Mapping the potential energy of micro-hydroelectric power in Limboto watershed

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Mapping the potential energy of micro-hydroelectric power in Limboto watershed

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Abstract. The use of river water flow energy for electricity generation has been widely developed to meet the electricity needs of the community. Reality in the field indicates that most of the micro-hydro power plants that are built in the river flow cannot be relied upon to meet the electrical energy needs of the community, especially in remote areas. Many micro-hydro plants cannot operate for a long time and even have a damaged condition. This is because the construction of the power plant has not gone through the proper planning and assessment process of the potential of the river flow energy to be able to operate the power plant continuously. This study aims to find out the potential of the perennial river flow energy through the hydrological modeling technique. The energy of the perennial river flow can be approached due to the amount of rain discharge in the catchment area and the components of the watershed system that affect the water flow. To determine the value of river discharges, it is carried out through the analysis of the dependable flow of the river. The results showed that the electrical energy that can be produced in Alo River is 192.55 KW, in Bionga River is 136.45 KW, in Batulayar River is 408.67 KW, in Marisa River is 147.44 KW, and in Talumelito River is 81.22 KW.

1. Introduction

The construction of a hydroelectric power plant depends entirely on how the volume/discharge of river flow and the parameters of the watershed system affect the water flow in the watershed system. These components are the amount of rainfall discharge that falls in the catchment area, the extent of the catchment area, land use, soil conditions, and other elements that affect water that seeps into the ground. To analyze the potential of river flow energy based on the parameter of the catchment area system, it can be carried out through the hydrological modeling technique.

Micro-hydro power plants or hydroelectric power plants depend on how large the volume and discharge of the river flow that can be obtained from a river is. The greater the volume and discharge of river flow, the greater the electrical energy that can be generated.

In line with the construction of micro hydro-power plants in several regions including in Gorontalo Province, it has not been able to provide hope in meeting the needs of electrical energy for the community. Many power plants that were built could not operate properly. Moreover, most of the conditions of those power plants were damaged. It is because the construction of micro-hydro power plants is not through proper planning and analysis. The value of river flow discharge is only based on a theoretical approach through the equation Q = v . A m^3/sec [1]. The use of this equation can only represent the value of river discharges when the measurement is conducted in the field. The changes in river discharge, due to climate change and components in the catchment area system such as the reduction of the forest vegetation area that has great potential in maintaining the sustainability of groundwater, cannot be known.

This study will create a model to determine the dependable flow of the river that can occur perennially using the hydrological modeling method. The results of this study are in the form of a perennial dependable flow hydrograph of the river which can be used as the micro-hydro power plant energy.

2. Methods

2.1. Data collection technique

In this study, the collected data consisted of primary data and secondary data. The primary data was obtained from direct measurements in the field to obtain river discharge values in several conditions according to the water level that occurs. The secondary data was in the form of rainfall data in the catchment area in which it was the data of the recording results from rain stations belonging to the Center of River Region II of Gorontalo and the Meteorology and Geophysics Agency of Gorontalo.

To analyze the physical condition of the catchment area, it used a topographic map of Indonesia on a scale of 1: 25,000 in 2016 from the Geospatial Information Agency and satellite photos using SPOT 6 in 2018 from the Indonesian National Space Agency.

2.2. Hydrological modeling technique

This hydrological modeling technique used the Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS). This HEC-HMS is a model that is able to simulate the transformation of rain into the flow [2]. The use of HEC-HMS aims to assist the researcher to find out the hydrographic characteristics (peak discharge, volume, and peak time) in various forms of land-use dynamics.

The characteristics of a catchment area can be found out through this HEC-HMS software. Data is in the form of the extent of the catchment area and hourly rainfall data on a particular rain event. The data was used to determine parameters related to land use and soil type to obtain the value of the curve number (CN) and the percentage (%) of the impervious area of the catchment area.

The used HEC-HMS modeling processes to present each component in the modeling stage are as follows [2]:

- Runoff discharge calculation modeling,
- Direct runoff modeling from runoff and interflow,
- Base flow modeling,
- Channel flow modeling.

2.3. Validation and calibration

A validation test was conducted to test the suitability level of the model output in the form of the calculated flow discharge hydrograph and the real flow discharge hydrograph based on the results of field measurements. The used model calibration process was sensitivity analysis.

The model output can be considered to be valid if the difference between the calculated flow discharge hydrograph and the results of field measurements has the peak value or shape that is similar.

2.4. The analysis of micro-hydro power plant energy

Hydro power generation is a form of power change from hydropower with a certain height level and discharge into electricity using water turbines and generators. The power generated can be calculated based on the equation (1) [3].

$$P = 9.8 \,.\, H \,.\, Q \,.\, \eta T \quad (1)$$

Where:
P = theoretically electric power (kilowatt)
H = effective water falls height (m)

Q = water discharge (m^3/s)
ηT= turbine efficiency

3. Results and discussion

3.1. The potential of the energy of Alo river flow

By inserting the CN value for the Alo sub-watershed area, the value of maximum storage capacity after the runoff has occurred is:

$$S = 25.4 \text{ x } ((1000 / 60.77) – 10) = 90.22 \text{ mm}$$

The surface water flow will flow through channels or ditches to the river. In the process of flowing water, there is an initial abstraction (Ia) or the loss before the flow occurs in the form of water that is stuck on the surface, water that is intercepted by vegetation, evaporation, and infiltration. Ia = 0.2 x S, Ia = 0.2 x 90, 22 = 18.04 mm [4].

Other sub-watershed parameter values obtained through the HEC-HMS process are presented in Table 1.

Table 1. Sub-watershed parameters from the HEC-HMS process.

No	Sub-watershed parameters	Value
1.	total sub watershed area	44,38 Km^2
2.	center of gravity	X=533.258,76
		Y=51.252,94
3.	Slope of sub watershed	18,30 %
4.	River length	11,54 Km
5.	River slope (S)	0,06
6	River segment height	upstream = 850 (m)
		outlet = 100 (m)

By inserting the rainfall data in the Limboto watershed and the HEC-HMS process, the hydrograph output of the dependable flow of Alo River was obtained which is **6.70 m^3/sec** with the hydrograph output of the river flow discharge as shown in Figure 1.

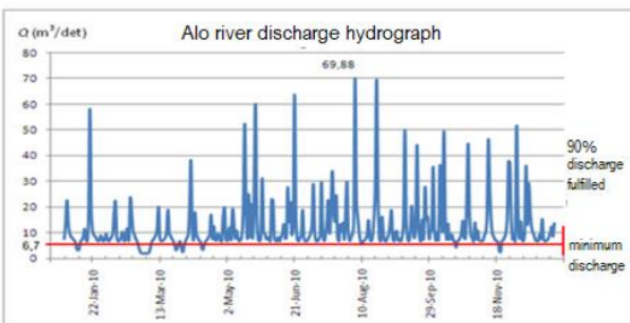

Figure 1. The hydrograph output of Alo river flow discharge. Source: Results of the HEC-HMS software analysis.

3.2. The potential of the energy of Bionga River flow

Based on the HEC-HMS process as applied to the analysis of the Alo River flow energy, the value of the dependable flow of Bionga River is **5.00 m^3/sec** with the hydrograph output of the river flow discharge as shown in Figure 2.

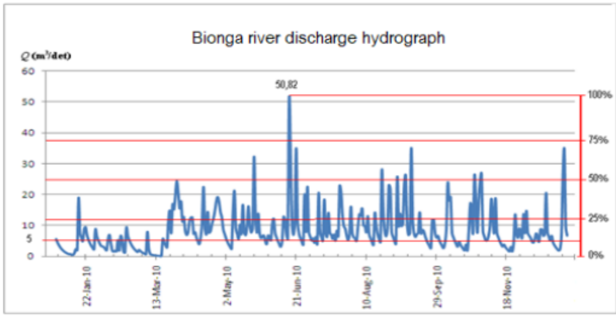

Figure 2. The hydrograph output of Bionga river flow discharge. Source: Results of the HEC-HMS software analysis.

3.3. The potential of the energy of Batu Layar river flow

Based on the HEC-HMS process as applied to the analysis of the previous river flow energy, the value of the dependable flow of the Batu Layar River flow is 8.00 m^3 / sec with the hydrograph output of the river flow discharge as shown in Figure 3.

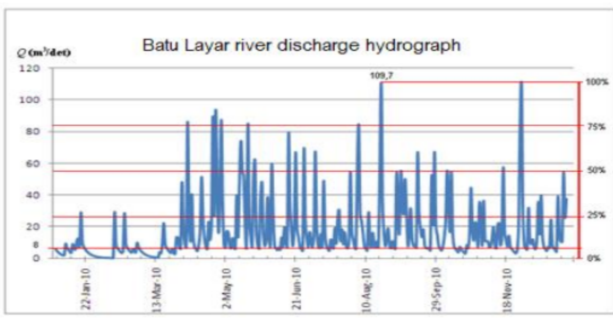

Figure 3. The hydrograph output of Batu Layar river flow discharge. Source: Results of the HEC-HMS software analysis.

3.4. The potential of the energy of Marisa river flow

Based on the HEC-HMS process as applied to the analysis of the previous river flow energy, the value of the dependable flow of Marisa River flow is 6.00 m3 / sec with the hydrograph output of the river flow discharge as shown in Figure 4.

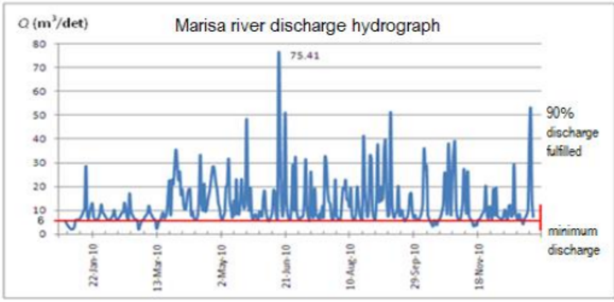

Figure 4. The hydrograph output of Marisa river flow discharge. Source: Results of the HEC-HMS software analysis.

3.5. The potential of the energy of Talumelito river flow

Based on the HEC-HMS process as applied to the analysis of the previous river flow energy, the value of the dependable flow of Talumelito River flow is **3.00** m3 / sec with the hydrograph output of the river flow discharge as shown in Figure 5.

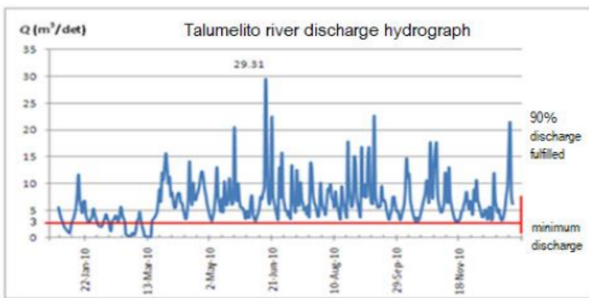

Figure 5. The hydrograph output of Talumelito river flow discharge. Source: Results of the HEC-HMS software analysis.

The results of the analysis of the energy potential of micro-hydro power plants in each river are shown in Table 2.

Table 2. The potential of the energy of micro-hydro power plants in each river in the Limboto watershed area.

No.	River	River discharge is fulfilled	Head	Micro Hydro Power (Kilo watt)
1	Alo	6,70	3,45	192.55
2	Bionga	5,04	3,25	136.45
3	Batulayar	8,92	5,50	408.67
4	Marisa	6,00	2,95	147.44
5	Talumelito	3,00	3,25	81.22
		Total		966,32

Using ArcGis software, the results of mapping the potential of the energy of micro-hydro power plants in the Limboto watershed area are illustrated as shown in Figure 6.

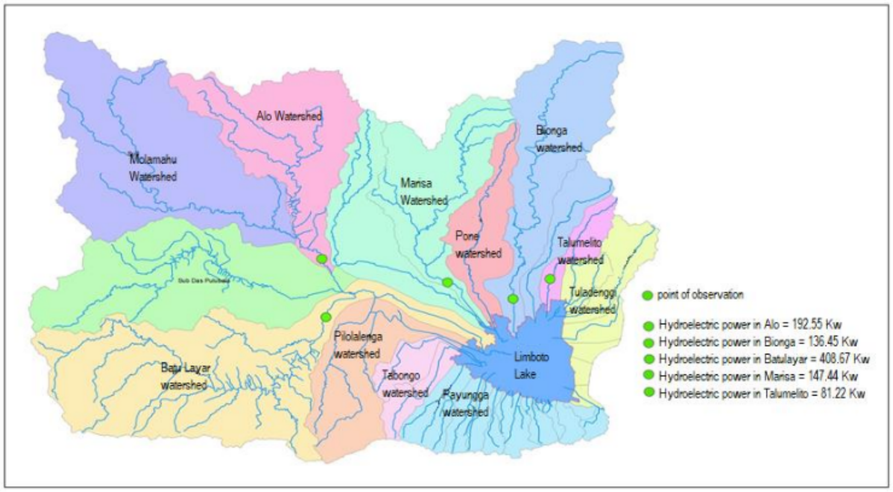

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Figure 6. Mapping the potential energy of micro-hydroelectric power in limboto watershed. Source: Results of the ArcGis software analysis.

4. Conclusion

The results showed that the electrical energy that can be produced in Alo River is 192.55 KW, in Bionga River is 136.45 KW, in Batulayar River is 408.67 KW, in Marisa River is 147.44 KW, and in Talumelito River is 81.22 KW.

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