The Advanced Analysis of Hydrodynamic and Sediment Transport Modelling in Agathis Lake

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Abstract. Resource Modelling Associates (RMA) was used to estimate the hydrodynamic process in Agathis Lake. The lake is situated in Universitas Indonesia, Depok, West Java, Indonesia. The model detects the velocity and total suspended solid distribution trends in the lake. RMA program generated the result of the trends. The program needs a calibration analysis to make the program output valid. Calibration analysis is conducted through sampling activities of field data. This research aims to do calibration analysis between the program output and the field data. The calibration analysis concludes that the present sampling locations are not sufficient to complete the calibration analysis. The research suggests adding sampling locations both from upstream to downstream and from surface water to bed surface of the lake.

1. Introduction
Suspended sediments have a primary role as pollutant source not only in urban areas but also coastal regions. The sediments get the role to determine the quality of coastal water [1, 2]. Moreover, sediments could role as flooding disaster root. The sediments attach the water physical body and fulfill the water body capacity.

Sophisticated technology today enforce scientist to develop tools to make users easier to understand environmental phenomena. Natural disasters like flood, earthquake, and sediment erosion become urban areas threat due to lack of environmental-friendly policy. The government, academia, and related stakeholders need to unite to achieve the policy. Hydrologic models are widely used by engineers, scientists, and hydrologists to understand and manage both natural and human activities that affect the watershed [3]. The hydrodynamic of hydraulic and total suspended solids are affected by several parameters. They are turbulent exchange coefficient both X and Y directions, turbulent diffusion both X and Y directions, turbulence factor, diffusion both X and Y directions and settling rate. All parameters are difficult to adjust to make the output program could represent the actual data. The successful output of the model depends on the calibration analysis [4].

The program model is based on the finite element method [5]. Most numerical models to simulate sediment transport use hydrodynamic models. The models could be classified according to their dimensionality, i.e. 1-Dimensional, 2-Dimensional, and 3-Dimensional [6,7]. Neary et al. [8] used 1-D models to study cohesive sediment while Zheng et al. [11] and Rao et al. [9] applied 2-D dimensional models. 3-D models are also widely used by several scientists to understand sediments phenomena like Gleizon et al. [10] and Zheng et al. [11]. The research uses the 3-Dimensional model to study the hydrodynamic process in the study area.
2. Research Method

Calibration analysis is conducted by analyzing field data and the output program. The velocity and total suspended solid distribution trends are observed 24-hour from the model. According to this limitation, sampling activities to obtain field data are conducted in 24 hours. The sampling locations are spread out from the upstream to the downstream part of the lake. The expected location and time are studied in the previous research by Prastica [6]. There are three main locations of sampling activities. The field data would be sampled in the inlet of the lake, water body, and the outlet. The sampling times range from 08.30 on March, 13th 2018 to 08.00 on March, 14th 2018. There are two main data that would be sampled: velocity and total suspended solids (TSS).

The sampling data would be analyzed in the laboratory to obtain the total suspended solids concentration. The RMA program output data would be calibrated by using the final field data from sampling activities.

3. Result and Discussion

3.1. Study area

The research studies Agathis Lake that is situated in Universitas Indonesia, West Java, Indonesia. The lake is located in the upstream part of the cascade-pond system in Universitas Indonesia. The lake is directly connected to the urban settlements. Figure 1 depicts the lake and sampling locations for calibration analysis [6].

![Figure 1. Sampling Locations in Agathis Lake [6].](image)

Agathis lake has a catchment area approximately 871,188 m². The lake only 0.87% of the total catchment area meanwhile the percentage of impervious cover reaches 70.21%. Agathis Lake is directly connected to the urban settlements, so most of the pollutants that enter the lake’s body come from the urban activities.

3.2. Resource Modelling Associates Program

There are four programs of Resource Modelling Associates (RMA): RMA-Gen, RMA-10, RMA-11, and RMA-PLT [6]. RMA-Gen transforms geometry to finite element method, RMA-10 simulates the 3-Dimensional model of velocity distribution, RMA-11 simulates the 3-Dimensional model of total suspended solid trends, while RMA-PLT visualises the result of the program running.
3.3 Sampling Activities

Sampling activities are studied from Prastica [6] and calibrated with the RMA output data in this research. Table 1 describes the location and time of sampling activities from Prastica [6]. Table 2 tells the exact location and time of sampling activities. The research calls several codes to understand the model easier. Figure 2 depicts the codes number to recall the sampling locations.

| Day       | Time     | Location I Sediment Trap Inlet | Location II Sediment Trap Outlet | Location III Floodway Path | Location IV Inlet of Agathis Lake | Location V Waterbody of Agathis Lake | Location VI Outlet of Agathis Lake |
|-----------|----------|--------------------------------|---------------------------------|---------------------------|-----------------------------------|-------------------------------------|-----------------------------------|
| March, 13th, 2018 | 08.30-09.00 |                                  |                                 |                           |                                    |                                     |                                   |
|           | 10.00-11.00 |                                  |                                 |                           |                                    |                                     |                                   |
|           | 12.00-12.30 |                                  |                                 |                           |                                    |                                     |                                   |
|           | 12.30-14.30 |                                  |                                 |                           |                                    |                                     |                                   |
|           | 15.30-16.00 |                                  |                                 |                           |                                    |                                     |                                   |
|           | 16.30-17.00 |                                  |                                 |                           |                                    |                                     |                                   |
|           | 19.00-20.00 |                                  |                                 |                           |                                    |                                     |                                   |
| March, 14th, 2018 | 07.00-08.00 |                                  |                                 |                           |                                    |                                     |                                   |

The location to take samples in the water depth is determined by dividing its width (W) and depth (D) into approximately half of the total each parameter. Figure 3 depicts the lake’s water column location to take water samples.

3.4. Calibration Analysis

The calibration analysis is conducted by analyzing the sum of squared error (SSE) percentage among the data. This analysis aims to make the model could represent the actual data. There are three kinds of approach to doing calibration: expert intuition, field sampling with actual system, and theoretical analysis. This research uses field sampling study [6]. RMA-10 model calibration uses velocity prediction data and actual velocity data and RMA-11 uses TSS prediction data and their actual data from Agathis Lake system. There are 9 nodes of RMA program that represent the field sampling location. Inlet of sediment trap, outlet of sediment trap, inlet of floodway, floodway channel, inlet of Agathis lake, water body of lake I, water body of lake II, water body of lake III, and outlet of Agathis lake are represented by nodes: 4422, 1344, 4188, 3823, 5, 504, 2015, 912, and 580, respectively. Table 2 figures the analysis of SSE percentage for calibration of velocity and TSS data.
Figure 2. Nodes Location for Model

This analysis needs further analysis to obtain the least percentage of SSE. In this research, the unknown variables that are used for RMA-10 are 0.1 m²/s for turbulent coefficient of x-direction, 0.1 m²/s for turbulent coefficient of y-direction, 0.1 m²/s for diffusion coefficient of x-direction, 0.1 m²/s for diffusion coefficient of y-direction, and 0.02 for turbulence factor, whereas the unknown variables that are used for RMA-11 are 0.002 m/s for settling velocity, 0.001 m²/s for diffusion coefficient of x-direction, and 1000 m²/s for diffusion coefficient of y-direction. It is predicted that the changes of variables could give the different percentage of SSE that are needed to be analyzed in the further analysis.

Table 2. RMA-10 and RMA-11 Calibration Analysis

| Time       | Node | V Field Data (m/s) | V Model (m/s) | SSE (%) | c Field data (mg/l) | c Model (mg/l) | SSE (%) |
|------------|------|-------------------|---------------|---------|---------------------|---------------|---------|
| 8:00:00 AM | 4422 | 0.470             | 0.508         | 0.3171  | 30                  | 29.3738       | 2.08    |
| 9:00:00 AM | 4422 | 0.450             | 0.449         | 0.0001  | 26                  | 25.5236       | 1.83    |
| 10:00:00 AM| 1344 | 0.320             | 0.322         | 0.0012  | 12                  | 11.4253       | 4.78    |
| 11:00:00 AM| 1344 | 0.300             | 0.322         | 0.1615  | 8                   | 8.6780        | 8.47    |
| 12:00:00 PM| 4188 | 0.400             | 0.424         | 0.1559  | 6                   | 5.6594        | 5.67    |
| 1:00:00 PM | 3823 | 0.150             | 0.211         | 2.4847  | 8                   | 8.7928        | 9.91    |
| 2:00:00 PM | 3823 | 0.180             | 0.211         | 0.5355  | 8                   | 8.3827        | 4.78    |
| 3:00:00 PM | 5    | 0.003             | 0.006         | 0.4583  | 1                   | 0.9265        | 7.35    |
| 4:00:00 PM | 5    | 0.003             | 0.006         | 0.4687  | 1                   | 0.9140        | 8.60    |
| 5:00:00 PM | 504  | 0.003             | 0.005         | 0.2908  | 2                   | 1.9757        | 1.21    |
| 6:00:00 PM | 2015 | 0.003             | 0.006         | 0.3958  | 3                   | 2.5871        | 13.76   |
| 7:00:00 PM | 2015 | 0.003             | 0.006         | 0.3975  | 3                   | 2.6023        | 13.25   |
| 8:00:00 PM | 912  | 0.050             | 0.041         | 0.1425  | 1                   | 1.0193        | 1.93    |
| 9:00:00 PM | 580  | 0.040             | 0.041         | 0.0060  | 1                   | 1.0193        | 1.93    |
| 7:00:00 AM | 580  | 0.040             | 0.041         | 0.0060  | 2                   | 2.1930        | 9.65    |
| 8:00:00 AM | 580  | 0.040             | 0.041         | 0.0060  | 2                   | 2.1942        | 9.71    |

According to the calibration analysis, the highest percentage of SSE for the velocity parameter is 2.49%. This result indicates that the RMA output data are well-represented with the actual condition. The highest SSE of velocity parameter is located in the channel that connected the inlet of sediment trap and inlet of Agathis Lake. The condition could happen due to the dynamic of a narrow channel. The least percentage of SSE for TSS distribution is located in the water body of the lake meanwhile the highest
percentage could be found in the water body of the lake near the outlet. The range of SSE for TSS distribution is 1.21% - 13.76%. The analysis concludes that the RMA data could represent the actual data but still need more elaboration to be valid.

![Figure 3. Water Sampling Location](image)

Samples are taken in the surface water. The 3-Dimensional model should represent X, Y, and Z directions of the water body. It means that the depth parameter is important to notice. The representative locations from water depth should be analyzed to capture the best representative samples locations.

There are two suggestions for future calibration analysis. Firstly, the default parameters that affect the RMA program result data should be analyzed and calibrated. Secondly, samples should be taken in various depth locations to obtain the best representative samples. To conclude, the advance calibration should notice both parameters and samples data from various water depth.

### 3.5. RMA Program Data Output

The program output data are visualized by RMA-PLT. Figure 4 – 6 depict the RMA-11 program running at 8.00 a.m., 9.00 a.m., and 12.00 p.m., respectively.

![Figure 4. RMA-11 Program Running Result at 8.00 a.m.](image)
4. Conclusion
This research concludes that the model prediction of velocity and TSS distribution could represent the actual data according to calibration analysis. The research suggests more iterations of parameters to obtain the least percentage of SSE for RMA-10 and RMA-11 calibrations. In addition, the three-dimensional model could be performed with various depth layers of the lake to observe the TSS distribution in the z-direction. The observation of various depth layers could lead to the finding of the best representative sample location of the lake depth for the hydrodynamic model.

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