EVALUATION OF DRAINAGE CAPACITY IN SUSTAINABLE LAND USE EFFORTS
(Case Study: Campus V of Sebelas Maret University, Indonesia)

*Sukatiman
Center for Disaster Studies, Sebelas Maret University

Corresponding Author: sukatiman@staff.uns.ac.id

Abstract. Climate change in recent years has become increasingly worrying for the earth's population, almost every country has been severely damaged by flood, and some even have to experience loss of life and property. A great effort from every land user to manage proper land use is needed in an attempt to prevent floods. This research aims to evaluate sustainable land use so that it does not cause runoff, which later will contribute to wider floods. The type of research applied is descriptive quantitative implementing survey research methods and evaluation of land flood discharge on campus V UNS Surakarta Indonesia. The calculation results of flood discharge that may occur then compared to the available drainage capacity. The results showed that land use still meets the requirements for the ratio of closed land and open land, as well as the available drainage is still able to accommodate the estimated rainfall discharge for the next seven-year period.

Keywords: Land Use, Drainage evaluation, Sustainable Development.

A. Introduction

Almost in every rainy season, news reporting floods spreads around the world, including Indonesia. It has caused chaos and disruption to social and economic activities, damaging road, and railroad vehicles, affecting property levels, loss of life, and increased vulnerability [1]. The impact of flood which has been mentioned previously can happen due to improper land use. The lack of consideration of the balance between closed lands such as buildings and open land which absorbs rainwater into the soil naturally. The regulation of the Minister of Public Works Number 06/Prt/M/2007 dated March 16, 2007, on General Guidelines for Building and Environmental Planning (2007: 20) construes the principles of structuring the intensity of functional land use, one of which is the use of sufficient open space to provide comfort for the environment with a ratio of 60% built space versus 40% green open space. Unfortunately, infrastructure development is more focused on the service of infrastructure benefits by ignoring the development of green infrastructure [2].

According to the Decree of the Minister of Environment Number 4 of 2000, there are five (5) main principles in the development of an environmentally sound campus, namely: 1) Maintaining and enriching existing ecosystems; 2) Minimum use of energy; 3) Strict control of waste and pollution; 4) Maintaining the sustainability the local socio-cultural system; 5) Developing a deeper understanding of environmental concepts. In complying with the ministerial regulation, this research focuses on a) maintaining and enriching ecosystems, and b) waste control in the form of rainwater waste control. Spatial planning is one of the attempts to raise the awareness
of sustainable development. In line with that, the existence of law in every spatial planning will greatly determine the success of the spatial planning policy itself [3].

The establishment of green infrastructures cannot be separated from good waste management, which realization is in the form of providing qualified drainage with adequate capacity. The provision of sustainable drainage will also increase land value [4]. Poor drainage provision, especially on highway drainage facilities, will cause inundation which is dangerous for transportation mobility [5]. Drainage performance measurement involves many elements and is important in the decision-making process to develop sustainable areas (La Rosa & Pappalardo, 2021).

The campus land demand depends on the number of accepted students. The economic growth, the number of the population, and the quality of the campus will determine a higher student acceptance number at Sebelas Maret University. However, the infrastructure development should be established based on the green campus concept. Regarding the green campus concept, Sebelas Maret University is included in the best 10 green campuses in Indonesia according to UI green metric in 2022 (https://greenmetric.ui.ac.id/rankings/ranking-by-country-2022/Indonesia), and achieved number 43 green campus on the world (Overall Rankings 2022 - UI GreenMetric). This research aims to maintain the quality of Sebelas Maret University. In achieving the purpose of this study, the research will be based on the following research question:

In facing globalization and climate change, a better understanding of sustainable land use and the prioritizing countermeasures that support sustainability have become very important for the world [6]. Has the campus maintained the ecosystem by attempting open land control and closed land utilization?

In complying with the decree of the minister regarding an environmentally sound campus, how will the rainwater control system be applied?

The flood evaluation concept established in this research consists of:

1) The hydrological data is collected from the statistical rainfall data of the province/location of the research site for the past 10 years.
2) The land use data tracing, both open and closed land, is used to calculate the runoff coefficient.
3) The topographic data tracing is in the form of channel shape and dimensions, channel length, and channel slope.
4) The calculation of land rainfall discharge.
5) The calculation of existing channel capacity.
6) The comparison of the discharge occurring on the land towards the channel capacity.
7) Follow-up actions.

Follow-up actions are necessary to prevent the continuous increase of rainfall discharge through a natural-based solution concept. This concept aligns with the natural-based solutions developed by the International Union for Conservation of Nature (IUCN) and the World Bank in 2008 [7]. These solutions refer to natural approaches and methods developed in response to various social challenges or disasters, aiming to achieve goals such as sustainable resource management, effective disaster risk management, disaster prevention, and mitigation, while simultaneously providing social and environmental benefits [8]; [9].
B. Research Methods

a) This research applied a quantitative descriptive approach. Based on its benefits, this research is categorized as applied research, designed to provide practical answers to real problems or address practical needs directly and specifically [10]. Data collection is conducted through field survey research to determine land area, land cover, length, and slope of the land. Participants in this research are students enrolled in the Water Building Construction course, totaling 25 students divided into 6 groups. The equipment used for data collection includes:

b) Handheld GPS to measure land area by tracing around the land to be measured, and also to measure channel length and road length.

c) A website containing a land map to show the research location, accessible globally.

d) Data analysis was conducted using Excel.

C. Result and Discussions

C.1 Calculating Average Rainfall

Daily rainfall data occurring in a certain area can be used to calculate flood discharge. In determining flood discharge, only the rational calculation will be discussed, considering that this formula is the most commonly used in the field, with the formula:

\[ Q = 0.278 \times C \times Cs \times I \times A \]  

In which,

- \( Q \) = Discharge (m\(^3\)/s)
- \( C \) = Flow coefficient
- \( Cs \) = Storage coefficient
- \( A \) = Watershed area (Km\(^2\))
- \( I \) = Rainfall intensity during the concentration period (mm/h)

To calculate the value of each symbol in the above formula, the elaboration and analysis are done as follows:

C.1.a Calculation of Flow Coefficient.

To obtain the average coefficient data from the studied area, a field survey is conducted using a Montana 500 handheld GPS. Measurements of building elements, asphalt roads, and paved garden paths are done by setting the GPS to measure the area, then tracing around the surveyed land to automatically obtain the area. The flow coefficient (runoff coefficient) is the ratio of the amount of rainwater flowing over the ground surface (surface runoff) to the amount of rainwater falling from the atmosphere. Here are the survey results of flow coefficients corresponding to land use. The displayed results already represent the average area of land covered by buildings, open land like roads, paved parking lots, as well as gardens that can still completely absorb runoff. The condition of the land is multiplied by the flow coefficient. The field survey results using GPS can be tabulated as follows:
<table>
<thead>
<tr>
<th>Land Elements</th>
<th>Area (m²)</th>
<th>Percentage (%)</th>
<th>Flow Coefficient</th>
<th>Average Flow Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed Land</td>
<td>8106.5</td>
<td>55.65</td>
<td>0.9</td>
<td>0.522</td>
</tr>
<tr>
<td>Open Land</td>
<td>5394.7</td>
<td>44.35</td>
<td>0.7-0.9</td>
<td>0.443</td>
</tr>
<tr>
<td>Natural Open Land</td>
<td>1066</td>
<td>0.2</td>
<td>0.2</td>
<td>0.346</td>
</tr>
<tr>
<td>Total</td>
<td>14567.2</td>
<td></td>
<td></td>
<td>0.333</td>
</tr>
</tbody>
</table>

Note: The details of land area calculations along with their respective coefficients are documented by the researcher.

The results of the analysis of the total building area compared to the open land and closed land areas can be explained as follows: for closed land in the form of buildings, it accounts for 55.65%, while for open land, it accounts for a total of 44.35%. These results indicate that the land usage ratio at the research site still meets the requirements of the regulation regarding the ratio of closed land to open land, with a ratio of 60% closed land to 40% open land. Spatializing open spaces is important to identify their coverage areas, with the intention of creating interconnected environments and providing water storage volume in strategic areas for flood control [11]. From the table above, the runoff coefficient (C) value is obtained as 0.333%.

C.1.b Calculation of Storage Coefficient.

Based on the rainfall data obtained from BMKG (Indonesian Meteorology, Climatology, and Geophysics Agency) from the Central Java Climatology Station, in accordance with the research location, the average rainfall in 2022 is 205.97 mm. Next, the storage coefficient (Cs) will be calculated with a planning recurrence period of 7 years. The following formula is used to calculate the storage coefficient:

\[ Cs = \frac{2Tc}{(2Tc+2Td)} \] ………………………………………… (1.2)

In which,
\( Cs \) = Storage Coefficient
\( Tc \) = Concentration Time (hours)
\( Td \) = Time of flow of water in the channel from the upstream to the measurement point (hours)
\( n \) = Manning's roughness coefficient, for asphalt and concrete = 0.013.

It is divided into two parts to calculate the concentration-time (tc):
\( T0 \) = The time required for water to flow on the land surface to the nearest channel.
\( Td \) = The time of travel from the point of entry into the channel to the exit point.

The concentration-time can be calculated using the formula:

\[ Tc = T0 + Td \] ………………………………………………………………………………… (1.3).

Values for \( T0 \), \( Td \), and \( Tc \) can be obtained from Kirpich's empirical formulas:

\[ T0 = 0.0195 \left( \frac{L_0}{\sqrt{S0}} \right)^{0.77} \] ……………………………………………………… (1.4)

Where:
To = Inlet time to the nearest channel (minutes)
Lo = Farthest flow distance above ground to the nearest channel (meters)
So = Slope of the ground surface over which the flow travels.
So = is the ratio of the height difference between the farthest point and the observation point, estimated to be equal to the average slope of the watershed.
Lo = Farthest flow distance above ground to the channel bottom (meters)

**Figure 1. Research Location Drainage System**

Field observations yield $n = 0.013$, $So = 2.0\%$, and $V = 0.9 \text{ m/second}$. The concentration-time ($tc$) of a watershed is the time it takes for rainfall to flow from the farthest point to the watershed's outlet (control point) after the soil becomes saturated and small depressions are filled.

The value of $T_d$ is determined by the length of the channel traversed by the flow and the flow velocity in the channel, as indicated in the formula:

$$T_d = \frac{1}{3600} \cdot \frac{L}{V}$$  \hspace{1cm} (1.5)

In which,

$T_d =$ Conduit time to the measurement point (hours)
$L =$ Distance traveled by the flow in the channel to the measurement point (meters)
$V =$ Flow velocity in the channel (meters/second)

The time it takes for water to flow in the channel ($T_d$) is determined by the formula, based on the channel conditions. For natural channels, their hydraulic properties are hard to determine, and $T_d$ can be estimated using the velocity approximation as follows:
Inlet Time:

\[ T_0 = 0.0195 \left( \frac{L_0}{\sqrt{S_0}} \right)^{0.77} \]

\[ T_0 = 0.0195 \left( \frac{50}{\sqrt{0.02}} \right)^{0.77} \]

To = 1,788 minutes

\[ T_d = \frac{1}{3600} \cdot \frac{L}{V} \]

\[ T_d = \frac{1}{3600} \cdot \frac{200}{0.6} \]

Td = 0,093 hour, Td = 5,555 minutes

\[ T_c = T_0 + T_d \]

= 1,788 + 5,555

= 7,343 minutes = 0,122 hours

After calculating the supporting components, the storage coefficient (Cs) can be analyzed as follows:

\[ C_s = \frac{2T_c}{(2T_c + 2T_d)} \]

\[ = \frac{2 \times 0.122}{[(2 \times 0.122) + (2 \times 5.555)]} \]

\[ = 0.215 \]

C.1.c Calculation of Designed Rainfall

Flood discharge for a 7-year recurrence interval is taken from the years 2010 to 2022, amounting to 196.35 mm/year. Sd represents the standard deviation, and it can be analyzed as follows:

\[ R = R + K \cdot Sd \]

\[ = 196.35 + 1.01 \cdot 47.58 \]

\[ = 216.70 \text{ mm} \]

(Note: Further calculations are stored in the researcher's document.)

C.2.a Calculating Flood Design

The analyzed data above consists of C = 0.333; Cs = 0.215; Tc = 0.122 hours, and area A = 0.0146 Km2, therefore:

\[ I = \frac{R_s \cdot 24}{24} \frac{24}{7} \]

\[ I = \frac{216.70 \cdot 24}{24} \frac{24}{0.122} \]

\[ = 33.825 \text{ mm/hours} \]

\[ Q = 0.278 \cdot C \cdot C_s \cdot I \cdot A \]

\[ Q = 0.278 \times 0.333 \times 0.215 \times 33.825 \times 0.0146 \]

\[ Q = 0.0976 \text{ m}^3/\text{det} \]

Thus, the design flood discharge for a 7-year recurrence interval for the urban drainage is 0.0976 m³/s.
C.2 Open Channels Flow Capacity

The trapezoidal channel has the following dimensions: Bottom Width = 0.50 m, Top Width = 1.05 m, Cross-sectional Height = 1.65 m. The flow velocity with a slope of 2% is 0.6 m/s. Based on the given data, the trapezoidal channel's area is calculated as follows:

\[ A = \frac{(\text{sum of parallel sides})}{2} \times \text{height} = \frac{(1.05 + 0.50)}{2} \times 1.65 = 1.279 \, \text{m}^2 \]

The water discharge that the trapezoidal channel can accommodate can be calculated as follows:

\[ Q = A \times V \]

In which,

- \( Q \) = water discharge in the channel (m³/s)
- \( A \) = cross-sectional area of the channel (m²)
- \( V \) = flow velocity in the channel (m/s)

The calculation result yields \( Q = 1.279 \times 0.66 = 0.844 \, \text{m}^3/\text{s} \).

Therefore, based on the calculation of the trapezoidal channel capacity, the runoff discharge is 0.844 m³/s.

D. Conclusion

Campus V of Sebelas Maret University (UNS), surrounded using Garmin Montana GPS, has a total area of 0.0142 km². It consists of closed land usage covering an area of 8106.5 m² (52%) and open land with paving covering an area of 6460.70 m² (44.35%). It can be concluded that the campus land still meets the requirement of the 60:40 ratio between closed and open land use according to the Regulation of the Minister of Public Works No.06/Prt/M/2007 dated March 16, 2007, concerning General Guidelines for Building and Environmental Planning [12]. In terms of flood management, the campus land has an average land flow coefficient (C) of 0.333, resulting in a flood discharge (runoff) of \( Q = 0.328 \, \text{m}^3/\text{s} \). On the other hand, the capacity of the channel, calculated based on the water discharge using a trapezoidal channel, is 0.8440 m³/s. This implies that the campus channel capacity is sufficient to accommodate the occurring flood discharge.

E. Recommendation

The flood evaluation of this land can serve as a standard reference for stakeholders to plan and implement controlled land use measures in accordance with government regulations [13]. This reference becomes a follow-up action for preventing larger floods, employing nature-based solutions through comprehensive public awareness to utilize planned land use. It also highlights the lack of government attention towards the implementation of regulations adhered to by stakeholders.

F. Limitation

To achieve more accurate field observation data, conducting additional field surveys during rainy periods is necessary. This approach ensures higher precision and accuracy in data collection.
References


