good**	**Very Good**
PBIAS	-2.911%	7.221%	3.896%	5.924%
	Very Good	**Very Good**	**Very Good**	**Very Good**
R2	0.984	0.976	0.980	0.991
S	0.939	0.923	0.936	0.955

3.2 Flow velocity

Flow velocity is driven by many factors including wind and water flow. Because the study is obscured by mangrove, the effect of wind can be extremely low. Simulation results are shown below.

- During the first water inflow (at 9 am on 25 April 2023)

In the first water diversion at 9:00 AM on 25 April 2023, the internal flow velocity reached the highest value at 0.225 m/s (Figure 3). Due to the impact of the incoming water flow, near the place where the water is conducted, the velocity reaches its maximum. In addition, at some locations, the velocity is quiet high compared to the other locations in the farm due to the narrow width of water channels. In the area where receiving water from a sewer pipe, a turbulent flow occurs. In between the mesh layers, flow vectors appear in the trend of linking into a water column swirling to the surface with a value of 0.075-0.225 m/s. In the rest of the areas, the same phenomenon also arises from the flow of water passing through, this is an inevitable trend.

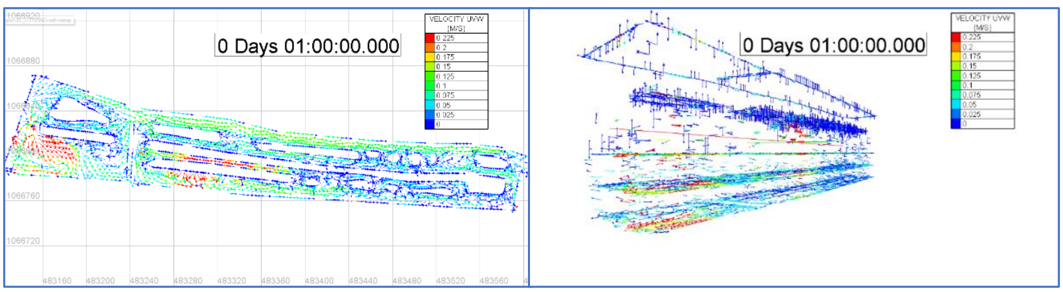

Figure 3. Flow velocity at the time of water conduction 1, 09:00 on 25/4/2023

The cross-section flow results show that at sections 1 and 2 (B and C) the velocity has a clear stratification with the velocity of 0.12-0.225 to 0.075-0.02 m/s (Figure 4). At sections 3-4 (D and E), due to the flow mixing (especially the D near the water inlet area), the flow is disturbed, and the flow velocity does not follow the stratification and decreases by depth. According to Yoshikai (2023), when the water flow reaches a stable level, the water velocity decreases by depth. Therefore, in this study, the velocity varies by depths due to water inflow being comprehensive.

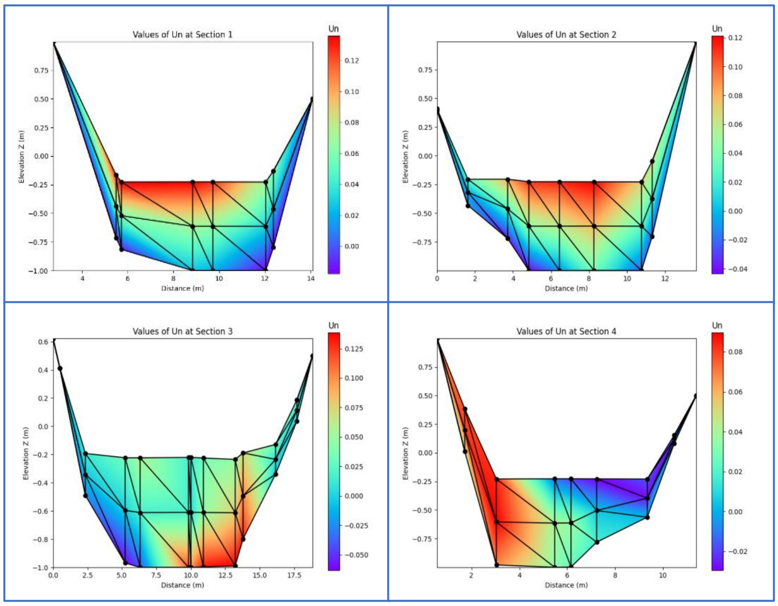

Figure 4. Cross-section flow velocity at B, C, D and E at the time of the first water diversion at 9 a.m. on April 25, 2023

- The second water Inflow (5:00 AM on 3 June 2023).

The simulation results are shown in the image above (Figure 5 and Figure 6) indicates water variation during the 2nd water diversion at 5:00 AM on 3 June 2023. The internal flow velocity tends to be the highest in areas near water inflows and narrow areas. There is a vortex in the water conduction area. the cross-sectional images show that there is an obvious trend of velocity stratification along 3 layers.

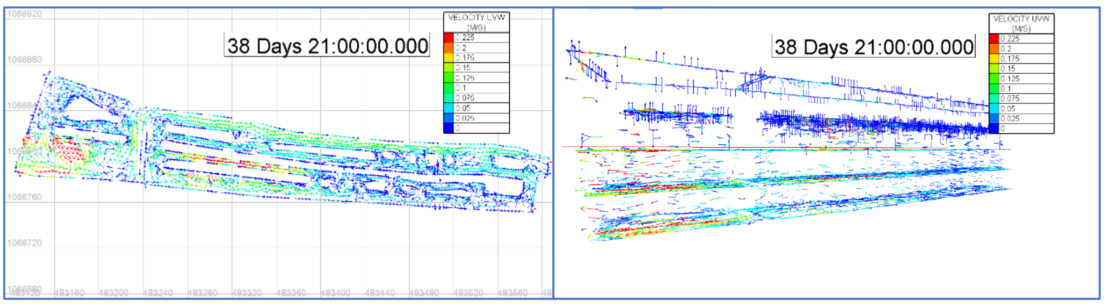

Figure 5. Flow velocity during the second water conduction process (5:00 AM on 3 June 2023)

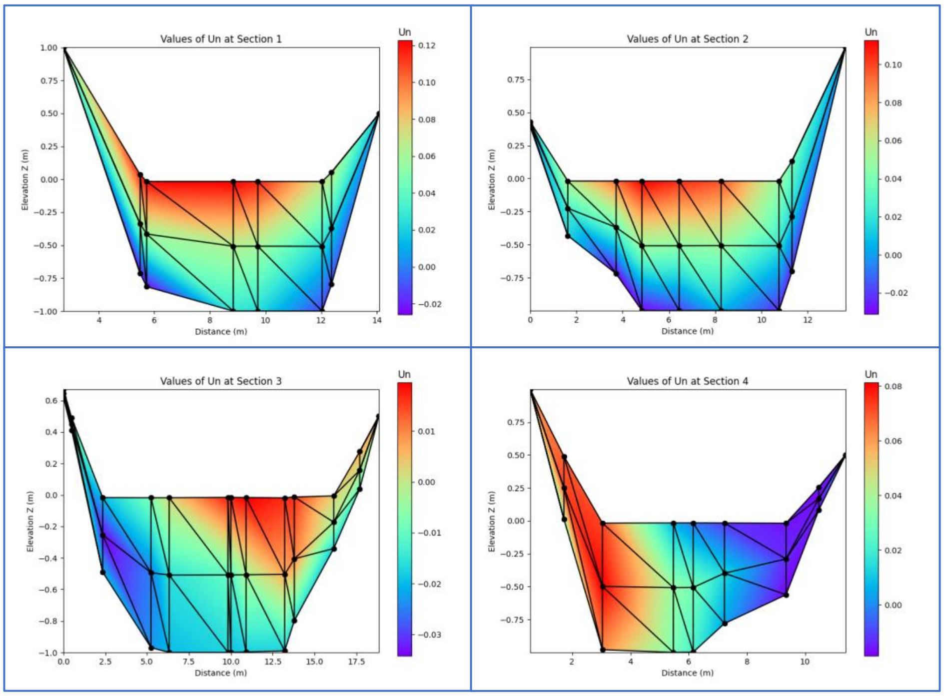

Figure 6. Cross-section flow velocity extraction at B, C, D and E during the second water conduction process (5:00 AM, 3 June 2023)

- Water Inflow (6:00 AM on 1 July 2023).

Simulation results are shown in the image above (Figure 7 and Figure 8) indicating the 3rd water diversion at 6:00 AM on 1 July 2023. The trend of the highest flow velocity was exuded in the area near the water inlet as well as some narrow areas. The trend is more obvious than the previous time with the tendency to have the vortex in the water channel area. There is a clear trend of velocity stratification.

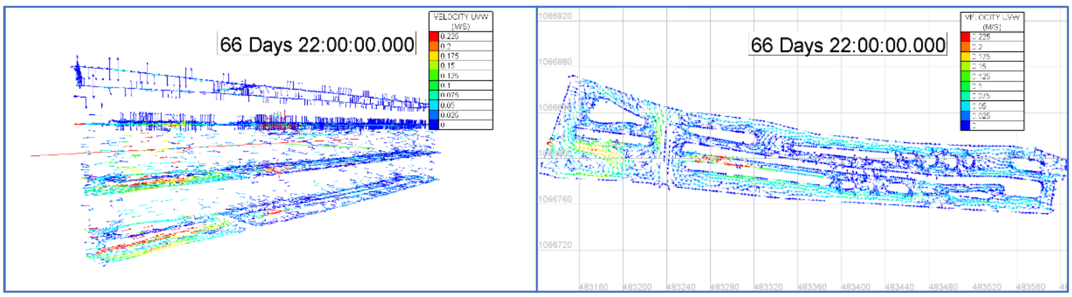

Figure 7. Flow velocity during the third water conduction process (6:00 AM 1 July 2023)

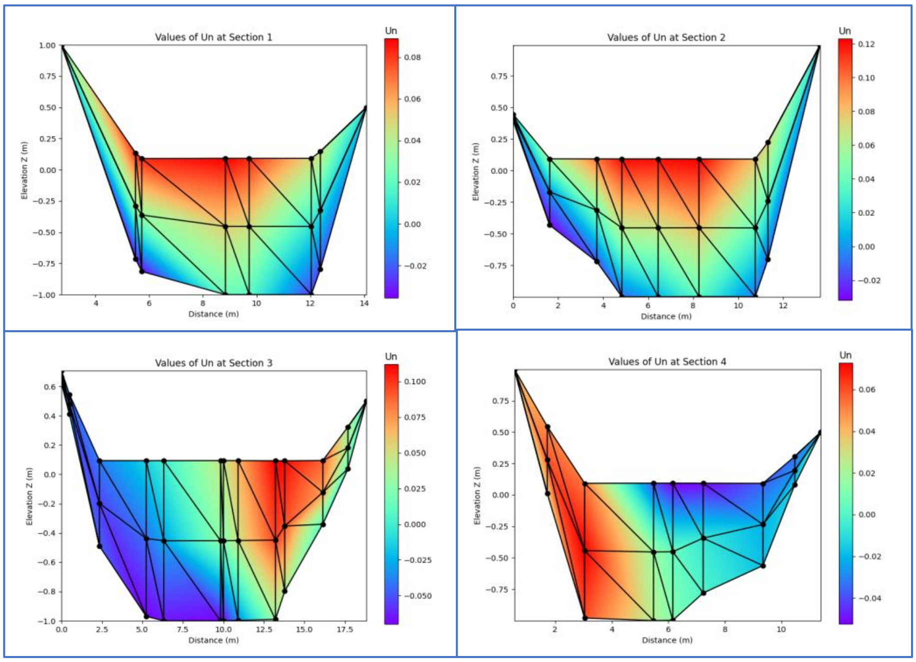

Figure 8. Cross-section flow velocity at B, C, D and E during the third water conduction process (6:00 AM on 1 July 2023)

3.3 Water Level

- Water Inflow for the first time (9;00 AM on 25 April 2023).

Simulation results at 9:00 AM (Figure 9) show that the introduced water has raised the water level higher than the original (only -0.45 m), the clearance of the top layer (layer 3) has reached -0.3 m (corresponding to a water depth of 0.7 m) and will continue to increase in the next simulation hour because water continues to flow into. The simulated water level after the first phase of water Inflow has reached 0.1 m (water depth 1.1 m).

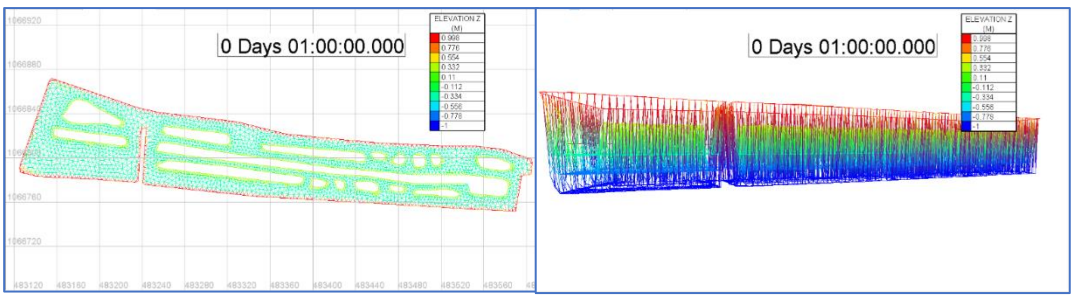

Figure 9. Water level during water conduction for the first time (at 9:00 AM on 25 April 2023)

- Inflow for the second time (5:00 Am on 3 June 2023).

Results in Figure 10 shows that the water brought in has improved the water level of the farm in which the surface clearance of the top layer (layer 3) has reached 0.3 m (the water depth reaches 1.3 m) and will continue to increase due to the water entering in the next hour. The simulated water level after the second phase of water Inflow has reached 0.32 m (water depth reaches 1.32 m).

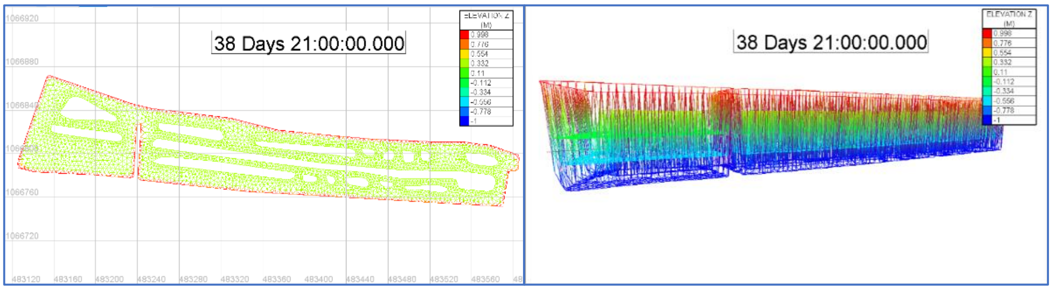

Figure 10. Water level during the 2nd water conduction process (5:00 AM on 3 June 2023)

- The third Inflow (8:00 AM on 1 July 2023).

After the third Inflow, the water introduced has improved the water level of the farm for the time of water loss, the water elevation has reached 0.554 m (water depth of 1.554 m) (Figure 11). The water level increases significantly at the time of water inflow and between water intakes and then decreases continuously due to the loss (i.e., percolation and evaporation). In 97 days, water elevation has the peak of 0.55 m (water depth reached 1.55 m) and the lowest of -0.3 m (water depth reached 1.3 m). The average water level reached 0.125 m (water depth reached 1,125 m).

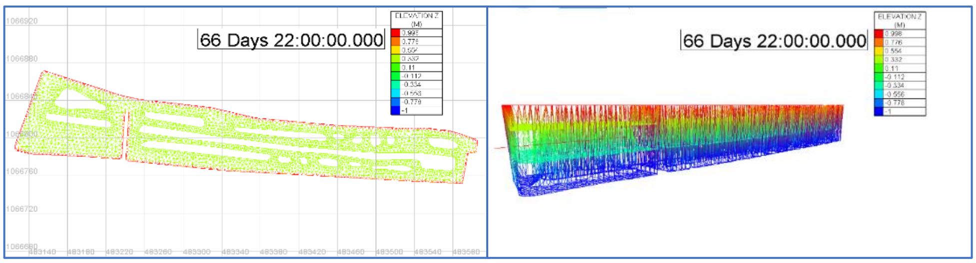

Figure 11. Water level after the third Inflow (8: 00 AM on 1 July 2023)

4. CONCLUSION

TELEMAC 3D model performed well for water level simulation of MSS regarding NSE, RSR, PBIAS, R2, and S. The water levels were found at 0.55 m (water depth reached 1.55 m) for the highest and -0.27 m (water depth reached 0.73 m) for the lowest. The water regulation by farmers is proper to maintain comprehensive water level for shrimp farming and mangrove protection. Depending on actual conditions, farmer owners can adjust the water depth to further suit the operation of the system.

Acknowledgement

I would like to give special thanks to the Climate Change Institute for supporting this research (TX2024-16-01).

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