Determination of channel length and tidal storage dimensions to support the tidal driven water circulation process in terantang reclamation unit

by Riza Miftahul Khair

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Determination of channel length and tidal storage dimensions to support the tidal driven water circulation process in terantang reclamation unit

R Riduan, R M Khair, M R C Hakim, and M N Ihsan

Environmental Engineering Department, Engineering Faculty, Lambung Mangkurat University, Banjarmasin, Indonesia

E-mail: ronyrdn@ulm.ac.id

Abstract. Land reclamation efforts are still experiencing several obstacles, including the accumulation of toxic concentrations in the reclamation channel. The main influencing factors are tidal force, channel length, and tidal water storage dimensions. Simulation using the EFDC (Environmental Fluid Dynamic Code) was used to analyze these problems. This research was conducted on primary-secondary channels in Terantang reclamation unit in South Kalimantan, Indonesia. The first stage is the identification of hydrodynamic and water quality conditions, followed by modeling. The final stage is the simulation of flow patterns, water age, and dissolved iron concentration for several scenarios of channel length and tidal storage dimensions. The results showed that the simulation with 75% of the channel length with standard tidal storage provided an adequate water circulation pattern and water age, although it still had accumulated dissolved iron concentrations at the tidal storage. Better results for water circulation patterns, water age, and accumulation patterns of dissolved iron concentration were obtained at 50% of the channel length, but must be accompanied by adjustments to the tidal storage dimensions to 50% of the initial depth. All simulation results without using tidal storage show the accumulation of dissolved iron concentrations at the end of the channel which is indicated by the occurrence of water circulation patterns that are not in line with tidal patterns, and high water age.

Keywords: reclamation channel, tides, Terantang unit, EFDC

1. Introduction

The occurrence of pyrite compounds and the accumulation of toxic materials in the reclamation channels become the problems in agricultural land reclamation [1]. The accumulation of toxic materials is dominated by iron (Fe), aluminum (Al), and sulphate (SO_4). The accumulation that occurs is usually found near the end of the secondary channel, and at the tidal storage [2]. The toxic substances accumulation problem has also occurred in the tidal wetland reclamation channel of Terantang, South Kalimantan, Indonesia [3].

Water quality modeling of the toxic materials fate and transport in reclamation channels requires a non-conventional method. The application of non-conventional method processes in water quality modeling can represent hydrodynamic aspects with toxic substances transport [4]. The water circulation

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process in the canal is influenced by the tidal force, channel length, and tidal storage dimension [5]. Further research is necessary to analyze the effect of tidal force on the length of the reclamation channel in circulating the water that carries toxic material out of the channel. The accumulation of dissolved iron (Fe) and TSS (total suspended solid) that occur in Terantang channel will be simulated using variations of channel length and tidal storage application, compared to existed tidal force.

This research is expected to give a contribution to the effort of reducing toxic substance accumulation problem that occurs in Terantang reclamation channel, through the adjustment of channel length and tidal storage dimensions to the existed tidal forces.

2. Materials and Methods

2.1. Research Location
This research was conducted on the primary and secondary reclamation channel in Terantang Village, Barito Kuala Regency, South Kalimantan. Terantang primary and secondary channel is located within coordinates 3^{O}07'33" S and 14^{O}35'43" E to 3^{O}09'52" S and 114^{O}40'11" E, almost 9 km length. Terantang reclamation channel has total length of ± 9 km consisting of a primary channel around 2 km and a secondary channel of about 7 km. This reclamation channel unit has experienced severe sedimentation so that the tidal storage is no longer functioning.

2.2. Research Procedure
The research procedure is divided into three steps: (1) identification of hydrodynamic and water quality conditions, (2) development of hydrodynamic and water quality model using EFDC software, and (3) simulation of flow patterns, water age, and dissolved iron concentration for several scenarios of channel length and tidal storage dimensions.

2.3. Data Analysis
Channel elevations are obtained through echo-sounding surveys, water quality and sediment property is obtained through field and laboratory measurements. The data is analyzed using descriptive methods to determine the effect of channel length to the accumulation of toxic substances from the three parameters (flow pattern, water age, and the concentration of toxic substances). Data from these three parameters are presented graphically, by plotting the velocity vector, water age, and toxic substances concentration.

3. Result and Discussion

3.1. Channels Dimensions and Water Level
Channel has variations in its depths which is ranged between 0.5 to 4.8 m. Existing condition of the tidal storage is no longer functioning because of sedimentation. Water level measurements were taken for one day at 4-hour intervals at four channel points of the reclamation unit (Figure 1). Point 1 is located near tidal storage, point 2 at the middle of channel length, point 3 at the beginning of the channel and point 4 at the tertiary channel. The tidal pattern is categorized as mixed pattern but tends to be semi-diurnal pattern, as it is kwown two peaks of high tide and low tide in one day [6].

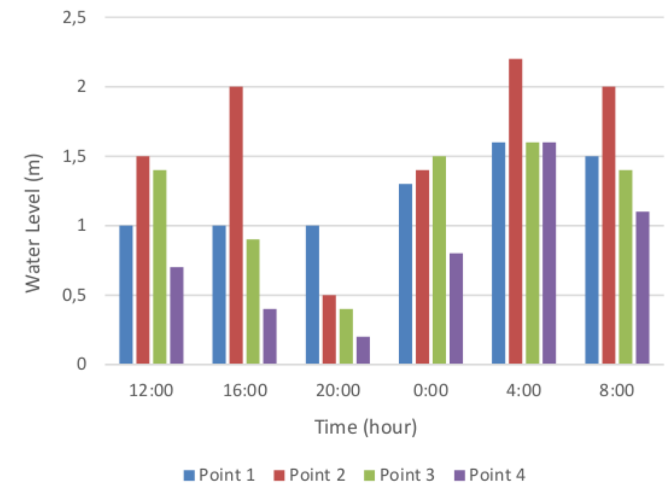

Figure 1. Water level fluctuation

3.2. Velocity and Flow Direction

Hydrodynamic analysis apart from measuring the water level is also measuring velocity and the direction of flow at high tide and low tide. The velocity measurement is conducted using a simple surface buoy. Stagnant water flow was found at point 1, which can be proven from the measurement of the velocity. The velocity at that location was almost 0 m/s and did not have flow direction. Velocity and flow direction measurement can be seen in **Figure 2**. This stagnant flow pattern was also identified in Barambai tidal reclamation channel as tidal force cannot reach the tidal storage [7].

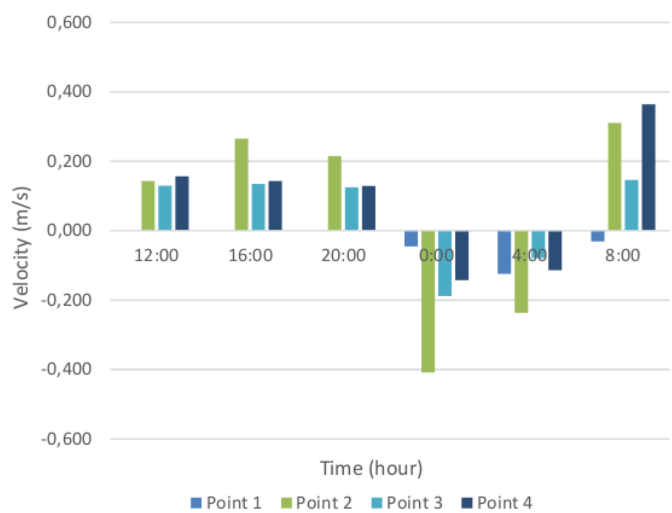

Figure 2. Velocity and flow direction

During the high tide, water could not reach tidal storage. At low tide, water also did not have time to flow out of the channel because the high tide has occurred again. Circulation pattern near the tidal storage was considered stagnant water flow and does not undergo a receding process with almost no velocity, and no flow direction [8].

3.3. Water Quality

Measurement of water quality was carried out to determine the water quality standards in the reclamation channel. The results of the measured parameters are in Table 1.

Table 1. Water quality laboratory test results

Parameters	Unit	Test Results				Method Specifications
		Point 1	Point 2	Point 3	Point 4	
Total Dissolved Solids (TDS)	mg/L	426	28	5,2	31	IKM-A-3-LABLING-KS
Total Suspended Solids (TSS)	mg/L	<2.5 *	24	201	98	SNI 6989.3-2019
pH	-	2,6	4,7	5,2	4,7	SNI 6989.11-2019
Dissolved Iron	mg/L	2.39	<0.3 *	<0.3 *	<0.3 *	SNI 6989.84-2019

The accumulation of toxic substances was determined by the dissolved iron and TDS concentration which is higher than the other sampling point. The concentration of dissolved iron parameters at point 1 is 2.39 mg/L, while the iron parameters at other points are still following water quality standards.

3.4. Hydrodynamic and Water Quality Model Development

Modeling was conducted to facilitate the scenario simulation process. The compilation of geometric data was obtained through an echo-sounding survey. Development of hydrodynamic and water quality must go through verification, calibration, and validation process [9].

Model verification was carried out to indicate that EFDC can be applied for this research. Sample of hydrodynamic and water quality conditions compiled with EFDC software. The flow pattern obtained from the verification results is in accordance with the same problem conducted by previous research [10].

Calibrations are carried out as an adjustment to the modeling parameters. The parameters were roughness coefficient, and partition coefficient based on water level and dissolved iron concentration. The analysis obtained from the comparison of water level data shows that the channel roughness coefficient calibration already has a high accuracy value because the RMSE is close to zero. The partition coefficient calibration obtained a value of 0.796 for cohesive sediment and 0.246 for non-cohesive sediment. The value obtained from the partition coefficient calibration is in accordance with previous research results on Terantang channel [5].

Model simulation is conducted to analyze the flow pattern, water age, and transport of toxic material accumulation in the Terantang reclamation channel. The scenarios are carried out with several variations, reducing the length of the reclamation channel by 25%, 50%, 75%, and 100% without tidal storage, and then differentiating between the simulations with tidal storage.

3.4.1. Simulation of Hydrodynamic

Simulation scenarios in hydrodynamic aspects were using 3 days of simulation time. The simulation results from the scenario produce a hydrodynamic flow pattern and water age. The scenario results as follows:

a) Existing condition

The simulation scenario of these existing conditions is experiencing irregular flow water during the tidal peak, resulting in stagnant flow at the end of the channel. The results of the flow pattern for this scenario are in Figure 3.

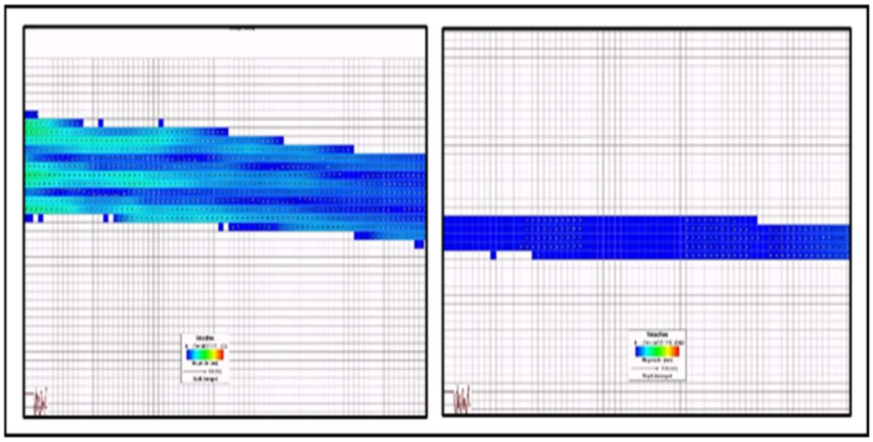

Figure 3. Flow pattern in an existing condition

The water age in this simulation illustrates that the water in most of the channel has long water age as an indication of the toxic substance accumulation (Figure 4) [11].

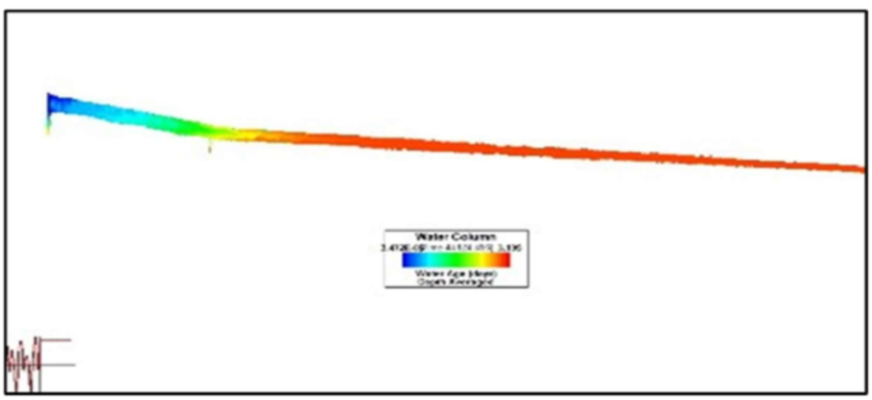

Figure 4. General Simulation Results of Water in Existing Conditions

b) Variation of channel length without tidal storage

The scenario for this simulation is variations from 25%, 50%, 75%, to 100% of the original channel length without tidal storage. The simulation results indicate that all variations without tidal storage did not give a good result on flow pattern and water age (Figure 5).

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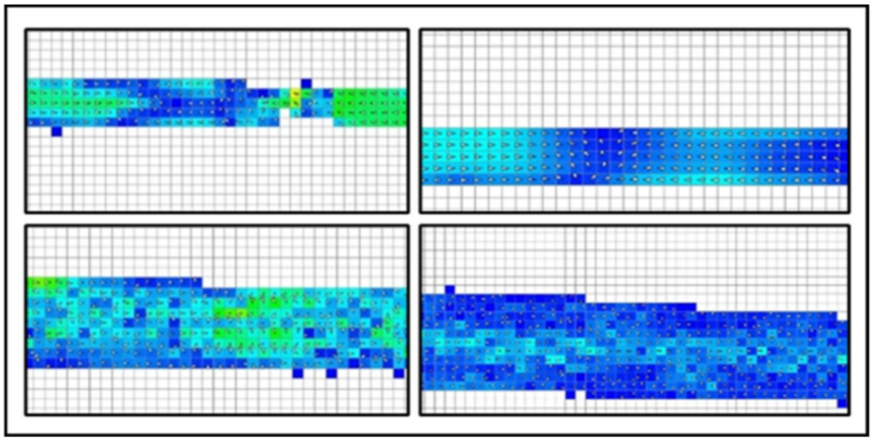

Figure 5. Simulation result of flow pattern without tidal storage

Long water age indicates the accumulation of toxic substances in the channel. Simulation result for all channel length variations without tidal storage can be seen in Figure 6.

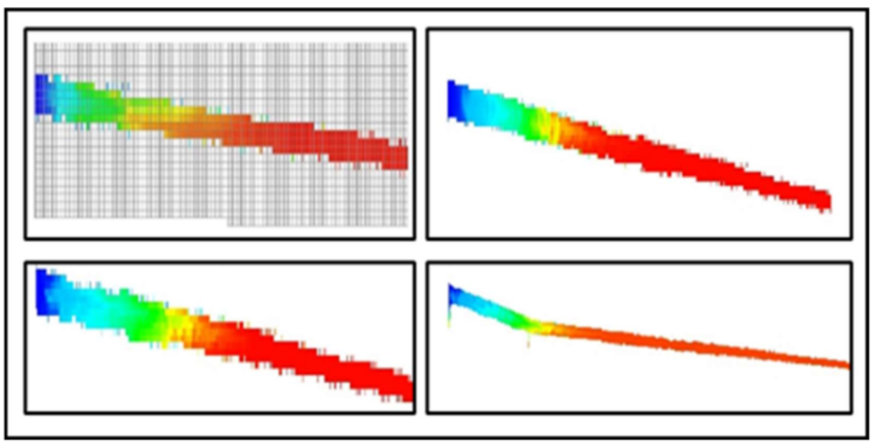

Figure 6. Simulation Results of Variation of Water Ages without Tidal Storage

c) Variation of channel length with tidal storage

There are 5 scenarios carried out to simulate channel length with tidal storage. The 100% and 25% channel length simulation scenarios with the tide storage have the same results. The current movement in these two scenarios is irregular and does not correspond to the tidal process. Both of these simulation scenarios have irregular flow patterns because the tidal process is too fast so the water in the tide storage does not have time to recede [12]. Water age also indicates the accumulation of water at the end of the channel (Figure 7).

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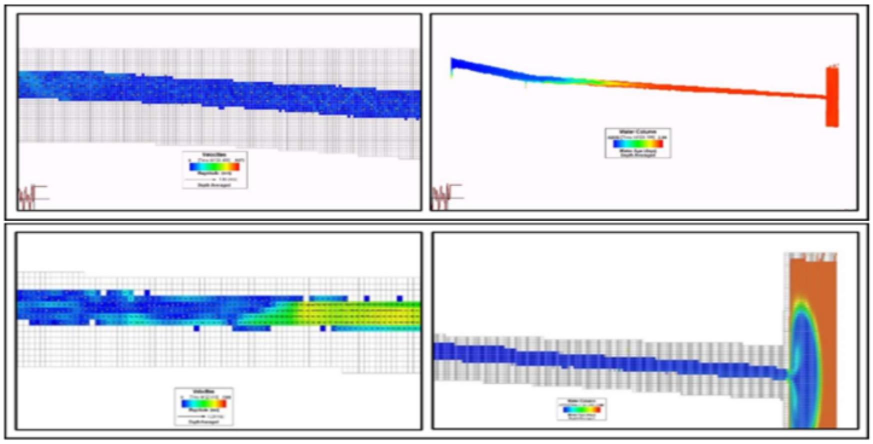

Figure 7. Simulation results for 100% and 25% length with tidal storage

The 50% and 75% simulation scenarios with tidal storage give different results than previous simulation, which is indicating a regular and inline flow pattern at high tide and low tide. Water circulation that occurs in this scenario is better than previous simulation, because the water can reach the end of the channel to the tidal storage, and the water age is less than simulation time. The results of the 75% and 50% channel length scenarios simulation with tidal storage can be seen in Figure 8.

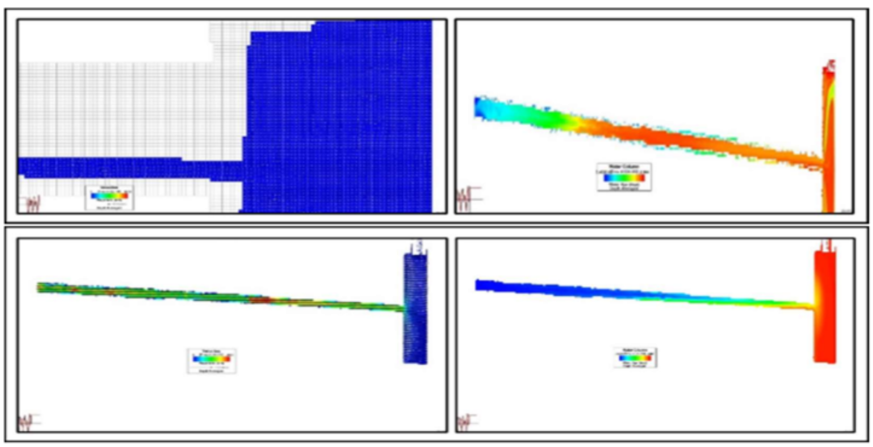

Figure 8. Simulation results for 50% and 75% length with tidal storage

3.4.2. Simulation of Water Quality

Simulation results obtained from each scenario are as follows:

a) Simulation with tidal storage

This simulation is based on the fate and transport of dissolved Fe and TSS parameters in the reclamation channel. The first scenario based on full length of the channel (100%) shows dissolved Fe concentration value of 1.87 mg/L to 1.91 mg/L and TSS concentration 3.071 to 61.53 mg/L. Second scenario based on ¾ total channel length (75%) shows the value of Fe concentration 1.28 mg/L to 1.35 mg/L, and TSS concentration 3.15 mg/L to 61.65 mg/L. The third scenario based on ½ of the total channel length (50%) shows the value of Fe concentration from 1.34 mg/L to 1.91 mg/L, and the value TSS concentration

3.14 mg/L to 62.68 mg/L. Fourth scenario based on ¼ total channel length (25%), shows the value of Fe concentration 1.8 mg/L to 2.95 mg/L, and TSS concentration 3.04 mg/L to 65.15 mg/L.

Simulation results for those scenarios indicate that 3/4 of the total channel length (75%) gives lowest range of dissolved Fe, and considered as best scenario. This scenario simulation result also in accordance with hydrodynamic scenario.

b) Simulation without tidal storage

In the first scenario, water quality model based on full channel length (100%) without tidal storage shows the concentration of dissolved Fe from 0 mg/L to 2.02 mg/L and TSS value from 3.08 mg/L to 60.72 mg/L. Second scenario based on 3/4 channel length (75%) without tidal storage shows dissolved Fe concentration 1.56 mg/L to 1.87 mg/L and TSS concentration 3.19 mg/L to 60.72 mg/L. Third scenario simulates the water quality model based on ½ total channel length (50%) without using tidal storage, gives dissolved Fe value 0.75 mg/L to 1.36 mg/L, and TSS concentration 3,34 mg/L to 60.72 mg/L. Fourth scenario simulates the water quality based on 1/4 of the total channel length (25%) without tidal storage indicate dissolved Fe concentration from 0 mg/L to 1.27 mg/L and TSS concentration from 3.29 mg/L to 60.72 mg/L.

Simulation results from those scenarios indicate that channel with ½ channel length (50%) gives lowest range of dissolved Fe, but still higher than scenario using tidal storage. Overall, the simulation of water quality models using tidal storage is considered better scenario compared to without tidal storage simulation. The best conditions were found at 50% and 75% channel length scenario for water quality simulation (

Figure 9).

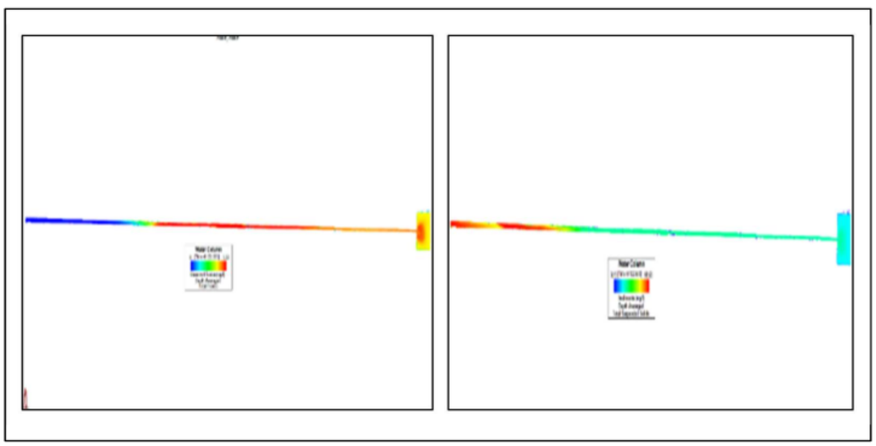

Figure 9. Water quality **s**imulation for 75% channel length scenario with tidal storage

3.5. Evaluation of suggested channel length and tidal storage dimensions

The simulation results of hydrodynamic aspects and water quality with the existing condition scenario illustrate that the water in channel could not give good water circulation and has poor water quality at the end of the channel. The channel should be reduced or shortened so that the water in the channel can reach the tidal storage using tidal force. Suggested scenarios are 50% and 75% channel length are adequate to fulfill its water circ ulation function. For the 50%, channel length scenario, the depth of tidal storage should be reduced to half depth to adjust with the suggested channel length.

4. Conclusion

The results showed that the simulation results with 75% of the channel length along with the standard tidal storage provided an adequate water circulation pattern and water age for the process of water circulation in the channel, although it still had accumulated dissolved iron concentrations in the tidal storage. Better results for water circulation patterns, water age, and accumulation patterns of dissolved iron concentration were obtained at 50% of the channel length, but must be accompanied by the adjustments of tidal storage dimensions to 50% of its initial depth. All simulation results without using tidal storage show the accumulation of dissolved iron concentrations at the end of the channel which was indicated by the occurrence of water circulation patterns that are not in accordance with tidal patterns, and high water age.

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