Application of mock hydrology model in estimating semi-monthly discharge in Sei Petani Sub-Watershed

D L S Nasution*, F V U Simanjuntak, E Susanto and N Ichwan
Department of Agricultural Engineering, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia.

E-mail: *nasutiondelima@usu.ac.id

Abstract. One of indicators which represent watershed condition is hydrology condition that can be represented by the value of monthly discharge, maximum discharge, minimum discharge, and river regime coefficient. This study aims to estimate the monthly discharge value of Sei Petani Sub-Watershed using the Mock Hydrology Model. The application of the Mock Model require some input data such as rainfall, climate data, and area of watershed. Optimum parameters could be obtained by model calibration and validation that was carried out by statistical and graphical test. Optimal parameters that has been obtained would be used to estimate discharge value in existing condition. The result showed that the model accuracy for calibration and validation process has the coefficient correlation (R) value more than 0.75, with volume error (VE) less than 0.05 that means there were strong relationship among calculated data and observed data. The optimum parameters value accomplished to estimating discharge value for existing condition. The watershed health based on hydrology indicators on Sei Petani Subwatershed could be seen with the value of specific maximum discharge, specific minimum discharge, and river regime coefficient that shown this watershed in well condition.

1. Introduction
Water is society primary needs and the watershed was the place where society live with their needs of water and other natural resources so that the health of watershed must be noticed that it determined the society life. Watershed was the place where human live together to fulfil their needs of food, water, healthy, and others. Human have an obligation to maintain the watershed according to the rules of conservation due to the sustainability of the watershed as a place for us to live and fulfil our needs. Healthy watershed describes healthy society. Health condition of a watershed determined by hydrology indicators, erosion, and sedimentation. Analysing watershed was very complex where its complexity requires an innovative hydrological approach in improving situation and in conserving water resources. [1] The assessment of watershed health needs an instrumentation in analysing the discharge value, water regime, water yield etc. The instrumentation is a mathematical equation that describes the process occurs in a watershed. These mathematical equations are usually imitating the hydrology process in a watershed that known as hydrology model.

The Mock hydrological model is a model with a relatively simple calculation method and easy to apply. This model has been used in tropical watersheds. From the results of previous research, this model has a good accuracy relationship. The objective of this research is to estimate the discharge value and other hydrology indicators of the Sei Petani Sub-Watershed using the Mock hydrological model.
2. Materials and methods
In this study, the Mock Hydrological Model was used in simulating the amount of maximum discharge, minimum discharge and river regime coefficient. The input module of the model is based on regional rainfall and evapotranspiration and the discharge value observation data at the same year. The calculation of regional rainfall and evapotranspiration using data at year 2017 for calibration and 2018 for verification and 2019 for simulation. The regional rainfall average calculated using arithmetic method and evapotranspiration calculated using radiation method by the climate parameters such as humidity, radiation, wind velocity, and temperature.

2.1. Mock hydrology model
Mock Hydrology Model is a simple rainfall runoff model simulation with good enough performance in assessment of monthly discharge. This model describes the responses of a watershed to hydrology process [2]. Mock Hydrology Model contains three artificial tanks that represent the transformation process of rainfall in the soil, then to atmosphere, and ground water system that adopting the water balance principle that describe in Figure 1. [3] F J Mock Model was the Hydrology Model that have been expanded by F J Mock [4] in the tropical region of Java Island Indonesia which is reported by Setyawan at al [5] and Sukirno and Susanto [6].

![Mock hydrology model tanks](image)

*Figure 1. Mock hydrology model tanks*

Mock Hydrology Model consists of thirteen parameters as describe in figure 1. The values of main parameters: initial soil moisture (ISM), soil moisture capacity (SMC), recession constant (K), initial ground water storage (IGWS), infiltration coefficient (Ci) were obtained during calibration process with trial and error using Microsoft Office Excel.

2.2. Model calibration and verification
It has rules in running a hydrology model before simulating, names calibration and validation. Model calibration aims to obtaining optimum parameter. It done by compared the model output to observation data which test by graphical and statistical test which perform as model accuracy. Model validation was done after model calibration process have been obtaining optimum parameter. Calibration and validation carried out by inputting different annual data. These processes were carried out by trial and error in obtaining optimal parameter which evaluate by statistical test and graphical test. After the parameter values are obtained in the calibration process, the verification process is carried out with different annual data input. The input rainfall and climate data for calibration process is rainfall and climate data at year 2017 as input and discharge value observation data at the similar year. The data needed for verification process is regional rainfall and climate data at year 2018 as input and discharge value observation at the similar year. In verification process, statistical tests and
graphical tests will be generated to obtain a correlation between observation discharge value and calculation discharge value from the Mock model.

In the Mock model, the statistical test results are obtained from the coefficient correlation\((R)\) and Volume error \((VE)\) values (equation 1 and 2) [7], which are the values that shown relation among model output and actual conditions (observation discharge data) where the error shows the difference in the volume of the output model and the results of the observations. Graphical test shown the attachment influenced of the calculation to observation.

\[
VE = \left(\frac{\sum_{i=1}^{N} Q_{obs} - \sum_{i=1}^{N} Q_{cal}}{\sum_{i=1}^{N} Q_{obs}}\right) \times 100 \% \tag{1}
\]

\[
R = \sqrt{\frac{D_{t}^{2} - D^{2}}{D_{t}^{2}}} \tag{2}
\]

\(R\) = Correlation Coefficient

\(D^{2}\) = Total of \((Q_{obs} - Q_{cal})\)

\(D_{t}^{2}\) = Total of \((Q_{obs} - \text{average}Q_{obs})^{2}\)

2.3. Hydrological indicator analysis

After obtaining the discharge value from the simulation results of the application of the hydrological model, then the watershed health hydrological indicator value will be calculated.

a. Maximum discharge \((Q_{max})\) is the peak discharge that occurred within one year \((m^{3}/s)\)

b. Minimum discharge \((Q_{min})\) is the value of debit lowest in a year \((m^{3}/s)\)

c. River regime coefficient \((RRC)\) is the ratio of maximum and minimum discharge in the watershed

\[
RRC = \frac{Q_{max}}{Q_{min}} \tag{3}
\]

3. Results and discussion

3.1. Calibration stage

| Table 1. Optimum parameters result for the Mock Model |
|-----------------------------------------------------|
| Parameters of the Watershed | Unit | Symbol of | Optimization Results |
|-------------------------------|------|-----------|----------------------|
| Area of watershed            | Km2  | A         | 11.91                |
| Infiltration Coefficient Wet Season | -   | WIC       | 0.1                  |
| Dry Season Infiltration Coefficient | -   | DIC       | 0.4                  |
| Initial Soil Moisture         | (mm) | ISM       | 155                  |
| Soil Moisture Capacity        | (mm) | SMC       | 200                  |
| Initial Groundwater Storage  | (mm) | IGWS      | 1600                 |
| Groundwater Recession Constant | -   | K         | 0.889                |

The calibration process is carried out to obtain parameter values to present actual watershed conditions so that the discharge value calculation \((Q_{cal})\) results is almost similar to the observed discharge value. Calibration stage conducted using data at year 2017. In this stage statistical tests and
graphical test were perform with the value of statistical analysis showed a correlation coefficient (R) = 0.879 and the value of the error (VE) = 0.19% and graphics test results of tests ($R^2$) is 0.772. The optimum parameter values for the Mock model are presented in Table 1.

A graphical test of the Mock hydrological model is presented in the diagram below:

![Mock hydrological model distribution diagram in calibration stage](image1)

**Figure 2.** Mock hydrological model distribution diagram in calibration stage

Figure 3 representing the relation among observation discharge value ($Q_{\text{obs}}$) and calculation discharge value of Mock Hydrology Model. This figure describes the fluctuation of discharge value both in observation and calculation with the regional rainfall data in calibration stage where in this figure it can be seen that the high rainfall value results high discharge calculation value.

![Calibration graph of semi monthly observation discharge with calculation discharge and rainfall](image2)

**Figure 3.** Calibration graph of semi monthly observation discharge with calculation discharge and rainfall

3.2. Verification stage

![The distribution diagram of the Mock model verification](image3)

**Figure 4.** The distribution diagram of the Mock model verification
Parameter values that have been obtained in the calibration process will be tested at the verification process. This process was conducted using data at year 2018. In the verification stage, the correlation coefficient (R) = 0.835 and the volume error (VE) is 0.21%, and the graphical test was obtained (R²) = 0.752. The graphical test at the verification stage is presented in the Figure 2 that is a comparison graph between the observation discharge and the calculation discharge from mock hydrology model.

The relationship of observation discharge value (Q obs) and Calculation discharge value of Mock Hydrology Model with the regional rainfall data is presented in Figure 5. The fluctuate of observation and calculation discharge with rainfall can be show in this figure for the verification process where it has the same trend to calibration process about the behaviour of rainfall in resulting calculation discharge.

In the calibration and verification process, it can be seen that the correlation between the observation discharge (Q obs) and the calculation discharge (Q cal) is almost fluctuates similar to the regional rainfall. Mock hydrology model can respond well with a good accuracy that can be seen by the statistical and graphical test in both calibration and verification stage. Nevertheless, Mock Hydrology Model was such a blackbox model that cannot give the perfect performance in representing watershed condition because of many assumptions occur in the watershed.

### 3.3. Simulation of discharge value, maximum discharge, minimum discharge, and river regime coefficient

Mock hydrological model was applied to calculate the discharge value at the upstream Sei Petani Sub-Watershed outlet and assess watershed health indicators for the recent time in this study. The input data for simulation using regional rainfall and climate data at year 2019 so the discharge simulation value for Sei Petani Sub Watershed condition at 2019 is presenting in Figure 6. Based on the Hydrological Mock Model simulations (Figure 6), the value of maximum discharge is 3.416 m³/s. The maximum discharge value compared to total area of Sei Petani Sub Watershed is 0.286 m³/s / km². The minimum discharge value is 0.770 m³/s. Minimum discharge compared to total area of Sei Petani Sub Watershed is 0.064 m³/s. The value of river regime coefficient is 4.46 which is comparison of maximum discharge and minimum discharge. The results of the maximum discharge, minimum discharge and river regime coefficient value, it shown that the Sei Petani Sub Watershed is in well health condition based on the assessment of hydrology indicators of watershed. One of many factors that caused this condition is landuse in this watershed. Landuse was the most important factor that influence the watershed health because the existing and the condition of vegetation and society farming pattern determined water infiltration to the watershed. This condition has taken many attentions by society as land user and government to sustainability the watershed health. Land use in
Sei Petani Sub Watershed is dominated by society farming but there still have enough forest and the society farming pattern do the rules of conservation.

**Figure 6.** Semi monthly discharge value simulation of Mock Model

4. **Conclusions**

The Mock Hydrological Model has a good performance which can be seen by the good accuracy for calibration and verification process. The Mock Hydrology Model is deserved to predict the hydrology indicators of Sei Petani Sub Watershed. Based on assessment of hydrologic indicators, Sei Petani Sub Watershed can be concluded in well condition that represented by the value of maximum discharge, minimum discharge, and river regime coefficient which is in under threshold permitted.

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