Curve Number Method to Determine the Runoff Height in the Upper Cimanuk Watershed

Dwi Ariyani*, Vera Aprilia, Atie Tri Juniati, Atri Prautama Dewi, Fadli Kurnia
Civil Engineering Department, Faculty of Engineering
Universitas Pancasila

* dwi.ariyani@univpancasila.ac.id

Abstract. Run off is one of the most important hydrological variables in supporting water resources development planning and activities. To predict the amount of runoff can be done in various ways one of them with the SCS-CN method. The SCS method was developed from years of rainfall observation and involved many agricultural areas in the United States. This method seeks to link watershed characteristics such as soil, vegetation, and land use with a runoff curve number which indicates the potential runoff water for a particular rainfall. The location of this research is Garut Regency, upstream of the Cimanuk river, which often floods every year due to overflowing of the Cimanuk River. Data used to determine CN values and runoff height are Digital Elevation Model (DEM), land use, soil, and rainfall data for the last 10 years, from 2009 to 2018, then the maps are processed using the Arc-Map program. From the analysis it can be seen that the CN value is 66.54%, and the runoff height is 1.17 cm with a 2 year return period, and 2.84 cm at 25 return period. Based on the CN value, it is known that the type of soil in the upstream Cimanuk watershed has a small infiltration rate and has bad properties in infiltrating water, so that it can cause run off for a long time, because the smaller CN value on a land use, so soil’s retention ability is greater and the less chance of runoff. The results of this study can be used for planning flood control buildings in the upper Cimanuk watershed.

1. Introduction
Watershed is defined as an area that drains water into rivers, this drainage is in the form of ground water or surface water or drainage caused by gravity. DAS as an overlay area / region is restricted by limiting the topography (hills) which receive, collect rain water, sediments and nutrients as well as running it over the creeks and out on the main river to the sea or lake. At a macro level, watershed consists of biotic elements (flora and fauna), abiotics (soil, water, and climate), and humans, where the three interact and interdependence to form a hydrological system. Flood events in the watershed depend on the type of soil and land use. Garut Regency is an upstream area of the Cimanuk River which often floods every year, this is due to land use that causes runoff. At the watershed there are various kinds of land use, land settlement areas more quickly produce rainfall runoff than forested land, the runoff is one variable hydrological very important in supporting the activities of the development of water resources, which are influenced by land use, to find out land use change using GIS, in Kundhapalam Watershed using GIS based SCS-CN method for estimating runoff, from the calculation was found that depth of run off is 72.5 mm for average annual rainfall of 173.5 mm [1]. To know distribution characteristics in garut by using statistical analysis such as log pearson type III, in Nigeria to calculate peak daily rainfall distribution show that the log pearson type III is the best occupying 50% from total station number [2]. Reliable prediction method for calculating rate of runoff
that comes from the ground and moving towards the river in a watershed that is not equipped with measuring devices (ungaged watershed) is a very difficult job and requires a long time. The approach taken to determine the height of runoff could determine the value of Curve Number (CN), in the Pappiredipatti watershed of the vaniyar sub basin, South India using SCS-CN method by GIS to define value of CN, it proved soil conversation service-curve number is efficiently proven as a better method [3]. CN method is based on the relationship infiltration on any type of ground with the amount of precipitation that falls on every time it rains, by knowing the value of CN can be seen high of runoff in a watershed area [4][5][6].

2. Method and Materials

2.1. Data Used

This research was conducted using secondary data, in the form of rainfall data from Bayongbong, Cikajang and Leuwingtis stations, for the past 10 years, from 2009 to 2018 (see fig. 1). Digital Elevation Model (DEM) map of 8m x 8m resolution is obtained from the National Digital Elevation Model (DEMNAS) according to the needs of research data. Land Use map data from Cimanuk Cisanggarung River Basin Center and Soil data from BBWS. The map data that has been obtained is processed using GIS. In this study there are several variables that will be used in analyzing, that is; (a) Land use includes the classification and intensity of land use (Settlements, rice fields, plantations, rivers, etc.), (b) The basic physical conditions of the area include rainfall and hydrology conditions, (c) The soil hydrology class is the hydrology soil group (HSG) which is very influential on the CN value [7].

Figure 1. Location of the Rain Station in the Upper Cimanuk River Basin

2.2. Method

The method of determining the direction flow using the DEM (Digital Elevation Model) analysis aims to determine the direction of flood flow by utilizing GIS software [8]. DEM data used for this study is high resolution, which is 8m × 8m for each pixel grid. Flood affected areas were analyzed from the critical land map overlay with the Upper Cimanuk watershed boundary mapx. Critical land maps and watershed boundary maps were obtained from BBWS. This analysis is used to determine the area affected by flooding due to overflow in the Cimanuk Hulu
watershed as seen from its critical land. Land use and soil hydrology groups were analyzed by overlay land use maps and Soil Group maps using the ArcMap program [9][10]. The results of this analysis are the extent of each type of land use and distribution in the Cimanuk Hulu watershed. The determination of soil hydrological groups is based on the potential of surface runoff, soil solum, soil porosity, permeability level and minimum infiltration rate. The data from the results of this analysis are then used in determining the CN value, with the following formula:

\[
WCN = \frac{A_1 \times CN_1 + A_2 \times CN_2 + \cdots + A_n \times CN_n}{A}
\]

where: WCN = Weighted Curve Number, A = land use area, CN = curve number of each land use. Surface Flow Curve Number (BK), or better known as CN (Runoff Curve Number) determined by observing the Soil Hydrology Group (HSG), AMC, and land use. Soil Hydrology Group (HSG) consists of four groups given the symbol A, B, C, and D. Total curah yang jatuh total rainfall (P) above ground with maximum potential soil for holding water (retention) (S), will be divided into three components; run off (Q), infiltration (F) and initial abstraction (Ia), with relation [11][12].

\[
Q = \frac{(P - Ia)^2}{(P - Ia + S)}
\]

with,

\[
S = 2.54 \left( \frac{100}{CN} - 10 \right)
\]

where: Q = Surface runoff volume (mm), Ia = initial abstraction, P = daily rain (mm), S = retention parameter (mm), CN = curve number, flowing water varies from 0 to 100.

P value is came from design rainfall is needed to calculated the run-off height, to find design rainfall each return period using Log Pearson Type III distribution method [13]. Rainfall data from three rain stations namely at the Bayongbong, Cikajang and Lewingitis rain stations, to get value regional rainfall using the Thiessen polygon method.

\[
\bar{P} = \frac{1}{A} \sum_{N=1}^{N} A_N \times P_N
\]

where: A = catchment area, AN = Catchment area of each polygon, P = Rainfall

3. Results and Discussion
3.1. Rainfall Analysis Result
In chapter three the maximum average rainfall data for 10 years from 2009 to 2018 at each rain station (see table below), then the data is analyzed using Polygon thiessen and ArcMap program, which has an extension facility in the form of Created Polygon thiessen (see fig.2) to get the average value of maximum monthly rainfall in each year (see table 1).
3.2. Result of Hydrology Soil Group Analysis

Hydrology Soil Group (HSG) Upstream Cimanuk watershed is dominated by group B and C with respective area of 405.14 km\(^2\) (34.62\%) and 389.05 km\(^2\) (33.25\%) of the watershed area, the rest is HSG A and D with each area 256.95 km\(^2\) (21.96\%) and 118.96 km\(^2\) (10.17\%) of the watershed area (see fig. 3). Land use in the Upper Cimanuk watershed consists of eleven types of land use namely, fresh water, shrub/bush, buildings, forests, mixed gardens/plantations, settlements, grass/vacant land, irrigated rice fields, rainfed rice fields, rocky land, fields/fields. Land use in the Upper Cimanuk watershed in 2012 was dominated by rain-fed rice fields, covering an area of 306.23 km\(^2\) (26.17\% of the watershed area). While the use of freshwater, buildings, grass/vacant land, and rocky land is less than 5\% of the Upper Cimanuk watershed (see fig. 4).
3.3. Curve Number Analysis Result

Based on land use and HSG, the largest CN value is found in the type of freshwater land use. However, the area of the type of freshwater land use is less than 5%. When compared with rainfed rice field which has the largest CN value after fresh water, then the area is much greater at 26.17%. From the rainfall data, AMC I is an initial humidity condition that has the largest percentage chance of occurrence at 51%. So based on land use, HSG and AMC the dominant CN value occurs in the type of rainfed rice field land use which includes HSG in AMC I is 54.45. Cimanuk watershed CN value for AMC I, II and III conditions were 56.43, 72.23 and 83.98 respectively. According to Arsyad (2010), AMC I is a condition when the soil is dry but does not reach the withering point and has been planted with satisfactory results. The CN value obtained is 66.54 from the results of the multiplication of percent area and CN II then averaged and divided by area of percent.

3.4. Run off high Analysis Result

Based on the results of the CN analysis (Curve Number) whose value is based on the amount of AMC (Antecedent Moisture Content), Where the AMC value determines the CN value [15], it can determine the value of the weighted CN. From CN value will obtain retention value parameter (S) of 127.71 mm (see table 1). Probability analysis of rainfall is used for this calculation, so we get a high amount of runoff (see table 2).

| Return (Years) | P (mm) | S (mm) | CN   | A (km²) | Pe (cm) |
|---------------|--------|--------|------|---------|---------|
| 2             | 82.84  | 127.71 | 66.54| 1170    | 1.77    |
| 5             | 90.16  | 127.71 | 66.54| 1170    | 2.17    |
| 10            | 95.40  | 127.71 | 66.54| 1170    | 2.47    |
| 25            | 101.67 | 127.71 | 66.54| 1170    | 2.84    |
| 50            | 106.13 | 127.71 | 66.54| 1170    | 3.12    |
| 100           | 110.46 | 127.71 | 66.54| 1170    | 3.39    |

4. Conclusion

Based on land use and HSG, CN weighted value Ciliwung for AMC condition I, II and III respectively 56.43, 72.23 and 83.98. so we get an average CN value of 66.54. Based on the
analysis of CN whose value regard to the AMC, which is where the AMC value is very influential on the value of CN. The amount of runoff that occurs in the Upper Cimanuk watershed based on rainfall plan with various return periods, obtained high runoff at 2 years return period of 1.77 cm, 25 years return period of 2.84 cm (see Table 1). Changes in land cover and AMC will contribute to the CN value, and affect the runoff.

5. References

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