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# One-Way Flow System Water Quality Modelling of Terantang Reclamation Channel

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# One-Way Flow System Water Quality Modelling of Terantang Reclamation Channel

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**Abstract.** The implementation of reclamation process in wetland has encountered some obstacles, such as the occurrence of pyrite oxidation, sedimentation, and accumulation of toxic materials, especially the concentration of Fe (iron) in the channel. The condition of the reclamation channel which is influenced by tidal events and environmental factors causes the dynamics of Fe concentration to be strongly influenced by hydrodynamic aspects and its interaction with dissolved and suspended particulates. An accurate model will be useful as a tool to evaluate alternative management of water systems to overcome the problem of Fe concentration accumulation in the tidal wetland reclamation channel. Fe fate and transport were modeled using a numerical model of hydrodynamics and water quality EFDC (Environmental Fluid Dynamic Code). The partition process separates the metal fraction into two phases (dissolved and solid), which is related to the value of the partition coefficient (Kp). The application of the partition process is considered to have a significant influence on the accuracy of the estimated Fe concentration. The simulation results of the model with the partition coefficient approach have better accuracy than the conventional model which tends to be over-predicted compared to the observation data. Simulation of one-way flow system shows a decrease of Fe concentration in the channel by an average of 52.9% compared to two-ways flow system. The application of one-way flow system is possible through the placement of flap gates that will direct the flow to the drainage channels.

**Keywords:** one-way flow, Terantang unit, Fe, EFDC

## 1. Introduction

The reclamation process gradually begins with building an open gravity system drainage followed by the application of water management systems, namely comb systems and fork or tidal pool systems. This system generally uses a two-ways flow pattern, in which the flow of water in and out occurs in the same channel. This system still requires further review of its effectiveness compared to one-way flow systems [1]. In its development, the implementation of reclamation experienced obstacles, such as pyrite oxidation, sedimentation, and toxic materials accumulation in segments of secondary channel [2]. Toxic materials accumulation is dominated by iron (Fe), aluminum (Al), and Sulfate ($SO_4$) occurs in the end segments of secondary channels and tidal pools [3]. This situation also occurred at the research location, Terantang reclamation channel, South Kalimantan.

Methods of estimating the distribution of toxic material concentrations in reclamation channels at research sites generally still use an advective-dispersive physical process approach and have not noticed the reactive properties of those materials. One-dimensional unsteady flow models with pollutant

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transport models based on physical processes (advection-dispersion) are still commonly applied to model the movement of pollutants in channels. Ball's research [4] showed that Fe (iron) and Al (aluminum) are constituents that not only undergo physical processes (advection-dispersion), but also experience interactions with sediments. Then Caruso [5] stated that modeling of metal interactions with sediments through the process of resuspension-deposition is needed in the analysis of water quality. Sediment resuspension and mixing events due to tidal currents in bodies of water also affect water quality conditions in water affected by tidal forces [6]. Riduan's research [7] also showed that modeling the fate and transport of toxic materials in reclamation channels in acid sulfate soils requires a non-conventional approach with not only physical processes but reactive processes of pollutants. For example, the application of partitioning processes on water quality modeling in reclamation channels will be able to improve the accuracy of modeling [8] and [9].
Based on these conditions, research is needed to evaluate the partition process approach on the accuracy of modeling the movement of toxic materials in reclamation channels, accompanied by the availability of representative models and modeling parameters on tidal wetland reclamation channels. The application of partitioning processes on the modeling of Fe (iron) fate and transport in this reclamation channel is expected to better represent the processes that occur in the channel. The model is also expected to help planners and managers of wetland reclamation units to be able to evaluate problems in the infrastructure supporting tidal wetland reclamation efforts.

## 2. Materials and Methods

### *2.1. Research Location*
The location of reclamation channel is in Terantang Village, Barito Kuala Regency, South Kalimantan. The reclamation 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 (Figure 1). Terantang wetland reclamation channel has a total length of ± 9 km consisting of around 2 km primary channel and around 7 km of secondary channel.

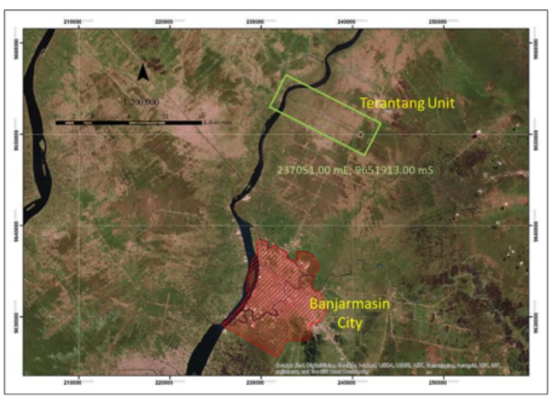


**Figure 1**. Location of Terantang Reclamation Channel

### *2.2. Research Method*
The research method is divided into three steps: (1) hydrodynamic and water quality conditions identification, (2) hydrodynamic and water quality model development using EFDC software, and (3) flow patterns and iron concentration simulation for one-way (Figure 2) and existing two-ways system.

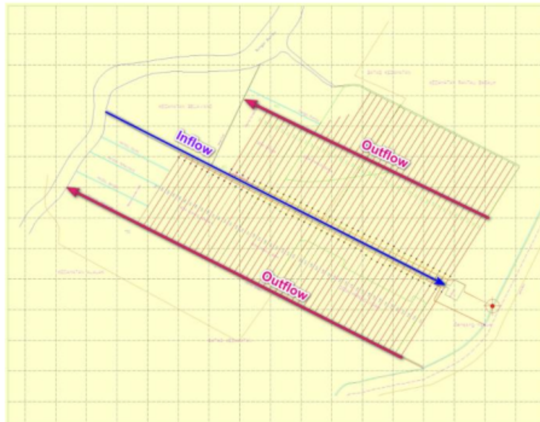


**Figure 2**. One-Way Flow System

Measurements of water level on the channel were taken for two days at 4-hour and 2-hours intervals at three locations on the reclamation channel. The first location (point 1) is located near the tidal pool, second location (point 2) is at the middle of secondary channel, and third location (point 3) is at the first segment of the secondary channel.
The construction of the model is carried out in several stages. The initial stage that must be done is the preparation of the network (grid) model, the determination of the initial condition and boundary condition of the model(boundary condition), and the identification of modeling parameters. The next stage is the data entry and model execution step, followed by the model calibration, model validation, and model simulation.

### *2.3. Data Analysis*

Channel geometry was obtained through echo-sounding surveys, tidal and channel water levels were measured in the field, and water quality data were obtained from laboratory analysis. The data and model simulation results were analyzed using error analysis (relative-error and average-error) to determine the accuracy of partition process and water quality condition improvement of the one-way flow system.

## 3. Result and Discussion

### *3.1. Model Boundary Condition*

The input for boundary condition of Terantang channel is an existed tidal pattern which is categorized as mixed pattern but tends to be a semi-diurnal pattern. The pattern consists of two peaks of high tide in one-day tidal cycle [10]. Tidal pattern and water level on tertiary channel were used as inlet boundary conditions, on 5x5 m model grid. The channel model boundary condition scheme is in Figure 3 below.

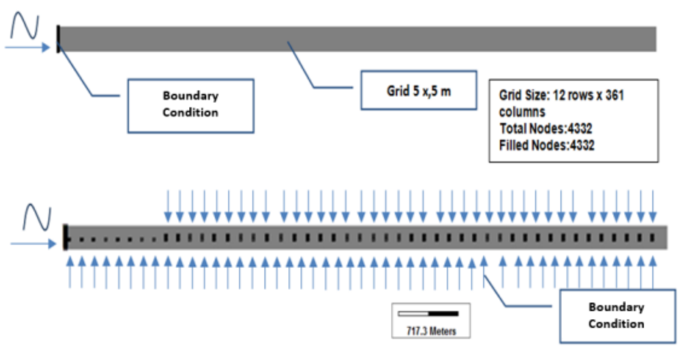


**Figure 3**. Grid and Boundary Condition

### *3.2. Water Quality*

Water quality measurement was carried out to determine the TDS, TSS pH and Fe concentration in Terantang reclamation channel. Sampling locations and its channel depth on the Terantang reclamation channel is shown in Figure 4.

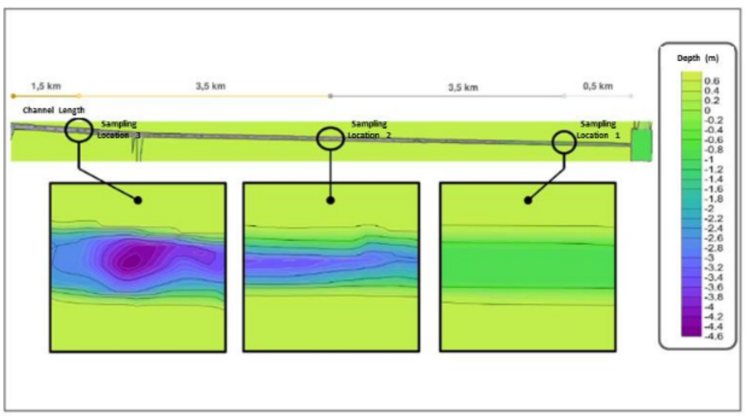


**Figure 4**. Sampling Location and Channel Depth

Water quality laboratory test results from those sampling location are in Table 1. Toxic substances accumulation on the channel occurred mostly at some locations near the tidal pool. This situation is also indicated by the higher TDS (Total Dissolved Solid) and iron concentration than the other sampling locations at the channel.

**Table 1.** Water Quality Condition in Terantang Channel

| Parameters | Unit | Location | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Total Dissolved Solids (TDS) | mg/L | 426 | 28 | 5,2 |
| Total Suspended Solids (TSS) | mg/L | <2.5 * | 24 | 201 |
| pH | - | 2,6 | 4,7 | 5,2 |
| Dissolved Iron | mg/L | 2.39 | <0.3 | <0.3 |

### *3.3. Model Development*
Modeling was conducted to simulate the one-way and two ways flow system scenario. Development of hydrodynamic and water quality model using EFDC (Environmental Fluid Dynamic Code) must undergo verification, calibration, and validation process [11].
Model verification was carried out to ensure that EFDC software can be applied for this simulation. A theoretical example of hydrodynamic and water quality problem was compiled using EFDC software. The flow pattern obtained from the verification stage had satisfactory results according to previous research [12]. The calibration process was carried out as an adjustment to the modeling parameters. The adjusted parameters were roughness coefficient (value between 0.02-0.05), and partition coefficient (0.796 and 0.246 for cohesive and non-cohesive sediment). These coefficient values were obtained based on water level and dissolved iron concentration. This value for partition and roughness coefficient is validated using data from previous research [7].

### *3.4. Simulation Result*
Channel performance was analyzed based on the flow pattern in the secondary channels that had a significant effect on the accumulation of toxic materials. Simulations were carried out in 2 stages: (1) Simulation of hydrodynamic aspects and water quality based on partition and non-partition models; and (2) Simulation of the one-way flow compared to two-ways flow system.
The simulation results showed that not only do the hydrodynamic aspects have a role in the accumulation of Fe concentrations in the channel, but other factors such as the partitioning process and the movement of pollutant transport. Based on the results, the difference between models that use partition coefficients and data has an average of 0.28 mg/L. The difference between models without using partition coefficients with data has an average of 4.7 mg/L. So that the average increase in accuracy between the partition coefficient model against non-partitions is 5.1 mg/L. The comparison of Fe modeling without partition coefficient and with partition coefficient for water level elevation can be seen in Figure 5.

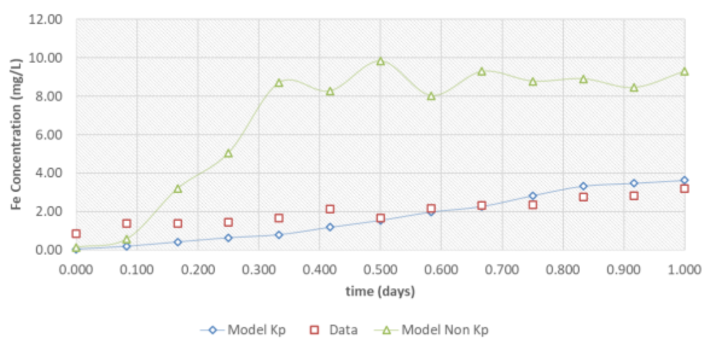


**Figure 5**. Model Comparison

Based on the above results, the partition approach will be used for the next simulation to model the difference in water level and Fe concentration between a one-way flow system and a two-way flow system. The simulation results for the water level at point-1 show a lower water level for a one-way flow system, and the pattern of water level shifts closer to the tidal pattern (Figure 6).

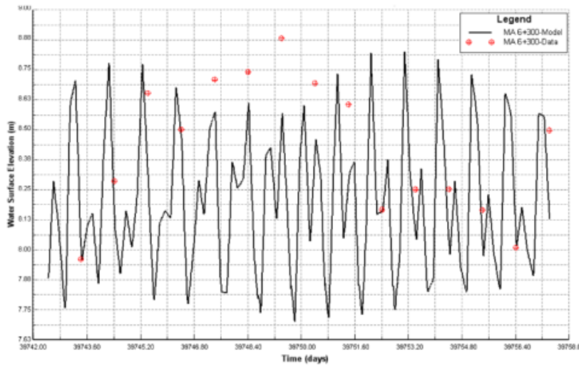


**Figure 6.** Water Level Difference of One-Way and Two-Ways Flow on Point-1

Simulation result for Fe concentration on point-1 location indicates that one-way flow system gives lower Fe concentration compared to the two-ways flow system (Figure 7).

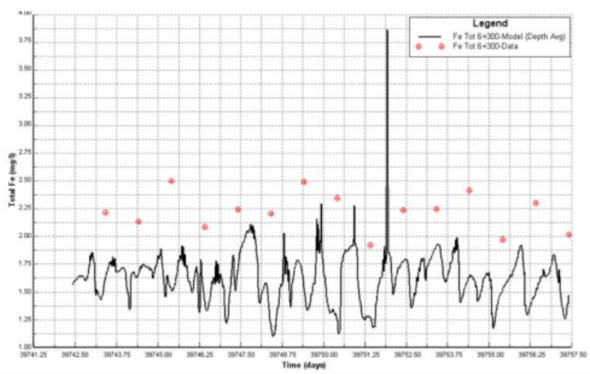


**Figure 7.** Fe Concentration Difference of One-Way and Two-Ways Flow on Point-1

The same results were also obtained for the water level and Fe concentration at point 2. In a one-way flow system, the water level also has a shift in tidal patterns and tends to have a lower maximum water level than the two-way flow system. Water level comparison between measurement data for existing two-ways flow system and water level model for one-way flow system on sampling location point-2 can be seen in Figure 8.

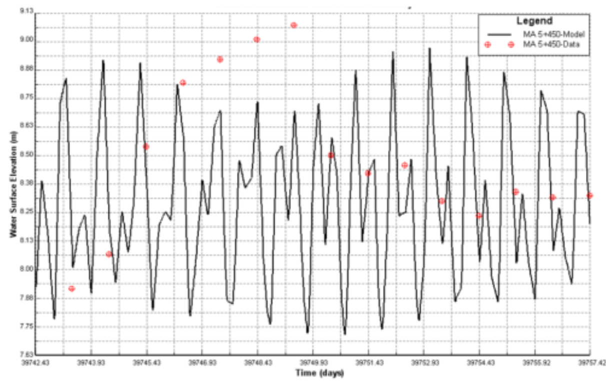


**Figure 8.** Water Level Difference of One-Way and Two-Ways Flow on Point-2

Fe concentration comparison between measurement data for existing two-ways flow system and water quality model for one-way flow system on location point-2 is as follows.

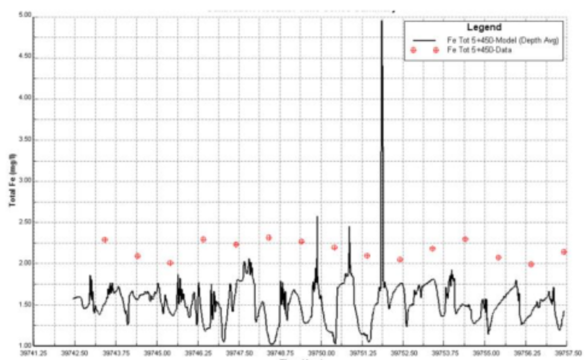


**Figure 9.** Fe Concentration Difference of One-Way and Two-Ways Flow on Point-2

The next comparison for water level and Fe concentration at point 3, has the same result as the previous result. Water levels for one-way flow systems tend to shift their pattern compared to two-ways flow system (Figure 10). The maximum and minimum level for one-way flow also shifted down compared to the two-ways flow system.

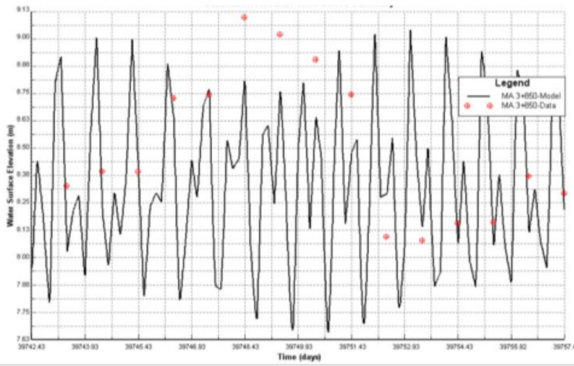


**Figure 10.** Water Level Difference of One-Way and Two-Ways Flow on Point-3

Fe concentration comparison between measurement data for existing two-ways flow system and water quality model for one-way flow system on location point-3 is as Figure 11 below. The Fe concentration tends to be lower for one-way flow system compared to two-ways flow system.

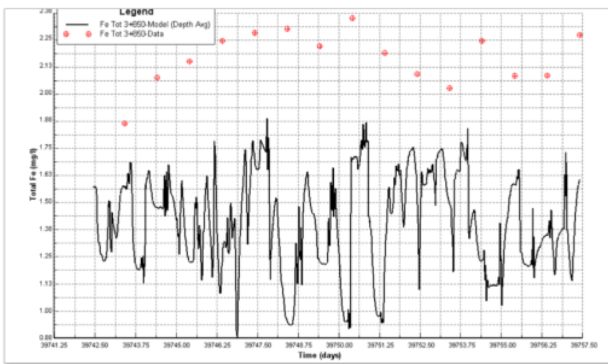


**Figure 11.** Fe Concentration Difference of One-Way and Two-Ways Flow on Point-3

The results of error analysis for the parameters of Fe concentration on one-way and two-way flow system conditions are in the following Table 2. Based on these results, the one-way flow system can reduce up to 55.66% Fe concentration in the channel. With an average reduction of Fe concentration of 52.9%, it can be concluded that the one-way flow system is an alternative solution of the macro water system that can be applied for toxic materials accumulation problems in the reclamation channel.

**Table 2.** Comparison Between One-Way System (Measurement) and Two-Ways Model

| Point | Fe Concentration Comparison | Average Error | Relative Error | Absolute Error |
|---|---|---|---|---|
| 1 | Measurement Data | 0.36 | 47.42 | 0.36 |
| | Two-Ways Model | 0.36 | 45.00 | 0.36 |
| 2 | Measurement Data | 0.40 | 52.88 | 0.40 |
| | Two-Ways Model | 0.41 | 52.00 | 0.42 |
| 3 | Measurement Data | 0.42 | 55.66 | 0.42 |
| | Two-Ways Model | 0.39 | 53.00 | 0.39 |

## 4. Conclusion

The existing flow pattern and distribution of Fe concentration in Terantang units tend to accumulate in certain segments in the channel. The simulation results using the partition coefficient approach have better accuracy than conventional models which tend to be over-predicted compared to observation data. Simulation of the one-way flow system shows a decrease in Fe concentration in the channel by an average of 52.9% compared to the two-way flow system.

## 5. Acknowledgment

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