Abstract. After the 2017 eruption, rainfall-induced debris flow was generated within several rivers in where upstream area at Mount Agung. On 27 November 2017, a debris flow occurred in the Yeh Sah River after a rainfall intensity of 32 mm/day was monitored at the Rendang Observation Station. Estimation of rainfall-runoff-induced debris flow at this event is difficult and uncertain because this event occurred at 01.00 – 06.00 local time. This study focused on analyzing curve number value to estimate debris flow based on the 27 November 2017 event at Yeh Sah River Basin. Daily rainfall on 27 November 2017 was distributed to 6 hours using the PSA coefficient and then applied to generate runoff potential using the modified NRCS-CN for the hydrologic loss method and the SCS Unit Hydrograph for the transform method, applied in HEC-HMS 4.10. Hydrological model results are verified with the debris flow modeling using 2-D non-Newtonian features in HEC-RAS 6.3.1 with geometry based on topography 2016 and 2020. The results of the hydraulic model are validated with debris plain boundaries obtained from Google Earth imagery in 2018 and field observations in 2022. The result showed that the estimation of the debris flow event on 27 November 2017 using curve number values which consider five days of rainfall depth and land use/land cover slope of Yeh Sah River Basin was more comparable to the real condition.

1 Introduction

Mount Agung (8.34° S, 115.51° E) in Bali, Indonesia is one of the most dangerous and active volcanoes in the world. The 2017 Eruption was the greatest since 1963, threatening approximately 200,000 people who live within the hazard zone and more than 140,000 people evacuate, causing airport closures in Denpasar, Lombok, Banyuwangi and Jember, Syahbana et al. in [1].
Mount Agung’s previous eruption in 1963, one of the ten largest volcanic eruptions of the 20th Century with a Volcanic Explosivity Index (VEI) of 5, killed more than 1000 people due to 19 – 26 km high plumes and 10.5 to 14 km in length pyroclastic flows (hot and cold lava), Kusumadinata in [2].

Several studies have been carried out to define hydrological thresholds for debris flows. Rainfall-induced debris flow could be smaller than the annual maximum rainfall. The minimum daily rainfall-induced debris flow varies between different basins, Cui, et al. in [3]. The debris flow in Mesilau River was induced by 66.3 mm cumulative rainfall recorded for seven days, with the highest intensity being 14.2 mm/h which triggered the 5 June 2015 event, Rosli, et al. in [4]. Syarifuddin, et al. in [5] and Lavigne, et al. in [6] stated that debris flow risk of 40-42 mm of rainfall in 2 hours is still hazardous following accumulate rainfall amount in 2 h was 40 mm on Mount Merapi. The rainfall data for the debris flow that occurred at Yeh Sah river on 27 November 2017, was 32 mm/day (from the Rendang Sta.). Rainfall on 27 November 2017 is smaller than research by Lavigne and Syarifuddin but larger than research by Wu, et al. in [7] which states the minimum daily rainfall necessary to trigger debris flows at Jianjia Ravine is 20 mm/day. Verification of rainfall data at several observation stations around the Yeh Sah river basin and the Geophysics Station in Denpasar was carried out to ensure that the rainfall that occurred on 26-27 November 2017 can be used.

Debris flow is a mixed flow of fine-coarse material and water that moves under the influence of the slope of the river, Takahashi in [8]. The main parameters in the triggering of debris flow are the geometrical and morphological characteristics of the site (slope and river cross-profiles), material availability and its size, and lastly, runoff discharge, Gregoretti and Fontana in [9]. The material composition of the debris flow is dominated by coarse material, as described by Hecras in [10] and shown in the following Figure.

![Fig. 1. Taxonomy of mud and debris flow, HEC-RAS in [8].](image)

This study focuses on CN value for the hydrologic loss method to generate runoff potential. The SCS-CN loss model provides better results for the hydrologic response of the catchment in generated rainfall-runoff debris flow, Berti, et al. in [11]. The runoff estimate using the NRCS-CN method provides three antecedent soil moisture condition (AMC) that depends on five days of rainfall depth. The AMC-I is a five-day rainfall depth of less than 35 mm, The AMC-II is 35 to 52.5 mm and the AMC-III is over 52.5 mm, Chow, et al. in [12]. Several hydrological models use the CN value for AMC-II (traditional/normal condition) and were assigned based on the traditional NRCS-CN method which does not consider slope such as Syarifuddin, et al. in [5] and Berti, et al. in [11] where the s slope of land use is the important parameter in determining runoff and affect runoff estimation significantly, Huang, et al. in [13] and Garg, et al. in [14].
The problem behind this research is that the use of the traditional NRCS-CN method (AMC-II) is not following the debris flow event on 27 November 2017. The purpose of this study was to analyze the CN value by considering the AMC and the effect of slopes on the 27 November 2017 debris flow event.

2 Study area

The study area was the Yeh Sah river basin and Yeh Sah River, which are located on the southwestern flank of Mount Agung. The Yeh Sah River suffered the effects of the 2017 eruption with the most significant debris flow, Syahbana, et al. in [1] and Andaru, et al. in [15]. Administratively, Yeh Sah River Basin belongs to Rendang District, Karangasem Regency, Bali, Indonesia.

2.1 Topography

Elevation in Yeh Sah River Basin varies from 450 m to 3000 m (Mount Agung Area). The Basin slope in the Yeh Sah river basin was generated from the Slope Degree Map of Bali Province obtained from BIG in [16]. Data Elevation Model (DEM) obtained from BIG in [17]. Geometries Data of Yeh Sah River obtained from BWS Bali-Penida were topographic surveys in 2016 [18] and 2020 [19].

2.2 Land use and land cover

Land use and land cover in the Yeh Sah river basin were generated from the Land Use and Land Cover Map (shape file format) of Bali Province, obtained from BIG in [20]. The harmonized World Soil Database (HWSD) map of the hydrological soil group (HSG) obtained from FAO Soils Portal in [21] is used to determine the correct hydrologic soil group for the Yeh Sah river basin.

3 Material and methods

3.1 Conceptual Method

The conceptual method in this study is how to analyze CN value in hydrological modeling so that the estimation of the debris flow was more comparable to the real condition.

![Conceptual diagram](https://doi.org/10.1051/e3sconf/202447601015)

Fig. 2. Conceptual diagram.
3.2 Rainfall

Rainfall data (Table 1) is daily rainfall (R24) obtained from the BWS Bali-Penida. Rainfall measurements were carried out starting at 07.00 so that the debris flood event in the early hours of 27 November 2017 was the rainfall data for 26 November 2017. The daily rainfall data is used as area rainfall using the Thiessen polygon method.

<table>
<thead>
<tr>
<th>No</th>
<th>Station</th>
<th>Rainfall depth (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rendang</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Pegotan</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Klungkung</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Selisihan</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Telengan</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Tampaksiring</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>Geofisika Denpasar</td>
<td>24.5</td>
</tr>
</tbody>
</table>

Table 1. Data availability of observation station around Yeh Sah river basin.

The area rainfall data is then multiplied by the area reduction factor, BSN in [22]. The area reduction factor is shown in the Table 2.

<table>
<thead>
<tr>
<th>Area (km²)</th>
<th>ARF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 10</td>
<td>0.99</td>
</tr>
<tr>
<td>10 - 30</td>
<td>0.97</td>
</tr>
<tr>
<td>30 - 30000</td>
<td>1.152 - 0.1233 Log A</td>
</tr>
</tbody>
</table>

Table 2. Area reduction factor and areal rainfall.

The distribution of hourly rainfall uses the PSA 007 method which is recommended in the Technical Guidelines for the calculation of flood discharge at dams issued by Balai Teknik Bendungan in [23]. In this study, the selected distribution was for 6 hours, according to the area of the watershed is relatively small and it is very rare for the rain to occur with a duration of more than 6 hours (Table 3).

Table 3. The distribution of daily rainfall.

<table>
<thead>
<tr>
<th>Time step (hour)</th>
<th>R/Rtotal</th>
<th>Time step (hour)</th>
<th>R/Rtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.05</td>
<td>4</td>
<td>0.16</td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>5</td>
<td>0.06</td>
</tr>
<tr>
<td>3</td>
<td>0.6</td>
<td>6</td>
<td>0.03</td>
</tr>
</tbody>
</table>

3.3 NRCS-CN calculation methods

The study adopted the NRCS-CN method to estimate. The NRCS-CN method is based on two fundamental hypotheses and water balance, SCS in [24]:

\[
P = Ia + F + Q
\]

\[
\frac{Q}{P-Ia} = \frac{F}{S}
\]

\[
Ia = \lambda \cdot S
\]

where P is the precipitation (mm), Ia is the initial abstraction (mm), F is the cumulative infiltration (excluding Ia), Q is the direct runoff (mm), S is the potential maximum retention.
Infiltration (excluding Ia), $Q$ is the direct runoff (mm), $S$ is the potential maximum retention (mm), and $\lambda$ is the ratio of initial abstraction. Combining Eq. (1), Eq. (2) and Eq. (3), can be expressed:

$$Q = \frac{(P-Ia)^2}{P+S-Ia} \quad (4)$$

Equation (4) is valid for $P > Ia$, differently, $Q = 0$. The parameter $S$ is defined as:

$$S = \frac{25400}{CN} - 254 \quad (5)$$

where $CN$ is the curve number of runoff for hydrologic soil cover, which is a function of land cover, and the type of soil, and varies with one of three AMC. The AMC depends on the rainfall depth of the five-day antecedent that depends on season/weather which is further categorized as AMC-I, AMC-II and AMC-III. The values of $CN$ range from 0 to 100. Huang, et al. in [13] proposed a simplified approach and an equation for slope-modified $CN$ for AMC-II ($CN_{2a}$):

$$CN_{2a} = CN_2 \frac{322.79+15.63(\alpha)}{\alpha+32.52} \quad (6)$$

Sobhani in [25] proposed an approach for AMC-I and III ($CN_1$ and $CN_3$):

$$CN_1 = CN_2 \frac{2.334-0.01334}{CN_2} \quad (7)$$

$$CN_3 = CN_2 \frac{0.4036+0.005964}{CN_2} \quad (8)$$

Sharpley and Williams in [26], proposed some slope adjustments to $CN_2$:

$$CN_{2a} = \frac{1}{3} (CN_3 - CN_2)(1 - 2e^{-13.86\alpha}) + CN_2 \quad (9)$$

Shobani in [25] proposed some slope adjustments to $CN_2$, as follows:

$$CN_{2a} = CN_{2a} \frac{2.334-0.01334}{CN_{2a}} \quad (10)$$

Hawkins [27] proposed some slope adjustments to $CN_3$, as follows:

$$CN_{3a} = \frac{CN_{2a}}{0.427+0.00573CN_{2a}} \quad (11)$$

where $CN_1$ is $CN$ for AMC-I, $CN_2$ is $CN$ for AMC-II, $CN_3$ is $CN$ for AMC-III, $CN_{2a}$ is slope-adjusted $CN_2$, $CN_{3a}$ is slope-adjusted $CN_3$ and $\alpha$ (m/m) is the slope.

All approaches (AMC I, AMC II and AMC II) for traditional, with and without slope adjustment, are used in this study to calculate the effect of slope-corrected on debris flow estimation. In this study, the Sobhani and the Hawkins equation have been used to calculate $CN_1$ and $CN_3$. Approaches from Huang, Sharpley, Sobani and Hawkins have been used to calculate slope adjustment (slope-modified $CN$). This is based on research by Mishra in [28] who suggested the Sobhani approach is best for $CN_1$ and the Hawkins for $CN_3$. The AMC is determined based on the daily rainfall data and slope of each land cover/land use was calculated based on the slope map using ArcMap 10.5. The Ia has been estimated using the expression equation (3), assuming $\lambda$ as 0.2 for sub-basins 2 and 3, 0.1 for Sub-basin 1. Finally, direct runoff in each sub-basin for the 27 November 2017 rain event was calculated by adopting equation (4).

### 3.4 Hydrologic model

The hydrological analysis uses Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). CN values were entered for each sub-basin using the Soil Conservation Service (SCS) sub-basin loss method Eq. (6) – (11). The imperviousness of the surface for sub-basin 1 was set for 75%, sub-basin 2 and sub-basin 3 using impervious values based on
USDA. The SCS unit hydrograph is used as a transform method to calculate the actual surface runoff for each sub-basin. The lag time was set according to Eqs. (12) – (13). The Muskingum use as a routing method and the base flow was neglected because of field observation of the upstream region of the Yeh Sah river basin showed dry conditions.

\[
T_c = \frac{L^{0.8}(S+1)^{0.7}}{1140Y^{0.5}}
\]

(12)

\[
Lag Time = 0.6T_c
\]

(13)

where \(T_c\) is the time of concentration (hour), \(L\) is the length of the main river (ft), \(S\) is the potential max. retention (mm) and \(Y\) is the average basin slope (°).

### 3.5 Debris flow discharge

The According to the manual of Sabo Works issued by JICA in [30], the debris flow discharge shall be decided by considering the ratio of sediment concentration \(Cd\).

\[
Q_S = Q . (1 + Cd)
\]

(14)

\[
Cd = \frac{\rho_w \tan \theta}{(\sigma - \rho_w)(\tan \phi - \tan \theta)}
\]

(15)

\[
Cd = \frac{1100 \cdot \tan 12.9°}{(2780-1100)(\tan 25° - \tan 12.9°)} = 0.6
\]

(16)

where \(Q_s\) is debris flow discharge including sediment (m³/s), \(Q\) is peak debris flow discharge (m³/s), \(Cd\) is the ratio of sediment concentration (%), \(\rho_w\) is water mass density (kg/m³), \(\sigma\) is sediment mass density (kg/m³), \(\phi\) is the internal friction of material (°) and \(\theta\) is the slope of water surface, and \(\bar{\psi}\) is the inclination angle of the current velocity direction. The critical term for this analysis is \(\tau\), the fluid stress. In the non-Newtonian model:

\[
\tau = \tau_r + \tau_{MD}
\]

(18)

where \(\tau_r\) is the basal stress and \(\tau_{MD}\) based on the stress-strain rheology (the model selected for the material). The function of the friction slope \(S_f\):

\[
\tau_r = \gamma RS_f
\]

(19)

where \(\gamma\) is the fluid unit weight, \(R\) is the radius of hydraulic, and \(S_f\) is the friction slope based on Manning’s equation:

\[
S_f = \left(\frac{nv}{R^2}\right)^2
\]

(20)

### 3.6 Hydraulic model

In this study, the hydraulic analysis uses HEC-RAS 6.3.1. Based on a non-Newtonian algorithm library called DebrisLib, HEC-RAS applies single-phase, rheological approaches to non-Newtonian simulations, Gibson, et al. in [30] and Floyd, et al. in [31]. This study uses full SWE (shallow water equation) and the non-Newtonian approach is Harchel-Bukley. The equation of momentum and conservation, HEC-RAS in [10] is as follows:

\[
\frac{\partial V}{\partial t} + (V \cdot \nabla)V = -g \cos \theta \frac{\partial u}{\partial x} + \frac{1}{h} \nabla \cdot (\gamma h \nabla V) - \frac{\tau_r}{\rho m} \cos \theta \frac{V}{|V|}
\]

(17)

where \(g\) is the acceleration of gravitational, \(u_r\) is a turbulent eddy viscosity, \(\phi\) is correction factor of the slope, \(\rho_m\) is the water-solid mixture density, \(R\) is the hydraulic radius, \(|V|\) is the magnitude of the velocity vector, \(\phi\) is the slope of water surface, and \(\bar{\psi}\) is the inclination angle of the current velocity direction. The critical term for this analysis is \(\tau\), the fluid stress. In the non-Newtonian model:

\[
\tau = \tau_r + \tau_{MD}
\]

(18)

where \(\tau_r\) is the basal stress and \(\tau_{MD}\) is based on the stress-strain rheology (the model selected for the material). The function of the friction slope \(S_f\):

\[
\tau_r = \gamma RS_f
\]

(19)

where \(\gamma\) is the fluid unit weight, \(R\) is the radius of hydraulic, and \(S_f\) is the friction slope based on Manning’s equation:
4 Results and discussions

The Yeh Sah river basin has an area of 19.05 km² and the length of the main river is 9.51 km. The Yeh Sah river basin is then divided into 3 sub-basins (Figure 3a).

Fig. 3. (a) Yeh Sah river basin (b) slope percent map of Yeh Sah river basin.

The Basin slope class of > 45% is 26.56%, 25-45% is 30.45%, 15-25% is 18.01%, 8-15% is 18.90% and 0-8% is 6.09% of the total area (Figure 3b).

Fig. 4. (a) Land use/land cover (b) soil group map of Yeh Sah river basin.

The ten major land use classes of Yeh Sah River Basin found were: grove area, primary dryland dense forest, residential area, mining area, agriculture, savanna/grassland, agriculture plantation, fallow land, dry farming mixed plantation and mixed dryland farming (Figure 4a). The percent coverage of each class for over sub-basin is tabulated in Table 4.
A 19.05 km² river basin area is shown in Table 6.

The daily rainfall data is used as area rainfall using the Thiessen polygon method. The results of the Thiessen polygon analysis using ArcMap 10.5 found that Rendang Station had 100% influence on the occurrence of rain in the Yeh Sah basin as shown in Figure 5. The area rainfall data is then multiplied by the area reduction factor (ARF). The ARF used for the 19.05 km² river basin area is 0.97 shown in Table 6.

The map of soil textural classes is prepared (Figure 4b) and the coverage area of each soil class has been calculated as shown in Table 5.

The polygon Thiessen of Yeh Sah river basin is shown in Figure 5.

**Table 4.** Slope and area of land use class.

<table>
<thead>
<tr>
<th>No</th>
<th>Land use class</th>
<th>Sub Basin-1</th>
<th>Sub Basin-2</th>
<th>Sub Basin-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Area (km²)</td>
<td>Slope (m/m)</td>
<td>Area (km²)</td>
</tr>
<tr>
<td>1</td>
<td>Grove area</td>
<td>0.63</td>
<td>0.13</td>
<td>1.89</td>
</tr>
<tr>
<td>2</td>
<td>Primary dryland forest</td>
<td>2.84</td>
<td>0.29</td>
<td>2.42</td>
</tr>
<tr>
<td>3</td>
<td>Residential area</td>
<td>0.00</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>4</td>
<td>Mining area</td>
<td>0.61</td>
<td>0.11</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>Agriculture</td>
<td>2.15</td>
<td>0.11</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>Savanna/grassland</td>
<td>0.37</td>
<td>0.39</td>
<td>0.17</td>
</tr>
<tr>
<td>7</td>
<td>Agriculture Plantation</td>
<td>0.04</td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>8</td>
<td>Fallow land</td>
<td>0.94</td>
<td>0.27</td>
<td>0.05</td>
</tr>
<tr>
<td>9</td>
<td>Dryland farming</td>
<td>0.00</td>
<td>0.00</td>
<td>3.27</td>
</tr>
<tr>
<td>10</td>
<td>Mixed dryland farming</td>
<td>0.00</td>
<td>0.00</td>
<td>3.04</td>
</tr>
<tr>
<td></td>
<td><strong>Σ</strong></td>
<td><strong>7.59</strong></td>
<td><strong>11.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.** Sub basin area covered by soil types.

<table>
<thead>
<tr>
<th>No</th>
<th>Soil Group</th>
<th>Loam Area (km²)</th>
<th>Loamy Sand Area (km²)</th>
<th>Total Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sb-1</td>
<td>5.67</td>
<td>1.93</td>
<td>7.59</td>
</tr>
<tr>
<td>2</td>
<td>Sb-2</td>
<td>10.76</td>
<td>0.24</td>
<td>11.00</td>
</tr>
<tr>
<td>3</td>
<td>Sb-3</td>
<td>0.46</td>
<td>0.00</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td><strong>Σ</strong></td>
<td><strong>16.89</strong></td>
<td><strong>2.17</strong></td>
<td><strong>19.05</strong></td>
</tr>
</tbody>
</table>

**Fig. 5.** Polygon Thiessen of Yeh Sah river basin.
The distribution of hourly rainfall data in Das Yeh is valid due to the limited available rainfall intensity data. The distribution of hourly rain data for 6 hours is shown in figure 6.

![Rainfall Distribution](image)

**Fig. 6.** The distribution of hourly rainfall.

Based on the depth of rainfall for 5 days in table 1, the CN value used is the CN value at AMC III. The slope of the Yeh Sah River Basin also has a significant effect on the CN value (Table 7).

<table>
<thead>
<tr>
<th>CN Composite</th>
<th>Area (km²)</th>
<th>CN</th>
<th>CN2α (Huang)</th>
<th>CN1 (Sobani)</th>
<th>CN3 (Sobani)</th>
<th>CN2α (Sharpley)</th>
<th>CN2α (Sobani)</th>
<th>CN3α (Hawkins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB.1</td>
<td>7.59</td>
<td>74.55</td>
<td>75.09</td>
<td>55.91</td>
<td>87.82</td>
<td>78.11</td>
<td>60.64</td>
<td>89.27</td>
</tr>
<tr>
<td>SB.2</td>
<td>11.00</td>
<td>76.62</td>
<td>76.99</td>
<td>58.82</td>
<td>88.92</td>
<td>79.48</td>
<td>62.73</td>
<td>89.99</td>
</tr>
<tr>
<td>SB.3</td>
<td>0.46</td>
<td>81.00</td>
<td>81.20</td>
<td>64.62</td>
<td>91.35</td>
<td>82.80</td>
<td>67.35</td>
<td>91.85</td>
</tr>
</tbody>
</table>

Initial abstraction is affected by the CN value. The Ia value for each CN method is different. CN in AMC-III with the influence of slope is the minimum value (Table 8).

<table>
<thead>
<tr>
<th>CN Types</th>
<th>Lag (min)</th>
<th>Ia (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>SB.1</td>
<td>SB.2</td>
</tr>
<tr>
<td></td>
<td>54.48</td>
<td>54.17</td>
</tr>
<tr>
<td>CN2α (Huang)</td>
<td>53.65</td>
<td>53.59</td>
</tr>
<tr>
<td>CN1 (Sobani)</td>
<td>88.91</td>
<td>87.23</td>
</tr>
<tr>
<td>CN2α (Sobani)</td>
<td>35.44</td>
<td>35.85</td>
</tr>
<tr>
<td>CN2α (Sharpley)</td>
<td>35.44</td>
<td>35.85</td>
</tr>
<tr>
<td>CN3α (Sharpley)</td>
<td>35.44</td>
<td>35.85</td>
</tr>
<tr>
<td>CN3α (Hawkins)</td>
<td>49.08</td>
<td>49.69</td>
</tr>
<tr>
<td>CN3α (Sobani)</td>
<td>33.49</td>
<td>34.34</td>
</tr>
</tbody>
</table>

Flood discharge modeling can be done after getting the results of the loss model parameters. Modeling the flood discharge in the Yeh Sah watershed using the SCS unit hydrograph (HEC-HMS 4.10) is shown in the Figure 7.
Using Eq. 14, debris flow discharge has been calculated as tabulated (Table 9).

<table>
<thead>
<tr>
<th>Discharge</th>
<th>SCS Qw (m³/s)</th>
<th>Debris Flow Qs (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>20.24</td>
<td>33.77</td>
</tr>
<tr>
<td>CN2α</td>
<td>20.55</td>
<td>34.29</td>
</tr>
<tr>
<td>CN1</td>
<td>14.89</td>
<td>24.84</td>
</tr>
<tr>
<td>CN3</td>
<td>36.02</td>
<td>60.10</td>
</tr>
<tr>
<td>CN2α (Sharpley)</td>
<td>22.72</td>
<td>37.91</td>
</tr>
<tr>
<td>CN2αs</td>
<td>15.14</td>
<td>25.26</td>
</tr>
<tr>
<td>CN3α</td>
<td>38.46</td>
<td>64.17</td>
</tr>
</tbody>
</table>

Table 9. The volume of the debris flow discharge is affected by sediment Qw

Based on the hydrological modeling results, it was found that the analysis of the CN value gave a significant difference to the debris flow discharge. Debris flows events on 27 November 2017 occurred in AMC III, where the Yeh Sah River Basin is dominant with steep slopes so hydrological modeling in this watershed needs to review AMC conditions and the influence of slope. Verification was carried out on the flood discharge results of CN, CN3 and CN3a with hydraulics modeling using the HEC-RAS 6.3.1 software with geometry from topographic surveys in 2016 and 2020. The modeling results were compared with the debris event boundary on 27 November 2017 obtained from Google Earth 2018 and field observation in August 2022 (Figure 8). The modeling was carried out on the 1.2 km long Yeh Sah River with an inundation area of 7.04 ha.
Using Eq. 14, debris flow discharge has been calculated as tabulated (Table 9).

The volume of the debris flow discharge is affected by sediment $Q_w$. Based on the hydrological modeling results, it was found that the analysis of the CN value gave a significant difference to the debris flow discharge. Debris flows events on 27 November 2017 occurred in AMC III, where the Yeh Sah River Basin is dominant with steep slopes so hydrological modeling in this watershed needs to review AMC conditions and the influence of slope. Verification was carried out on the flood discharge results of CN, CN3 and CN3a with hydraulics modeling using the HEC-RAS 6.3.1 software with geometry from topographic surveys in 2016 and 2020. The modeling results were compared with the debris event boundary on 27 November 2017 obtained from Google Earth 2018 and field observation in August 2022 (Figure 8). The modeling was carried out on the 1.2 km long Yeh Sah River with an inundation area of 7.04 ha.

<table>
<thead>
<tr>
<th>Item</th>
<th>Area (ha)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27-Nov-17 inundation boundary</td>
<td>7.05</td>
<td>100.00</td>
</tr>
<tr>
<td>Geometry 2016 - CN</td>
<td>2.69</td>
<td>38.12</td>
</tr>
<tr>
<td>Geometry 2016 - CN3</td>
<td>5.75</td>
<td>81.61</td>
</tr>
<tr>
<td>Geometry 2016 - CN3a</td>
<td>6.32</td>
<td>89.69</td>
</tr>
<tr>
<td>Geometry 2020 - CN3a</td>
<td>6.69</td>
<td>95.02</td>
</tr>
</tbody>
</table>

### Table 10. Percentage of the model area to 2017 debris flow event.

5 Conclusions

The daily rainfall on 27 November 2017 was 32 mm/day, increasing significantly when the CN was analyzed with the effect of the slope of the land cover and the appropriate AMC. This is evidenced by hydraulic modeling where inundation was generated in the review area.
close to the incident on 27th November 2017. The planning of water structures in the Yeh Sah watershed and other watersheds in the Gunung Agung volcanic area, where field data and historical information on past debris flow activities are limited, the parameters analyzed in this study must be carried out so that the buildings are not over or under-designed. Further research should encourage scientists to examine the validity of proposed approaches in other watersheds by comparing the results of hydrological and hydraulic models with debris flow events. However, using this approach for blind prediction where verification and validation parameters are not available, is exercised with special caution.

Acknowledgement

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