Jurnal Syntax Imperatif: Jurnal Ilmu Sosial dan Pendidikan
Volume 6, No 4, September 2025, pp. xx-yy
P-ISSN: 2721-2491 E-ISSN: 2721-2491
DOI: http://doi.org/10.54543/syntaximperatif.v6i4.792
Published By: CV. Rifainstitut

Hydrological Analysis of Mini Hydro Power Plants (PLTM) Using The Flow Duration Curve Approach

Nengah Bennuwardana[1*], Sukendra Martha[2], Yosef Prihanto[3], Dangan Waluyo[4], Firmansyah[5], Bachtiar Rifai[6]

[1] Faculty of Science and Technology, Republic of Indonesia Defense University, Indonesia
[2,3,4] Lecturer at the Republic of Indonesia Defense University, Indonesia
[5,6] Indonesian Agency for Meteorology, Climatology, and Geophysics, Indonesia

ARTICLE INFO

Article history:
Received August 15, 2025
Revised September 15, 2025
Accepted September 17, 2025
Available online September 17, 2025

Kata Kunci :
Pembangkit Listrik Tenaga Mini Hidro (PLTM), Analisis Hidrologi, Debit Handal, Kurva Durasi Aliran

Keywords:
Mini Hydro Power Plant (PLTM), Hydrological Analysis, Reliable Discharge, Flow Duration Curve

ABSTRAK

Analisis hidrologi sangat penting dalam perencanaan Pembangkit Listrik Tenaga Mini Hidro (PLTM). Penelitian ini bertujuan untuk mengkaji aspek hidrologi PLTM Way Besai yang terletak di Desa Bonglai, Kabupaten Way Kanan, Provinsi Lampung. Pembangkit Listrik Tenaga Mini Hidro (PLTM) Way Besai merupakan skema PLTM aliran sungai yang terletak sekitar 242 km di utara Kota Bandar Lampung, Provinsi Lampung, Indonesia. Data yang digunakan meliputi data curah hujan harian dari enam stasiun hujan, data elemen iklim dari Stasiun Meteorologi Radin Inten II, dan data aliran keluar dari PLTA Besai. Data curah hujan dianalisis konsistensinya menggunakan metode Kurva Massa, dengan hanya tiga stasiun yang dianggap konsisten. Evapotranspirasi potensial dihitung menggunakan metode Penman yang Dimodifikasi. Selanjutnya, data curah hujan dikonversi menjadi data debit harian menggunakan metode hidrologi F.J. Mock Rainfall to Runoff. Luas daerah tangkapan air adalah 449,14 km2 di lokasi intake dan curah hujan tahunan rata-rata mencapai 2.366 mm/tahun. Hasil analisis digunakan untuk menentukan debit utama (debit pembangkit) dan debit banjir rencana melalui Kurva Durasi Aliran (KDAL). Berdasarkan hasil ini, PLTA Way Besai diproyeksikan memiliki daya pembangkit sebesar 9,2 MW dan energi tahunan sebesar 67.513 GWh, yang dihasilkan dari pemanfaatan muka air efektif 67,45 m dan debit pembangkit maksimum 16,5 m³/detik.

ABSTRACT

Hydrological analysis is crucial in the planning of a Mini-Hydro Power Plant (PLTM). This study aims to examine the hydrological aspects of the Way Besai PLTM, located in Bonglai Village, Way Kanan Regency, Lampung Province. The Way Besai Mini-Hydro Power Plant (PLTM) is a runoff-river PLTM scheme located approximately 242 km north of Bandar Lampung City, Lampung Province, Indonesia. The data used include daily rainfall data from six rainfall stations, climate element data from the Radin Inten II Meteorological Station, and outflow data from the Besai PLTA. The rainfall data were analyzed for consistency using the Mass Curve method, with only three stations deemed consistent. Potential evapotranspiration was calculated using the Modified Penman method. Furthermore, the rainfall data were converted into daily discharge data using the F.J. Mock Rainfall to Runoff hydrological method. The catchment area is 449.14 km^2 at the intake site and the average annual rainfall reaches 2,366 mm/year. The analysis results are used to determine the mainstay discharge (plant discharge) and the planned flood discharge through the Flow Duration Curve (FDC). Based on these results, the Way Besai Hydroelectric Power Plant is projected to have a generated power of 9.2 MW and an annual energy of 67.513 GWh resulting from the utilization of an effective water head of 67.45 m and a maximum plant discharge of 16.5 m^3/second.

1. INTRODUCTION

Administratively, the planned location of the Way Besai PLTM is located in Bonglai Village, Banjit District, Way Kanan Regency - Lampung Province. Geographically, Way Kanan Regency is located between 6° 45’ - 3° 45’ South Latitude and 103° 00’ - 105° 50’ East

*Corresponding author
E-mail addresses: nengahbennu@gmail.com (Nengah Bennuwardana)

Longitude, bordering the East Oku Regency of South Sumatra Province to the north, North Lampung Regency of Lampung Province to the south, Tulang Bawang Regency of Lampung Province to the east, and West Lampung Regency of Lampung Province to the west. The topography of Way Kanan Regency can be divided into two topographical groups, namely hilly to mountainous topographical areas and river basin areas. The Way Besai PLTM scheme is located in a protected forest area. While the catchment area is mostly forest. The catchment area is part of the slopes of Bukit Benatan and Gunung Haji as well as the Bukit Barisan Mountain range.

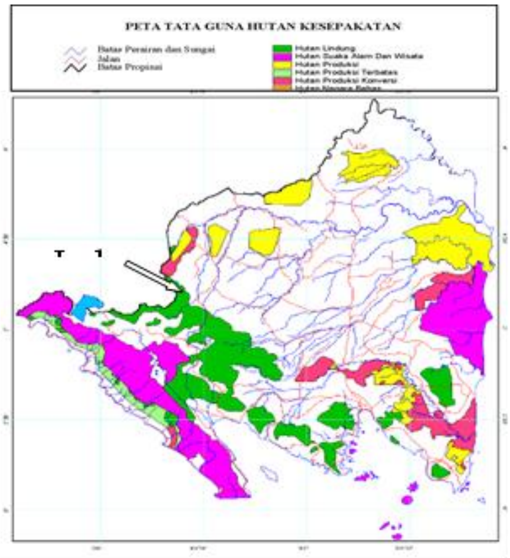

Figure 1. Map of the Way Besai Micro Hydro Power Plant Planned Forest Area

In the planned location of this study, the Way Besai River flows, which has a river section that has the potential to be used as a source of medium-scale hydroelectric power generation (PLTM) by utilizing digital elevation, river network data and hydrological models. (Yuksel & Demirel, 2021). The watershed (DAS) is predominantly forested, allowing the Way Besai River to provide sufficient flow. This study aims to assess the potential of the Way Besai River in Bonglai Village, Banjit District, Way Kanan Regency, Lampung Province, which is located downstream of the Besai Hydroelectric Power Plant (PLTA). The outflow of the Besai Hydroelectric Power Plant (PLTA Besai) can be utilized for a Mini-Hydro Power Plant (PLTM) (Wang et al., 2020). Thus, it is necessary to conduct research that includes technical aspects in the form of hydrological studies to obtain a clearer picture of the level of hydrological capability (Coron et al., 2012) of the Way Besai PLTM plan.

The research on the hydrological capability of the Way Besai PLTM plan consists of, (1) the magnitude of the mainstay discharge (plant discharge) and the discharge that is always available (firm discharge) which will be used for the design of PLTM components, (2) the discharge curve (rating curve) and the duration curve (flow duration curve), (3) a review of the conditions and characteristics of the river basin (DAS), climate, and meteorology, and (4) the magnitude of the planned flood discharge. The main objective to be achieved from the Way Besai PLTM planning is to obtain an additional supply of clean and cheap electrical energy in order to meet the electrical energy needs (Almeida et al., 2022) for the Southern Sumatra region, especially Way Kanan Regency and its surroundings, which is expected to be able to accelerate regional economic development in order to support national economic development.

2. LITERATURE REVIEW

The climate conditions in the study area are basically the same as those in Indonesia in general, which are divided into two seasons per 1 (one) year period which include the rainy season and the dry season, with fairly good forest conditions in the upstream areas of the Watershed (DAS). Climatological data is very important in hydrological analysis, because the amount of rainfall that occurs in an area is influenced by physical and climatological conditions (Reynolds et al., 2018). The location of the Way Besai Hydroelectric Power Plant dam is located in the middle of the Way Besai Watershed which is in the Way Kanan Regency, Lampung Province. Based on the spatial slope analysis that has been carried out, the area of the Way Besai Hydroelectric Power Plant watershed (DAS) is ± 452.73 square kilometers. The shape of the Way Besai Hydroelectric Power Plant watershed is included in the Radial type, where the watershed shape resembles a fan, tributaries concentrate to a point radially, generally relatively large floods occur at the meeting point of the tributaries (Griffith et al., 2020). The flow pattern of the Way Besai River follows a dendritic pattern, meaning the river flow pattern is shaped like a tree branching, irregular branching with various directions and angles, with small river branches coming from various directions on steep hill slopes then joining in the main river, namely the Way Besai River which flows through the valley.

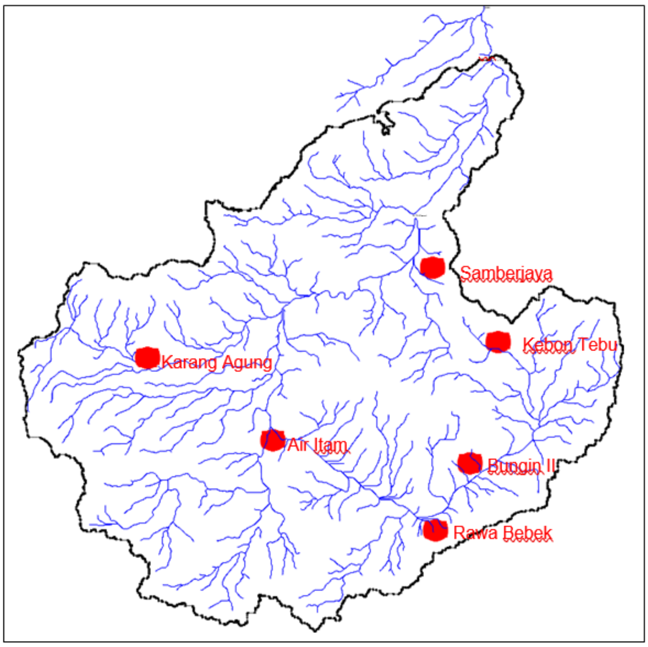

Figure 2. Way Besai Hydroelectric Power Plant Watershed and Rainfall Station Location

Watershed

The Way Besai Hydroelectric Power Plant (PLTM) watershed analysis is interpreted from the 1:50,000 scale Digital Topographic Map published by Bakosurtanal. The Way Besai Hydroelectric Power Plant (PLTM) watershed covers an area of 449.14 km2 and has a main river length of 33.24 km. In general, the Way Besai Watershed is a protected forest and nature reserve area. The watershed contains relatively few residential areas. The project site is a protected forest. The watershed conditions at the Way Besai Hydroelectric Power Plant location can be seen in Figure 3 as follows:

Figure 3. Watershed Conditions at the Planned Location of the Way Besai Hydroelectric Power Plant

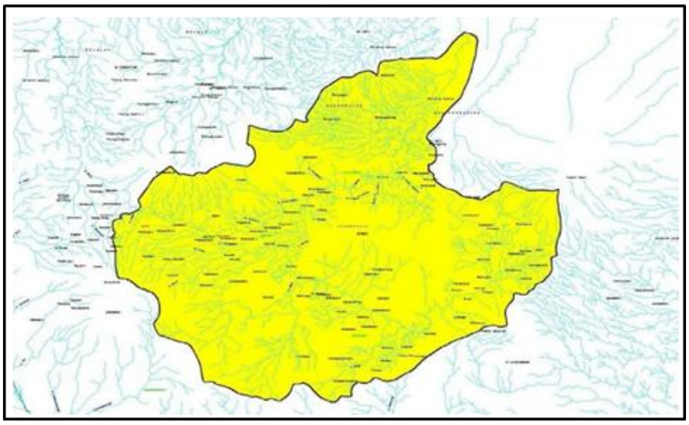

Figure 4. Catchment Area Map of Way Besai Hydroelectric Power Plant

Flood Discharge Recurrence Period

Various types of water structures require hydrological calculations as part of their planning. Selecting the design flood return period for a water structure is a problem that relies heavily on statistical analysis of the sequence of flood events, both in terms of river discharge and rainfall (Okoli et al., 2019). To simplify the problem-solving process, economic considerations are ignored, thus relying solely on probability theory, often referred to as the risk of failure, or the probability of a design flood occurring once or more during the life of a water structure.

The selection of a design flood analysis technique depends on the available data and the type of water structure (Okoli et al., 2019). The flood return period selection criteria only consider the possibility of a flood greater than or equal to the design flood, once or more times during the water structure's existence. The selection of the return period for a structure's design is generally based on the river system and the type of project, which is based on the total population. The return period of the design rainfall used to calculate the design flood depends on the area of the river basin (DAS) (Vangelis et al., 2022).

Table 1. Flood Recurrence Period Based on Watershed

River System	Based on Project Type Based on Total Population	Early Phase (Year)	Final Phase (Year)
River	Emergency project New project	5	10
	For rural and/or urban areas with a population < 2,000,000	10	25
	For urban areas	25	50
Primary drainage system (DPS>500ha)	Rural	3	5
	Urban population < 500.000	5	10
	Urban 500.000 < P < 2000.000	5	15
Secondary drainage system (DPS<500ha)	Rural	1	2
	Urban population < 500.000	2	5
	Urban 500.000 < P < 2000.000	2	5
Tertiary drainage system (DPS<10 ha)	Rural and Urban	1	2

Source: Flood Control Guidelines, Directorate General of Water Resources, Volume I, 1996

With the area of each DPS mentioned above, in the calculation of the planned flood, a return period of 50 years is used, river drainage systems for rural and/or urban areas with a population of <2,000,000)

FJ Mock Method

The F.J. Mock method adopts the hydrological cycle which assumes that rain falling on a river catchment area will be partially lost as evapotranspiration, some will directly become surface runoff (direct run-off), and some will enter the soil (infiltration) (Soerya et al., 2023). This infiltration will first saturate the topsoil and then percolate into the groundwater reservoir which will eventually flow into the river as base flow. In this case, there must be a balance between falling rain and evapotranspiration, direct run-off and infiltration as soil moisture and groundwater discharge. Flow in a river is the sum of flow directly on the ground surface (direct run-off) and base flow. The F.J. Mock method has two principal approaches to calculating surface flow that occurs in rivers, namely the water balance above the ground surface and the groundwater balance, all of which are based on rainfall, climate, and soil conditions.

Flow Duration Curve (FDC)

Flow Duration Curve (FDC) is a graph of the relationship between the amount of discharge and the probability of each discharge. The FDC is created by sorting all the discharge results from all years of data, sorted from the largest to the smallest amount. The discharge with the largest amount has the smallest probability, the smaller the amount of discharge, the greater the probability percentage. The FDC is used as the basis for analysis to determine the discharge of a micro-hydro power plant (Liucci et al., 2014). By optimizing the amount of each discharge, the ratio between the smallest annual cost and energy will be found.

3. RESEARCH METHOD

The data used in this hydrological analysis is sourced from daily rainfall data available in this study consisting of 6 rainfall stations within the Way Besai Watershed (DAS) or the closest to the DAS location. Some of these rainfall stations are Air Itam, Bungin II, Kebun Gula, Rawa

Bebek, Sumber Jaya, and Karang Agung. Rainfall data will be used for the analysis of mainstay discharge and flood discharge with the Rainfall to Run-off method using the Rainfall to Run-off hydrological model FJ. Mock, after going through a data consistency test process using the rain mass curve method.

Climatology data for the Way Besai Hydroelectric Power Plant (PLTM) is taken from the Radin Inten II Meteorological Station, Bandar Lampung City, starting from 2011 to 2021. The Radin Inten II Meteorological Station is the closest meteorological station to the Way Besai Hydroelectric Power Plant (PLTM) location, because there is no Climatology Station in Way Kanan Regency and its surroundings. Climatology data is used to calculate evapotranspiration, which is one of the parameters used in the FJ. Mock hydrological model. Evapotranspiration calculations use the modified Penman method. The Modified Penman method uses 4 parameters, namely Temperature (T), relative humidity (RH), solar radiation (N) and wind speed (W).

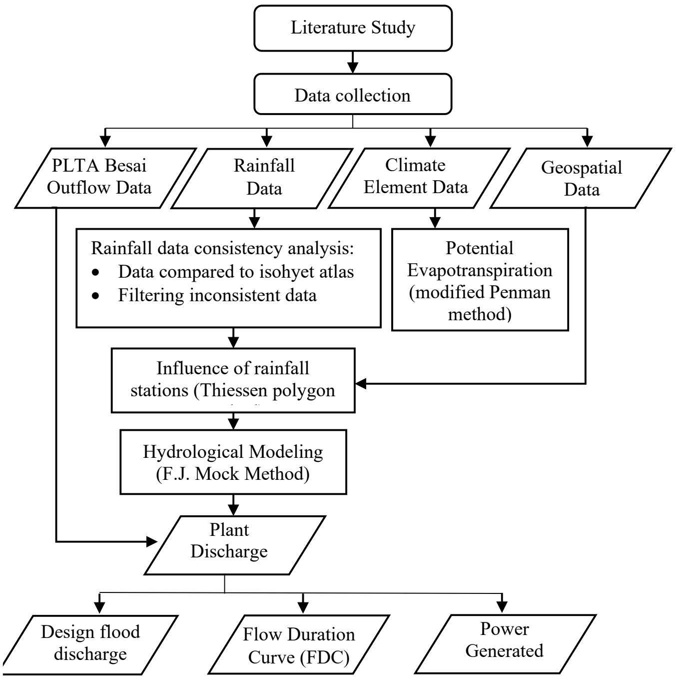

Figure 5. Research Flowchart

4. RESULT AND DISCUSSION

Hydrological analysis in micro-hydro power plant planning is essential for power and energy calculations. The hydrological data required for this analysis include long-term runoff and flood discharge data. Therefore, the hydrological analysis conducted includes water availability analysis or low-flow/reliable flow analysis, which will be used as the basis for designing civil structures and turbines for the micro-hydro power plant and analysis of planned flood discharge for various return periods at the weir and tailrace locations. The secondary hydrological data used in this study consists of nine years of Besai hydropower outflow discharge data, 10 years of daily rainfall data from six rainfall stations, and 10 years of climate data including evaporation, air temperature, humidity, and sunshine duration from the Radin Inten II Meteorological Station in Bandar Lampung.

Plant Discharge Analysis

The water availability of the Way Besai Hydroelectric Power Plant (PLTM Way Besai) is obtained from the outflow data of the Besai Hydroelectric Power Plant (PLTA Besai) which is located ± 4 km (geographic distance) upstream of the planned location of the Way Besai Hydroelectric Power Plant (PLTM Way Besai) dam. This data is the most suitable data for the analysis of the water availability of the Way Besai Hydroelectric Power Plant (PLTM Way Besai) because the Way Besai Hydroelectric Power Plant is located downstream of the Besai Hydroelectric Power Plant so that the discharge to be used by the Way Besai Hydroelectric Power Plant is highly dependent on the outflow discharge of the Besai Hydroelectric Power Plant. The accuracy of the analysis results of the operating data of the Way Besai Hydroelectric Power Plant equipment can of course be accounted for, because to obtain the discharge data only requires an inversion process from the energy data produced to the discharge data to run the turbine using the equations and data of the generating equipment used. However, because the data is operational pattern data, the data cannot be said to represent the natural discharge data of the Way Besai River as a whole, especially for observing the base flow because there is a storage factor owned by the Way Besai Hydroelectric Power Plant.

To determine the natural discharge data of the Way Besai River, rainfall data analysis is required to then be converted into discharge data, taking into account climatological factors and land use within the Catchment Area of the Way Besai Hydroelectric Power Plant. At this stage, the available data will be tested using the Mass Curve method. The Mass Curve method is to test the consistency of a data series by comparing it with data from other sources. In this study, annual rainfall data from each rainfall station, namely the Air Itam, Bungin II, Kebon Tebu, Rawa Bebek, Samberjaya and Karang Agung Rain Stations will be compared with Isohyet atlas data published by the Geospatial Information Agency and BMKG.

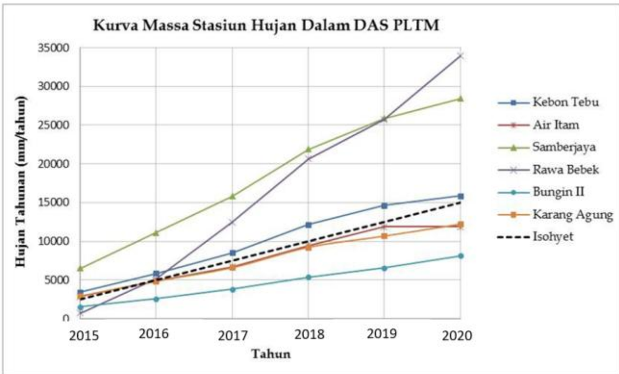

Figure 6. Mass Curve of All Rainfall Stations in the PLTM Watershed

Based on the graph, it can be seen that the rainfall price in the Catchment Area of the Way Besai Hydroelectric Power Plant ranges between 2500 mm – 3000 mm per year. It can be seen that the data lines from Samberjaya and Rawa Bebek Stations deviate far upwards from the dotted line of the Atlas Isohyet data, so it can be concluded that the data from the two stations are inconsistent, so they are not used in the analysis of the Way Besai Hydroelectric Power Plant's mainstay discharge. There are 3 stations whose data is recommended for the analysis of the Way Besai Hydroelectric Power Plant's mainstay discharge, namely; Bungin II Station, Kebon Tebu Station and Karang Agung Station.

Calculation of Potential Evapotranspiration with Modified Penman

Evapotranspiration is the combination of evaporation from the free soil surface (evaporation) and evaporation from plants (transpiration). Evaporation is influenced by climate, while transpiration is influenced by climate, variety, plant type, and age. Potential evapotranspiration is calculated using the modified Penman method as follows:

E = □/(□□+ c) *[1/58 (1 -r) R] - □/(□□+c) [1/58*117*10-9[t(a)+273]4 [0.56-0.092 (e)0.5)]*[0.10+0.90*n/N]+ c/(□+c)*[0.35 * [1+0.54 u][e(s) - e(a)]]

di mana ;

E	=	evaporation (mm/day)
	=	slope vapour pressure (oC)
c	=	Physical coefficient, c = 0.485
r	=	Reflection coefficient
R	=	solar radiation
t(a)	=	average temperature (ºC)
e(s)	=	water vapor pressure (mmHg)
e(a)	=	saturated water vapor pressure at the dew point (mmHg)

Based on this equation, the results of the potential evapotranspiration calculation using the Modified Penman method can be seen in Table 2 below.

Table 2. Calculation of Potential Evapotranspiration Using the Modified Penman Method

No	Description	Notation	Unit	Jan	Peb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Okt	Nop	Des
1.	Temperature	ta	°C	26.51	26.22	26.42	27.21	27.11	26.19	26.05	26.22	26.65	26.99	26.76	26.55
2.	Vapour pressure curve	v		0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
3.	Vapour pressure curve	w		-1.80	-1.80	-1.80	-1.80	-1.80	-1.80	-1.80	-1.80	-1.80	-1.80	-1.80	-1.80
4.	Coefficient of physics	c		0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485	0.485
5.	Slope of the vapor	O		1.44	1.42	1.43	1.50	1.49	1.41	1.40	1.42	1.45	1.48	1.46	1.44
6.	O / (O + c)			0.75	0.74	0.75	0.76	0.75	0.74	0.74	0.74	0.75	0.75	0.75	0.75
7.	Reflection coefficient /	r		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
8.	Solar Radiation at top	R(top)	ls/day	896.75	907.59	893.04	844.00	780.84	743.49	756.92	808.67	865.76	895.78	893.86	888.16
9.	Solar Radiation	a		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
10.	Solar Radiation	b		0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
11.	Intensitas Penyinaran	n	hour	5.35	4.59	4.88	6.53	6.53	5.38	6.87	6.50	6.14	5.79	4.65	4.54
12.	Intensity of Solar	N	hour	12.35	12.30	12.15	12.00	11.90	11.85	11.85	11.95	12.10	12.20	12.35	12.39
13.	Solar Radiaton	R	ls/day	411	389	395	431	401	348	400	413	427	428	385	378
14.	(A) = O/(O+c)*[1/58*(1-			3.97	3.75	3.82	4.22	3.91	3.35	3.84	3.98	4.14	4.17	3.74	3.66
15.	Vapour pressure curve	p		5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05	5.05
16.	Vapour pressure curve	q		16.13	16.13	16.13	16.13	16.13	16.13	16.13	16.13	16.13	16.13	16.13	16.13
17.	Saturated water vapor	es	mm/Hg	26.13	25.66	25.99	27.28	27.11	25.61	25.40	25.67	26.35	26.91	26.53	26.18
18.	Relative Humidity	RH	%	79.9	81.8	81.1	79.3	79.7	81.5	75.5	77.5	79.0	79.9	82.0	84.3
19.	Saturated water vapor	ea	mm/Hg	20.88	20.99	21.08	21.62	21.59	20.88	19.16	19.89	20.81	21.50	21.74	22.08
20.	1/58 * 117 * 10^(-9)*[ta +			16.23	16.17	16.21	16.38	16.36	16.16	16.13	16.17	16.26	16.34	16.29	16.24
21.	0,56 - 0,092* (ea)^0.5			0.14	0.14	0.14	0.13	0.13	0.14	0.16	0.15	0.14	0.13	0.13	0.13
22.	0,10 + 0,90 (n/N)			0.49	0.44	0.46	0.59	0.59	0.51	0.62	0.59	0.56	0.53	0.44	0.43
23.	(B) = (6) * [(20)*(21)*(22)]			0.83	0.73	0.77	0.97	0.97	0.85	1.17	1.06	0.95	0.87	0.70	0.67
24.	c/(O + c)			0.25	0.26	0.25	0.24	0.25	0.26	0.26	0.26	0.25	0.25	0.25	0.25
25.	Wind velocity	u	m/sec	0.62	0.55	0.53	0.48	0.58	0.62	0.63	0.55	0.53	0.57	0.58	0.60
26.	0,35 * [0,50 + 0,54 * u]			0.29	0.28	0.28	0.27	0.29	0.29	0.29	0.28	0.28	0.28	0.29	0.29
27.	[es - ea]			5.25	4.68	4.90	5.66	5.52	4.74	6.23	5.78	5.55	5.41	4.79	4.11
28.	(C) = (24) * [(26) * (27)]			0.39	0.33	0.34	0.37	0.39	0.35	0.47	0.41	0.38	0.38	0.34	0.30
29.	**Potential**	**Etp**	**mm/day**	**3.53**	**3.36**	**3.39**	**3.62**	**3.33**	**2.85**	**3.14**	**3.33**	**3.57**	**3.68**	**3.38**	**3.29**

Source: Calculation Results

Thiessen polygon

The Thiessen Polygon is a line that divides the Catchment Area based on the influence of each rainfall station. The way to create this Thiessen Polygon is by drawing a line connecting each station, then determining the midpoint of each line connecting each station and then drawing a perpendicular line from the midpoint to the line connecting each station, thus forming an area as shown in Figure 7 below. From the data consistency analysis, we obtained three rainfall stations whose data we used for the analysis of the Way Besai PLTM's mainstay discharge. The three rainfall stations and their areas of influence can be seen in Table 3 and Figure 7 below.

Table 3. Area affected by Rainfall Station

No	Station Name	Area (Km2)	Affected
1	Kebun Tebu	113.93	44

No	Station Name	Area (Km2)	Affected
2	Karang Agung	198.00	31
3	Bungin II	140.80	25
	Jumlah	452.73	100

Source: Calculation Results

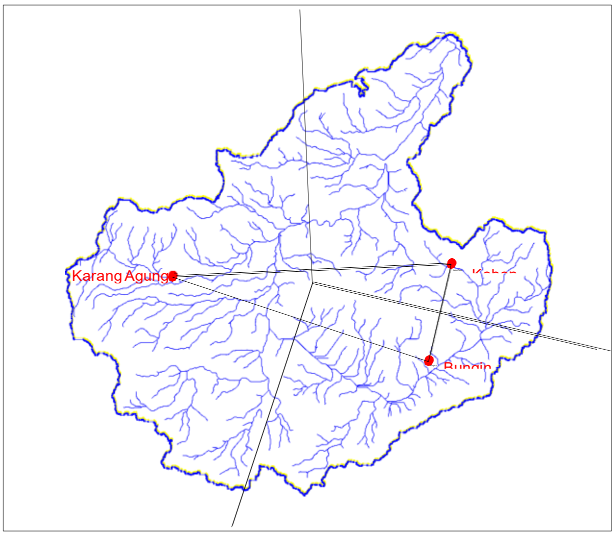

Figure 7. Influence Area of the Way Besai Hydroelectric Power Plant Watershed Rainfall Station (Source: Calculation Results)

Since the Thiessen Polygon is used to determine the influence of rainfall stations based on their area, the total rainfall amount is the rainfall height of each station multiplied by each percentage number of its influence and then added to the rainfall height of the other stations. In addition to first calculating the rainfall height based on the influence of the station, it is also possible to calculate the discharge of each rainfall station first, then multiply it by the percentage number of influence of each rainfall station and then add it to the other stations. The results of the rainfall data calculation become daily discharge data using the FJ method. The mock for the Way Besai PLTM can be seen in Figure 8 below.

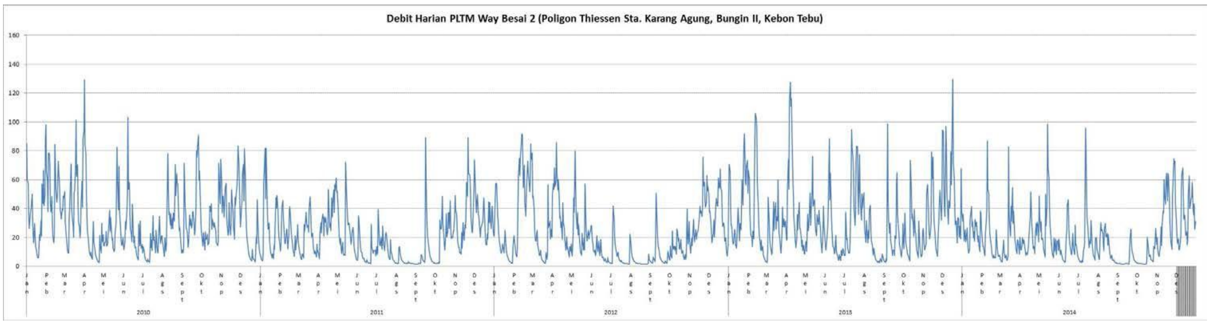

Figure 8. Daily Discharge of Way Besai Hydroelectric Power Plant 2015-2020

Flow Duration Curve (FDC)

Utilization of river discharge for micro-hydro power plants (PLTM) must take into account maintenance flow to ensure the continuity of river flow. A minimum of 10% of river discharge must be released downstream of the dam to meet environmental requirements. The river discharge utilized by the Way Besai PLTM has already factored in a maintenance flow of 15%. These monthly discharges are then combined and their probability of occurrence is determined. This is then used to create a Flow Duration Curve. The way to determine FDC is by arranging the discharge data from largest to smallest and each discharge is given a probability calculated using the Weibull equation as follows:

$$p = \frac{i}{n+1} \, x \, 100$$

Description
p = Probability exceeded
I = Simulation debit sequence number
n = Simulation discharge amount

The simulated discharge and its probability are then depicted in a Flow Duration Curve which describes the percentage of water availability and the amount of discharge, as shown in Figure 9 below.

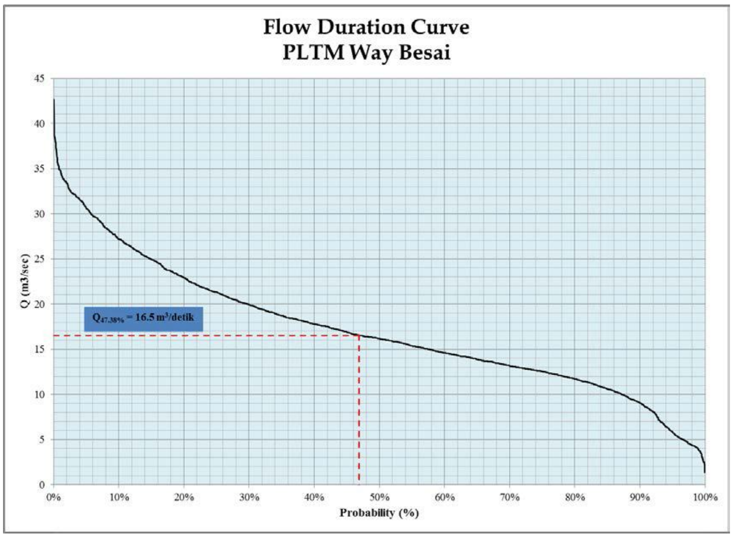

Figure 9. FDC of Way Besai Hydroelectric Power Plant

The discharge determination criteria for turbines can begin with occurrence (confidence) as the initial criterion; it is best to start with an occurrence of at least 95% and determine subsequent turbines with an occurrence of up to <50%, provided that it is economically viable to increase profits. The mainstay discharge determined for the Way Besai Hydroelectric Power Plant is 16.5 m3/s with a probability of 47.38%. This discharge value is the best value based on the results of simulations of the capacity and construction costs of the Hydroelectric Power Plant.

Discharge of planned power generation

The Way Besai Hydroelectric Power Plant (PLTM) is planned to use two turbine units with a generation discharge ranging from a maximum of 16.5 m3/s for two operating units to a minimum of 3.3 m3/s for one operating unit. It should be noted that the minimum operating discharge for a Francis-type turbine is estimated to be 40% of the maximum generator discharge. The maximum generator discharge is set at approximately the 173-day discharge of 16.5 m3/s given by the Flow Duration Curve and the minimum generator discharge is at approximately the 364-day discharge of 3.3 m3/s. Power generation will be available for river discharges between 16.5 m3/s and 3.3 m3/s by selecting the appropriate operating mode of two units or one operating unit. The generator discharge will cover the flow range as shown in Figure 10.

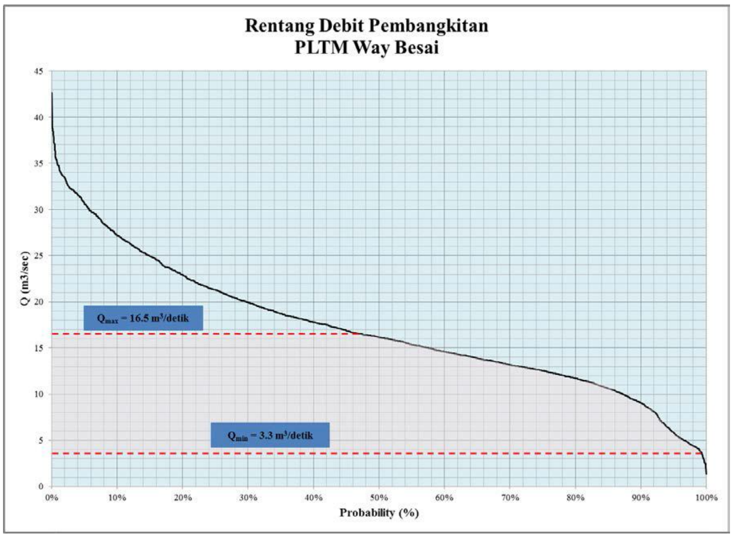

Figure 10. Hydroelectric Power Plant Discharge Range

Power Generation Output

Based on the calculation results, the normal water level at the weir is at an elevation of +342.0 m, the water level in the stilling pool is at +339.78 m, while the tailrace water level is at an elevation of +271.32 m, so the gross head is 70.67 m. Headloss or loss of height/energy along the weir to the tailrace is calculated at 3.23 m, so the net head is 67.45 m.

The generated power output can be calculated using the formula below:

$P = Q \times H_n \times g \times \eta$

dimana,

P = Power generated (kW)
Q = Plant discharge (m3/detik)
Hn = Net height (m)
G = Earth's gravitational force (9,81 m/detik2)
H = Efficiency, which consists of turbine and generator efficiency

Table 4. Annual Energy Production Simulation

	Days	H (m)	Qdesign (m3/sec)	kW	kWh meter	kWh	Units in Operation
47.38	172.94	67.00	16.500	9,891	9,396	38,999,803	2
50	9.56	67.00	16.150	9,671	9,188	2,107,997	2
55	18.25	67.00	15.367	9,175	8,716	3,817,570	2
60	18.25	67.00	14.596	8,669	8,235	3,607,104	2
65	18.25	67.00	13.869	8,155	7,748	3,393,481	2
70	18.25	67.00	13.157	7,647	7,264	3,181,796	2
75	18.25	67.00	12.548	7,229	6,868	3,008,063	2
80	18.25	67.00	11.729	6,627	6,296	2,757,442	2
85	18.25	67.00	10.599	5,925	5,629	2,465,439	2
90	18.25	67.00	9.052	5,280	5,016	2,197,066	2
95	18.25	67.00	5.839	3,363	3,195	1,399,518	1

99.46	16.28	67.00	3.300	1,557	1,479	577,860	1
Total Days	**363.03**	**Annual Energy Production (kWh)**				**67,513,140**	

5. CONCLUSION

Based on the analysis conducted, it can be concluded that the Way Besai River in Way Kanan Regency has sufficient hydrological potential for the construction of a Mini-Hydro Power Plant (PLTM). Calculations using the F.J. Mock method and Flow Duration Curve (FDC) analysis indicate that the Way Besai PLTM can be designed to produce a power output of 9.2 MW (2 x 4.6 MW) utilizing an effective head of 67.45 m and a plant discharge of 16.5 m3/s, determined for turbine design, with a 47.38% probability of availability. The annual energy output is estimated at 67,513 GWh.

The catchment area is 449.14 km2 at the intake site, and the average annual rainfall is 2,366 mm/year. The estimated average annual discharge is 20.93 m3/s, obtained from the Besai PLTA Outflow Data. The peak flood discharge at the intake location is estimated at 921.05 m3/s for a possible 100-year flood, 848.48 m3/s for a possible 50-year flood, and 780.14 m3/s for a possible 25-year flood. The results of this study provide a clear picture of the hydrological feasibility of the Way Besai PLTM project and support the utilization of water resources as a source of clean energy in the area.

6. REFERENCES

Almeida, R. M., Schmitt, R. J., Castelletti, A., Flecker, A. S., Harou, J. J., Heilpern, S. A., Kittner, N., Mathias Kondolf, G., Opperman, J. J., Shi, Q., Gomes, C. P., & McIntyre, P. B. (2022). Strategic planning of hydropower development: balancing benefits and socioenvironmental costs. In *Current Opinion in Environmental Sustainability* (Vol. 56). https://doi.org/10.1016/j.cosust.2022.101175

Coron, L., Andréassian, V., Perrin, C., Lerat, J., Vaze, J., Bourqui, M., & Hendrickx, F. (2012). Crash testing hydrological models in contrasted climate conditions: An experiment on 216 Australian catchments. *Water Resources Research*, *48*(5). https://doi.org/10.1029/2011WR011721

Griffith, H. V., Wade, A. J., Lavers, D. A., & Watts, G. (2020). Atmospheric river orientation determines flood occurrence. *Hydrological Processes*, *34*(23). https://doi.org/10.1002/hyp.13905

Liucci, L., Valigi, D., & Casadei, S. (2014). A new application of flow duration curve (FDC) in designing run-of-river power plants. *Water Resources Management*, *28*(3). https://doi.org/10.1007/s11269-014-0523-4

Okoli, K., Breinl, K., Mazzoleni, M., & Di Baldassarre, G. (2019). Design flood estimation: Exploring the potentials and limitations of two alternative approaches. *Water (Switzerland)*, *11*(4). https://doi.org/10.3390/w11040729

Reynolds, J. E., Halldin, S., Seibert, J., & Xu, C. Y. (2018). Definitions of climatological and discharge days: do they matter in hydrological modelling? *Hydrological Sciences Journal*, *63*(5). https://doi.org/10.1080/02626667.2018.1451646

Soerya, S. F., Asdak, C., Kendarto, D. R., Yan, T., & Riyadi, A. (2023). F.J Mock Method For Hydrological Moel In Water Reliability Study In Leuwi Padjadjaran II Reservoir. *Journal of Advanced Zoology*. https://doi.org/10.53555/jaz.v44i5.3292

Vangelis, H., Zotou, I., Kourtis, I. M., Bellos, V., & Tsihrintzis, V. A. (2022). Relationship of Rainfall and Flood Return Periods through Hydrologic and Hydraulic Modeling. *Water (Switzerland)*, *14*(22). https://doi.org/10.3390/w14223618

Wang, F., Noda, K., Azechi, I., & Senge, M. (2020). Potential for and feasibility of small hydropower generation at headworks in Japan. *Hydrological Research Letters*, *14*(1). https://doi.org/10.3178/hrl.14.23

Yuksel, I., & Demirel, I. H. (2021). Investigation of the optimal method for determining hydropower potential of small streams: a case study Batman Basin in Turkey. *Arabian Journal of Geosciences*, *14*(7). https://doi.org/10.1007/s12517-021-06877-y