INTRODUCTION

Estimating peak discharge poses a challenge for hydrologists due to the potential risks of overflow (Barid and Afanda, 2022; Imaaduddin et al., 2022; Suharyanto, 2021). This crucial task involves determining the maximum volume of water flowing through a river or channel during a specific period, usually during extreme weather events such as heavy rainfall or snowmelt (Saadi et al., 2021). Accurately predicting peak discharge is vital for designing hydraulic structures, including dams, bridges, culverts, and flood control systems, as it helps ensure that these structures can effectively handle to anticipate water flow and prevent potential damage or failure (Avila and Ávila 2016; Pambudi et al., 2021).

Hydrologists and engineers use various methods to estimate peak discharge, considering catchment characteristics, rainfall intensity, topography, land use, morphometrics, and historical flow data (Echeverri-Díaz et al. 2022; Tao et al. 2019). Due to the hydrologic system's complexity and the catchment's specific characteristic, it is necessary to choose the appropriate method for a particular catchment (Sultan et al. 2022;
Gerick and Smithers, 2014). These methods may include statistical analysis of historical records, hydraulic modeling, and empirical equations based on observed relationships between rainfall and streamflow (Echeverri-Diaz et al. 2022; Tao et al. 2019). Additionally, advancements in technology, such as remote sensing and computer simulations, have provided new tools and techniques to improve the accuracy of peak discharge estimations (Azizian 2019; Seong and Sung 2021).

The peak discharge information results from the hydrologic analysis are needed in planning water structures both in the present and for future planning, assuming the characteristics of the catchment stay the same (Imaaduddin, Saud, and Santos 2022). Estimating peak events could be done by hydrologic modeling (Guo et al. 2021), and rainfall is the main factor contributing to the cause of peak discharge (Ansori et al., 2023) and estimating peak discharge using various hydrological methods through a long data series of peak discharge (>10 years) (Gerick and Smithers 2014). The peak discharge analysis was done using statistical methods. In the condition that the available data was maximum daily rainfall and river catchment characteristics, the recommended methods were superposition of the instantaneous unit hydrograph (IUH) and Synthetic Unit Hydrograph (SUH), introduced in 1932 by Sherman (Seong and Sung 2021; Shaikh et al., 2022). The data required to derive the hydrograph of the measuring unit in the catchment under review are automatic rain data and discharge recordings at specific observation points, known as observed peak discharge (Shaikh et al., 2022). However, synthetic peak hydrograph analysis was not available when the rainfall data was required to compile the hydrograph of the units of size Calculated peak discharge using synthetic unit hydrograph methods commonly used in Indonesia include the Snyder-SCS, Snyder-Alexeyev, Nakayasu SUH, GAMA-1, DPMA-IOH, and HSS-αβγ methods (Ansori et al., 2023; Natakusumah et al., 2011). The other way to estimate peak discharge was Rational, Melchior, Weduwon, and Hasper, known as lumped methods (Ansori et al., 2023; Bout and Jetten, 2018; Moges et al. 2021; Unami, 2023; Pambudi and Moersidik 2019). Due to various forms, there was an opportunity to employ a calculated process similar to the characteristics of Java Island, especially in East Java (Februant et al., 2021; Pambudi and Moersidik 2019; Roestamy and Fulazzaky 2021). The research was conducted to analyze an ideal and appropriate model from a variety of methods of peak discharge that approximate the catchment characteristics (Boothroyd et al., 2023; Metselaar, 2023; Salvadore et al., 2015).

This research analyzed and identified an appropriate catchment in East Java Province, Indonesia, to accomplish this aim. Considering the numerous available catchments, the Brantas River Catchment is the largest river in East Java Province, covers nine regencies and six cities with a population of 18.6 million people, which is 43 percent of the population of East Java Province. One of the upstream catchments of Brantas River was the Lesti River in Malang Regency (Februant et al., 2021). The Lesti River has an outlet in the Sengguruh dam, which served as a cofferdam for the Sutami weir. The Sutami weir has a crucial role in flood control, irrigation water supply, and significant supply of most of the hydroelectricity in East Java Province (Roestamy and Fulazzaky, 2021; Legono et al., 2021). However, erosion hazard levels were observed in 2021 due to the Lesti River contributing to erosion at 153,868 tons ha/year (exceeding the tolerable erosion rate of 30 (ton ha/year) (Pambudi and Moersidik, 2019; Pambudi et al., 2021). The annual increasing trend of decline and the continued land use/cover changes of the Lesti River are critical factors in selecting this Upper Lesti River Catchment (ULRC) as the study location (Bekti et al. 2018; Pambudi and Moersidik 2019; Pambudi, Moersidik, and Karuniasa 2021). As previously highlighted, the ULRC’s water discharge significantly contributes to the Brantas River water discharge (Pambudi and Moersidik 2019; Legono et al., 2021). Therefore, numerous hydrologists conducted research to estimate the peak discharge calculation of the ULRC, and the results have shown various values (Ansori et al., 2023; Natakusumah et al., 2011). Despite the availability of sophisticated methods, estimating the peak discharge of ULRC is challenging due to the inherent uncertainty and complexity of natural hydrological systems (Gerick and Smithers 2014; Kim and Jeong, 2021). Optimized physical parameters play a major role in generating varied peak discharge values, emphasizing their importance in the estimation process.

The accurate hydrological input data is essential for effectively estimating peak discharge in the Lesti River and mitigating potential damage or failure. The accuracy of estimation was influenced by various factors, including the availability and quality of data, the scale of analysis, the assumptions made in the estimation methods, and probability distributions. Therefore, this paper examines various methods, including SUH, Melchior, and the Rational method, to determine the varied peak discharge values in the Lesti River (Februant et al., 2021; Pambudi et al., 2021; Roestamy and Fulazzaky 2021). The main objective of this study is to analyze the most relatively accurate method for peak discharge estimation. Selecting an accurate peak discharge method by comparing observed and calculated peak discharge.
MATERIALS AND METHODS

Study site
The study site is in the ULRC connected to the Brantas River (Roestamy and Fulazzaky 2021; Pambudi et al., 2021). The coordinates’ locations were 7°40’-7°55’ S and 112°10’-112°25’ E. The automatic water level recorder (AWLR) location of the ULRC was 112°41’4.8", 8°13’49.3" in the village of Tawangrejeni, Turen district area.

The ULRC area is located in Malang Regency of East Java Province, Indonesia. The study area is Lesti River catchment, one of the upstream of Brantas catchment with outlet in Sengguruh Dam (Fig.1). There were three rainfall stations of ULRC and the location is shown in Table 1.

Catchment delineation

The delineation was conducted using a 30-m digital elevation model (DEM) in the watershed modeling system (WMS) (Abdulwahd et al., 2020; Yang and Cao, 2021). Then, the flow direction and accumulation were determined, and the river network was defined synthetically (Yang and Cao, 2021). The outlet of the catchment was determined, and the parameters were calculated. The topographic maps, scaling 1:25, were used to analyze the physical characteristics of the catchment, such as catchment boundary, area, slope, and length of the main river (Gaurav and Singh, 2022).

Observed peak discharge data

The hourly discharge data were collected from the AWLR for 2006-2020 when the study was conducted, known as observed discharge (Shaikh et al., 2022; Winter et al. 2019; Kilonzo, 2022). The maximum observed discharge data was chosen as peak discharge, known as Qp obs.

Daily rainfall data

The data period varied depending on the rainfall station data and the quality of usable data for acceptable analysis. The oldest data were from 2000, while a few stations started operation in 2004 (Kilonzo, 2022). The usable data were determined after validating the rainfall and discharge data. In this case, statistics has an important role in helping to select and evaluate data as the usage of inferential statistics. Statistics provided tools and methods to find structure and to provide deeper data. The data were screened through scatter plots and outliers (95 percentile< data<5 percentile) (Kilonzo, 2022).

The peak discharge was analyzed using maximum daily rainfall data across the ULRC. In principle, the methodology used in this study includes catchment delineation, rainfall data analysis, and validation analysis. The diagram of the methodology used is shown in Fig. 2.

Rainfall intensity

The average maximum rainfall intensity in the ULRC was analyzed for each year. The 15 years (2006-2020) data recorded by rainfall stations were used. The Thiessen polygon method was used to determine the average rainfall intensity in the catchment. The data was converted into hourly rainfall intensities to analyze the peak discharge after determining daily-rainfall intensities (Suharyanto, 2021). The hourly rainfall intensity analysis results can be used as input data to analyze the discharge. The Mononobe was used to assess maximum rainfall intensity (mm hr⁻¹). The Mononobe equation is derived in equation 1

\[
R_t = \frac{R_{24}}{7} \left(\frac{T}{7}\right)^{3/2}
\]

Eq. 1

Where Rt is hourly intensity [mm hr⁻¹], R24 is daily rainfall [mm day⁻¹], T is the duration of rainfall (equal to 24 hr. for daily rainfall), and t is the actual rainfall duration [hr].

Calculated peak discharge

The calculated peak discharge, known as Qpcal, was carried out using the SUH and lumped method. The SUH used in this study was Natakusumah et al. (2011). The SUH described the physical characteristics of the catchment and the rainfall intensity. The catchment’s physical features include the area of the catchment (A), length of the river (L), and the surface runoff coefficient (C) (Ansori et al., 2023; Natakusumah et al., 2011; Suharyanto et al., 2021). The hourly rainfall intensity was used as input data to analyze SUH discharge.
Nakayasu SUH
Nakayasu SUH was used to analyzed peak discharge analyses. The formula of Nakayasu SUH can be expressed as follows (Suharyanto et al., 2021):

\[
Q_p = \frac{1}{6} \left( \frac{A \times R_s}{0.3 \times T_r + T_{0.3}} \right)
\]

\[
T_\sigma = T_\sigma + 0.3 \ T_r
\]

\[
t_\sigma = 0.4 + 0.058, L > 15 \ km, L < 15 \ km
\]

\[
T_{0.3} = 0.21 L^{0.7}
\]

\[
T_{0.3} = \alpha t_\sigma
\]

Rising limb (0 < t < Tp)

\[
Q_t = Q_p \left( \frac{t-T_p}{0.3} \right)
\]

Decreasing limb (0 ≤ t ≤ (Tp+T_{0.3})

\[
Q_t = Q_p \left( \frac{(t-T_p)}{T_{0.3}} \right)
\]

On Decreasing limb

\[
(T_p+T_{0.3}) ≤ t ≤ (T_p+T_{0.3} + 1.5T_{0.3})
\]

On Decreasing limb

\[
Q_t = Q_p \left( \frac{(t-T_p)}{1.5T_{0.3}} \right)
\]

Snyder SUH
The synthetics unit hydrograph of Snyder was determined by elements including Qp (m^3 sec^-1), Tb (hr), tp (hr), and tr (hr). These elements are related to A, which is the area of catchment (km^2), and L, which is the length of the main river (km). Using these elements, Snyder developed a synthetic unit hydrograph model as follows:

\[
Q_p = \frac{C \times A}{T_p}
\]

Eq. 11

\[
t_p = \frac{C \times (L \times T_{0.3})^{0.3}}{T_{0.3}}
\]

Eq. 12

\[
Q_p = \frac{C \times A}{T_{0.3}}
\]

Eq. 13

\[
T = 3 + \frac{T_{0.3}}{a}
\]

Eq. 14

Fig. 3. Schematic of The Nakayasu SUH
Source: (Suharyanto, 2021)
Where: \( t_p \) is time lag (hr), \( Q_p \) is peak discharge (\( m^3 \) sec\(^{-1} \)), \( T_b \) is base time (hr), \( Q_{pR} \) is unit discharge per unit area (\( m^3 \) sec\(^{-1} \) km\(^{-2} \)); \( t_r \) is effective rain duration (hr), \( C_t \) and \( C_p \) are coefficients that depend on the units and characteristics of the catchment (Boothroyd et al., 2023). The coefficients \( C_t \) and \( C_p \) values need to be determined empirically because they vary between regions. In the metric system, \( C_t \) ranges from 0.75 to 3.00, while \( C_p \) ranges from 0.90 to 1.40 (Ansori et al., 2023; Labdul and Alitu 2021; Shaikh et al., 2022). The typical Snyder SUH is illustrated in Fig. 4.

Snyder developed a model to calculate the peak discharge and the time required to reach the peak of a single hydrograph. Therefore, to obtain the entire hydrograph curve, it takes time to calculate its parameters. Due to expedite this process, the Alexejev formula is provided, which gives the form of the unit hydrograph. The Alexejev equation is as follows (Barid and Afanda, 2022; Labdul and Alitu, 2021):

\[
Q = f(t)
\]

\[
Y = \frac{Q}{Q_p}
\]

\[
X = \frac{t}{T_p}
\]

\[
Y = 10^{a(\frac{1-x}{x})^2}
\]

\[
\lambda = \frac{Q_p T_p}{h A}
\]

\[
\alpha = 1.32 \lambda^2 + 0.15 \lambda + 0.045
\]

**Analysis of Lumped method**

The Lumped method is generally applied at a single point or within a specific region to analyze the hydrologic processes (Y,u 2015). The lumped method has taken the capability to estimate runoff in areas ungauged stations within the catchment, predict the consequences of land use changing (Baiamonte, 2020; Brirhet and Benaabidate, 2016). Considering the spatial variability of rainfall and physical characteristics within a catchment using distributed modeling obtained an appropriate method. However, recent studies have indicated that distributed modeling approaches un-consistently to analyze the catchment (Moges et al., 2021; Yang and Cao, 2021).

**Melchior method**

The Melchior method is used with the following formula (Natakusumah et al., 2011; Ansori et al., 2023):

\[
Q_n = \alpha x \beta x q x A \times \frac{R_n}{200}
\]

Where \( Q_n \) is peak discharge for period-n (\( m^3 \) sec\(^{-1} \)) \( \alpha \) is the runoff of coefficient, \( \beta \) is coefficient of reduction, \( q \) is maximum rainfall (mm), \( A \) is area of catchment (km\(^2\)), and \( \frac{R_n}{200} \) is maximum rainfall data (mm)

**Rational method**

The Rational method used the following formula (Al-Amri, Ewea, and Elfeki, 2022; Baiamonte, 2020):

\[
Q_p = 0.278 x C x I x A
\]

Where \( Q_p \) is peak discharge (\( m^3 \) sec\(^{-1} \)), \( C \) is the runoff of coefficient (dimensionless), \( I \) is intensity (mm hr\(^{-1} \)), and \( A \) is the area of the catchment (km\(^2\)). This method assumes that the rainfall intensity remains consistent throughout the rainfall and uniformly distributed across the entire catchment.

**Peak discharge validation**

It is important to understand that there is no such thing as the best approach or method. The level of accuracy would be indicated by the quality of the application of the method (Abdulwahd et al., 2020). Many measures such as MAPE, MAE, and MASE are used to indicate the accuracy of estimated methods that have been previously recommended for use, and several authors
have made recommendations about what should be used when comparing the accuracy of estimated methods applied and observed (Goodwin and Lawton, 1999). The accuracy in hydrology methods helped hydrologist to understand how various calculated methods and observations differ. There are two accuracy measures reported in this study:

The Mean Absolute Percentage Error (MAPE) is commonly regarded as the most frequently used measurement for assessing the accuracy of estimations (Armstrong and Collopy, 1992; Goodwin and Lawton, 1999; Ren and Glasure, 2009). This simple measurement is reliable, easy to interpret and support statistical analysis (Khairina et al., 2020). The performance of the estimating method is highly accurate estimating if the MAPE value is below 10%, good estimating if the MAPE value is between 10% and 20%, reasonable estimating if the MAPE value is between 20% to 50% and inaccurate estimating if the MAPE value more than 50% (Moges et al., 2021; Prayudani et al., 2019). The MAPE formula is as follows:

\[
MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{Q_{\text{obs}} - Q_{\text{cal}}}{Q_{\text{obs}}} \right| \times 100\% \quad \text{Eq. 28}
\]

Where: \( Q_{\text{obs}} \) is observed peak discharge, \( Q_{\text{cal}} \) is calculated peak discharge and \( n \) is amount of data.

The Mean Average Error (MAE) calculates the mean of the absolute differences between estimated values and actual values (Moges et al., 2021; Willmott and Matsuura 2005). In other words, MAE calculates the average absolute error in predictions. The MAE value close to 0 is the better performance of the method (Birihet and Benaabidate 2016; Moges et al., 2021). The MAE formula, can be expressed as follows (Willmott and Matsuura 2005):

\[
MAE = \frac{1}{n} \sum_{i=1}^{n} |Q_{\text{obs}} - Q_{\text{cal}}| \quad \text{Eq. 29}
\]

Where: \( Q_{\text{obs}} \) is observed peak discharge, \( Q_{\text{cal}} \) is calculated peak discharge and \( n \) is amount of data.

The four methods were used to analyze the Lesti River flood discharge and compared which method results were the closest analysis of the flood discharge from

<table>
<thead>
<tr>
<th>Land cover</th>
<th>C</th>
<th>Land cover</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Lawns</td>
<td>0.70-0.95</td>
<td>Lawn. Sandy Soil</td>
<td>0.05-0.10</td>
</tr>
<tr>
<td>Downtown</td>
<td>0.50-0.70</td>
<td>Flat. 2%</td>
<td>0.10-0.15</td>
</tr>
<tr>
<td>Neighborhoods</td>
<td>0.30-0.50</td>
<td>Lawn. Heavy Soil</td>
<td>0.15-0.20</td>
</tr>
<tr>
<td>Residential</td>
<td>0.40-0.60</td>
<td>Flat. 2%</td>
<td>0.17-0.17</td>
</tr>
<tr>
<td>Single-family</td>
<td>0.60-0.75</td>
<td>Average. 2% -7%</td>
<td>0.18-0.22</td>
</tr>
<tr>
<td>Multi Units. detached</td>
<td>0.25-0.40</td>
<td>Steep. &gt;7%</td>
<td>0.25-0.35</td>
</tr>
<tr>
<td>Light</td>
<td>0.50-0.80</td>
<td>Agriculture Area</td>
<td>0.30-0.50</td>
</tr>
<tr>
<td>Heavy</td>
<td>0.60-0.90</td>
<td>Open Land</td>
<td>0.20-0.50</td>
</tr>
<tr>
<td>Parks. Cemeteries</td>
<td>0.10-0.25</td>
<td>Flat</td>
<td>0.30-0.60</td>
</tr>
<tr>
<td>Playground</td>
<td>0.20-0.35</td>
<td>Rough</td>
<td>0.20-0.50</td>
</tr>
<tr>
<td>Railroad yard</td>
<td>0.20-0.35</td>
<td>Cultivated Area</td>
<td>0.20-0.50</td>
</tr>
<tr>
<td>Unimproved</td>
<td>0.10-0.30</td>
<td>Heavy Soil. No Vegetation</td>
<td>0.30-0.60</td>
</tr>
<tr>
<td>Pavements</td>
<td>0.70-0.85</td>
<td>Sandy Soil. No Vegetation</td>
<td>0.20-0.50</td>
</tr>
<tr>
<td>Asphalt</td>
<td>0.70-0.95</td>
<td>Sandy Soil. Vegetation</td>
<td>0.10-0.25</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.70-0.85</td>
<td>Meadow</td>
<td>0.15-0.45</td>
</tr>
<tr>
<td>Stone/Brick</td>
<td>0.75-0.85</td>
<td>Heavy Soil</td>
<td>0.05-0.25</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>0.75-0.95</td>
<td>Sandy Soil</td>
<td>0.20-0.25</td>
</tr>
<tr>
<td>Roofs</td>
<td>0.75-0.95</td>
<td>Forest. Vegetation</td>
<td>0.05-0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bare Land</td>
<td>0.60-0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flat. impervious</td>
<td>0.20-0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rough</td>
<td>0.50-0.70</td>
</tr>
</tbody>
</table>

Source: Winter et al., 2019
observations of peak discharge using Mean Absolute Percentage Error (MAPE) and Mean Average Error (MAE).

RESULTS AND DISCUSSION

The characteristic of measure results of ULRC’s catchment using the Software (Gaurav Singh & Singh, 2022) showed that the catchment (A) is equal to 395 km². The main river length (L) is 29.49 km from upstream to downstream. The catchment’s location, topography and shape are shown in Fig. 5.

The elevation of Lesti River is approximately 378-3665 m above mean sea level (MSL). The topographic map of the catchment is shown in Fig. 6.

Rainfall intensity

The maximum daily rainfall intensity data from 2006 to 2020 were selected from rainfall stations (Tarasova et al., 2019). The rainfall intensity in the catchment analyzed using the Thiessen polygon is shown in Fig. 7. The observed peak discharged data from 2006-2020 was selected to compare the calculated peak discharged (Q_{pcal}) and the observed peak discharged (Q_{pobs}). The recorded Q_{pobs} data in AWLR was chosen based on the highest Q_{pobs} value. The available data was selected as shown in Table 3. The rainfall data was taken on the dates related to the Q_{pobs} among the three affected stations. The average rainfall intensity and the hourly rainfall intensity was calculated using the obtained data. Based on the rainfall intensity and the catchment characteristics, the Q_{pcal} was calculated using various methods.

Table 3 shows the rainfall intensity of ULRC from 2006 to 2020. The average weighted rainfall over the area was calculated based on the Thiessen polygon. Fig. 7 shows that each polygon area was affected by Wajak, Poncokusumo and Dampit stations by 0.329, 0.287 and 0.384, respectively.

Runoff Coefficient

Seven categories of land cover types in ULRC were classified using Terra-Modis 1B imagery seven (Li et al., 2022), as shown in Fig. 8. The land cover types and area of each type are shown in Table 2.

The C value based on land cover is shown in Table 4 (Hidayati et al., 2021). The weighted average of the C value ranges from 0.25 (2006-2010), 0.26 (2010-2015) and 0.27 (2016-2020), respectively. The ULRC has variation values of runoff coefficient in time period, indicating that it might be related to changes in land use, soils (layers, porosity), relief (slope, river channel gradient), and precipitation (height, duration and intensity) (Ru et al., 2022).

Calculated peak discharge

The calculated annual peak discharge method using Nakayasu SUH, Snyder SUH, Melchior and Rational method applied to the ULRC is shown in Table 5. Analysis results show that the Q_{pcal} showed varied and confident results than Q_{pobs}

Varied peak discharge

This study states varied peak discharge rates of the ULRC among methods. Therefore, it was listed and discussed in the following sections. The calculated peak discharge in the ULRC required accurate data as input for hydrological and morphometric parameters.
Both assumptions and estimated values can contribute to variations in the results. Additionally, the variability of input data, the accuracy of the model or analysis method, and other factors can also cause variations in the estimated values. Fig. 9 shows the varied values of peak discharge among methods with an observed peak discharge.

It is important to critically evaluate the varied peak discharge value obtained by the assumptions used and the level of uncertainty that may exist in the estimated input values. Uncertainty, as an aspect of estimation, reflects the degree of confidence or reliability associated with estimated values. It acknowledges that inherent limitations, potential errors, or unknown factors can affect the estimation's accuracy or validity. Uncertainty is often expressed in terms of confidence intervals, probability distributions, or qualitative assessments of the likelihood of different outcomes (Moges et al., 2021).

**Comparison of methods**

It may be argued about the varied peak discharge among methods in ULRC. Each method has unique strengths and limitations, and none can be considered the best fit (Moges et al., 2021). The difference results obtained from various hydrological and physical parameters. This is due to the complexity and high level of uncertainty involved in hydrological systems, which include factors such as future forcing input variables and decision-making in environmental change. The uncertainty input can result from inaccurate measurement, spatial interpolations, assumptions in boundaries, initial conditions, and missing data (Moges et al., 2021).

Hydrologists also need to make rational choices regarding the method that is most appropriate for the characteristics of the catchment. The calibration process can result in a relatively accurate method which approaches to ULRC characteristics. This process is used to compare the calculated with the observed method. The comparisons between calculated and observed peak discharge among methods are illustrated in Fig. 10.

Based on the results shown in Fig. 10, illustrated the $Q_{p\text{obs}}$ values that were determined using the Nakayasu SUH, Snyder SUH, Rational and Melchior method. These methods showed large deviations for the corresponding values determined using $Q_{p\text{obs}}$. It was found that the highest values of calculated peak discharged

### Table 3. Rainfall intensity in Lesti River

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Wajak</th>
<th>Pon kokusumo</th>
<th>Dampit</th>
<th>Average (mm day$^{-1}$)</th>
<th>Average Rainfall Intensity (mm hr$^{-1}$)</th>
<th>$Q_{p\text{obs}}$ (m$^3$ sec$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13/04/2006</td>
<td>41</td>
<td>20</td>
<td>17</td>
<td>25.92</td>
<td>15.29</td>
<td>102.00</td>
</tr>
<tr>
<td>2</td>
<td>26/12/2007</td>
<td>105</td>
<td>151</td>
<td>225</td>
<td>164.32</td>
<td>99.67</td>
<td>1485.00</td>
</tr>
<tr>
<td>3</td>
<td>09/12/2008</td>
<td>48</td>
<td>45</td>
<td>85</td>
<td>61.35</td>
<td>37.13</td>
<td>444.00</td>
</tr>
<tr>
<td>4</td>
<td>02/12/2009</td>
<td>70</td>
<td>80</td>
<td>74</td>
<td>74.41</td>
<td>41.00</td>
<td>360.00</td>
</tr>
<tr>
<td>5</td>
<td>08/11/2010</td>
<td>0</td>
<td>9</td>
<td>62</td>
<td>26.41</td>
<td>19.75</td>
<td>119.00</td>
</tr>
<tr>
<td>6</td>
<td>04/04/2011</td>
<td>28</td>
<td>12</td>
<td>16</td>
<td>18.79</td>
<td>10.67</td>
<td>73.00</td>
</tr>
<tr>
<td>7</td>
<td>20/03/2012</td>
<td>46</td>
<td>13</td>
<td>26</td>
<td>28.84</td>
<td>15.88</td>
<td>131.00</td>
</tr>
<tr>
<td>8</td>
<td>15/12/2013</td>
<td>3</td>
<td>2</td>
<td>53</td>
<td>21.92</td>
<td>16.52</td>
<td>737.27</td>
</tr>
<tr>
<td>9</td>
<td>09/01/2014</td>
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were obtained using the Rational method and the lowest values of calculated peak discharge were obtained using the Snyder SUH method. The Nakayasu SUH method is shown slightly close to observed peak discharge but has significant bias inconsistent peak discharge. Indeed, the Nakayasu SUH method was relatively closer to observed peak discharge than other methods.

### Performance of the Calibrated method

The selected method presented relative accuracy in estimating peak discharge and indicated an approach similar to characteristics of the catchment.

### Conclusion

The present study analyzed peak discharge in ULRC using the Nakayasu SUH, Snyder SUH, Melchior and Rational method. The same physical parameters, including the area of the catchment (A) of 395 km²,
length of river (L) of 29.5 km and dimensionless runoff coefficient (C) ranged from 0.25 - 0.27 identified using GIS and obtained varied results of peak discharge. Each method has unique strengths and limitations; none can be determined universally superior. In selecting an appropriate method for ULRC characteristics, it emphasised comparing and validating the calculated peak discharge result among methods. Based on the results, it argued in comparison that the calculated peak discharge of Nakayasu SUH method was slightly close to the observed peak discharge. The performance of methods also validated by using error measurement showed that the Nakayasu SUH method has a highly accurate estimate of peak discharge in Lesti River. Based on the performance, the Nakayasu SUH method was considered relatively accurate in providing the estimated peak discharge value of the Lesti River.

<table>
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<th>No.</th>
<th>Year</th>
<th>(Q_{\text{pobs}}) (m(^3)sec(^{-1}))</th>
<th>(Q_{\text{pcal}}) (m(^3)sec(^{-1}))</th>
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Table 6. Error measure values

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<tr>
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<td>Snyder SUH</td>
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<td>Melchior</td>
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</table>

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Works Department). This work was made possible through their collective efforts.

Conflict of interest
The authors declare that they have no conflict of interest.

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Unami, Koichi (2023). Fractional Interpolation of the Unit-Hydrograph Method and the Lumped Flow Routing Meth-


