Original Article

Integrated Hydrological Modeling for Estimating Peak Discharge in the Tondano Watershed

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Abstract - The Tondano River Basin in North Sulawesi plays an important role in regulating surface runoff to downstream areas, particularly the city of Manado. Increased peak discharge, which can cause risks in downstream areas, is caused by changes in land use and increased variability in rainfall intensity in a watershed. Watersheds are complex river flows, so conventional empirical hydrological analysis is often unable to describe the spatial and temporal diversity of these hydrological processes. This study aims to simulate peak discharge (Qp) using an integrated hydrological modeling approach. Modeling was performed using HEC-HMS, with the Thiessen method using rainfall data from six stations processed to determine the area of influence of each station. This study used the SCS Curve Number (CN) parameter. The six-hour design rainfall was obtained through frequency and hourly distribution analysis. The simulation results show that the peak discharge ranges from 253.2 m³/s (T=2 years) to 415.0 m³/s (T=100 years), which illustrates rapid surface runoff caused by steep topography and low infiltration rates. The results also show that urban growth in the upstream and downstream zones, together with low infiltration capacity, significantly increases the risk of flooding during heavy rains. This model provides a solid basis for estimating peak flood discharge and can be used for flood mitigation planning in the Tondano River Basin. The results of this study emphasize the importance of increasing infiltration rates and managing land use to reduce flooding. Further research is recommended to integrate hydrodynamic models of the estuary.

Keywords - HEC-HMS, Hydrology, Modeling, Peak Discharge, Tondano Watershed.

1. Introduction

Rainwater flows from higher to lower areas, such as estuaries, through a single channel called a river watershed, making it an important hydrological unit. This watershed will eventually form an integrated socioecological system [1, 2]. This system can be used for water storage, flood prevention, groundwater infiltration, and can be utilized in agriculture, urban water supply, and environmental conservation [3, 4]. The way a watershed responds to discharge can be determined by land cover, watershed soil type, contour, and rainfall. These elements directly influence the peak discharge that can occur.

The Tondano river basin is located in North Sulawesi Province, Indonesia, stretching from Lake Tondano to its headwaters at the Manado estuary. This area provides water for agriculture, fisheries, and water needs for more than 500,000 residents living in cities [5]. Although this watershed is very important for economic and social needs, there has been little research conducted on estimating peak discharge values in this watershed. Chen et al. (2022) and Rohmat et al. (2023) focused solely on analyzing flood events and rainfall

patterns; they did not examine the relationships between river watershed characteristics, rainfall variation, soil type, and land use on river flow response [6, 7]. This indicates a research gap in understanding the extent to which surface flow dynamics can be influenced by land use, rainfall, and soil type, as represented by integrated hydrological models that are increasingly important in addressing the apparent climate change. A recent study by author shows that the area most frequently affected by flooding is the city of Manado, which is downstream of the Tondano watershed. Flooding occurs when rainfall intensity exceeds 21.79 mm with cumulative rainfall of more than 52.64 mm. This study proves that rainfall intensity has a direct effect on increasing surface runoff and emphasizes the importance of further research to determine peak discharge (Qp) values. Therefore, analysis of peak flood discharge predictions in the Tondano River Watershed (DAS) needs to be carried out to support science-based disaster risk management strategies.

Conventional hydrological analysis generally still relies on empirical methods with the application of uniform return periods at all rainfall stations. The Tondano watershed is a

complex hydrological system and one of the largest watersheds in existence. This method often fails to describe geographical variations and changes in rainfall intensity and surface runoff response in areas with complex and large hydrological systems. This inaccuracy can lead to less accurate peak discharge analysis and reduce the reliability of hydrological design [8, 9]. Therefore, a more comprehensive and integrated modeling analysis is needed to describe the hydrological processes at the watershed scale, so that the interactions between rainfall, morphological characteristics, land cover conditions, and soil types that contribute to flood formation in downstream areas can be described more clearly. Integrated hydrological modeling is an effective approach to understanding how the dynamics of a watershed's hydrological system work. This approach has advantages such as comprehensive representation of physical processes, accuracy and predictability, as well as flexibility and scalability [10-12].

This study uses Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) as the main software to simulate surface flow formation processes and calculate peak flood discharge (Qp). HEC-HMS is also used to digitally delineate the Tondano river basin based on elevation data (DEM). In this process, sub-basins and drainage networks are also formed. Meanwhile, ArcMap is used to process spatial analyses such as land cover, soil type, and Thiessen polygon analysis to determine the area of influence of each rainfall station used, while Google Earth is used to obtain rainfall station location data in Keyhole Markup Language (.kml) format. This data is then input into ArcMap to be converted into shapefiles and further analyzed spatially. The integration of these three tools enables a more comprehensive and accurate analysis of the hydrological and spatial characteristics of watersheds.

Modeling using HEC-HMS has been actively used in similar tropical river watersheds. Klau et al. (2021) examined the efficacy of the Soil Conservation Service - Curve Number (SCS-CN) method in forecasting peak flood discharge in the Manikin watershed, emphasizing the correlation between precipitation and runoff for water infrastructure planning, specifically the Manikin Dam [13]. Bunganaen et al. (2021) examined the rainfall-runoff process utilizing the HEC-HMS model to elucidate the hydrological dynamics of extensive and flood-prone watersheds [14]. Previews study confirmed the validity of HEC-HMS in the Binjeita watershed for return periods of 25, 50, and 100 years. No one has put together Thiessen weighted rainfall from six stations, 30 m DEM-based sub-watershed delineation, and composite CN mapping of important parts for the diverse Tondano watershed system, though.

In this study, the main observation point (sink point) was placed in the Tondano watershed estuary, which functions as the main outlet point of the flow system. The placement of this point ensures that the entire catchment area, from the upstream area around Lake Tondano to the downstream area that flows into Manado Bay, is fully covered in the modeling process. So, the integrated hydrological model's simulation results can show how the whole watershed reacts to heavy rain events over time and space. It can also make estimates of peak discharge (Qp) in the main channel more accurate. This study aims to develop a hydrological integration model using HEC-HMS, ArcMap, and Google Earth to simulate peak flood discharge (Qp) in the Tondano river basin. This approach combines spatial analysis, integrated hydrological modeling, and calculations with historical observation data to obtain results that represent field conditions. The results of this study are expected to have a direct impact on the scientific development of model-based flood simulation methods in tropical regions, as well as provide a basis for sustainable planning and management of the Tondano watershed.

2. Materials and Methods
2.1. Research Approach

This study uses a quantitative approach and simulation methodology by creating an integrated hydrological model using several software programs. The objective of this study is to model the peak discharge of the Tondano river basin. This model combines rainfall data, land use data, and soil data, which are processed using integrated software. There are five main steps in the modeling process: (1) collecting and processing spatial and hydrometeorological data, (2) analyzing rainfall frequency and intensity, (3) determining hydrological parameters such as Curve Number (CN) and concentration time, (4) simulating rainfall-surface runoff with HEC-HMS, and (5) calibrating and validating the model. Since field discharge data were not available, calibration was performed theoretically (proxy calibration) using reference values and results from similar river basins that had been studied previously.

2.2. Study Area

The research area covers the entire Tondano Lake Watershed, located from the headwaters of Lake Tondano in Minahasa Regency to the mouth of the Tondano River in Manado City, North Sulawesi Province, Indonesia. This watershed is a complex hydrological system, consisting of interconnected upstream, middle, and downstream areas. The upstream part of the watershed is characterised by steep volcanic terrain and functions as the main water reservoir, while the middle part consists of agricultural and mixed land use, and the downstream part is dominated by dense urban settlements in and around Manado City. The Tondano watershed has six influential rain gauge stations, namely the Paleloan Station, Tikala Kaleosan Station, Tikala Rumengkor Station, Tikala Sawangan Station, Noongan Winebetan Station, and Bailang Kayuwatu Station. An image of the Tondano watershed can be seen in Figure 1.

Due to its complex topography and diverse land use conditions, the Tondano watershed is highly sensitive to high rainfall and changes in land use, which significantly increase surface runoff and flood potential, especially in the low-lying coastal areas of Manado.
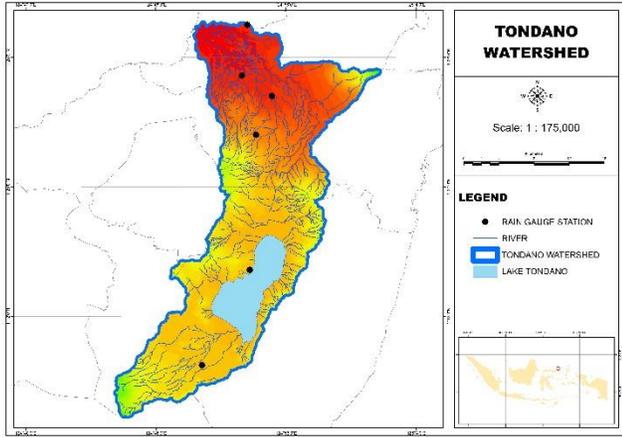

Fig. 1 Tondano Watershed

2.3. Data Collection

This research utilized secondary data from various relevant sources. The Sulawesi I River Basin Agency, which has six major rainfall stations that affect the hydrological conditions in the Tondano watershed, gave the maximum rainfall data. Then, the Thiessen Polygon Method was used on the data from the six rain stations to determine the area of influence of each station, and the maximum rainfall value was taken to be used in the modeling.

The Digital Elevation Model (DEM) was obtained from the Tanah Airku-Geoportal website to determine the flow network and draw river basin lines through delineation performed on HEC-HMS. Land use data was obtained from the Regional VI Forest and Environmental Stabilization Agency, while soil type data was obtained from the Indonesian Geospatial Information Portal website. Using this type of data and a combination of land cover classes and soil hydrology groups (HSG), we calculated the Curve Number (CN) value, which is the basis for calculating water loss parameters in hydrological modeling. Land cover and soil type maps for the Tondano river basin can be seen in Figures 2 and 3.

2.4. Data Analysis

Before hydrological modeling, rainfall data must be checked for consistency, stationarity, and reliability. This is to make sure that the results of discharge simulations are not biased. The analysis stages include consistency, trend, stationarity, and outlier testing to make sure that the data is the same across all observation periods. Using rainfall frequency analysis and a number of probability distributions, such as Normal, Log-Normal, Log Pearson Type III, and Gumbel, the design rainfall based on a certain return period is then calculated. To find the best distribution, the Smirnov–Kolmogorov and Chi-Square tests are used. The last step was to figure out how heavy the rain was and make a planned rainfall hyetograph. This was the main input for the HEC-HMS meteorological model, which simulated how rainwater flows in the Tondano watershed.
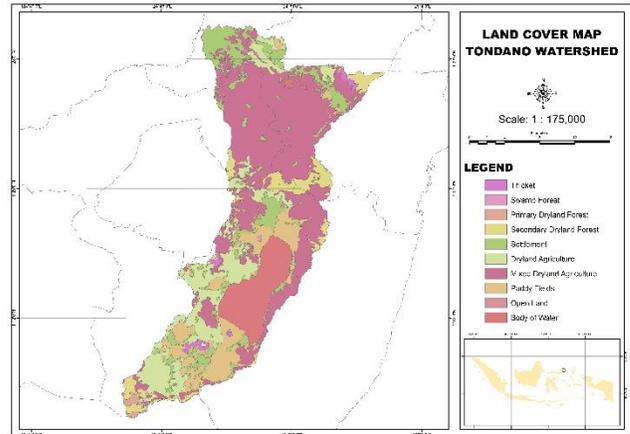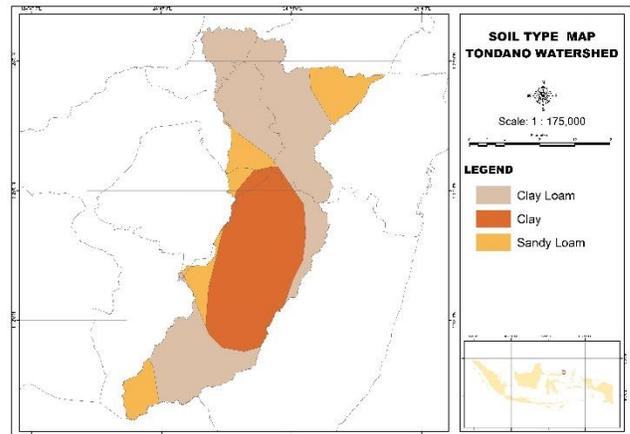

Fig. 2 Land cover map

Fig. 3 Soil type map

2.4.1. Rainfall Data Consistency Test

The Rescaled Adjusted Partial Sums (RAPS) test is a test to check the suitability of rainfall data obtained by comparing it with data from the station itself. This test is very useful in hydrological calculations because it can identify patterns that are often overlooked by ordinary time series analysis, such as changes in subperiods, anomalies, and repetitions in rainfall. We used the Rescaled Adjusted Partial Sums (RAPS) Test to make sure that the rainfall data was consistent by comparing it to data from the station itself [15]. Rainfall Data Consistency Test can be calculated based on Equations (1), (2), and (3).

$$S_k^* = \sum_{i=1}^{k}(Yi - Y) \text{ with k = 1, 2, 3, ..., n} \quad (1)$$

$$S_k^{**} = \frac{S_k^*}{Dy} \tag{2}$$

$$Dy^2 = \frac{\sum_{i=1}^{k}(Yi-Y)}{n} \tag{3}$$

Where Yi is rainfall data for - i, Y is average rainfall data for - i, Dy is average deviation, and n is the amount of data.

2.4.2. Testing for the Absence of Trends in Rainfall Data

Analysis of rainfall data trends is very important to conduct, as this data aims to determine trends or changes in rainfall patterns over time. Testing for the absence of trends in rainfall data is conducted to determine trends or tendencies in periodic rainfall data series. If there are trends or tendencies in the periodic data series, the data is not recommended for use [16].

2.4.3. Rainfall Data Stationary Test

The stationarity test is conducted to test the homogeneity of data by observing the stability of the variance and mean values of the time series. The stationarity test consists of the F test, which aims to test the variance values of the time series, and the T test, which aims to test the stability of the mean [17].

2.4.4. Rainfall Data Outlier Test

Outlier testing is conducted to determine whether there is data that statistically deviates significantly from the data set. Outlier detection in rainfall data is very important to ensure the quality of hydrological analysis, weather forecasting, and water resource management. Instrument or field recording errors or extreme phenomena can cause outliers. An appropriate detection method is needed to make the analysis results more accurate [18]. There are three conditions for testing outlier data: first, if the skewness coefficient of the sample data is > 0.4, an upper outlier check must be performed; second, if the skewness coefficient of the sample data is < -0.4, a lower outlier check must be performed; and finally, if the skewness coefficient is between -0.4 and 0.4, both upper and lower outlier checks must be performed before deleting data considered to be outliers.

2.4.5. Rainfall Frequency Analysis

To figure out the design rainfall, frequency analysis looks at annual maximum rainfall data, which shows how likely extreme rainfall events are [19]. This analysis is used as the basis for determining the design peak discharge (Qp) in HEC-HMS hydrological modeling.

There are three primary phases to the analysis. To characterize the features of the rainfall data distribution, statistical parameters (mean, standard deviation, coefficient of variation, skewness, and kurtosis) are first computed. Second, four probability distributions—Normal, Log Normal, Log Pearson Type III, and Gumbel (Extreme Value Type I)—were used to estimate design rainfall (XT) for return periods of 2, 5, 10, 25, 50, and 100 years. Third, to find the most representative distribution for empirical data, a distribution suitability test was performed using Smirnov–Kolmogorov (K–S) and Chi-Square (χ^2).

The best distribution from the test results was then used to generate a 24-hour design rainfall, which was converted into rainfall intensity and planned rainfall hyetograph as input in the rainfall-runoff simulation on HEC-HMS.

An outlier test is conducted to determine whether there is data that statistically deviates significantly from the data set.

2.4.6. Rainfall Intensity Calculation

This research used the Mononobe method to figure out how much rain fell. The height or volume of water that falls in a certain amount of time is how rainfall intensity is measured. The Mononobe method is commonly employed in tropical areas, as it effectively characterizes the empirical correlation between the duration and intensity of extreme rainfall [20]. The equation used can be seen in Equation (4).

$$I = \left(\frac{R_{24}}{t}\right) \times \left(\frac{t}{T}\right)^{\frac{2}{3}} \tag{4}$$

Where I is the rainfall intensity, R_{24} is the maximum rainfall in 24 hours (mm), and t is the duration of rainfall.

2.4.7. Water Loss Analysis Using the SCS Curve Number Method

The Soil Conservation Service Curve Number (SCS-CN) method is one of the most commonly used methods for calculating the amount of rainwater that flows from the soil surface. This method is simple, easy to use, and does not require a lot of data to produce optimal results. The "Curve Number" (CN) parameter in SCS-CN indicates the amount of surface runoff that is likely to occur based on soil type and land use. The higher the CN value, the greater the likelihood of surface runoff [13].

The SCS-CN method defines the relationship between total rainfall (P), initial loss (Ia), watershed storage potential (S), and direct runoff (Pe). The equation can be seen in Equation (5).

$$P_e = \left\{\frac{(P-I_a)^2}{P-I_a+S}\right\} \tag{5}$$

With the relationship between I_a and S as seen in Equations (6) and (7).

$$I_a = 0.2S \tag{6}$$

$$S = \frac{25400-254CN}{CN} \tag{7}$$

Where Pe is cumulative rainfall surplus (mm), P is cumulative rainfall (mm), I_a is initial water loss (mm), S is potential storage in the catchment area (mm), and CN is obtained from the overlay between the Land Cover map and the soil type map using ArcGIS. The CN value for each combination is then determined based on the USDA-SCS (1972) standard table.

2.5. Validating and Calibrating the Model

Because there was no field discharge data, proxy calibration was used. Parameter modifications were implemented utilizing empirical data derived from prior studies on tropical watersheds exhibiting analogous geomorphological traits. The most important things that were calibrated were the Curve Number (CN), the lag time, and the baseflow coefficient. To calculate the delay time, the Kirpich formula is used, taking into account the length and slope of the main channel. The CN value is adjusted based on the land cover data obtained.

Model validation was conducted qualitatively and comparatively by juxtaposing simulated peak discharge results with findings from prior studies in analogous watersheds, including the Benanain River Basin (Bunganaen et al., 2021) and the Manikin River Basin (Klau et al., 2024). The simulated peak discharge varied from 253.2 to 415.0 m³/s, which is consistent with realistic values for tropical basins with steep terrain and high CN values.

Also, internal model consistency checks were done by looking at how design rainfall, runoff volume, and time to peak are all related to each other. The model was deemed stable when an augmentation in the rainfall return period produced a corresponding increase in peak discharge, devoid of hydrological anomalies.

The main limitation of this study is the lack of observed flow data for direct numerical calibration. However, the theoretical validation and comparison results show that this model can accurately represent the hydrological behavior of the Tondano River Basin and can serve as a basis for future model development.

3. Results and Discussion
3.1. Rainfall Data Testing

Rainfall analysis in the Tondano watershed was conducted using maximum daily rainfall data from six rain stations, namely the Tikala Kaleosan Rainfall Station, the Tikala Sawangan Rainfall Station, the Tikala Rumengkor Rainfall Station, Paleloan Rainfall Station, Noongan Winebeten Rainfall Station, and Bailang Kayuwatu Rainfall Station, obtained from the Sulawesi One River Basin Agency. Data from the six rainfall stations were then analyzed using the Thiessen polygon method to obtain the area of influence of each station. The maximum daily rainfall data to be used can be seen in Table 1.

3.1.1. Rainfall Data Consistency Test

The Rescaled Adjusted Partial Sums (RAPS) method is used to test the consistency of rainfall data. It aims to detect systematic changes in annual rainfall data series.

The test results show that the data is consistent (accepted) because it has a value below the control limit of 95%. Thus, there is no indication of systematic changes in the rainfall data at the observation station. This shows that the rainfall data series has temporal stability and is suitable for use in further analysis stages such as trend testing, stationarity, and frequency analysis. The test results are presented in Table 2.

Table1. Maximum daily rainfall

Year	Month												Maximum Annual Rainfall
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2013	48.2	73.7	37.3	57.3	33.4	45.0	49.3	30.0	37.4	43.7	34.0	18.9	73.7
2014	111.1	30.5	43.0	21.0	57.9	59.2	39.0	29.6	23.9	30.2	41.9	84.4	111.1
2015	51.0	45.4	32.1	43.3	59.2	31.1	14.4	8.0	6.6	9.6	57.7	58.4	59.2
2016	66.7	52.3	30.7	96.4	52.6	56.6	60.3	47.6	84.3	72.0	54.5	59.2	96.4
2017	74.7	94.9	62.7	42.7	75.0	75.8	68.7	36.1	58.4	55.9	74.5	81.9	94.9
2018	53.3	73.2	81.6	66.7	44.9	54.9	47.2	55.9	35.5	63.6	73.8	69.6	81.6
2019	42.9	66.3	47.0	79.9	70.8	35.3	29.0	20.5	7.8	62.1	43.7	54.9	79.9
2020	56.4	74.5	86.0	64.6	79.0	33.0	58.7	44.6	35.3	47.2	35.7	76.0	86.0
2021	83.4	63.3	60.2	45.3	96.1	90.5	86.0	54.7	67.6	58.6	48.8	72.1	96.1
2022	70.4	43.8	49.3	69.5	36.7	29.8	36.8	52.9	39.5	67.6	65.1	61.0	70.4
2023	56.4	61.4	49.8	74.5	64.6	63.0	41.7	14.5	32.1	34.4	47.3	33.6	74.5

Table 2. Rainfall data consistency test

Year	Rain (mm)	Sk*	Sk**	|Sk**|
2013	73.7	-10	-0.70	0.70
2014	111.1	27	1.84	1.84
2015	59.2	-25	-1.68	1.68
2016	96.4	12	0.84	0.84
2017	94.9	11	0.74	0.74
2018	81.6	-2	-0.16	0.16
2019	79.9	-4	-0.28	0.28
2020	86.0	2	0.14	0.14
2021	96.1	12	0.82	0.82
2022	70.4	-14	-0.92	0.92
2023	74.5	-9	-0.64	0.64
Total	923.63	Sk** min		-1.68
Average	84	Sk** max		1.84
n	11	R		3.52
S	14.76	Q		1.84
Control 95 %				
$Q/n^{0.5}$	0.555	<	1.148	ACCEPTED
$R/n^{0.5}$	1.060	<	1.295	ACCEPTED

3.1.2. Testing for the Absence of Trends in Rainfall Data

The trendlessness test was conducted to determine whether the annual rainfall data had a significant pattern of increase or decrease during the observation period [21]. The test was conducted using Spearman's Rank Correlation method, with hypothesis testing as follows:

- H_0 (null hypothesis): there is no trend, rainfall data is random (independent), and the values of Rt and Tt are independent of each other.
- H_1 (alternative hypothesis): there is a trend, the rainfall data shows an increasing or decreasing trend.

The test criteria are set as follows:

- If T calculated < T table, then H_0 is accepted - there is no trend.
- If T calculated > T table, then H_0 is rejected - there is a trend.

The test results show that Ho is accepted, which means that the rainfall data does not have a significant trend. Statistically, this indicates that the rainfall data is random and there is no systematic increase or decrease during the observation period. This condition shows that changes in rainfall values in the Tondano watershed are more influenced by annual climate variability than by long-term climate change. The calculation results are presented in Table 3.

These results meet the recommendations for hydrological analysis according to Anzolin et al. (2024) in the Water Management System Ecademy School, where data stability without trends is an important prerequisite for frequency analysis and the determination of representative design rainfall [22].

Table 3. Testing for the absence of trends

Years	CH Maks	Rank	Rank		dt	dt²
			CH	Rt		
2013	73.7	1	111.1	2	1	1
2014	111.1	2	96.4	4	2	4
2015	59.2	3	96.1	9	6	36
2016	96.4	4	94.9	5	1	1
2017	94.9	5	86.0	8	3	9
2018	81.6	6	81.6	6	0	0
2019	79.9	7	79.9	7	0	0
2020	86.0	8	74.5	11	3	9
2021	96.1	9	73.7	1	-8	64
2022	70.4	10	70.4	10	0	0
2023	74.5	11	59.2	3	-8	64
Total						188.00
n						11
kp						0.145
t						0.44

3.1.3. Rainfall Data Stationary Test

Stationarity tests are conducted to ensure that rainfall data have a constant mean and variance throughout the observation period. Stationarity is important to ensure the validity of frequency analysis and hydrological modelling, as unstable statistical parameters can lead to inaccuracies in design rainfall and peak discharge calculations [23].

Based on both tests, namely the Variance Stability Test (F-test) and the Mean Stability Test (t-test), the results show that both the mean and variance of rainfall data are stationary. Thus, the rainfall data used is statistically stable and suitable for use in the rainfall frequency analysis stage of the design.

3.1.4. Rainfall Data Outlier Test

Outlier testing was conducted to detect extreme data (too high or too low) that deviated significantly from the general pattern of annual rainfall data. The testing was carried out using the guidelines of the Department of Public Works (1999).

Based on the results of testing 11 years of maximum annual rainfall data in the Tondano watershed, the analysis indicates that all annual rainfall data values fall within the

lower and upper limits, indicating no upper or lower outliers. Thus, the rainfall data can be considered homogeneous and free from anomalous values, and suitable for use in frequency analysis and design rainfall determination. The outlier test results are presented in Table 4.

Table 4. Data ourlier test

No	Xi	ln Xi
2013	73.7	4.30
2014	111.1	4.71
2015	59.2	4.08
2016	96.4	4.57
2017	94.9	4.55
2018	81.6	4.40
2019	79.9	4.38
2020	86.0	4.45
2021	96.1	4.57
2022	70.4	4.25
2023	74.5	4.31
Average		4.42
Skew		-0.21
SD		0.18
K_N		2.880
X_H		138.2
THERE IS NO OUTLIER ABOVE		
X_L		49.6
THERE IS NO LOWER OUTLIER		

Overall, the test results show that the rainfall data used is homogeneous, consistent, stationary, and free from extreme values, making it suitable for use as a basis for frequency analysis and peak discharge modelling using HEC-HMS.

3.1.5. Design Rainfall Calculation

Rainfall in the Tondano watershed is determined by the Gumbel, Normal, and Log Pearson Type III probability distribution models. The analysis was conducted for return periods of 2, 5, 10, 25, 50, 100, 200, and 1,000 years, covering a wide range of hydrological recurrence intervals. To determine the probability distribution that best fits the maximum annual rainfall data, two statistical goodness-of-fit tests were used, namely the Kolmogorov-Smirnov (K-S) test and the Chi-Square (χ^2) test. The results of the S–K test analysis show that all three distributions have Dmax values smaller than the critical D value. This indicates that each model fits the observed data well. The Log Pearson Type III distribution, on the other hand, provides the lowest Dmax and χ^2 values, which means that this distribution is the most suitable for the actual rainfall records. The Log Pearson Type III distribution is used to determine the design rainfall value to be used in further hydrological analysis.

Thus, all three distributions were accepted at a 95% confidence level, indicating that, in general, all probability models could describe the empirical data pattern well. Based on the results of the Chi-Square test, it can be concluded that the Normal and Log Pearson Type III distributions are accepted as representative models of the distribution of annual maximum rainfall data in the Tondano watershed, while the Gumbel distribution is rejected because it shows a significant deviation from the observed data.

However, because the Log Pearson Type III distribution is better able to represent the characteristics of positively skewed data and is commonly used in tropical hydrological analysis, this distribution was selected as the best distribution for determining the design rainfall in the next stage. The results are presented in Table 5.

Table 5. Recapitulation of rainfall calculation results design

No.	Repeat Period (Years)	Rain Design (mm)		
		Method Gumbel	Method Normal	Method Log Pearson Type III
1	2	82.03	83.97	83.96
2	5	98.51	95.79	95.63
3	10	109.43	101.98	102.46
4	25	123.21	107.04	110.02
5	50	133.44	112.81	115.05
6	100	143.60	116.75	119.65
Smirnov-Kolmogorov Test				
D Maximum, D Max		0.045	-0.083	-0.083
Degree of Significance		5.000	5.000	5.000
D Critical		0.396	0.396	0.396
Hypothesis		Accepted	Accepted	Accepted
Chi-Square Test				
Chi-Square calculation		4.64	1.00	3.18
Critical Chi-Square		3.84	3.84	3.84
Degrees of Freedom		1.00	1.00	1.00
Degree of Significance		5.00	5.00	5.00
Hypothesis		Not Accepted	Accepted	Accepted

3.1.6. Rainfall Intensity Calculation

The analysis of annual maximum rainfall frequency using the Type III Log Pearson Distribution yielded the 24-hour planned rainfall (R_t) values for different return periods. Using the Mononobe Method, which is often used to describe the real-world link between the length and strength of heavy rain in tropical areas, these numbers were then changed into rainfall intensity (I).

The calculation was performed with a rainfall duration of 6 hours, as this duration is considered the most representative of dominant rainfall events that have the potential to cause significant runoff in the Tondano watershed. The results of the calculation show that rainfall intensity increases with increasing return period. The highest intensity value recorded was 108.12 mm/hour for a 100-year return period, while the lowest value was 59.10 mm/hour for a 2-year return period. Figure 4 shows that the relationship between extreme rainfall and the probability of its occurrence is nonlinear, where rainfall with a lower probability of occurrence can produce much greater intensity.
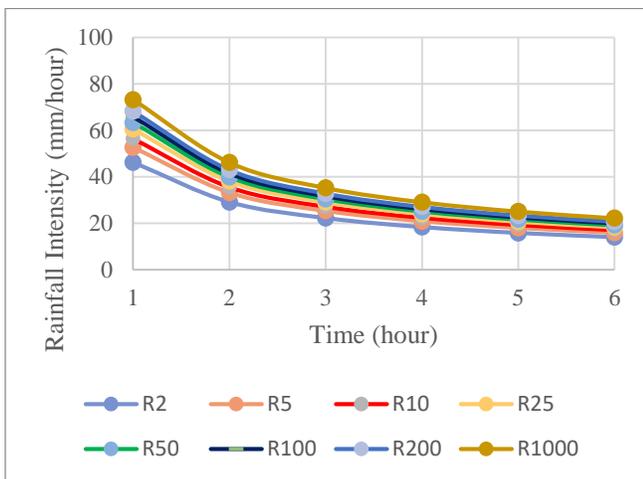

Fig. 4 Graph of Rainfall Intensity VS Time

Next, the 6-hour planned rainfall is distributed into hourly rainfall patterns (planned rainfall hyetograph) using the Alternating Block Method (ABM). This method arranges the sequence of decreasing rainfall intensity, with the highest intensity placed in the middle of the rainfall period, to resemble the natural rainfall patterns commonly found in tropical regions.

The distribution of the 6-hour planned rainfall for a 100-year return period shows that around 45% of the total rainfall is concentrated in the two hours around the peak of the event, while the rest is distributed at the beginning and end of the duration. This pattern confirms that the rainfall characteristics in the Tondano watershed are intensely convective, where high-intensity rainfall occurs in a short period of time.

The hourly rainfall hietograph resulting from these calculations was then used as input for the Meteorological Model in HEC-HMS to simulate the rainfall-runoff process and generate the design peak discharge (Qp) at the mouth of the Tondano watershed.

3.2. Design Peak Discharge with HEC - HMS

The delineation of rivers and river basin boundaries is the first step in hydrological modelling in HEC-HMS. The main objective is to determine the natural boundaries of the flow system, the direction of surface water flow, and the position of the outlet or main observation point (sink point) to be used in peak discharge (Qp) simulations.

This process makes sure that the whole catchment area that feeds into the estuary is found both spatially and quantitatively, so that the model can show how the watershed as a whole responds to water. This research used Digital Elevation Model (DEM) data from Ina-Geoportal with a spatial resolution of 30 meters to draw the watershed lines. The sink, or outlet point, was at the mouth of the Tondnao River. Figure 5 shows the results of the delineation.

The design peak discharge simulation was conducted using HEC-HMS with the SCS Curve Number (SCS-CN) method for water loss calculations and SCS Unit Hydrograph (SCS-UH) for rainfall-runoff transformation. The model was run using 6-hour planned rainfall data compiled in the form of hourly hietographs through the Alternating Block Method (ABM).

The modeling results show a clear relationship between the increase in rainfall return period and the magnitude of peak discharge at the Tondano watershed outlet, as shown in Table 6. Results show that peak discharge increases progressively with rainfall return periods, indicating a strong hydrological response to extreme rainfall events. Peak discharge values (Qp) range from 253.2 m³/s for a 2-year return period to 415.0 m³/s for a 100-year return period, with an increase of approximately 64% between the two scenarios.

This pattern indicates that the Tondano watershed has a flashy response, where high-intensity rainfall over a short duration (6 hours) can immediately produce large discharges at the outlet. This condition is reinforced by the steep morphological characteristics in the upstream area, a cumulative Curve Number (CN) value of 84.29, which indicates low infiltration capacity, and land cover dominated by settlements and open agricultural land. The combination of these factors makes the Tondano River Basin (DAS) hydrological system highly sensitive to extreme rainfall. A significant increase in peak discharge for a return period of more than 25 years also indicates that the risk of flooding in downstream areas, especially in Manado City, increases significantly under extreme rainfall conditions.
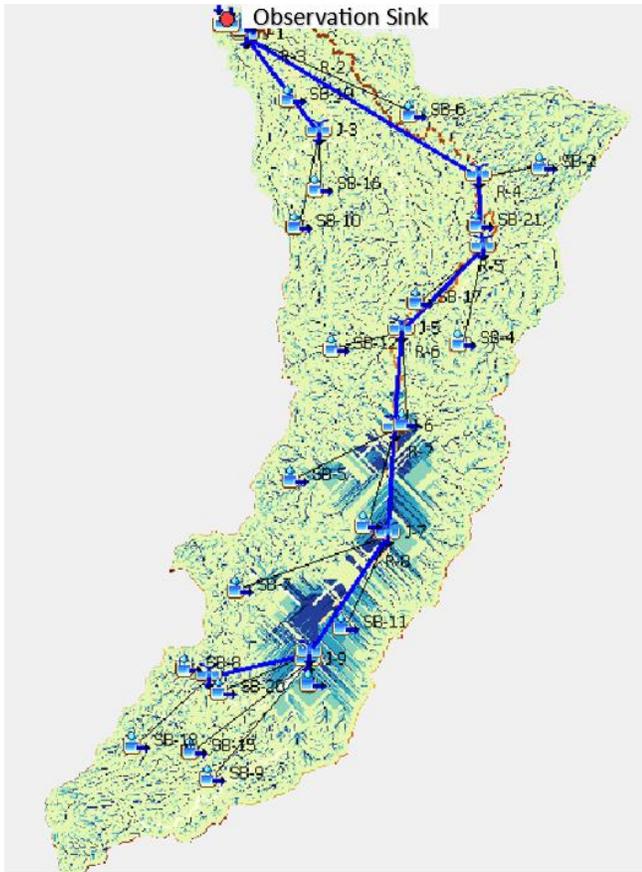
Fig. 5 Watershed delination

Table 6. Design of peak discharge

Return Period (Year)	Design of Peak Discharge (m³/s)
2	253.2
5	305.2
10	336.1
25	370.6
50	393.7
100	415

A fairly sharp increase in peak discharge for a return period of more than 25 years also indicates that the risk of flooding in downstream areas, especially Manado City, increases significantly during extreme rainfall conditions. These findings are in line with the results of Bunganaen et al. (2021) and Xiao et al. (2022), which state that watersheds with complex morphometric characteristics and high CN values tend to produce sharp hydrographs and short peak times [14, 24].

The results of the hydrological analysis show that the HEC-HMS model combined with the SCS-CN method is capable of accurately describing surface runoff behavior in the Tondano River Basin (DAS). The peak discharge (QP)

values obtained can be used as a basis for analyzing channel capacity, designing flood control structures, and developing land conservation strategies in the DAS area.

The integrated modeling between HEC-HMS, Arc Map, and Google Earth Pro developed in this study proved to be more effective than other methods that had been studied previously. This was mainly due to the use of spatially distributed rainfall data, high-resolution geospatial data, soil data, and the use of better parameters. This model produces more accurate peak discharge estimates and hydrograph shapes compared to conventional centralized or semi-distributed models, taking into account the diversity of rainfall, soil, and land cover conditions. Model calibration using theoretical proxies, supported by parameter modifications based on literature and sensitivity analysis, improves model reliability even in the absence of field discharge data. The use of internal consistency checks and high-resolution DEM data also facilitates the determination of flow paths and hydrograph timing. These methodological improvements result in better agreement between simulated and expected hydrological responses. They worked better than the best HEC-HMS applications in tropical basins and provided a stronger framework for estimating floods and managing watersheds in areas with little data.

4. Conclusion

This research effectively created a comprehensive hydrological model to evaluate and simulate the design peak discharge (Qp) in the Tondano Watershed, utilizing the SCS Curve Number (SCS-CN) method as applied in HEC-HMS. The watershed's hydrological response was represented quantitatively and realistically through a series of processes, including rainfall frequency analysis, converting design rainfall into hourly intensity and temporal distribution (6 hours), and simulating rainfall-runoff.

The Log Pearson Type III distribution was found to be the best probability model for annual maximum rainfall data. This led to design rainfall values between 83.96 and 119.65 mm for return periods of 2 to 100 years. The HEC-HMS simulations showed that the design peak discharge goes from 253.2 m³/s (T = 2 years) to 415.0 m³/s (T = 100 years). This is because the land is steep, the average CN value is 84.29, and there is a lot of low-infiltration land cover in the middle and downstream areas. At the same time, it was found that it is very important to preserve forest areas, as these areas can control the hydrological behavior of the Tondano River Basin, as evidenced by the fact that forests in the upper reaches slow down water flow and delay peak discharge times.

Overall, the results of the study indicate that the SCS-CN method used in the HEC-HMS model can provide accurate discharge estimates for tropical river basins with complex

spatial characteristics. The model's ability to combine distributed rainfall variables, topography, and land use makes it a reliable tool for flood assessment and planning.

The results of this study emphasize the importance of flood mitigation strategies that combine structural and non-structural measures, including preserving forest areas upstream, implementing infiltration-based rainwater management systems, and implementing land use zoning in flood-prone downstream areas, such as Manado City. These measures can significantly reduce peak discharge levels and minimize flood risk.

The HEC-HMS model produces representative results; however, this study faces limitations, particularly related to rainfall data resolution and the lack of directly measured discharge measurements for calibration. Future research should integrate field discharge data and investigate the synergy between hydrological and hydrodynamic models to improve the understanding of floodplains and the accuracy of predictions in flood mitigation strategies. Parameters used. The lack of integration between hydrological and hydrodynamic models means that the flood flow process is not fully represented.

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