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PREDICTION OF STREAMFLOW OF THE ANAI-WEIR CATCHMENT USING BOTH THE SWAT AND MOCK MODELS

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Abstract*. This research focuses on predicting the streamflow of the Anai-weir catchment using the SWAT (Soil and Water Assessment Tools) and Mock models. The catchment studied is approximately 34,024 ha wide. The rainfall and climatological data were collected from the three nearest rainfall stations, namely Kandang IV (13.8 km far), Kasang (15.2 km far), and Sicincin Stations (11.2 km far), from 2010 to 2019. The first research methodology is to delineate the catchment, form a Hydrologic Response Unit (HRU), and then enter the climatological data into the SWAT model to estimate the daily streamflow. This daily streamflow is then averaged over a semi-monthly period. The second research methodology is to estimate an evapotranspiration depth based on the climatological data using the Modified Penman method, and then predict the semi-monthly average-daily streamflow using the Mock model. The results obtained from both methods are then compared with the Anai-weir AWLR-data. The average results from each method, namely, the SWAT model, the Mock model, and the AWLR data have the same tendency, but the Mock model results are closer than the SWAT model results to the AWLR data. This indicates that the Mock model is more suitable than the SWAT model for the existing data conditions. Even though the SWAT model considers more variables than the Mock model does.*
Keywords: rainfall-runoff models; SWAT; mock; streamflow; Anai weir

1. Introduction

There are several hydrological models that can be used to simulate processes in either a watershed or a catchment, including MIKE SHE, TOPMODEL, HEC-HMS, VIC Model, IHDM, WATFLOOD and SWAT (Sakti & Suprayogi, 2016). SWAT stands for Soil and Water Assessment Tools and is a GIS-based hydrological model that can be used to analyze hydrological conditions. The SWAT model is used to simulate the quality and quantity of surface and groundwater and to predict the environmental impact of land use, land-management practices, and climate change. The SWAT is also widely used in assessing soil erosion prevention and control, non-point source pollution control, and regional management in watersheds (SWAT, 2022). The SWAT is an eco-hydrological watershed-scale model which was initially developed in the early 1990s to simulate the impacts of land use, management systems, and climate on hydrology and/or water quality (Gassman *et al.*, 2022). The SWAT model can also be used to predict water balance components in a sub-watershed (Guug *et al.*, 2020; Juma *et al.*, 2022), and to predict streamflow in a watershed (Ayivi & Jha, 2018; Singh & Saravanan, 2020). The predicted streamflow can be used to estimate either peak streamflow (Liyantono, 2014) or dependable streamflow (Priyanto, 2016). Several other studies that used this SWAT model as the main tool, include: Abbas *et al.*

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(2022) studied blue water; Felix and Jung (2022) studied climate data effects; Srinivas *et al.* (2022) and Raij-Hoffman *et al.* (2022) studied model comparison, Vagheei *et al.* (2022) and Ntona *et al.* (2022) studied data interface, Nkwasa *et al.* (2022) and Lamane *et al.* (2022) investigated sediment loss and transport, Wang *et al.* (2022) studied irrigation impacts, Rigby *et al.* (2022) and Mengistu *et al.* (2022) explored land-use change, and Getahun and Keefer (2022) and Singh and Saravanan (2022) studied cropping system assessment.

The Mock method is a conventional method commonly used to predict semi-monthly average-daily streamflow (Sudinda, 2019). Both the SWAT and Mock methods use rainfall data as the main data. The objectives of the present study are to predict the streamflow of the Anai-weir catchment using both the SWAT and Mock models, then compared them with the streamflow based on the Anai-weir AWLR (Automatic Water Level Recorder) data. The Anai weir is located at a latitude of -0.638893° and longitude of 100.337134°.

2. Methods

2.1. Data Collection

All data used in the present study are secondary data obtained from related agencies. The first one is a topographic map containing information on the state of vegetation cover and contours (Figure 1, a). The topographic map is in the form of a DEM (Digital Elevation Model) map obtained from the BWS SV (River Basin Office – Sumatra V) and the DEMNAS (National Digital Elevation Model). The second one is a soil map obtained from the BAPPEDA (Regional Development Planning Agency) of West Sumatra (Figure 1, b). The third one is a land-use map obtained from the BIG (Geospatial Information Agency) (Figure 1, c). The fourth data are AWLR and climatological data including data on rainfall, evaporation, climate, air humidity, and solar radiation (Figure 1, d). The fourth data are obtained from the Office of SDA-BK (Water Resources and Construction Development) and BMKG (Meteorology, Climatology and Geophysics Agency) of West Sumatra. There are three nearest rainfall stations to the Anai weir, namely Kandang IV (lat. -0.513333°; lon. 100.335000°) is about 13.8 km far, Kasang (lat. -0.775006°; lon. 100.315705°) is about 15.2 km far, and Sicincin Stations (lat. -0.545270°; lon. 100.297830°) is about 11.2 km far.

2.2. SWAT Model

In this stage, three steps must be done before running the SWAT model. The first step is the delineation of the watershed. This is the process of delineating or forming rivers in a watershed under review. The second step is the establishment of HRU (Hydrology Response Unit Analysis). HRU can describe the influence of an area on hydrological factors by using land-use maps, land-slope maps, and soil-characteristics maps. The final step is to enter rainfall and climatological data (humidity, wind speed, temperature, and solar radiation) into the climate data generator. Then the SWAT model is run by selecting the “daily” in the setup simulation. Then select column labelled “FLOW m^3/s” in the output files of the SWAT model as indicated as the daily streamflow.

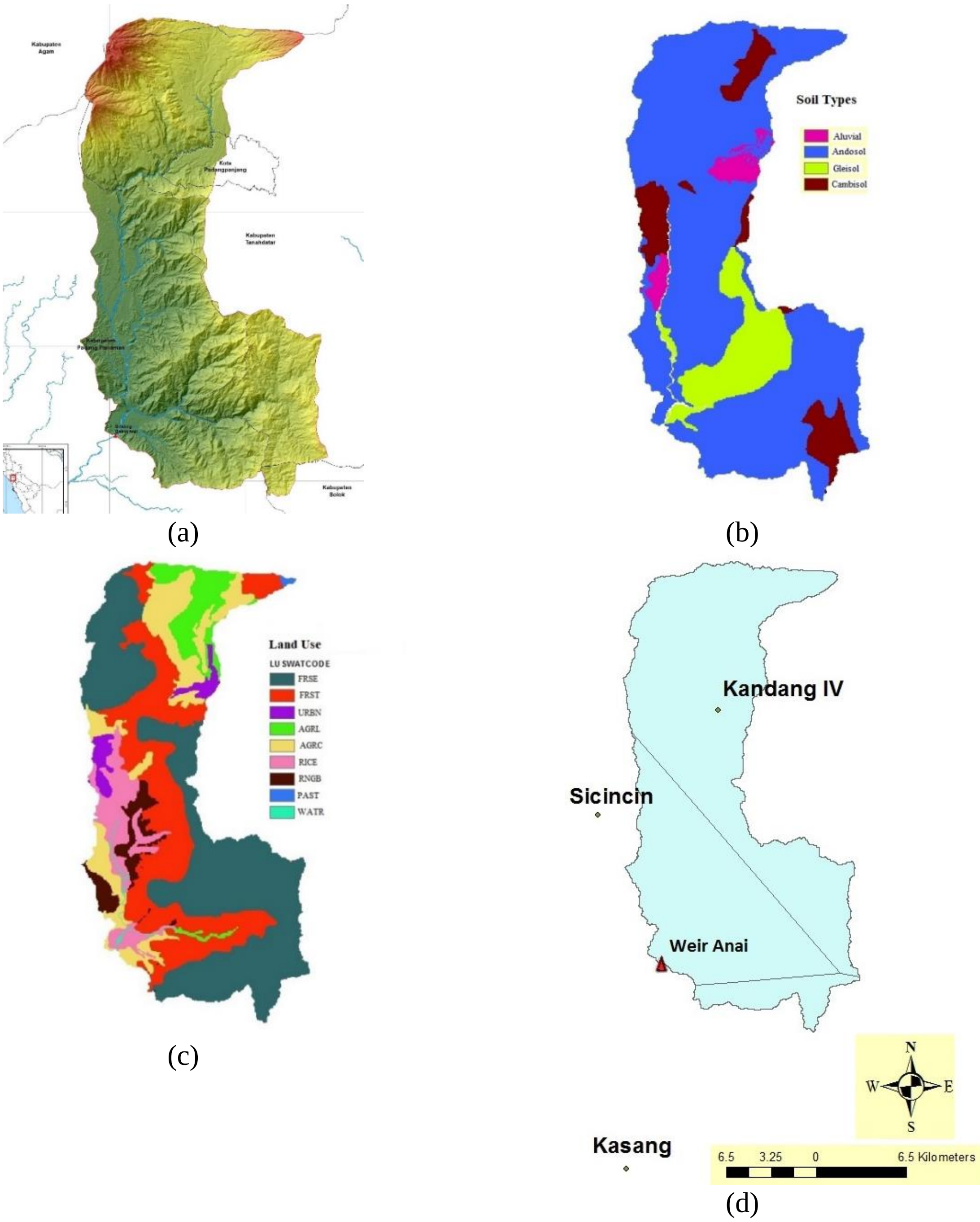

Figure 1. Topographic map (a), soil map (b), land-use map (c), and map of AWLR and rainfall stations (d)

2.3. Mock Method

The data needed in the prediction of streamflow using the Mock method are the depth of semi-monthly rainfall (mm), the number of half-rainy days (days) in half a month, and climate data. The semi-monthly rainfall depth is the cumulative daily rainfall depth for 15 days. Furthermore, the calculation of the average rainfall depth is carried out using the Thiessen polygon (Figure 1, d). Then evapotranspiration depth is predicted using the Modified Penman method.

Finally, the average-daily streamflow for the semi-monthly is obtained.

2.4. Streamflow

All streamflow values generated by the SWAT model are daily streamflow (m^3/s). However, all the streamflow values generated by the Mock method have been averaged for 15 days. So all the daily flows from the output of the SWAT model and from the AWLR data must be averaged for 15 days to get half-month average-daily streamflow like the output of the Mock method. In one year there will be 24 semi-monthly average-daily flows, marked Jan-1, Jan-2, ..., Dec-1, Dec-2. If the length of the data is 10 years, for example, then there will be 10 semi-monthly average-daily flows marked each as Jan-1, Jan-2, ..., Dec-2, Dec-2. The semi-monthly average-daily flows with the same marks are then sorted from largest to smallest. Streamflow with maximum and minimum values can be determined by using the ranking method. The dependable streamflow with a certain probability is then determined by the Weibull distribution (KPU, 2011) as Formula (1).

$$P = \frac{m}{n+1} \times 100\% \qquad (1)$$

where P is the probability of streamflow Q occurring on the m^{th} order, m is the serial number of the data, and n is the number of data. If $n = 10$ as in Table 1, then the P value for each sequence can be determined. Because $P_{50\%}$ and $P_{80\%}$ are not exactly in sequence numbers, it is necessary to interpolate the streamflow values before and after them. After that, these streamflow values are plotted into bar charts.

Table 1. Probability of streamflow occurring on the m^{th} order

m	1	2	3	4	5	6	7	8	9	10	**Interpolation**	
P	9.1%	18.2%	27.3%	36.4%	45.5%	54.5%	63.6%	72.7%	81.8%	90.9%	**50%**	**80%**
Q [m^3/s]	56.20	52.77	37.34	34.80	34.61	31.10	30.70	27.01	25.61	16.30	**32.86**	**25.89**

Table 1 also shows that the maximum streamflow is a flow with a probability of 9.1% occurring, while the minimum streamflow is a flow with a probability of 90.9% occurring.

3. Results and Discussion

3.1. Maximum Streamflow

Figure 2 shows the comparison of the maximum semi-monthly average-daily flows of the Anai-weir catchment obtained from the SWAT model, the Mock method, and the AWLR data. The SWAT model results always give the lowest values except for Apr-1, Apr-2, and Jul-1. While the results obtained from the AWLR data are almost always higher than the Mock outputs except for Apr-1, Nov-1, and Nov-2. In general, all maximum semi-monthly average-daily flows from the SWAT are the smallest, all those from the AWLR data are the largest, and all those from the Mock are in between except for both halves of April, Jul-1, Sep-2, both halves of November. In general, all maximum semi-monthly average-daily flows from both the SWAT and the Mock give close results compared to those from the AWLR data.

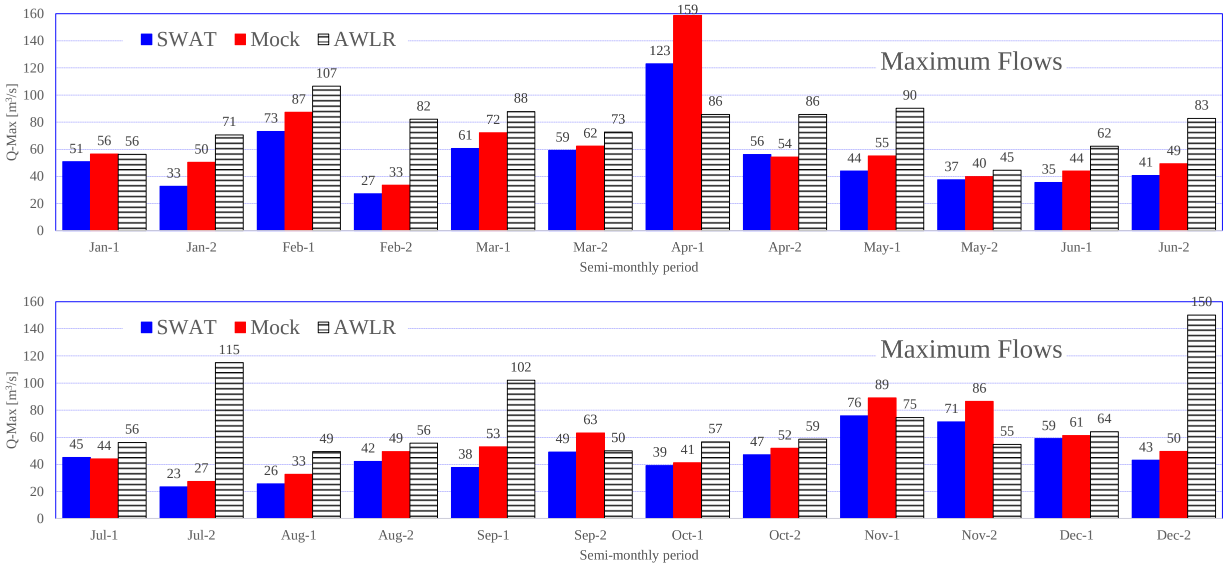

Figure 2. Maximum semi-monthly average-daily flows are obtained from the SWAT model, the Mock method, and the AWLR data.

3.2. Minimum Streamflow

Figure 3 shows the comparison of the minimum semi-monthly average-daily flows of the Anai-weir catchment obtained from the SWAT model, the Mock method, and the AWLR data. It is difficult to see the trend of the results of these three methods. Only 9 semi-monthly periods (Mar-2, both halves of May, Jun-1, both halves of September, Oct-1, and both halves of December) have the same trend, namely, the SWAT model results are the smallest, the results of the Mock method are slightly higher than those of the SWAT model, and the AWLR data are the highest.

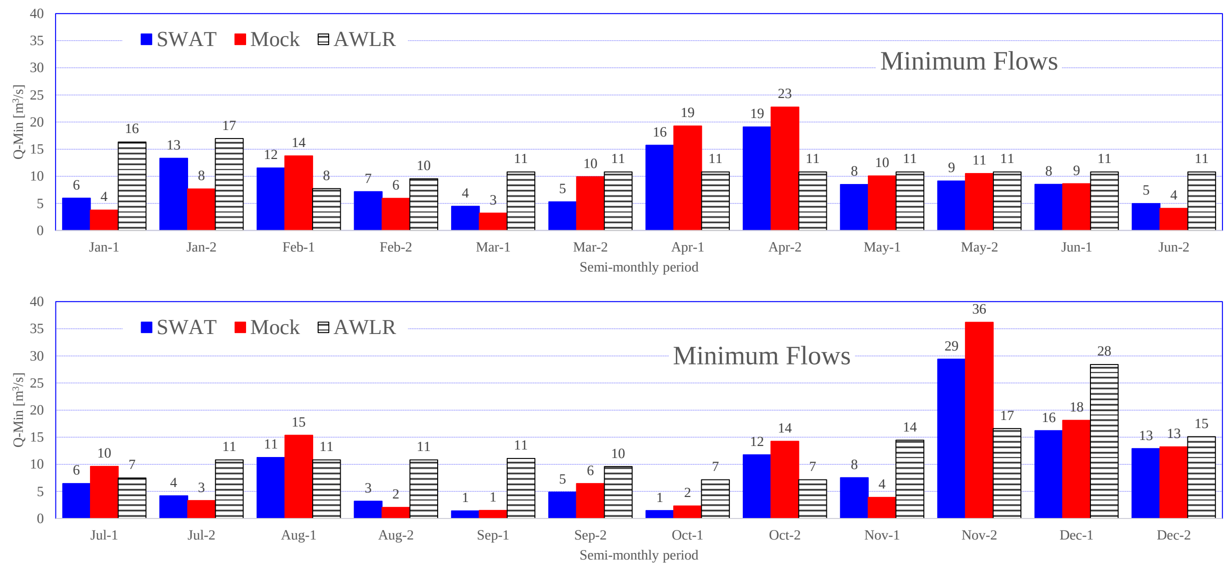

Figure 3. Minimum semi-monthly average-daily flows are obtained from the SWAT model, the Mock method, and the AWLR data.

3.3. Dependable Streamflow of 50%

The 50% dependable streamflow is usually used for irrigating secondary crops (Soemarto, 1999; KPU, 2013). Figure 4 shows the comparison of the 50% dependable flows of the Anai-weir catchment obtained from the SWAT model, the Mock method, and the AWLR data. About 50% of the dependable streamflow have the same tendency, namely, the results of the SWAT model are the lowest, the results of the Mock method are slightly higher than those of the SWAT model, and the AWLR data are the highest.

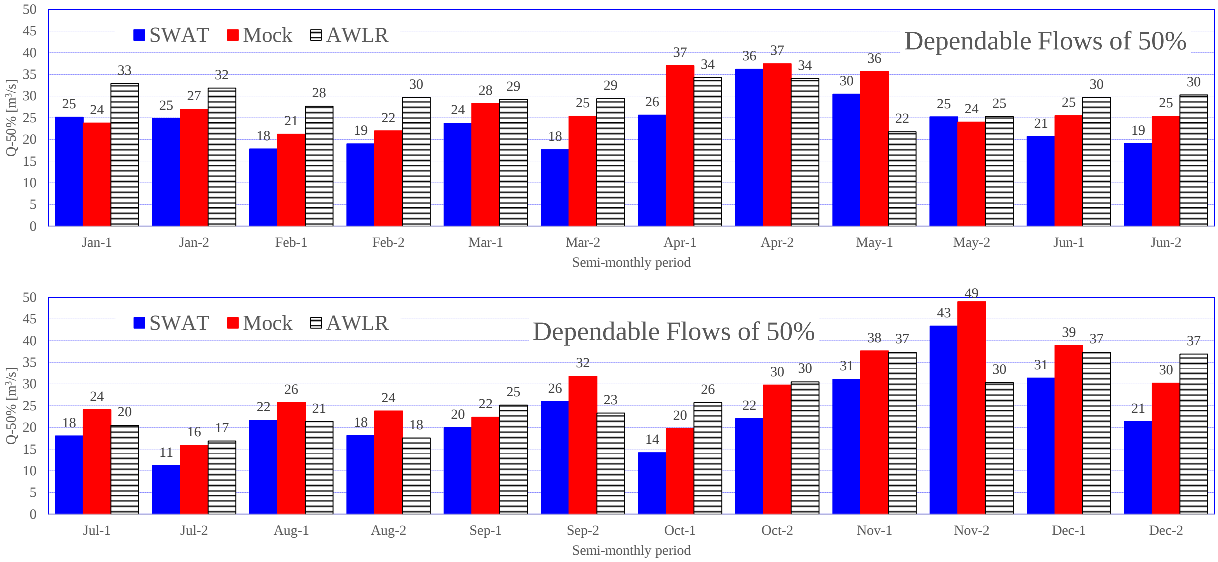

Figure 4. The dependable flows of 50% are obtained from the SWAT model, the Mock method, and the AWLR data.

3.4. Dependable Streamflow of 80%

The 80% dependable streamflow is usually used for irrigating rice plants (Soemarto, 1999; KPU, 2013). Figure 5 shows the comparison of the 80% dependable flows of the Anai-weir catchment obtained from the SWAT model, the Mock method, and the AWLR data. It is difficult to see the trend of the results of these three methods. Only 9 semi-monthly periods (Jan-1, both halves of March, both halves of June, Jul-1, Sep-1, Oct-1, and Dec-1) have the same trend, namely, the SWAT model results are the smallest, the Mock method results are slightly larger than those of the SWAT model, and the AWLR data are the largest.

3.5. Average Streamflow

All maximum semi-monthly average-daily flows from each method are then averaged from Jan-1 to Dec-2. The average is also applied to the minimum semi-monthly average-daily flows, the dependable flows of 50%, and the dependable flows of 80%. Figure 6 shows the comparison of the average flows of the Anai-weir catchment obtained from the SWAT model, the Mock method, and the AWLR data. All semi-monthly periods have the same tendency, namely, the results of the SWAT model are always the smallest, the AWLR data are always the highest, and the results of the Mock method are always in between.

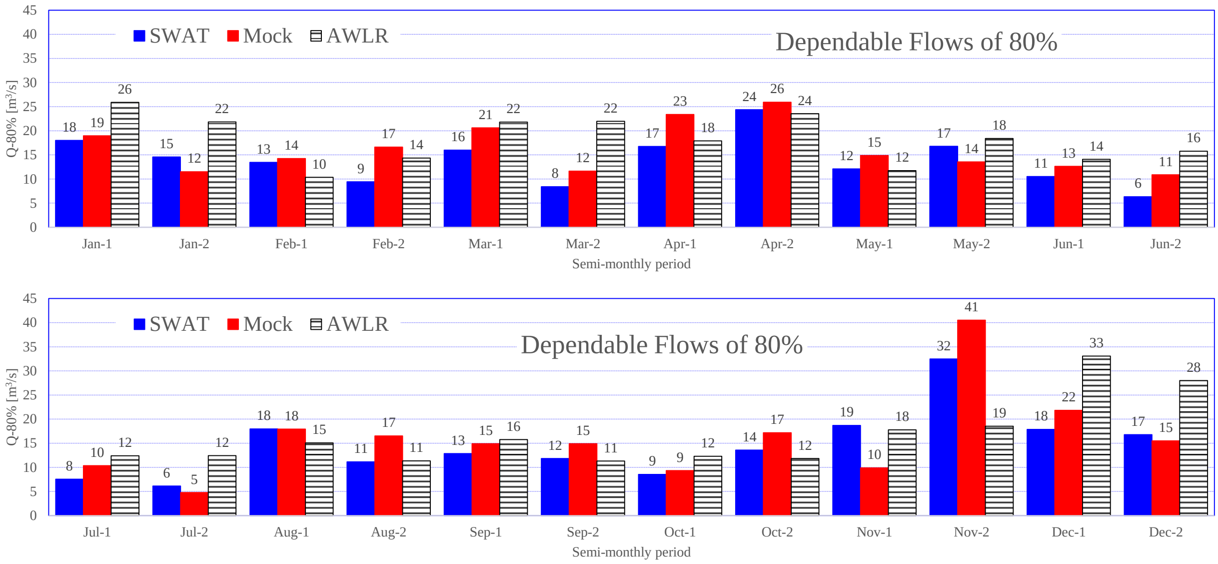

Figure 5. The dependable flows of 80% are obtained from the SWAT model, Mock method, and AWLR data.

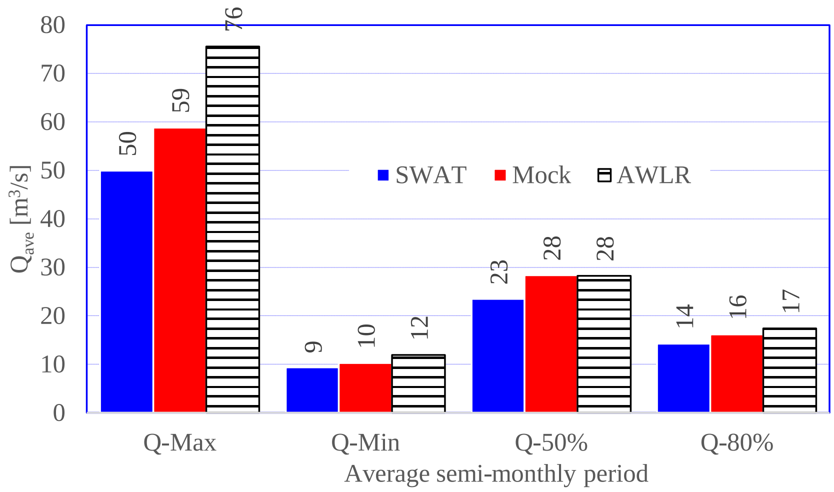

Figure 6. Average streamflow

4. Conclusions

All the average semi-monthly average-daily flows produced by these three methods give almost the same values with the same trend except for the average maximum semi-monthly average-daily flows. The SWAT model gives slightly smaller averages, AWLR data gives slightly larger averages, and the Mock method gives averages in between. If the AWLR data are considered the most correct, then the Mock method is more recommended than the SWAT model to predict the daily streamflow of the Anai-weir catchment. The SWAT model considers more variables compared to the Mock model in estimating the streamflow of a river. Logically, the SWAT model should be more accurate than the Mock model. The accuracy of the results of a rainfall-runoff model is measured based on the closeness of the results to the AWLR data. For future research, it is highly recommended to calibrate the AWLR data in West Sumatra, especially at Anai weir.

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