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Konversi Data Hujan Harian ke Jam-Jaman Berdasarkan Data GPM untuk Pemodelan Banjir di Kuranji

GPM-based Conversion of Daily to Hourly Rainfall Data for Flood Modelling in Kuranji

Jose Cristobal[1,2] Doddi Yudianto[1)*] Qiaoling Li[2] Albert Wicaksono[1]
[1] Faculty of Civil Engineering, Parahyangan Catholic University
Ciumbuleuit 94, Bandung, Indonesia 40141
[2] College of Hydrology and Water Resources, Hohai University
Xikang Road No. 1, Gulou District, Nanjing, China 210098
**Corresponding author*: doddi_yd@unpar.ac.id

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Abstract

Tapin District, located in the Kuranji Watershed of South Kalimantan Province, frequently experiences flooding due to heavy rainfall. Flood event simulation can be utilized to generate hourly discharge data for flood early warning systems, addressing the absence of observed hourly discharge data from the Kuranji Automatic Water Level Recorder (AWLR). Moreover, limited watershed parameters and the unavailability of hourly rainfall data pose challenges in developing a hydrological model for the Kuranji Catchment. To overcome this issue, the hourly rainfall distribution pattern from 10 Global Precipitation Measurement Mission (GPM) Satellite grids were used to convert daily rainfall observations recorded at the Talaga Langsat, Lok Paikat, and Tapin Utara rainfall stations Hourly rainfall data from each GPM grid were matched with several synthetic hourly rainfall distribution patterns. The chosen distribution pattern was subsequently applied to simulate flood events using the HEC-HMS model. Two flood events, dated 4–7 March 2017 and 21–23 March 2018, were used for trial fitting to estimate catchment parameters. Simulated hourly discharges were compared with daily discharge data from the AWLR at Kuranji station, using Total Relative Volume Error (TRVE) and Root Mean Square Error (RMSE) as performance indicators. The simulation results demonstrate that daily-to-hourly rainfall conversion is applicable for estimating catchment parameters, with average TRVE and RMSE values of 1.955% and 7.025 m^3/s, respectively. Furthermore, the trial fitting results indicate that the simulated discharge values align well with observed peak daily discharge data. Acquiring and incorporating hourly discharge data would enhance the accuracy of daily-to-hourly rainfall conversion by synchronizing the temporal resolution. Additionally, incorporating more flood events into trial fitting tests could produce more robust and representative outcomes.

Keywords: *Trial fitting test; estimated catchment parameters; hourly flood discharge modelling; daily rainfall conversion; HEC-HMS*

Abstrak

Kabupaten Tapin, yang berada di Daerah Aliran Sungai (DAS) Kuranji, Provinsi Kalimantan Selatan, sering mengalami banjir akibat curah hujan yang tinggi. Simulasi kejadian banjir dapat dimanfaatkan untuk memperoleh data debit simulasi jam-jaman sebagai bagian dari sistem peringatan dini, mengingat keterbatasan data debit teramati per jam di AWLR Kuranji. Keterbatasan parameter DAS dan minimnya data curah hujan per jam menjadi tantangan dalam pengembangan model hidrologi di DAS Kuranji. Untuk mengatasi masalah ini, pola distribusi curah hujan per jam dari 10 grid Satelit Global Precipitation Measurement Mission (GPM) digunakan untuk mengonversi data curah hujan harian yang tercatat di stasiun hujan Talaga Langsat, Lok Paikat, dan Tapin Utara. Data curah hujan per jam dari setiap grid GPM dicocokkan dengan berbagai pola distribusi curah hujan sintetis. Pola distribusi terpilih kemudian digunakan untuk mensimulasikan kejadian banjir menggunakan model HEC-HMS. Dua kejadian banjir, yaitu pada 4-7 Maret 2017 dan 21-23 Maret 2018, digunakan untuk uji pencocokan parameter DAS. Debit simulasi per jam dibandingkan dengan data debit harian dari AWLR Kuranji, menggunakan Total Relative Volume Error (TRVE) dan Root Mean Square Error (RMSE) sebagai indikator kinerja. Hasil simulasi menunjukkan bahwa konversi curah hujan harian ke per jam dapat digunakan untuk mengestimasi parameter DAS, dengan nilai rata-rata TRVE sebesar 1,955% dan RMSE sebesar 7,025 m^3/s. Selain itu, hasil uji pencocokan menunjukkan bahwa nilai debit simulasi mampu mendekati nilai puncak debit harian. Pemanfaatan data debit per jam akan meningkatkan akurasi dalam konversi curah hujan harian ke format jam-jaman. Di samping itu, pemodelan lebih banyak kejadian banjir dapat memberikan hasil yang lebih andal dan representatif.

Kata Kunci: *Uji pencocokan; pendekatan parameter DAS; pemodelan debit banjir jam-jaman; konversi hujan harian; HEC-HMS*

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INTRODUCTION

Rainfall is a crucial component of the hydrologic cycle, as it is the primary source of runoff and river discharge in a catchment area through various hydrological processes, which also depend on the catchment's characteristics (Sheth, 2018; Joshi, et al., 2019). Climate factors influencing this process include the relationship between precipitation and evapotranspiration, and atmospheric factors including temperature, humidity, and radiation. On the other hand, physical geographic factors such as land slope, land use, and soil type influence water losses within a catchment area. When a catchment's storage capacity (both surface and groundwater) is insufficient to accommodate high-intensity or long-duration rainfall, excess runoff may lead to flooding (Dingman, 1994). The Central Bureau of Statistics of Indonesia recorded a total of 286 flood events from 2012 to 2019 in South Kalimantan Province due to high-intensity rainfall (Pratama, et al., 2021; Azmie & Helda, 2021).

To mitigate flood disasters, early warning systems are required to provide alerts before flood events occur, thereby enabling mitigation efforts. One of the critical components of an early warning system is observed flood discharge data. In Indonesia, information regarding observed flood discharge data is often lacking or incomplete in certain areas. An alternative approach to overcome this difficulty is through rainfall–runoff modelling to obtain the simulated discharge of the catchment. This can be achieved by calibrating the catchment parameters and comparing the simulated discharge based on the rainfall data with the available discharge data. For example, a study in Indonesia applied rainfall–runoff simulation to estimate flood discharge in the Benanain River, which informed flood control design (Bunganaen, et al., 2021). Similarly, Ramly and Tahir (2016) successfully applied HEC-GeoHMS and HEC-HMS to simulate rainfall-runoff processes for flood modelling in the upper Klang-Ampang River Basin in Malaysia. Another study in 2021 utilized HEC-HMS and HEC-RAS to simulate and model the rainfall-runoff of the Tabuk watershed in Saudi Arabia to assess its flood hazard (Alsubeai & Burckhard, 2021). These studies demonstrate that simulation of rainfall-runoff processes in a particular catchment is the basis for flood discharge estimation.

In addition to the lack of flood discharge data, rainfall data scarcity is also a major problem in Indonesia which hampers rainfall–runoff modelling for flood estimation. Rain gauge data in Indonesia are mostly limited, only providing daily data, and they are also incomplete which causes difficulty in doing further hydrology analysis (Ramadhan, et al., 2022). Various studies around the world have shown that application of satellite-based products has yielded promising results for rainfall-runoff processes simulation (Gebere, et al., 2015; Najmaddin, et al., 2017; Parisouj, et al., 2021). One strategy to address this challenge is by using the hourly rainfall distribution pattern from the GPM Satellite to convert daily rainfall from rainfall stations into hourly rainfall data for flood event simulation in the Kuranji Catchment. The GPM Satellite was selected for its ability to record half-hourly rainfall with high reliability and significantly less missing data. Studies have indicated that GPM Satellite data are strongly related to observed rainfall data and the hourly GPM rainfall data are able to yield highly accurate hydrological modelling results (Pakoksung & Takagi, 2016; Cho, 2023).

Kuranji Catchment is considered to be an ungauged catchment as there are only five rainfall stations around the catchment that are located outside of Kuranji Catchment, and they record incomplete daily rainfall data. In addition, the Kuranji AWLR (Automatic Water Level Recorder) only records daily discharge data with no access to the rating curve of the AWLR as further discussed in the Methodology. These issues have become problems in developing a rainfall-runoff model for early warning system in Kuranji Catchment that frequently experiences flooding since early release warning system requires hourly discharge data.

Thus, the main objective of this study is to evaluate the daily-to-hourly conversion using GPM satellite-based data through trial tests, to estimate the catchment parameters in the Kuranji Catchment's HEC-HMS model, and to obtain the simulated hourly discharge of Kuranji Catchment using the data available. Trial tests were conducted using converted daily-to-hourly rainfall data during two flood events, and the resulting simulated discharge was compared to daily discharge data from the Kuranji AWLR to evaluate performance. These trial tests were evaluated using two objective functions, namely the Total Relative Volume Error (TRVE) and Root-Mean Square Error (RMSE). Furthermore, this study aims to verify the ability of the HEC-HMS model to simulate flood events in ungauged basins with limited hourly rainfall and discharge data, as the case in Kuranji Watershed, where all rainfall stations are located outside the catchment and provide only incomplete daily rainfall records. HEC-HMS simulates the rainfall-runoff process by dividing it into four interrelated sub-models: runoff-volume, direct runoff, baseflow, and routing, each with selectable methods. In this study, the SCS Curve Number, SCS Unit Hydrograph, and Recession Methods are used to model runoff in the Kuranji Catchment as further discussed in the Methodology section.

METHODOLOGY

Study Area

Tapin District is one area in South Kalimantan Province that frequently experiences flooding due to heavy rainfall from the upstream area (Nugroho, 2013; Halmien, 2014; Health Crisis Center, 2020; Supriatin, 2022). It is located downstream of Tapin River in the Kuranji Watershed and comprises multiple sub-catchments, including the Tapin Catchment Area Watershed. The Tapin River spans 38 km and drains a catchment area of 288.7 km^2, terminating at the Kuranji AWLR, which is geographically located at 02° 57' 34" S, 115° 09' 06" E (Kamila, et al., 2022).

The surrounding area consists mainly agricultural land and residential settlements. Local news outlets have reported numerous flood events in Tapin District since 2013 until 2022 that inundated and affected residential areas, including hundreds of houses and schools, with water level between 10-80 cm (Nugroho, 2013; Halmien, 2014; Health Crisis Center, 2020; Supriatin, 2022). Additionally, the Indonesian Ministry of Tourism and Creative Economy recorded 23 flood events that occurred in the Kuranji Catchment between 2005 and 2019 (Indonesian Ministry of Tourism and Creative Economy, accessed April 2023).

Data

Before modelling the flood events using HEC-HMS, the flood events were selected by analyzing daily rainfall data from rainfall stations and daily discharge data recorded by the Kuranji AWLR. Flood events were confirmed when there was a correlation between high rainfall and high discharge data. Two flood events were selected for modelling in this study using HEC-HMS: 4–7 March 2017 and 21–23 March 2018. The two events are selected because they are the only events for which all three rainfall stations—Talaga Langsat, Lok Paikat, and Tapin Utara—recorded high daily rainfall. In addition, the location of these three rainfall stations is spatially distributed throughout the Kuranji Catchment which will allow regional rainfall analysis to be implemented in the rainfall analysis process. These events were used for trial fitting tests.

In order to model a flood event, it is recommended to utilize hourly rainfall data as it yields significantly improved rainfall-runoff simulations (Ficchì, et al., 2016). Moreover, due to the small area and steep slopes of the Kuranji Watershed, its concentration time is less than one day. For these reasons, the modelling of the selected flood events will be carried out using hourly rainfall data. However, no hourly rainfall data were available from the stations; only daily data were recorded. One strategy to address this issue is by utilizing hourly GPM satellite rainfall data to derive the hourly rainfall distribution for each day of the selected flood events. There are 10 GPM grids that covers the Kuranji Catchment as shown in **Figure 6**.

According to JAXA, each GPM Grid has a spatial resolution of 0.1° × 0.1° or approximately 10 km × 10 km, with a temporal resolution up to 30 minutes (JAXA, 2018). The hourly rainfall data of each grid on both selected flood events are fitted towards various synthetic hourly rainfall distribution patterns, such as using Soil Conservation Service (SCS), Huff, and PSA rainfall distribution patterns. The PSA distribution pattern is a guideline standard used in hydrological analyses to distribute daily rainfall data into hourly intervals that is developed by the Ministry of Public Works in 1984. These synthetic hourly distribution patterns are dimensionless rainfall time distribution, consisting of coefficients that transform daily rainfall into hourly hyetographs. After the hourly distribution pattern of the GPM hourly rainfall have been selected, it will be applied to convert daily rainfall from the stations into hourly data by multiplying the pattern coefficients with the daily rainfall, producing hourly hyetographs. Subsequently, the Thiessen Polygon method was used to compute the regional from the available stations.

The Kuranji Automatic Water Level Recorder (AWLR) is used in this study as it provides daily discharge data for the Kuranji Catchment at its downstream end. The AWLR recorded daily discharge from **1 January 2001 to 31 December 2018**, spanning a period of **19 years**. Observed daily discharge is derived by converting hourly water level data into a **time-weighted mean**, which is then translated into discharge using the **rating curve equation** developed for this station (Indonesian Water Resources and Construction Education and Training Center, 2017). However, essential data such as the rating curve and raw water level measurements were not accessible, so only daily discharge data were used. Due to this issue, more in-depth evaluation of the AWLR data could not be conducted. The maximum daily discharge recorded was 194.3 m^3/s on 13 March 2014, and the average daily discharge was 13.157 m^3/s. **Figure 1** below shows the discharge recorded at Kuranji AWLR.

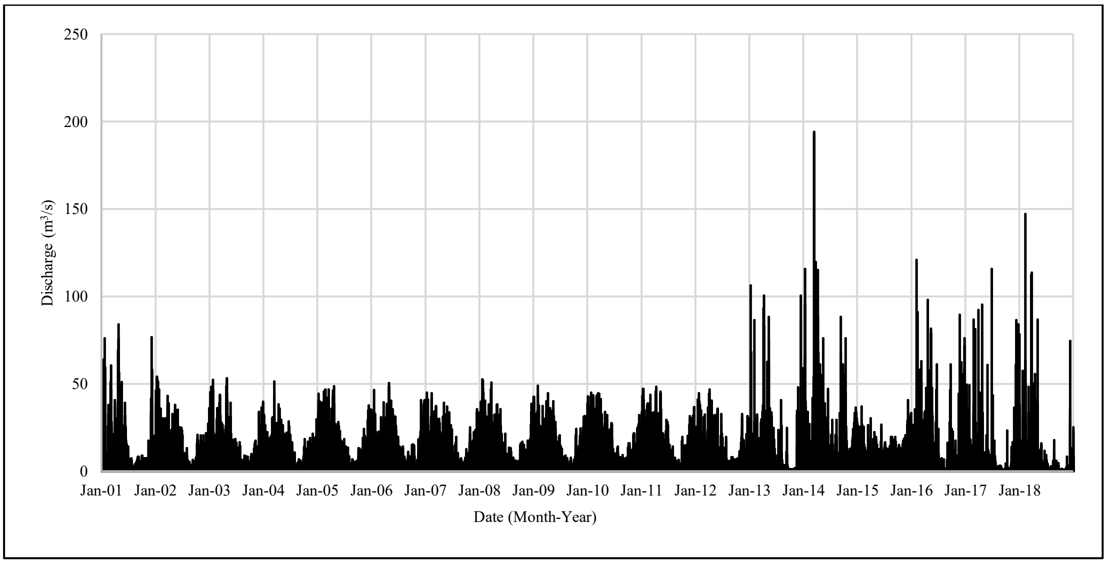

Figure 1 Daily Discharge Data of Kuranji AWLR

Rainfall Runoff Model

There are various rainfall-runoff models that have been developed by various researchers around the world, and the Hydrologic Engineering Center–Hydrologic Modeling System (HEC-HMS), developed by the United States Army of Engineers – Hydrologic Engineering Center (USACE-HEC), is one of the most widely used. As of 2022, HEC-HMS has been applied in over 180 peer-reviewed studies to simulate rainfall–runoff processes in various watersheds in Indonesia due to its flexibility in integrating multiple methods and modular structure (Ikhwali, et al., 2022). For this reason, HEC-HMS is selected to be implemented in this study. HEC-HMS is a deterministic, catchment-scale hydrological model that can be configured as an empirical or conceptual model (Scharffenberg, 2013). It simulates the rainfall–runoff process by dividing the watershed into four interconnected sub-models: runoff-volume, direct runoff, baseflow, and routing (Feldman, 2000; Sarminingsih, et al., 2019). Each sub-model provides multiple method options, allowing the user to choose according to the watershed characteristics.

In this study, the methods selected for each sub-model include:

- SCS Curve Number for the Loss (Runoff-Volume) model,
- SCS Unit Hydrograph (SCS UH) for the Transform (Direct Runoff) model,
- Recession method for the Baseflow model,
- and Muskingum-Cunge Standard Section for the Routing model.

Table 1 below presents the selected methods and their associated parameters:

Table 1 Methods and Parameters for HEC-HMS model of Kuranji Catchment

Sub-Model	Method	Parameters
Runoff-Volume	SCS Curve Number (CN)	Initial Abstraction (I_a) Curve Number (CN)
Direct Runoff	SCS UH	Lag Time
Baseflow	Recession	Initial Discharge Recession Constant Ratio to Peak
Routing	Muskingum-Cunge Standard Section	Channel Length Channel Geometry Manning Slope

As shown in Table 1, some parameters were derived from the Digital Elevation Model (DEM) data, while others were estimated. Curve Number (CN) and all routing-related parameters (Channel Length, Channel Geometry, Manning, and Slope) were obtained from DEM analysis. The remaining parameters—Initial Abstraction, Lag Time, Initial Discharge, Recession Constant, and Ratio to Peak—were estimated. To provide context for these estimated parameters, their physical meanings and typical value ranges are listed in **Table 2**. The flowchart of this study is shown in **Figure 2**.

Table 2 Physical Meaning and Value Range of the Estimated Parameters (Feldman, 2000)

Parameters	Physical Meaning	Value range
Initial Abstraction	The amount of precipitation that must fall before surface excess results (initial loss)	Varies depending land covers, soil types, and vegetation
Lag Time	The time difference between the peak of a rainfall event and the corresponding peak of the resulting hydrograph	0.1 - 24 hours
Recession Constant	The rate which baseflow recedes between storm events	0.1 - 0.9
Ratio to Peak	The value which baseflow resets based on the peak discharge value	0.1 - 0.9

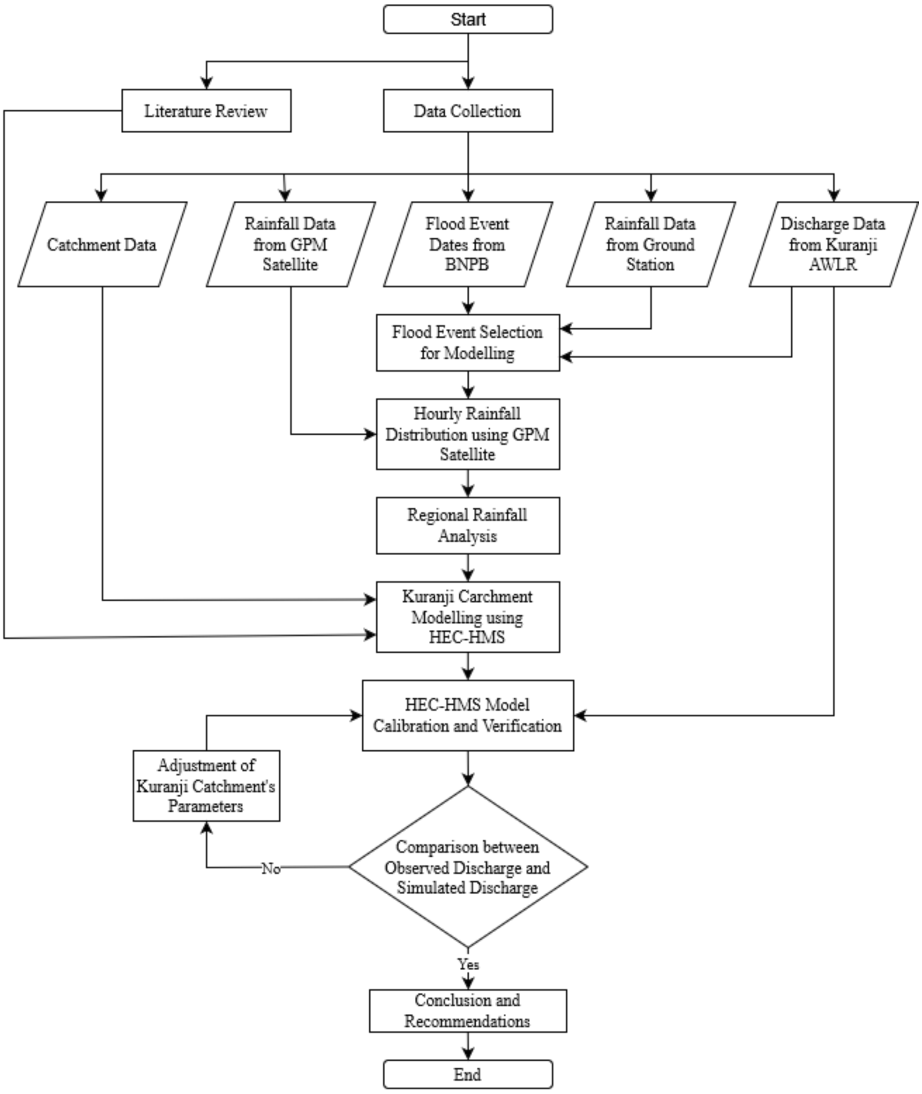

Figure 2 Research Flowchart

The upstream region of the Kuranji Catchment consists of mountainous terrain with steep slopes, while the slope gradually decreases downstream. **Figures 3** and **4** illustrate the slope and topography of the Kuranji Catchment.

According to a study conducted by the Indonesian Ministry of Public Works (2022), the majority of land use in Kuranji Catchment comprises shrubs (51.92%), forests (21.69%), and plantation areas (12.43%), with the Hydrologic Soil Groups classified as Class C and D.

Each sub-catchment has its own Curve Number (CN), previously calculated using ArcGIS in the same 2022 study. According to Feldman (2000), the Curve Number values for forest, shrub, and plantation land uses in Soil Group C and D generally range from 70 to 84. The land use map of Kuranji Catchment is shown in **Figure 5**, where:

- Dark green represents forest,
- Light green represents shrub, and
- Pale green represents plantation.

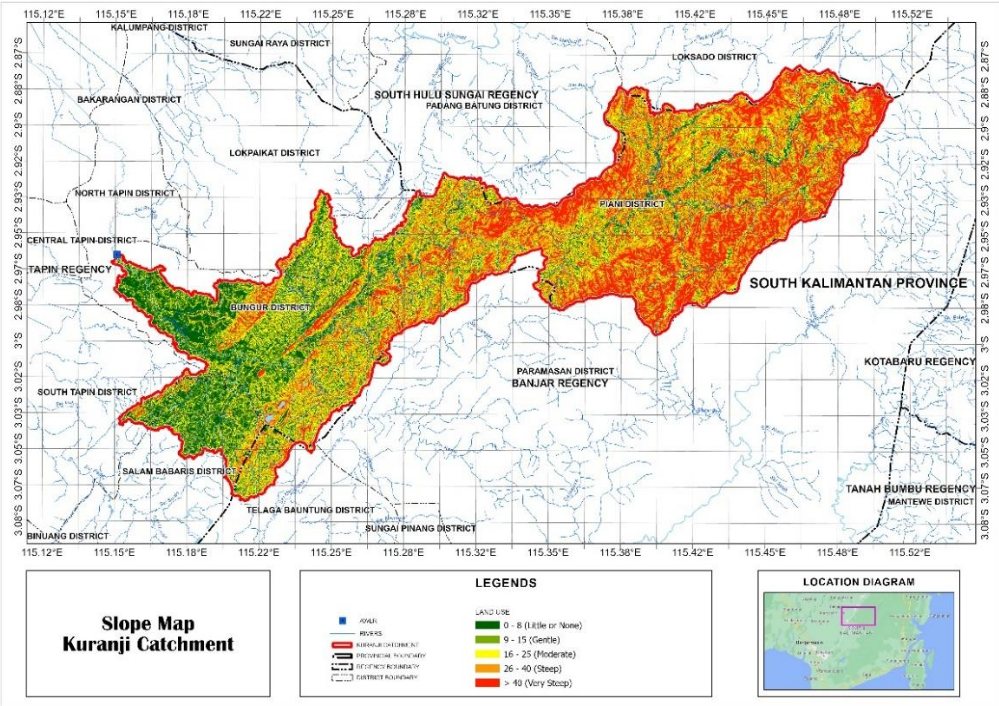

Figure 3 Slope Map of Kuranji Catchment

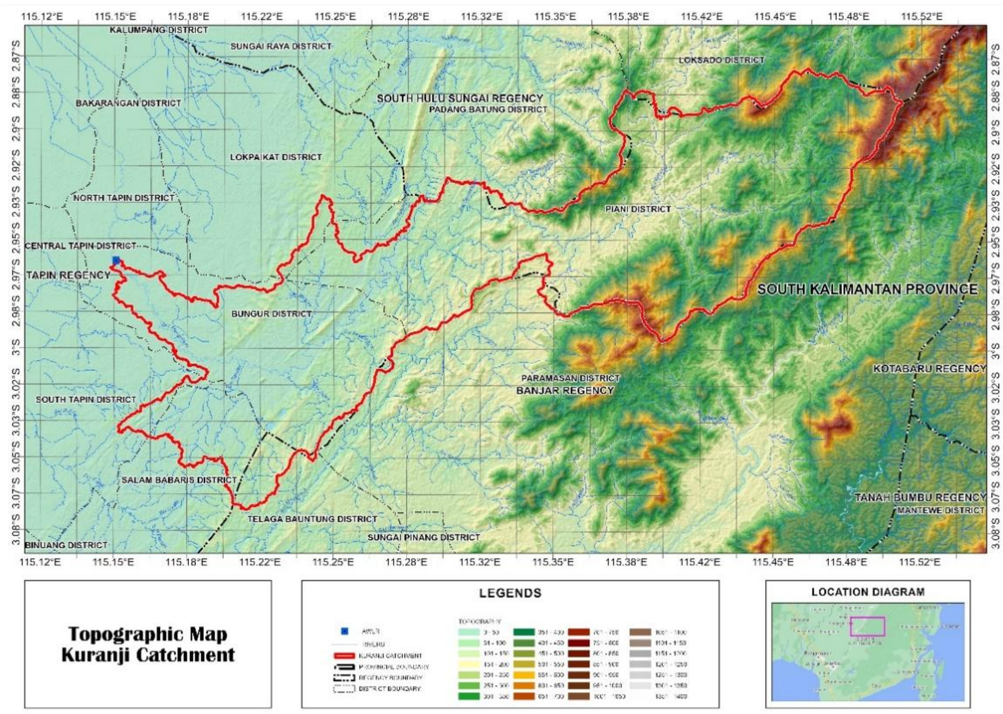

Figure 4 Topography Map of Kuranji Catchment

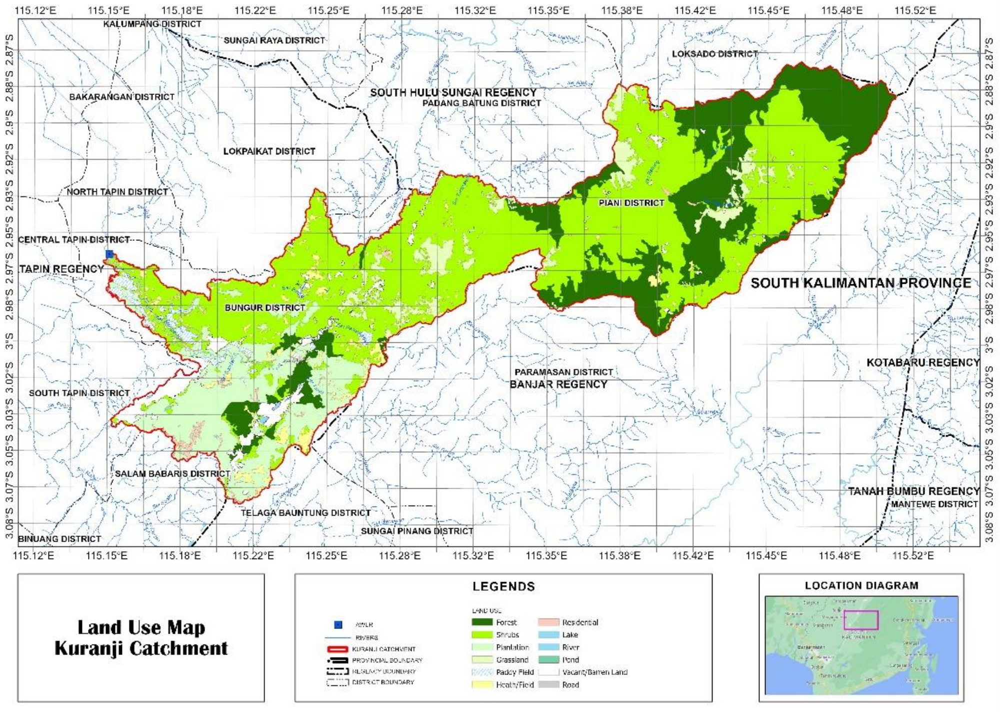

Figure 5 Land Use Map of Kuranji Catchment

Rainfall Analysis

Daily rainfall of Kuranji Catchment is recorded by several ground rainfall stations. There are five rainfall stations located within and surrounding the Kuranji Catchment that record daily rainfall data: Tapin Utara, Miawa, Talaga Langsat, Binuang, and Lok Paikat Rainfall Stations. Aside from these stations, the Kuranji Catchment also includes 10 grids of NASA's Global Precipitation Measurement (GPM) Satellite, which will be used to determine hourly rainfall distribution. This will be discussed further in the next sub-section.

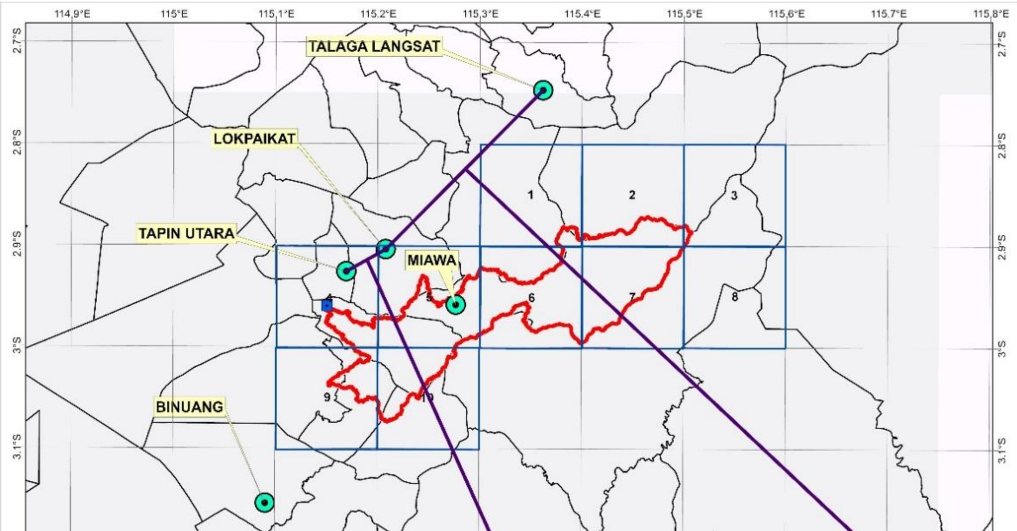

Figure 6 Location of rainfall Stations, GPM Grids, and Thiessen Polygon of Kuranji Catchment

As shown in **Figure 6**, the Binuang Rainfall Station is located outside the Kuranji Catchment and has less than 10 years of rainfall data with a significant amount of missing values. Therefore, it will be excluded from further analysis. Talaga Langsat Station, although located outside the catchment, is retained because it is the only station representing the upstream region of the Kuranji Catchment. Conversely, the downstream region is better represented by the Tapin Utara Station. Three remaining rainfall stations record daily rainfall with varying durations of data availability. **Table 3** below summarizes the data availability for each station and the GPM Satellite:

Table 3 Data Availability of Ground Rainfall Stations and GPM Satellite for Kuranji Catchment

Rainfall Recorder	Recorded Data Years	Total Data (year)	Coordinates
Talaga Langsat	1986 – 2005 2016 – 2022	27	02°44'6.7" S 115°20'15" E
Miawa	1986 – 2005	20	02°56'30" S 115°14'0" E
Tapin Utara	2001 – 2020	20	02°55'33" S 115°10'10.5" E
Lok Paikat	2011 – 2020	10	02°46'30" S 115°12'30" E
Binuang	2011 – 2020	10	03°09'0" S 115°01'30" E
GPM Satellite	2000 – 2021	22	-

According to the Indonesian Ministry of Public Works (PUPR, 2017), hydrological analysis in Indonesia must be based on a minimum of 20 years of rainfall data to ensure robustness and reliability. As seen in Table 3, Lok Paikat Station only has 10 years of data, and therefore does not meet the PUPR standard. Despite this, Lok Paikat will still be included because the study will convert daily rainfall into hourly rainfall for simulating specific flood events. The HEC-HMS model will use event-based hourly rainfall inputs, making long-term continuous data less critical for this specific application. Table 3 also shows that the GPM Satellite has provided rainfall data for 22 years (2000–2021), which demonstrates temporal alignment with the rainfall station records. This similarity allows the use of GPM's hourly data to derive hourly rainfall distribution for converting daily rainfall into hourly values — a process that will be explained in the following section.

To calculate regional rainfall for selected flood events, the Thiessen Polygon method was used, incorporating data from Talaga Langsat, Tapin Utara, and Lok Paikat stations. These three stations form an obtuse triangle, dividing the Kuranji Catchment into three sub-areas with coverage of 89.976 km^2, 124.153 km^2, and 74.571 km^2, respectively. The weighted average rainfall based on these Thiessen areas is used to compute the event-based hourly rainfall input for the HEC-HMS model.

RESULT AND DISCUSSION

Result

The HEC-HMS model of the Kuranji Catchment is created using Digital Elevation Model (DEM) data obtained from a research conducted by the Indonesia Ministry of Public Works (PUPR) in 2022. The DEM data was obtained from NASA's Shuttle Radar Topography Mission (SRTM) and has already been processed using GIS by the Indonesia Ministry of Public Works (PUPR) into a ".shp" file format, which is compatible with the HEC-HMS software. The Kuranji Catchment has a catchment area of 288.7 km^2 and is divided into 49 sub-catchments based on tributary streams. The HEC-HMS scheme of the Kuranji Catchment as shown in **Figure 7** below will be used to model the flood events that occurred on 4-7 March 2017 and 21-23 March 2018.

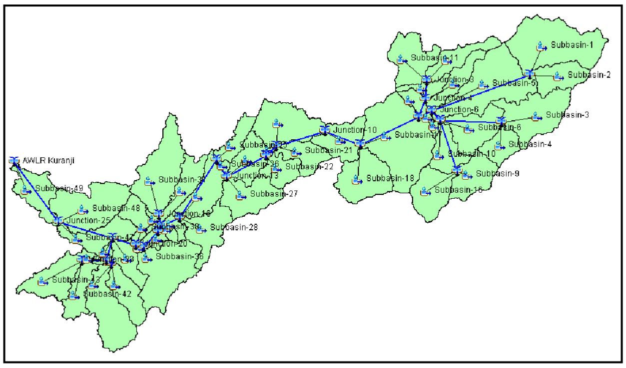

Figure 7 HEC-HMS Model Scheme of the Kuranji Catchment

The GPM hourly rainfall distribution patterns of each day are compared independently with the three synthetic hourly rainfall distribution patterns mentioned. The synthetic hourly rainfall distribution pattern is selected based on the cumulative rainfall distribution curve shape of each day, prioritizing the initial and early shape of the curve. The daily cumulative rainfall distribution curve for the flood events on 4-7 March 2017 and 21-23 March 2018 is shown in **Figure 8** below.

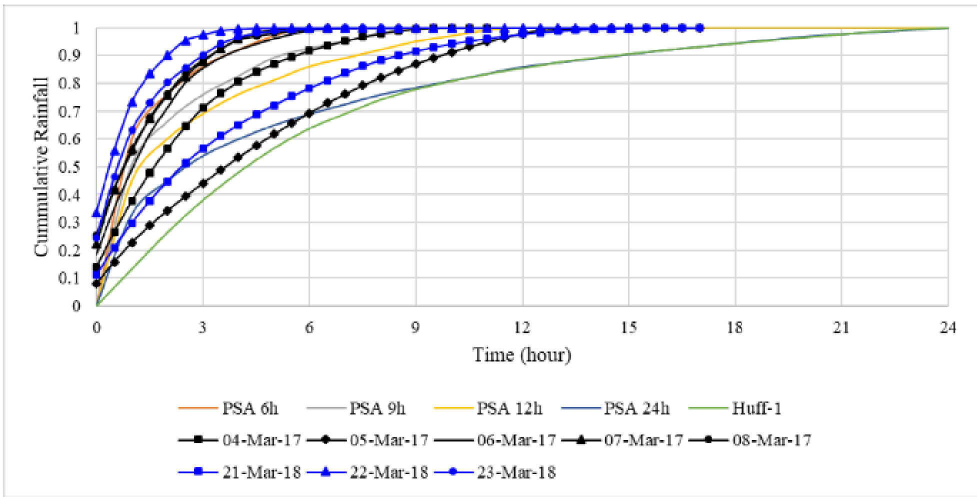

Figure 8 Cumulative Rainfall Distribution Curve of Selected Flood Events

Table 4 Selected Synthetic Hourly Rainfall Distribution Patterns

Date	Synthetic Hourly Rainfall Distribution Pattern
4 March 2017	PSA 12h
5 March 2017	Huff 1
6 March 2017	PSA 6h
7 March 2017	PSA 6h
21 March 2018	PSA 24h
22 March 2018	PSA 6h
23 March 2018	PSA 6h

Based on the various shapes of the cumulative rainfall duration curve shown in **Figure 8** above, the synthetic hourly rainfall distribution pattern selected to convert daily-to-hourly rainfall data from rainfall stations are shown in **Table 4.** From **Table 4**, it can be seen that the PSA distribution pattern was selected six times, while the Huff distribution was applied once (on 5 March 2017). The selection of synthetic rainfall distribution pattern is based on the shape of the duration curve. The curve duration of average hourly GPM rainfall is fitted towards the synthetic hourly rainfall distribution pattern, while prioritizing the initial and early rainfall pattern. Since rainfall patterns vary daily, the cumulative duration curve for each day also differs accordingly.

Based on the distribution pattern shown in Table 4, the daily-to-hourly conversion results from Talaga Langsat, Lok Paikat, and Tapin Utara rainfall stations during 4-7 March 2017 and 21-23 March 2018 are presented in **Figure 9** and **Figure 10**, respectively.

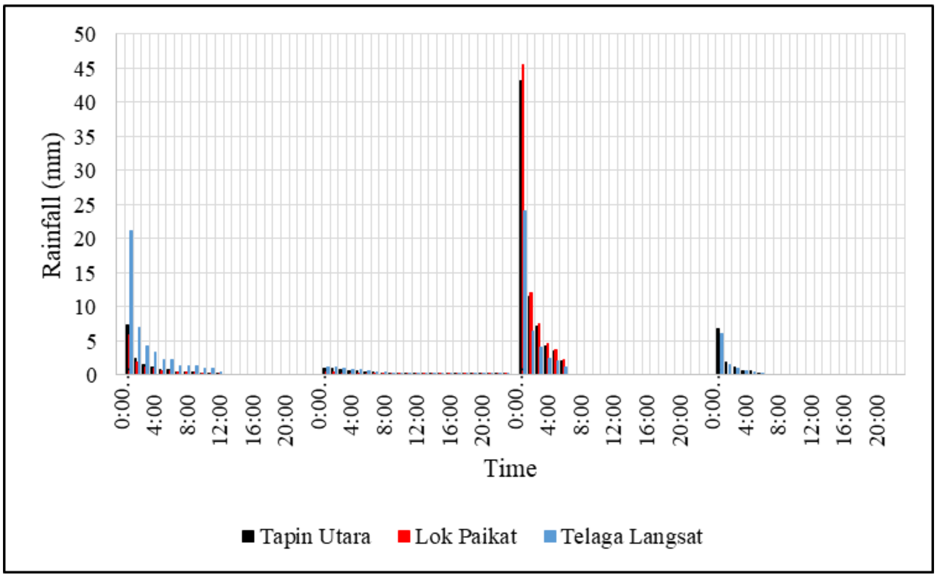

Figure 9 Hourly Rainfall Distribution Result of 4-7 March 2017

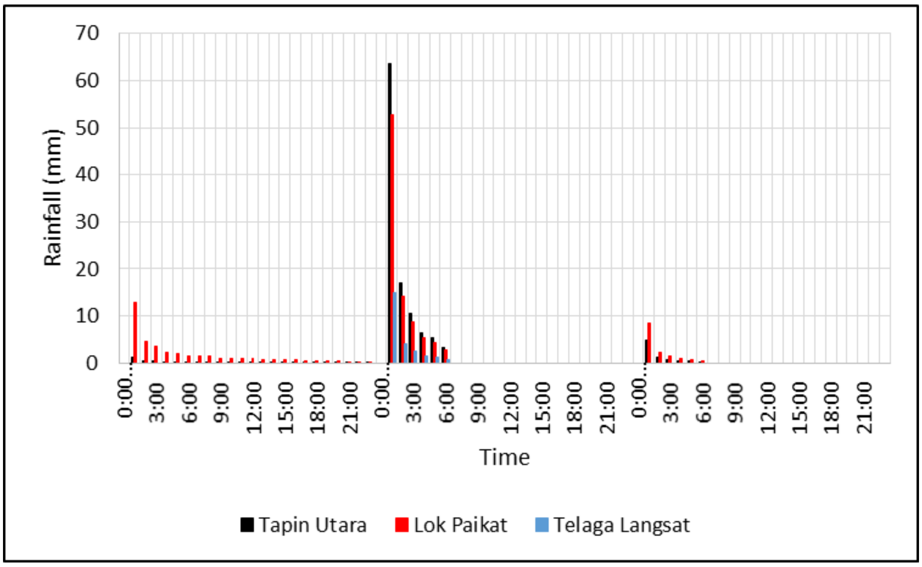

Figure 10 Hourly Rainfall Distribution Result of 21-23 March 2018

In order to confirm that the results shown in **Figure 9** and **Figure 10** above are suitable for flood modeling, the selected distribution pattern was then implemented in the rainfall-runoff modelling of the Kuranji Catchment. In order to confirm whether the trial fitting test results are correct, two objective functions are selected, namely the Total Relative Volume Error (TRVE) and Root-Mean Square Error (RMSE). The two objective functions are selected because the observed and simulated discharges have different temporal dimensions, where the observed discharge is recorded in a daily time step, while the simulated discharge is simulated hourly.

The parameter result summary used in the trial fitting test of the 4-7 March 2017 flood event is shown in **Table 5**, showing the lowest, average, and highest values from all 49 sub-catchments of the Kuranji Catchment.

Table 5 Estimated Kuranji Catchment Parameter Implemented for Trial Fitting Test

Parameter	Lowest Value	Average Value	Highest Value
Initial Abstraction (mm)	36.25	58.91	81.75
Lag time (minutes)	24.12	95.75	259.68
Recession Constant	0.6	0.6	0.6
Ratio to Peak	0.6	0.6	0.6

Results from implementing the estimated HEC-HMS model parameters values in **Table 5** above to the 4-7 March 2017 flood event are illustrated in **Figure 11** below.

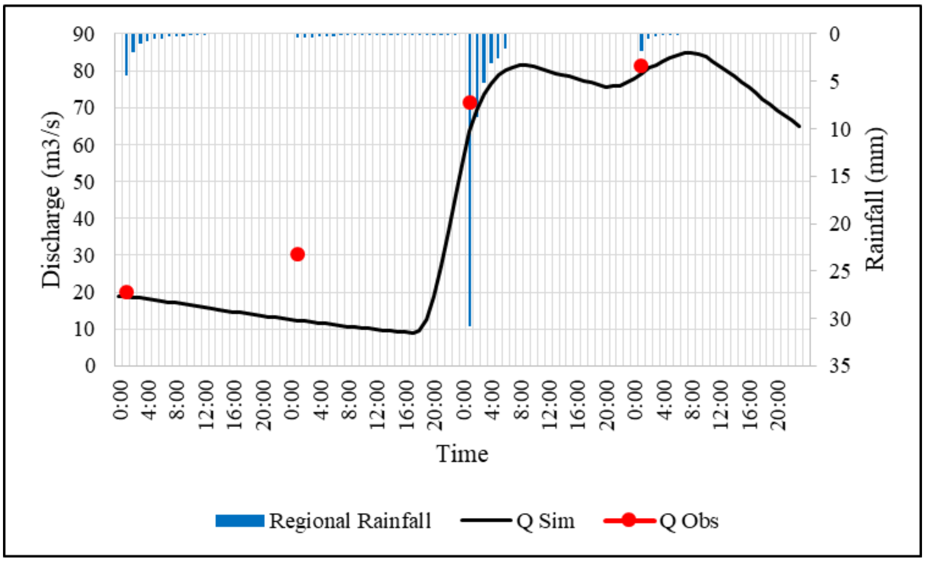

Figure 11 Trial Fitting Test Results of 4-7 March 2017 Flood Events

The trial fitting test results shown in **Figure 11** above yields a TRVE and RMSE value of -4.384% and 4.45 m^3/s respectively. Generally, the acceptable range of TRVE and RMSE is ±5% and ±15 m^3/s. Thus, this trial fitting test of the HEC-HMS model of Kuranji Catchment is considered to be successful for the 4-7 March 2017 flood event because the TRVE and RMSE values fall within.

Afterwards, the second trial fitting test using the 21-23 March 2018 flood event simulation was conducted in order to confirm and verify the previous result and estimated catchment parameter values. The second trial fitting test yields a result as shown in **Figure 12** below.

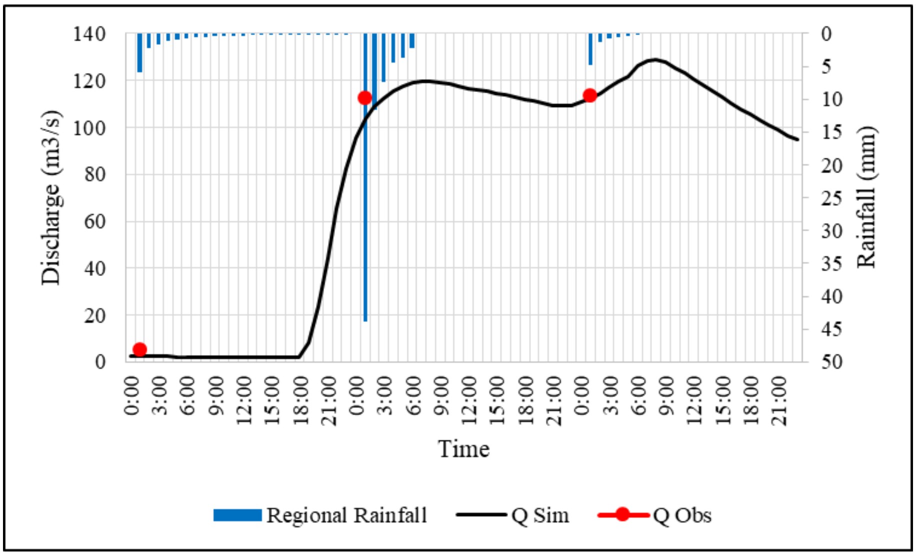

Figure 12 Trial Fitting Test Results of 21-23 March 2018 Flood Event

The verification results shown in **Figure 12** above yields a TRVE and RMSE value of 8.294% and 9.6 m^3/s, respectively. Due to such values, the estimated parameters of the Kuranji Catchment are considered sufficiently representative of the catchment characteristics.

Discussion

The observed discharge data of Kuranji Catchment in **Figures 11** and **12** are mean daily discharge data converted from hourly recorded water level data using a rating curve. The observed discharge data for both flooding events are assumed to start at 00:00 each day due to unknown actual measurement times. Due to this decision, the catchment parameters used are only estimates obtained from trial fitting.

The estimated catchment characteristics obtained from the trial fitting indicate that Kuranji Catchment has an average Initial Abstraction value of 58.91 mm, an average Lag Time of 95.75 minutes, and Ratio to Peak and Recession Constant of 0.6.

Based on the hourly hydrograph simulated during both trial fitting tests, the simulated discharges tend to be underestimated. This might happen due to the limitations of the HEC-HMS model, scarcity of rainfall and discharge data, and sensitivity of estimated parameters. The HEC-HMS model has limitations in the methods used to simulate the two events. As HEC-HMS is a hydrologic model, its ability to replicate real-world conditions is inherently limited despite using physically-based parameters. These methods include SCS Curve Number Method, SCS Unit Hydrograph Method, and Recession Method. However, each method has limitations that may contribute to underestimation.

In addition to model limitations, underestimation may result from the estimated parameters used. Those catchment parameters were determined through trial-and-error, and small changes in values significantly impacted the simulation results, indicating parameter sensitivity. The high Initial Abstraction parameter values might cause the underestimation of the simulated discharge, with an average value of 58.91 mm. This high value leads to greater rainfall loss before generating runoff, resulting in underestimation during low-flow conditions. Lower values of Initial Abstraction have been tested during trial fitting, but they produced extreme discharge simulations with large errors.

Another factor that might lead to the underestimation is the Lag Time parameter because delayed runoff may accumulate from prior rainfall.

This is plausible since there are 49 sub-catchments in Kuranji Catchment with each sub-catchment having different soil types, areas, stream lengths, Curve Numbers, Initial Abstractions, and Lag Times. As shown in Table 5, the Lag Time across all 49 sub-catchments ranges widely from 24.12 to 259.68 minutes, as determined from trial fitting with minimal error. Underestimation might also occur due to the selected synthetic rainfall distribution patterns used to convert daily rainfall to hourly.

However, even though the parameters and model have limitations, the results show that the model performance is acceptable. The TRVE value for 4-7 March 2017 and 21-23 March 2018 flood events is -4.384% and 8.294%, respectively. In addition, the RMSE obtained for 4-7 March 2017 and 21-23 March 2018 flood events is 4.45 m^3/s and 9.6 m^3/s, respectively. These values are within acceptable limits, confirming the model's reliability. As seen from the results shown in Figures 11 and 12, the estimated parameters reasonably represent the catchment's hydrological response. Also, the objective function results support the use of the selected synthetic hourly rainfall distributions. Thus, the selected synthetic hourly distribution pattern is deemed suitable for the model. With the lack of data in this study, the modelled hourly discharge successfully captured the peak values of observed daily discharges. This indicates that daily-to-hourly rainfall conversion can be considered a viable approach for early warning system development in data-scarce catchments.

CONCLUSIONS

Based on the results obtained from the modelling of the two flood events, the conversion of daily-to-hourly rainfall station data using GPM satellite data can be applied in the Kuranji Catchment. This is confirmed by the objective function values obtained in the study, which are within acceptable limits when compared with observed data. The results also indicate that the estimated catchment parameters from the trial fitting tests are capable of representing the hydrological characteristics of the Kuranji Catchment.

Despite the assumption of placing daily discharge data at 00:00, the simulated discharge values were still able to match the peak daily discharge values during both flood events. It can therefore be concluded that peak discharge values of flood events can be estimated even in data-scarce conditions. This approach may be utilized as an alternative method for flood modeling in support of early warning system development

Although the results are satisfactory, there is still room for improvement based on the limitations identified in this study. One possible enhancement would be the acquisition and use of hourly discharge data, which would allow for a more accurate comparison of simulated and observed discharge within the same temporal resolution. Additionally, modeling more flood events for both calibration and verification purposes would help to improve model reliability and overall performance. Since the ground stations used in this study are located outside the catchment, implementing bias-corrected GPM satellite data might also improve the results. Lastly, the initial soil moisture data will also improve the model accuracy since the Initial Abstraction parameter does not explicitly account for initial soil moisture. By adding the initial soil moisture data, the model will represent the catchment more accurately.

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