MORFAI JOURNAL Multidisciplinary Output Research For Actual and International Issue

Multidisciplinary Output Research For Actual and International Issue (MORFAI Journal) ISSN (e): 2808-6635
Volumes 5 No. 5 (2025)

ANALYSIS OF SURFACE RUNOFF DISCHARGE OF PONGKERU WATERSHED AT LEDU-LEDU DAM AND CLEAN WATER PIPE NETWORK

Franita Leonard[1]*, Hasanuddin[2], Wahyuni[3]
Universitas Atma Jaya Makassar, Indonesia [1]
Politeknik Indonesia, Indonesia [2]
Sekolah Tinggi Teknologi Nusantara Indonesia, Indonesia [3]
Corresponding E-mail: nitaa.8287@gmail.com[1], hasanasis645@gmail.com[2], wahyuni.chem@gmail.com[3]

Received	: 21 May 2025	Published	: 09 July 2025
Revised	: 30 May 2025	DOI	: https://doi.org/10.54443/morfai.v5i6.3348
Accepted	: 22 June 2025	Link Publish	: https://radjapublika.com/index.php/MORFAI/article/view/3348

Abstract

Surface runoff is one of the important hydrological components to understand, especially in the context of land use planning and drainage systems. This study aims to analyze the amount of surface runoff discharge that occurs in the Pongkeru River Basin (DAS) using the rational method. The calculation results show that the runoff discharge in the Pongkeru DAS reaches 5.31 m³/second. Changes in land use and reduced infiltration areas play a major role in increasing runoff discharge. Therefore, integrated watershed management and environmentally friendly land use planning are essential as a basis for making the right decisions in sustainable environmental and water resource management.

Keywords: ***Runoff Discharge, Rational Method, Pongkeru DAS, Runoff Coefficient.***

INTRODUCTION

Water is one of the natural resources that is very vital for human life and the environment. In the hydrological cycle, rain that falls on the earth's surface will undergo various processes, such as infiltration, interception, evaporation, and surface runoff. One important component that needs to be considered is surface runoff, which is the flow of water that flows over the surface of the land towards rivers or other water bodies due to rainfall that is not absorbed by the soil. Surface runoff discharge is an important indicator in assessing the potential for flooding, soil erosion, land degradation, as well as spatial planning and water resource management. In urban areas, the increase in built-up areas that are impermeable, such as roads, sidewalks, and buildings, reduces the ability of the soil to absorb water, so that the volume of surface runoff increases significantly. Meanwhile, in agricultural areas or river basins (DAS), changes in land use also have a major impact on changes in runoff patterns. Surface runoff discharge analysis is important to obtain accurate data to support soil and water conservation planning, flood disaster mitigation, and the development of dam infrastructure and water pipe networks. A dam is a water structure that functions to raise the water level of a river so that it can be channeled into an irrigation channel or pipeline to be used as a source of raw water, such as the Ledu-ledu dam. Raw water from the dam will be channeled by gravity to the water reservoir, then from the reservoir, the water will be channeled, also by gravity, to the homes of residents, which number around 57 families, so that the raw water network discharge requirement to serve the population with that number is only around 168 m3/day, or around 2 l/sec. Considering that the mainstay discharge of the Pontawa River is relatively large, around 651 l/sec (DED Ledu-ledu Dam, 2023) then in the future, the number of beneficiary families will be increased to 250 families.

The purpose of building the Ledu-ledu dam and raw water pipeline is to regulate and control the flow of water from the Pontawa River so that it can be utilized optimally and channeled to residents' homes for the provision of raw water. The benefits of building dams and water pipelines are providing water for bathing, washing, and other household needs, supporting regional policies in providing basic services for residents, increasing social stability because the basic needs of the community are met, and strengthening the industrial and business sectors that depend on water, such as manufacturing, tourism, and services. In the context of dam construction and operation, hydrology plays a very important role. Therefore, hydrological factors at a location such as rainfall, topography and landforms, land use, soil, density and flow patterns, and surface runoff and so on that affect the water catchment discharge in the Sub-DAS that supplies water to the dam need to be considered, because they are related to the planning and operation of the dam that will be built or operated.

METHOD

The Dam and Raw Water Network Development Plan is administratively located in Ledu-ledu Village, Wasuponda District, East Luwu Regency, South Sulawesi Province. Geographically, the location of the dam to be built is at coordinates 2°32'59.38"S and 121°15'41.95"E, while the raw water network stretches from the dam to the water storage / tank location (reservoir) along 1200 m at coordinates 2°33'30.89"S and 121°16'2.36"E to the Southeast, (Figure 1).

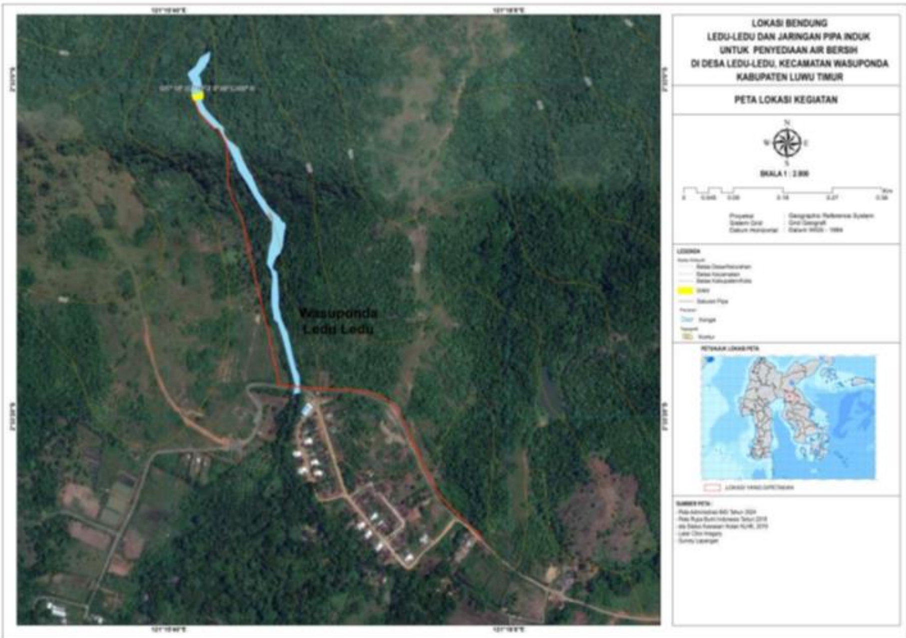

Figure 1. Location of the dam and raw water network in Leduledu Village, Wasupponda District, East Luwu Regency

Activities that are very commonly found at the activity location and its surroundings are in the form of secondary forests, plantations and community settlements that will be the recipients of raw water. All activities at the activity location and its surroundings, residential areas and agricultural areas have the potential to produce waste that will cause pollution to water bodies (Pontawa River). Runoff discharge can be calculated using the rational method by estimating the peak discharge caused by rain in the water catchment area (DTA) (Ardiansyah et al., 2022). Rain intensity, rain duration, frequency, catchment area, abstraction (water loss due to evaporation, interception, infiltration, and surface storage), and flow concentration are some of the hydrological parameters that are taken into account in the rational method (Triatmodjo, 2014). Estimation of the amount of surface runoff discharge of the Pongkeru Watershed where the dam and raw water pipe network are located, is carried out using the Rational method, with the equation:

$$Q = 0.0028 \times C \times I \times A$$

Where:
Q = Surface runoff discharge (m3/second)
C = Surface Flow Coefficient (depending on land cover type)
I = Rainfall intensity (mm/hour)
A = Catchment area (ha)

RESULTS AND DISCUSSION

Surface runoff occurs when the soil's ability to absorb water cannot keep up with the level of rainfall that occurs on the surface. Usually, runoff does not occur immediately after rain falls, but rather takes time to reach its infiltration capacity. The volume of runoff is greatly influenced by the characteristics of rainfall in the area, such as intensity, duration, and distribution patterns. According to Prabowo (2015), in addition to these main factors, there are several other elements that play a role in determining the volume of runoff, including:

1. Soil type
   The ability of the soil to absorb water depends on the permeability of the soil which determines the amount of water that can be stored and also affects how well water can seep into deeper layers. In areas with dry conditions, runoff may only occur if the level of rainfall exceeds the local absorption capacity. Conversely, in saturated areas, runoff can occur at lower or moderate rainfall intensities.
2. Vegetation
   The influence of vegetation in an area is closely related to the density of vegetation in the area. The denser the vegetation in an area, the less runoff occurs, and conversely, in arid areas, the resulting runoff will be higher.
3. Slope and size of the catchment area
   Steep slopes produce more runoff compared to gentle angles. In small areas, the runoff that occurs is also greater than in larger areas. This is due to the low flow velocity and the longer time it takes for water to reach the outlet location (Sharma, 1987).
4. Soil density
   The denser the soil, the greater the runoff produced.

To obtain the results of the surface runoff discharge analysis for the Pongkeru Watershed, it is necessary to first know the hydrological conditions at the study location. Ledu-ledu Dam, in general, receives water supply from the Pangkeru Sub-DAS (Figure 1) which is approximately 46 km2 in area, and the river length reaches 11.95 km, therefore the river density of the Sub-DAS can be calculated as follows:

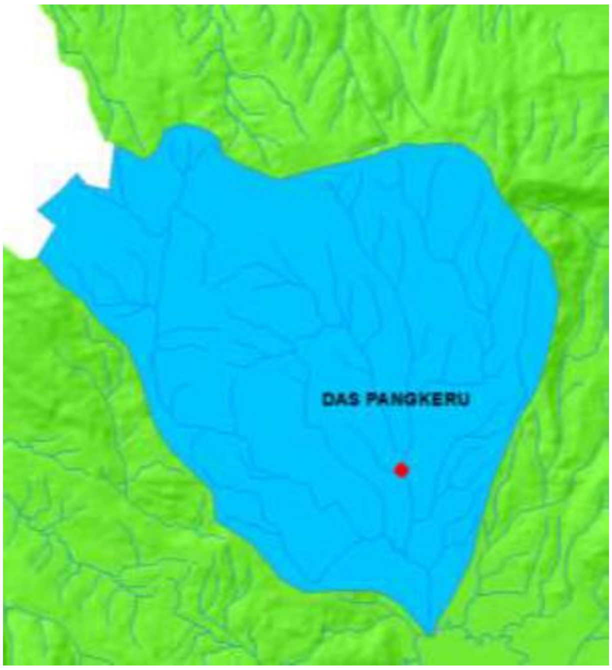

Figure 2. Pongkeru watershed, which is the source of water for the Ledu-ledu Dam

$$D = L / A$$

where, D is the river density index (km/km2), L is the total length of the entire river channel (km), and A is the watershed area (km2). With the area and length of the river as above, the Pongkeru watershed obtained is 0.26 km/km2 which is classified as medium density. Horton (1949) in the Basic Principles of Watershed Management by Ramdan (2004) stated that river density is related to the drainage properties of the watershed. Rivers with a density of less than 0.73 generally have poor drainage or often experience flooding, while rivers with a density between

0.73-2.74 generally have good drainage conditions or rarely experience flooding. If associated with the flow density category, the drainage density category is classified as a low flow density category, below 1 km/km2. By observing Figure 2 above, the river flow pattern in the Pongkeru Sub-watershed area, geometrically tends to be dendritic with parallel sub-watersheds. With a shorter or more compact watershed geometric shape, such as the Pongkeru watershed above, the water flow becomes faster towards the river, potentially producing a higher peak flood discharge in a short time, even though the watershed area is smaller. The rainfall intensity (I) at the activity location is calculated by utilizing the maximum daily rainfall data series recorded for 1991 - 2022 from CHIRPS (Climate Hazards Group Infrared Precipitation with Stations) as follows:

Table. 1 Daily Rainfall Data 1991-2022

Years	Daily Maximum Rainfall (mm)	Years	Daily Maximum Rainfall (mm)
1991	24	2007	24
1992	22	2008	26
1993	7	2009	26
1994	27	2010	28
1995	27	2011	26
1996	22	2012	25
1997	22	2013	23
1998	27	2014	22
1999	27	2015	24
2000	25	2016	23
2001	25	2017	28
2002	22	2018	30
2003	23	2019	24
2004	26	2020	25
2005	26	2021	23
2006	26	2022	26

to provide a more comprehensive picture of how rainfall data behaves and assist in better planning, especially for rare extreme events, the maximum daily rainfall data above needs to be tested with a continuous distribution test. There are several forms of continuous distribution functions (theoretical), which are often used in frequency analysis for hydrology using existing theoretical methods. Some types of distributions include:

1. Gumbel Distribution
2. Normal Distribution
3. Log Pearson III Distribution

Testing the maximum daily rainfall data with the distribution method above is important to find out whether the existing data follows a certain distribution pattern. The goal is to understand the statistical properties of the rainfall data and to choose the most appropriate distribution in analyzing or modeling the data. In this case, a distribution fit test is carried out to determine the type of method that best suits the discharge or rainfall data. The method test is carried out with a distribution fit test which is intended to determine whether the selected probability distribution equation can represent the statistical distribution of the analyzed data sample (Soewarno, 1995).

The type of distribution fit test in this analysis is the Chi-Square test. The principle of testing with this method is based on the number of observations expected in class division, and is determined by the number of observation data read in the class, or by comparing the chi square value (X2) with the critical chi square value (X^2cr). Based on the results of the Chi-Square test of the data, the best type of distribution is obtained to calculate the return period of 5 years, 10 years, 20 years, 50 years and 100 years of rainfall. The best distribution is the Gumbel Distribution, with the values obtained for each return period respectively, 26.71 mm, 28.06 mm, 29.36 mm, 31.04 mm, and 32.30 mm.

In this hydrological study, 5-year return period data was selected for the calculation of surface flow discharge. With the consideration that the data obtained will later be used to help predict the availability of water that can be used as raw water and other water needs such as irrigation. The maximum rainfall data of the Gumbel distribution is then used in the calculation of rainfall intensity (mm/hour). which is derived from empirical daily rainfall data (mm), using the Mononobe method, rainfall intensity (I) in the rational formula can be calculated based on the formula:

$$I_t = \frac{R_{24}}{24}\left(\frac{24}{tc}\right)^{\frac{2}{3}}$$

where:
I_t = rainfall intensity for rainfall duration t (mm/hour),
tc = rainfall duration (hours),
R_{24} = maximum rainfall for 24 hours (mm)

Next, tc can be calculated using the Kirpich method which is written as follows:

$$tc = \left(\frac{0,87 \times L^2}{1000 \times S}\right)^{0,345}$$

where:
L = length of flow (km)
S = slope of land (m/m)

Using the Mononobe formula, the rainfall intensity is obtained as follows.

Area (ha)	Flow Length (m)	Height Difference (m)	Slope	Concentration Time (Hours)	Rainfall T5 (mm)	Rain Intensity (mm/hour)
4.556	11950	638	0.1	2.23	26.71	11.96

Furthermore, with a catchment area (A) of 4,556 ha, and the Surface Flow Coefficient (C) in the watershed which is determined based on land cover as follows:

Location	Land Closure				Total Area (ha)	Weighted C Coefficient
	Forest	Settlement	Ricefield	Fields/Fields		
Coefficient C	0.03	0.6	0.2	0.1		
Pongkeru Watershed (Matabuntu Sub-Watershed)	4,342.63	4.36	59.99	149.46	4,556.44	0.04

*Source: Kodoatie and Syarief (2005)

Then the Surface Runoff Discharge for the Pongkeru Watershed, where the Ledu-ledu Dam is located, is 5.31 m^3/sec.

CONCLUSION

The characteristics of the watershed area, such as land cover type, slope gradient, and soil infiltration capacity, also affect the amount of runoff discharge. Changes in land use, such as conversion of forest to agricultural land or settlements, can increase the runoff coefficient and increase the potential for flooding. Based on the results of research on surface runoff discharge in the Pongkeru River Basin Area (DAS), it can be concluded that the runoff discharge that occurs in the Pongkeru DAS is 5.31 m^3/second. This figure reflects the volume of water flowing on the surface due to rainfall with a certain intensity, which cannot be absorbed by the soil and vegetation in the area. Integrated watershed management is important to implement, such as preserving land cover vegetation, building adequate drainage systems, and land use planning that takes into account environmental carrying capacity, to reduce the risk of hydrometeorological disasters such as floods.

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