

# Identification of Renewable Energy Potential in Ciberang River, Cisarua Village, Bogor, West Java

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**Abstract.** This paper presented the analysis of potential energy in Ciberang River, Cisarua Village, Bogor West Java. The objective of this work is to ascertain the availability of water due to rainfall (discharge simulation). The simulation required data in the form of rainfall intensity, climate, evapotranspiration and water discharge. The rainfall station is determined by Thiessen Method and located in Cislak-Baru Station. Rainfall data from 1997-2012 was used. The area of Ciberang River basin is about 46.19 km<sup>2</sup> and not influenced by the change of land area used per year. The height of waterfall allowed was 160 meters due to its topography. The result of water availability was analysed using NRECA method and calibration was done using water data recording (Automatic Water Level Recorder) in downstream of Ciberang-Sabagi station. Calibrated result analysis was then plotted to show the Flow Duration Curve (FDC). Potential capacity of power was obtained from the amount of discharge with the reliability level of 50-60%. At 60% reliability level, calculation of discharge equal to 5.8 m<sup>3</sup>/s and then was used for design parameter. The generated power capacity is 45,813,400.21 kWh/year with the assumptions of net head 159 meters, generator's efficiency of 0.95 and turbine's efficiency of 0.85. The result shows that Ciberang River has a potential to be developed as a hydro power plant.

**Keywords:** Ciberang, Rainfall-Discharge Simulation, Flow Duration Curve, Discharge, Hydropower Potential

## 1. Introduction

The Government of Indonesia has launched a 35,000 MW electricity development program by employing river flow kinetic energy. The Ministry of Energy and Mineral Resources (ESDM) reported that the potential of small to large-scale energy in Indonesia reached about 75,670 MW, and only 4,200 MW or 5.6% was used. On the other hand, the potential of mini to micro-scale energy (hydropower) has been estimated for about 500 MW, and approximately 210 MW (or equivalent to 42%) has been built [7]. The potential of mini and micro scale hydropower was apparently much larger than the estimated number of 500 MW if the hydro power energy of small and large-scale will being used. The report shown that the development of many PLTMH (*Pembangkit Listrik Tenaga Mikro Hidro*) in Indonesia have likely to be sizable capacity due to several reasons such as the amount of electrical conformity, investment cost, and local resources capability.



To fulfil the above needs, the study and analysis of the river stream's reliability is required. One of the potential source for hydro power station is Ciberang River located at Cisarua Village, Bogor, West Java. The river provides sufficient discharge every year and make it a promising source of river flow kinetic energy. The area is fairly high and not influenced by the change of land area used per year. It is one of the national park area in place. Having located at Halimun Salak Mountain National Park, which has strong current and suitable for rafting, Ciberang River is a potential candidate for the energy sources [5,7,8,9]. Two important characteristics possessed by of Ciberang Rivers are the head and flow current. The height of its location make Ciberang River has enough potential and kinetic energy. Thus, the discharge and river flow are ensured to be available throughout the years. The main objective of this work is to determine the discharge availability that can be generated by Ciberang River as input of rainfall-discharge modelling.

## 2. Descriptions of The Study

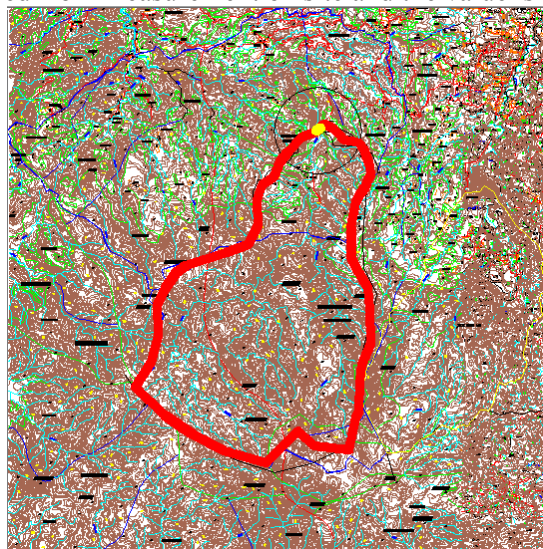
In this study, the upstream river flow of Ciberang River at Halimun Salak National Park area was used. The research area administratively is located in Kampung Lebak Sanab, Cisarua Village, Cigudeg District, Bogor Regency. Coordinates of the weir plant at X: 661412.21 and Y: 9267156.2. The estimated area of the catchment is about 46,19 km<sup>2</sup> and its topography mainly mountainous with a steep slope. There is a river gauging station with Automatic Water Level Recorder located downstream to the proposed weir position on the same river.

## 3. Methodology

Assessment of hydropower potential energy requires the followings: 1). topography map, 2). location of proposed weir and power house, 3). rainfall data, and 4). evapotranspiration. Location of proposed weir and power house will determine the falling height (head) [4,5,2,3] while evapotranspiration will be obtained from climate data at climate station.

### 3.1 Topography Map

Figure 1 shows the topography map obtained from Bakosurtanal with the scale of 1:25.000 (unit in mm). The catchment area was then calculated from the figure and approximately equal to 46,19 km<sup>2</sup>. Falling height was determined from measurement on site and the value is 160 m.



**Figure 1.** Estimated Catchment Area

### 3.2 Rainfall Data

Discharge analysis on rainfall data was conducted on Cisalak Baru Station, where the location is considered to be the closest to the area being studied. The rainfall statistics was obtained from the recorded data since 1997-2012, it was statistics showing the information of daily rain.

### 3.3 Evapotranspiration Data

To obtain the evapotranspiration data, Penman Modification Method [1] was used by considering the following parameters:

- a) Air temperature
- b) Sunshine radiation
- c) Humidity
- d) Wind velocity

The equation used to calculate the magnitude of the evapotranspiration is written below.

$$E = C \cdot (W \cdot R_n + (1 - W) \cdot F(u) \cdot (e_a - e_d)) \quad (1)$$

Where:

$E$  = daily potential evapotranspiration (mm/day)

$C$  = regulator factor

$W$  = weighting factor

$R_n$  = Radiation net

$F(u)$  = function of wind velocity (m/s)

$e_a$  = saturated vapour pressure

$e_d$  = actual vapour pressure

### 3.4 NRECA Water Balance

One of the models used in obtaining water availability is the NRECA model [1,2,3]. The water equilibrium model in NRECA is based on a common water equilibrium processes. It was determined by the rainfall over the soil surface and evaporation of crops that cover the area, some will flow on the surface and the rest will seep into the soil. If the water infiltration saturates the soil surface, it will creep into percolation and then come out into the river as base flow. This model can simulate the monthly water equilibrium in a catchment area in order to calculate the total run-off of values: monthly rainfall, evapotranspiration, soil moisture and groundwater availability. The difference of the NRECA model with other water equilibrium models is only the number of parameters taken. The input data required for this NRECA model include:

- The monthly rain
- Evapotranspiration
- Monthly average temperature
- Intensity of sunlight
- Relative humidity
- Wind speed
- Initial conditions of moisture content
- Ground count of ground water
- Index of soil moisture storage capacity in the catchment area
- Percentage of run off that flows on the subsurface path
- Percentage of water entering into groundwater flow.

### 3.5 Flow Duration Curve

To calculate the level of debit reliability, the flow duration curve was used [1,2,3]. The flow duration curve is a graph showing the river flow for a certain period of time in a year [2,3,4,5]. Its value was determined from the arc at flow duration graph plotted from discharge data recorded from the last 10 years.

The mainstay debit is the minimum flow of the stream with the possibility of a certain percentage of debit being fulfilled, e.g. 90%, 80% or any other value, so it can be used for a particular need. The level of discharge reliability is selected based on the probability of occurrence following the Weibull formula below [1,9,10].

$$P = \frac{i}{(n+1)} \times 100\% \quad (2)$$

Where:

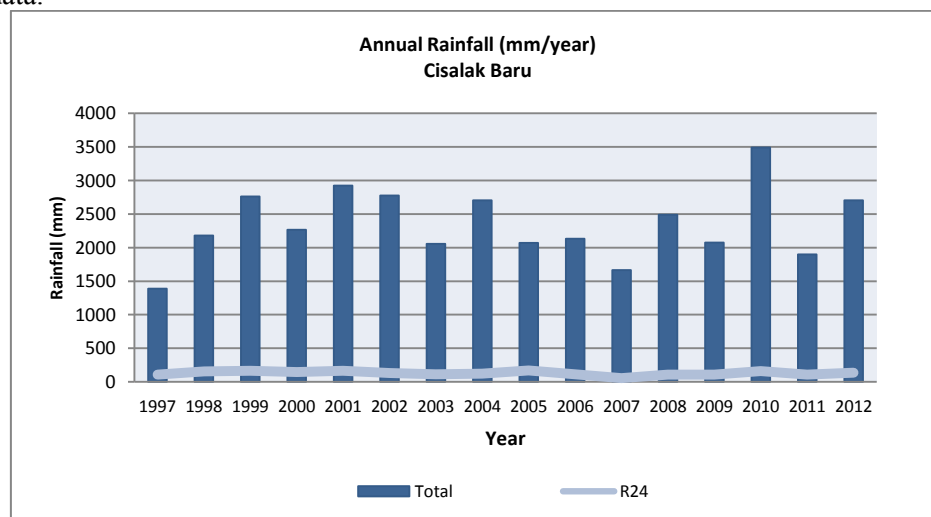
$i$  = Order number of discharge,

$n$  = amount of data,

$P$  = Probability of the set of values during the observation period (%).

#### 4. Result and Discussion

The reliable discharge data was estimated by developing the model of Ciberang River based on the available data.



**Figure 2** Cislak Baru annual rainfall

To calculate potential evapotranspiration, the data used was derived from climatological data at Taktakan Climatological Station, the station closest to the location of the study. Using the Penman modification method (eq.1), the calculation result is presented in Table 1.

**Table 1.** Result of Potential Evapotranspiration

Month	Eto (mm)	
	normal	
Jan	1	46.7
	2	62.1
Feb	1	39.4
	2	56.0
Mar	1	69.1
	2	73.4
Apr	1	53.7
	2	70.5
Mei	1	49.8
	2	64.3
Jun	1	66.5
	2	54.4
Jul	1	66.6

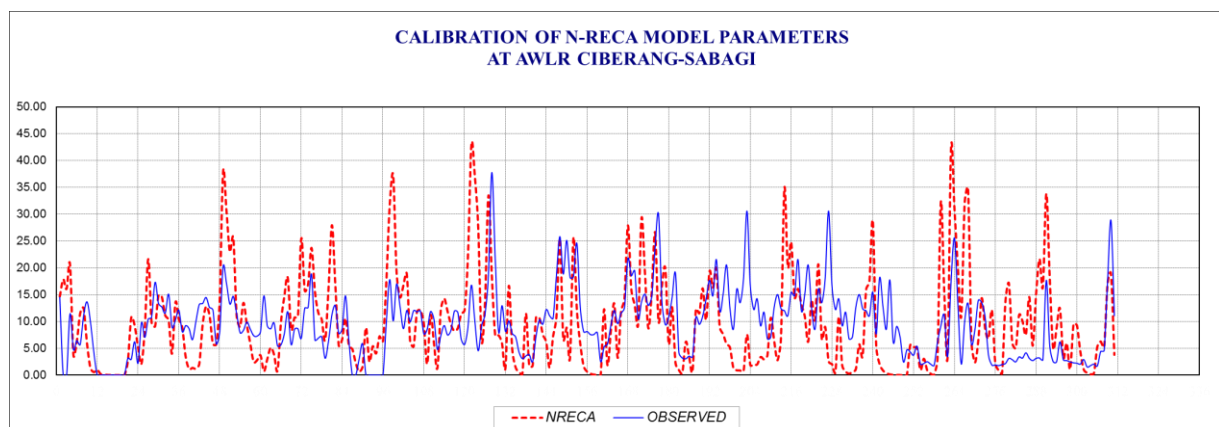
	2	71.5
<b>August</b>	1	65.8
	2	81.0
<b>Sep</b>	1	75.1
	2	86.2
<b>Oct</b>	1	64.7
	2	90.3
<b>Nov</b>	1	68.7
	2	62.8
<b>Des</b>	1	70.1
	2	56.7

The data and analysed results that have obtained from the previous step, the reliable discharge then can be modelled. The model was calibrated using logging debit data at AWLR Ciberang-Sabagi Station with a wide range of watersheds of 301.2 km<sup>2</sup>. The recorded discharge data used for the calibration model was taken from year 2010 to 2012 and compared with the discharge data from Cibeureum's rainfall station from the same year.

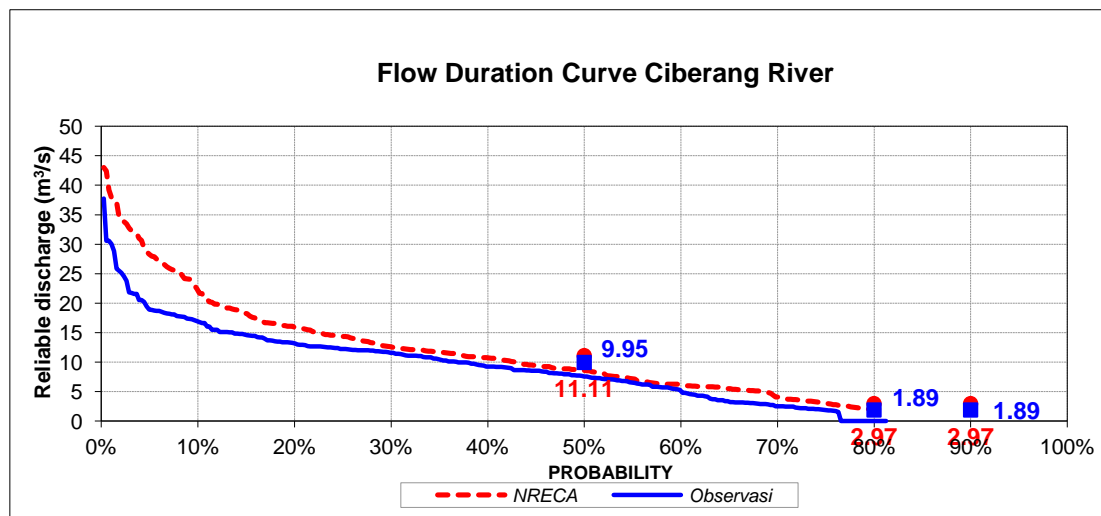
**Table 2.** Parameter Calibration

<b>Catchment Area</b>	<b>46.19</b>	<b>km<sup>2</sup></b>	<b>R<sup>2</sup></b>	<b>0.26144</b>
<b>Average Annual Rainfall</b>	2382.83	mm		
<b>Coefficient C</b>	0.50		Storage	2400.00 mm
<b>Nominal</b>	1291.42		IGWS	220.00 mm
<b>PSUB</b>	0.50		Rain Factor	3.57
<b>GWF</b>	0.60			

From the model that has been calibrated, the initial model of Ciberang River is depicted as follows:



**Figure 3.** Calibration of NRECA Model Parameters



**Figure 4.** Flow Duration Curve Ciberang River

To know the capacity of power that can be utilized from Ciberang River, it can be taken the amount of discharge with the reliability level of 50% - 60%. In this study, the reliability taken for power capacity calculation is a 60% reliability level equal to 5,8 m<sup>3</sup>/s (Table 3.)

**Table 3.** Result of Reliable Discharge Calculation

Percentage	Debit	NRECA	Observed	Difference
5%	49.49%	19.2	28.25	18.9
10%	30.84%	38.4	22.12	16.9
20%	20.40%	76.8	15.87	13.18
30%	8.87%	115.2	12.6	11.58
40%	15.87%	153.6	10.72	9.25
50%	11.68%	192	11.11	9.95
60%	13.90%	230.4	5.8	5.09
70%	61.23%	268.8	4.07	2.52
80%	57.63%	307.2	2.97	1.89
90%	57.63%	345.6	2.97	1.89
95%	57.63%	364.8	2.97	1.89

The result of reliable discharge analysis from NRECA method with probability of 60% was equal to 5,8 m<sup>3</sup>/s. Its value was used as input for discharge design to determine the energy that can be produced for one year. Capacity of power plant was generated with the following three assumptions: the height of 159 meters (net), efficiency of generator 0.95 and efficiency of turbine 0,85 (based on the FDC) were presented in Table 4.

**Table 4.** Result of Calculation of Energy Capacity Per Year

<b>Qmax</b>	5.80	m <sup>3</sup> /s
<b>Head</b>	159.00	m
<b>Eff. gen</b>	0.95	
<b>Eff. turbine</b>	0.85	

Prob.	FDC	Qgen	Power (kW)	Energy (kWh)
5%	28.95	5.80	7,305.28	3,155,879.43
10%	20.67	5.80	7,305.28	3,155,879.43
15%	18.24	5.80	7,305.28	3,155,879.43
20%	15.81	5.80	7,305.28	3,155,879.43

25%	13.99	5.80	7,305.28	3,155,879.43
30%	12.18	5.80	7,305.28	3,155,879.43
35%	11.23	5.80	7,305.28	3,155,879.43
40%	10.27	5.80	7,305.28	3,155,879.43
45%	9.57	5.80	7,305.28	3,155,879.43
50%	8.87	5.80	7,305.28	3,155,879.43
55%	7.34	5.80	7,305.28	3,155,879.43
60%	5.80	5.80	7,305.28	3,155,879.43
65%	4.63	4.63	5,830.82	2,518,914.12
70%	3.46	3.46	4,355.43	1,881,545.80
75%	2.61	2.61	3,290.80	1,421,626.07
80%	1.77	1.77	2,226.17	961,706.35
85%	1.18	1.18	1,488.08	642,849.47
90%	0.60	0.60	749.98	323,992.59
95%	0.35	0.35	444.94	192,212.61
100%	0.00	0.00	0.00	0.00
			<b>TOTAL</b>	<b>45,813,400.21</b>
			<b>capacity</b>	<b>63,994,221.83</b>
			<b>plant factor</b>	<b>71.59%</b>

From the above table, the total capacity equal to 45.813.400,21 kWh/year. This result concludes that the development of Ciberang River has potential for hydro power plant.

## 5. Conclusion

This work has concluded that Ciberang River has potential as a renewable energy source with 60% discharge of 5,8 m<sup>3</sup>/sec. Capacity of energy that can be produced with the assumption of height of 159 meters, efficiency of generator 0,95 and efficiency of turbine 0,85 is equal to 45.813.400,21 kWh/year. Some parameters need to be considered for future work: a better analysis result and recorded data of water discharge at specific location of Ciberang River for one year. Further surveys and analysis need to be done to determine a more precise falling height.

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