Available online on: http://ejournal.undip.ac.id/index.php/teknik

TEKNIK, 46 (2), 2025, 154-161

Water Availability Analysis at Margatiga Dam

Ega Rizky Setyawanto*, Dyah Ari Wulandari

Department of Civil Engineering, Faculty of Engineering, Diponegoro University,
Jl. Prof. Soedarto, SH, Tembalang, Semarang, Indonesia 50275

Abstract

A Dam is a building structure built to hold or store water and functions to channel water for raw water, irrigation, and hydroelectric power generation. The Margatiga Dam is the third dam located downstream of the Sekampung River Cascade Dam series in Lampung Province. The Margatiga Dam functions to supply irrigation water and raw water as well as flood control. To meet water needs, a water availability analysis must be conducted. This study aims to determine the discharge of water availability in wet years, normal years, and dry years at the Margatiga Dam. In this study, the data used is satellite rainfall data calibrated with ground station rainfall data in 2001 - 2023. The methods used in this study are satellite rainfall data correction, potential evapotranspiration analysis using the modified Penman method, flow discharge analysis using the F.J. Mock method, and reliable discharge analysis using the Weibull method. The results of this study indicate that the availability of water at the Margatiga Dam in a wet year is 13.96 m^3/sec, in a normal year it is 10.34 m^3/sec, and in a dry year it is 8.13 m^3/sec.

Keywords: *Water availability; Evapotranspiration; Dependable discharge; F.J. Mock; Margatiga Dam; Engineering*

1. Introduction

A dam is a structure made of earth, rock, or concrete built not only to hold and store water but can also be used to hold mine waste or slurry to form a reservoir. The reservoir itself is an artificial reservoir created by the construction of a dam (Kementerian PUPR, 2023).

Reservoirs play a significant role and contribution in meeting water needs during the dry season, reducing the negative impacts of excess water volume, and providing various benefits to people in different sectors. To maximize their function, proper calculations regarding the availability and demand of water in the reservoir are necessary. Therefore, effective water management and control are needed so that water use can support survival by maintaining its availability. (Kalbuardhi et al., 2018).

The two main factors influencing changes in the hydrological cycle and affecting water availability are land use change and climate change, which include variables such as temperature, solar radiation, evaporation, and precipitation (Krajewski et al., 2021). The water balance is the relationship between inflow and outflow over some time and includes several components such as streamflow, precipitation, evapotranspiration, percolation, soil moisture, and groundwater storage. The water balance can show whether there is a surplus or deficit of water. (Byeon, 2014).

Water availability and demand data are required to determine the reservoir operation pattern. To meet the water demand of the Margatiga Dam, it is important to consider the amount of water available in the dam. The availability of water in the Margatiga Dam comes from the outflow of the Argoguruh Dam and the flow of water in the Margatiga Dam Catchment Area (DTA). To maintain the availability of water in the Margatiga Dam, it is necessary to pay attention to the operation of the Argoguruh Dam and the preservation of the Margatiga Dam Catchment Area.

To calculate water availability, complete rainfall data over a long period is required. Rainfall data from ground stations in the Sekampung watershed are incomplete and some data are missing. Therefore, satellite rainfall data is used as the basis for calculating water availability. This research aims to calculate water availability in Margatiga Dam using satellite rainfall data corrected with ground station rainfall data.

2. Materials and Methods

2.1 Research Location

Margatiga Dam is located in Negeri Jemanten Village, Margatiga Subdistrict, East Lampung Regency, Lampung Province, on the Way Sekampung River, Way Sekampung River Basin, at coordinates 105º29'08" East - 05º12'27" LS. The function of Margatiga Dam is to supply water to Jabung Dam to meet the irrigation needs of D.I. Jabung Kiri covering 5,638 ha and the irrigation potential of D.I. Jabung Kanan covering 10,950 ha as well

*) Corresponding Author.
E-mail: ega311094@gmail.com

doi: 10.14710/teknik.v46i2.67856 p-ISSN: 0852-1697, e-ISSN: 240-9919

Figure 1. Location of Margatiga Dam

as to meet the raw water needs (BBWS Mesuji Sekampung, 2021). The location of the Margatiga Dam is shown in Figure 1.

2.2 Data Collection

The data used to analyze the water availability at Margatiga Dam are from the Mesuji Sekampung River Basin. The data required in this study include technical data of the dam, rainfall data, climatology data, watershed characteristics data, and discharge measurement data. The following data are available for this study:

a. Rainfall data from rain stations (year 2000 - 2021)
b. Satellite precipitation data (year 2001 - 2023)
c. Climatology data (year 2019 - 2023)
d. Land use and Soil type data
e. Argoguruh Dam discharge data (year 2010 - 2023)

2.3 Stages of Data Analysis

This research performed several stages of analysis. Figure 2 shows a flowchart of the analysis stages.

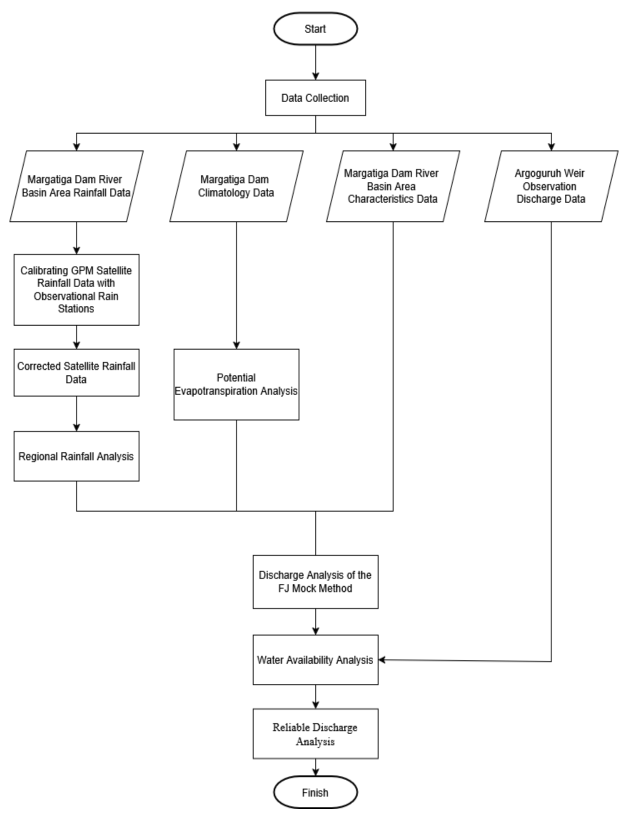


Figure 2. Flowchart of the Margatiga Dam water availability study

doi: 10.14710/teknik.v46i2.67856

2.4 Basic Theory

2.4.1 Satellite Rain Data Correction

Rainfall data from ground stations in the catchment area of the Margatiga Dam are incomplete. The limitations of rainfall data in the past can be overcome by using the latest technology such as satellite remote sensing. This technology provides a modern method of rainfall data collection, allowing data to be collected with flexibility in time and location. Some of the advantages of this technology include higher resolution, larger area coverage, near real-time data availability, continuous recording, and free download of data. (Krisnayanti et al., 2020).

Although satellite-derived hydrometeorological data are now highly accurate and easily accessible anytime, anywhere, their use still requires prior correction (Nugroho & Sachro, 2024). The satellite data were corrected based on the equation obtained from the combination of variables that produced the largest correlation coefficient (R) and coefficient of determination (R2). The equation type that produces the largest R2 value is selected as the appropriate correction equation for the satellite precipitation data (Maulana et al., 2019). Various equation forms of regression methods are considered, including linear regression, logarithmic functions, exponential functions, polynomial functions, and exponential functions (Jarwanti et al., 2021).

The validation method uses statistical analysis to evaluate the accuracy of satellite rainfall data compared to ground station data. This research uses the correlation coefficient (R) test. This analysis is defined by the following equation (Ramadhan et al., 2022):

$$R = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2] - [n\sum y^2 (\sum y)^2]}} \quad (1)$$

where n is the number of samples, x is satellite-based rainfall, and y is observed rainfall.

The value of the correlation coefficient ranges from -1 to +1. A close/strong correlation has a coefficient close to -1 or +1, while a weak correlation has a coefficient close to 0. If the correlation coefficient is positive, then the two variables have a unidirectional relationship. Conversely, if the correlation coefficient is negative, the two variables have an inverse relationship. The criteria for the value of the correlation coefficient (R) are listed in Table 1.

Table 1. Criteria for the value of the correlation coefficient (R)

Correlation Value	Criteria
0,000 – 0,199	Very weak
0,200 – 0,399	Weak
0,400 – 0,599	Sedang
0,600 – 0,799	Strong
0,800 – 1,000	Very Strong

2.4.2 Regional Rainfall

The regional rainfall analysis was performed on the semi-monthly rainfall and number of rainy days from each satellite grid. To determine each grid's influence, the DTA of the Margatiga Dam was cut with a grid line to obtain the area of influence of each grid, which was then multiplied by the semi-monthly rainfall of each grid.

2.4.3 Potential Evapotranspiration Analysis

Evapotranspiration is an important factor in estimating streamflow from precipitation and climatology data using the F.J. Mock method. The process of water loss through evaporation and transpiration can reduce the water storage in water bodies, soils, and plants that provide a large fraction of the generation of streamflow (Adiningrum, 2015).

The modified Penman evapotranspiration method is a method modified from the Penman equation by the Food and Agriculture Organization of the United Nations (FAO) in 1977 (Sudjarwadi, 1979). The calculation of modified Penman evapotranspiration is shown in the following equation:

$$ET_0 = c(Wx\ R_n + (1 - W)\ x\ f(U)\ x\ (ea - ed)) \quad (2)$$

where ET_0 is potential evapotranspiration (mm/day), c is weather adjustment factor, W is solar irradiance factor, Rn is net radiation (mm/day), f(U) is wind speed factor, ea is saturated vapor pressure (mbar), ed is actual vapor pressure (mbar).

2.4.4 Low Flow Discharge Analysis

The F.J. Mock method can be used to empirically calculate the amount of minimum flow that flows in a river. The data needed to calculate runoff using the F.J. Mock method are precipitation data, climatology data, area, and land use of the watershed (Limantara & Putra, 2016).

2.4.5 Reliable Discharge Analysis

The mainstay discharge is the available discharge that can be calculated for specific purposes throughout the year. The higher the reliability number, the lower the resulting discharge. The mainstay discharge calculation is used here to find the amount of discharge that is suitable for raw water and irrigation water use. The first step in determining the mainstay discharge is to sort the existing discharges from largest to smallest. The calculation of the mainstay discharge is done using the basic month method. This method is most often used to describe the reliability of runoff in the wet and dry seasons. The formula used is the Weibull formula (Sosrodarsono & Takeda, 1985):

$$P = m/(n + 1)\ x\ 100\% \quad (3)$$

where P is the probability, m is the sequence number of the discharge data, and n is the number of data.

Water balance simulations to determine reservoir operating patterns are based on a certain level of reliability of discharge. If the average discharge for a normal year is approximately 100%, which is equivalent to a 50% reliable discharge, then a wet year (115% of average) would be equivalent to a reliable discharge of less than 35%, while a dry year (85% of average) would

doi: 10.14710/teknik.v46i2.67856 p-ISSN: 0852-1697, e-ISSN: 240-9919

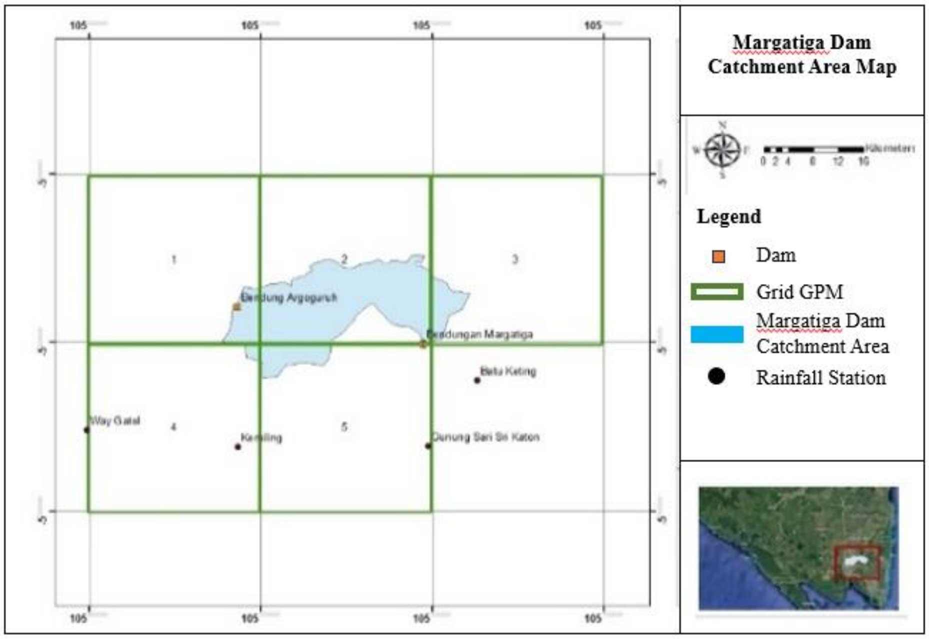


Figure 3. Map of GPM Margatiga Catchment Area

be equivalent to a reliable discharge of greater than 65% (Kementerian PUPR, 2017).

3. Results and Discussion

3.1 Satellite Rain Data Correction

Rainfall data contained in the Margatiga Dam Catchment Area (DTA) is recorded in 5 (five) rainfall stations including Batu Keting Rainfall Station, Argoguruh Dam Rainfall Station, Gunung Sari Sri Katon Rainfall Station, Kemiling Rainfall Station, and Way Gatel Rainfall Station.

Satellite rainfall data is also used to fill in some gaps in the ground station rainfall records. The use of satellite data must be corrected with ground station rainfall data that has similar rainfall characteristics and regions. The search for correction factors is done by trial and error using the Mean Absolute Error (MAE) objective function, where the error is calculated from the difference in probability of the same rainfall event. For this GPM satellite data is available from 2001 to 2023, with daily rain output up to 15 daily data for water availability analysis. Rainfall data is downloaded from the GPM satellite through the website. The research site consists of 5 GPM grids with a size of 28 km x 28 km as shown in Figure 3.

Based on the available ground station rain data and GPM satellite rain data, the correlation values for each grid and rain post are shown in Table 2. The correlation value between satellite data and ground station data is calibrated based on the location and similarity of rain characteristics between the rainfall station and the GPM satellite grid.

Table 2. Correlation of ground station and satellite rainfall data

Rainfall	Batu Keting	Bendung Argoguruh	Gunung Sari Sri Katon	Kemiling	Way Gatel
GRID 1		0,69			
GRID 2		0,71			
GRID 3	0,39				
GRID 4				0,61	0,66
GRID 5			0,47		

The correlation of rainfall in Grid 2 with Argoguruh Dam has the highest correlation value because the Argoguruh Dam Rainfall Post is located within Grid 2.

To obtain the correction value of satellite data against ground station data, obtained by comparing the two data. After correcting the GPM satellite rain data with the ground station data, the daily rain value from 2001 to 2023 is obtained for each grid. The error value of satellite rain data between before and after correction is shown in Table 3.

Table 3. Error value of rain data before and after correction

Error Value	GRID 1	GRID 2	GRID 3	GRID 4	GRID 5	Mean
Before Correction	0,0234	0,0277	0,0236	0,0209	0,0232	**0,0238**
After Correction	0,0066	0,0070	0,0201	0,0082	0,0142	**0,0112**

Based on the error value between rain data before and after correction, it shows a decrease in the error value

doi: 10.14710/teknik.v46i2.67856

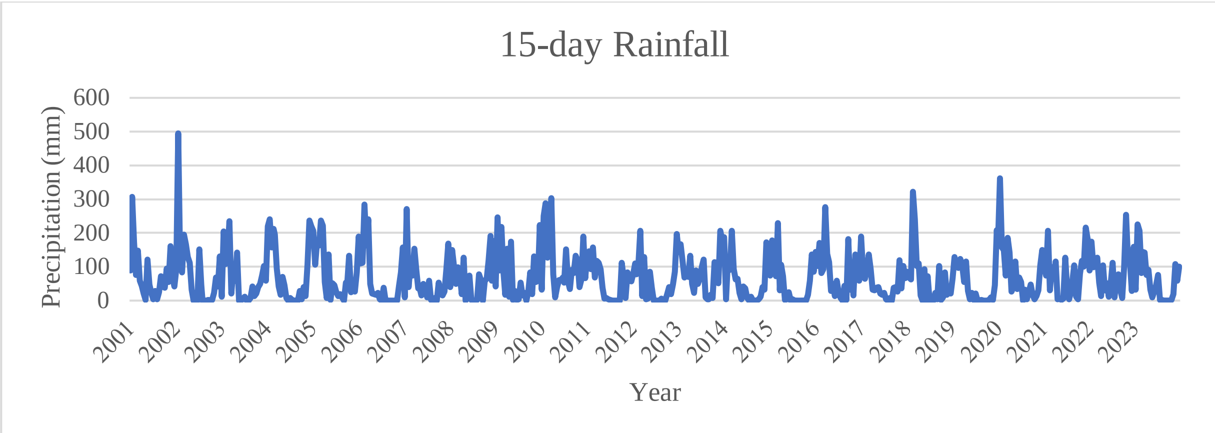


Figure 4. Graph of 15-day rainfall at the Margatiga Dam catchment area

after correction of satellite rain data to ground station rain data.

3.2 Regional Rainfall

The corrected satellite precipitation data is then used to calculate the regional precipitation for each grid. The grid influence area factor is seen based on the DTA area within each grid. Once the coefficient of influence of each grid on the DTA area is known, the GPM satellite rain data for each corrected grid is multiplied by the coefficient value. The sum of these results is the value of regional rainfall in the Margatiga Dam DTA. The 15-day rainfall graph for the Margatiga Dam catchment area is shown in Figure 4.

3.3 Calculate potential evapotranspiration

The calculation of evapotranspiration using the modified Penman method requires data on temperature, humidity, wind speed, and sunshine duration. The climate data used in this study was obtained from the Way Sekampung Climatology Station. This climatological data consists of temperature, humidity, wind speed, sunshine duration, and evaporation. After obtaining the climatological data, the values of saturated vapor pressure (ea), solar irradiation factor (W), temperature function value (f(t)), and extraterrestrial radiation (Ra) are then sought.

From the value of climatological factors, the potential evapotranspiration can be calculated. The table of potential evapotranspiration values in the Margatiga Dam catchment area for each month is shown in Table 4. The potential evapotranspiration values are used to analyze the low-flow discharge using the FJ. Mock method.

3.4 Low Flow Discharge Analysis

The calculation of synthetic discharge using the FJ Mock method requires some data, namely watershed area, open land area (m), infiltration coefficient (i), groundwater flow recession factor (k), minimum soil moisture, maximum soil moisture (SMC), and initial soil moisture. Some parameters used in the FJ Mock analysis are as follows:

m = 30
Soil Moisture Capacity (SMC) = 200 mm
Infiltration Coefficient (i) = 0,60 ($0 < i < 1$)
Groundwater flow recession factor (k) = 0,50 ($0 < k < 1$)
Heavy rainfall flow factor (PF) = 10 %

Table 4. Potential evapotranspiration value

	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Saturated vapor pressure [ea]	mbar	37,75	38,17	38,06	38,75	39,3	37,22	37,8	38,26	37,97	38,95	38,81	38,51
Real vapor pressure [ed]	mbar	34,73	37,02	36,16	36,81	37,33	34,62	35,91	36,35	35,31	37,78	34,15	33,89
The weighting factor for Rn [W]		0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,77	0,78	0,77
Air temperature and altitude factors [1 - W]		0,23	0,23	0,23	0,23	0,23	0,23	0,23	0,23	0,23	0,23	0,23	0,23
Temperature function [f (t)]		16,3	16,34	16,33	16,39	16,43	16,25	16,3	16,34	16,32	16,4	16,4	16,37
Extra-terrestrial radiation [Ra]	mm/day	15,07	15,5	15,7	14,9	14,4	10,8	10,94	12,46	14,56	16,09	16,42	16,81
Potential Evaporation [ET*]	mm/day	3,24	2,4	3,48	3,94	4,37	3,42	3,29	3,2	4,51	4,77	5,2	4,75
Potential Evapotranspiration [ET_o]	**mm/day**	**3,56**	**2,65**	**3,48**	**3,54**	**3,93**	**3,07**	**2,96**	**3,2**	**4,96**	**5,25**	**5,72**	**5,23**

doi: 10.14710/teknik.v46i2.67856

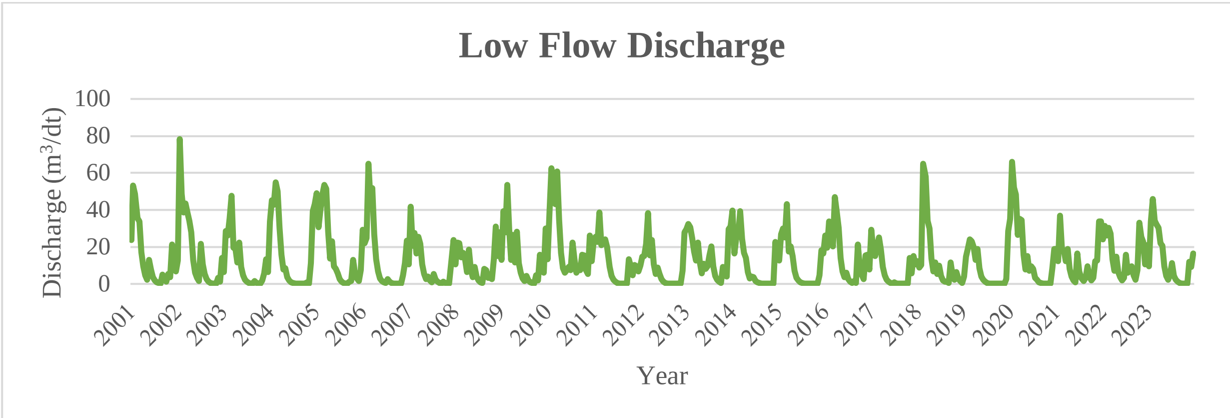


Figure 5. Low flow discharge graph of FJ Mock method

The results of the FJ Mock method discharge calculation are assumptions and cannot be calibrated because there is no AWLR discharge data available for Margatiga Dam. The calculated discharge using the FJ Mock method is shown in Figure 5.

3.5 Inflow discharge of Margatiga dam

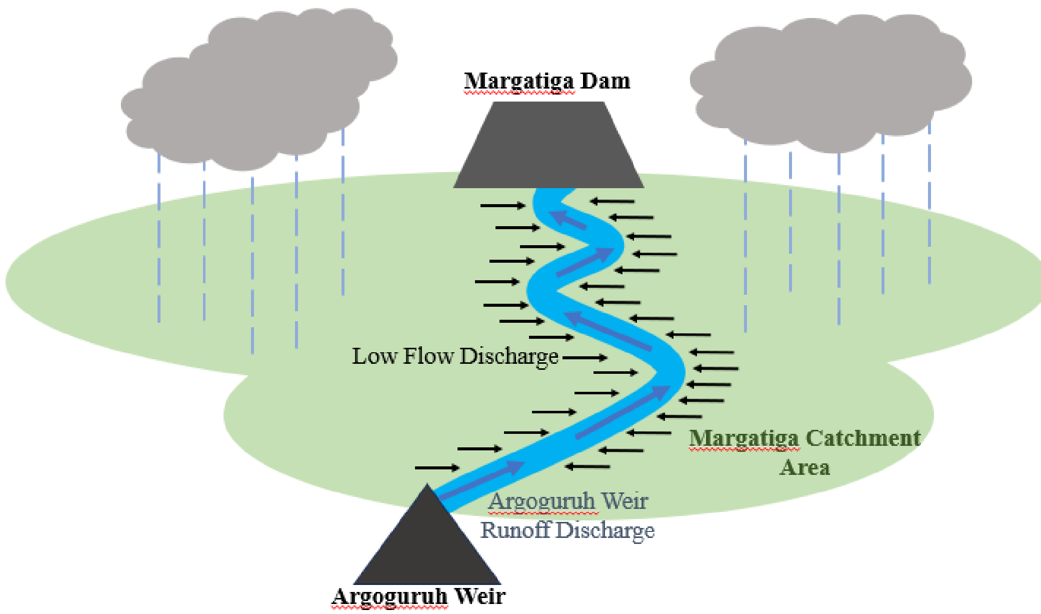
The inflow of the Margatiga dam, apart from the water flowing from the Margatiga catchment area (DTA), also receives additional runoff from the Argoguruh dam. The Argoguruh Dam discharge is the difference between the available discharge and the discharge. The Margatiga Dam inflow scheme is shown in Figure 6.

Available Argoguruh Dam discharge data starts from 2010 - 2023. From the results of the calculation of the FJ Mock low-flow discharge and the Argoguruh Dam runoff data, the amount of the Margatiga Dam inflow discharge is obtained. The inflow discharge at the Margatiga dam is the sum of the low-flow discharge of the FJ Mock DTA of the Margatiga dam and the Argoguruh dam discharge data.

3.6 Reliable Discharge Analysis

The analysis of reliable discharge using the base month method is almost identical to the flow characteristic method. This method is most commonly used because the reliability of the flow is calculated from January to December. The basic month method is better able to describe the reliability in the dry season and the rainy season.

The calculation of the mainstay discharge probability using the Weibull method is by sorting the discharge data from the largest to the smallest order for every 15 days from 2010 to 2023. In this study, the classification of flow discharge has a probability value in wet years (65%), normal years (50%), and dry years (35%). The graph of Margatiga Dam mainstay discharge



doi: 10.14710/teknik.v46i2.67856

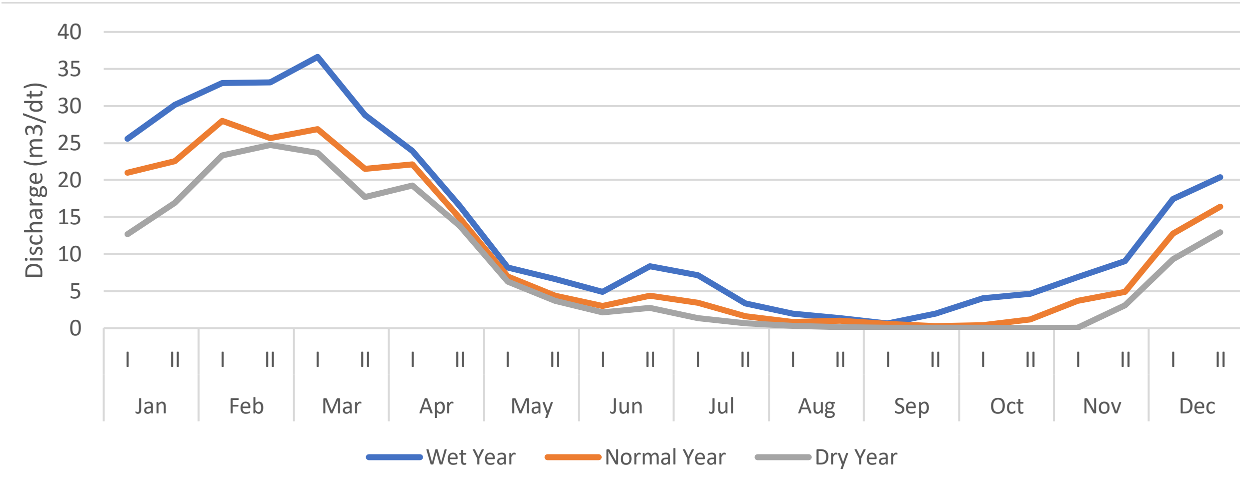


Figure 7. Graph of mainstay discharge

for the wet year, normal year, and dry year is contained in Figure 7.

Figure 7 shows that the average mainstay discharge of Margatiga Dam for a wet year is 13.96 m³/det, a normal year is 10.34 m³/det, and a dry year is 8.13 m³/det. For the maximum value of the mainstay discharge of the Margatiga Dam for the wet year is 36.63 m³/det, the normal year is 27.99 m³/det, and the dry year is 24.73 m³/det. The minimum value of the mainstay discharge of the Margatiga dam for a wet year is 0.63 m³/det, a normal year is 0.28 m³/det, and a dry year is 0.02 m³/det.

4. Conclusion

Based on the results of the analysis, the availability of water in Margatiga Dam varies according to the hydrological conditions. The average mainstay discharge obtained is 13.96 m³/det in wet years, 10.34 m³/det in normal years, and 8.13 m³/det in dry years. The discharge decreased in the dry season and increased in the wet season. These results show the importance of optimal water management to maintain the availability of water resources in Margatiga Dam.

Acknowledgments

The authors would like to thank the Mesuji Sekampung River Basin (BBWS) of the Ministry of PUPR, especially the SNVT of Dam Construction for their guidance and assistance in data collection and experience sharing, as well as the supervisors of the Master of Hydrometeorological Operations and Instrumentation of Dams of Diponegoro University who supported the smooth running of this research.

Bibliography

Adiningrum, C. (2015). *Analisis Perhitungan Evapotranspirasi Aktual Terhadap Perkiraan Debit Kontinyu dengan Metode Mock* (Vol. 13, Issue 2).

BBWS Mesuji Sekampung. (2021). *Laporan Akhir Pola Operasi Kaskade Bendungan Batutegi, Bendungan Way Sekampung dan Bendungan Margatiga*.

Byeon, S. J. (2014). *Water Balance Assessment for Stable Water Management in Island Region*.

Jarwanti, D. P., Suhartanto, E., & Fidari, J. S. (2021). Validasi Data Curah Hujan Satelit TRMM (Tropical Rainfall Measuring Mission) dengan Data Pos Penakar Hujan di DAS Grindulu, Kabupaten Pacitan, Jawa Timur. *Jurnal Teknologi Dan Rekayasa Sumber Daya Air*, *1*, 772–785.

Kalbuardhi, R., Suwarno, D., Luhur, P. I., & Dhuwur, B. (2018). Analisis Ketersediaan Air Waduk Jatiluhur Sebagai Dasar Penerapan Pola Operasi Pembangkit Listrik Tenaga Air (Studi Kasus: PLTA Waduk Jatiluhur Kabupaten Purwakarta, Jawa Barat). In *Teknik Sipil Unika Soegijapranata Semarang |* (Vol. 2).

Kementerian PUPR. (2017). *Modul Operasi Waduk*.

Kementerian PUPR. (2023). *Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 7 Tahun 2023 tentang Perubahan kedua atas Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 27/PRT/M/2015*.

Krajewski, A., Sikorska-Senoner, A. E., Hejduk, L., & Banasik, K. (2021). An Attempt to Decompose the Impact of Land Use and Climate Change on Annual Runoff in a Small Agricultural Catchment. *Water Resources Management*, *35*(3), 881–896. https://doi.org/10.1007/s11269-020-02752-9

Krisnayanti, D. S., Welkis, D. F. B., Hepy, F. M., & Legono, D. (2020). Evaluasi Kesesuaian Data Tropical Rainfall Measuring Mission (TRMM) dengan Data Pos Hujan Pada Das Temef di Kabupaten Timor Tengah Selatan. *JURNAL*

doi: 10.14710/teknik.v46i2.67856

SUMBER DAYA AIR, *16*(1), 51–62. https://doi.org/10.32679/jsda.v16i1.646

Limantara, L. M., & Putra, W. R. (2016). Analisa Keandalan Tampungan Waduk di Embung Tambak Pocok Bangkalan. *Jurnal Teknik Sipil*, 127–134.

Maulana, H., Suhartanto, E., & Harisuseno, D. (2019). Analysis of Water Availability Based on Rainfall Satellite in The Upper Brantas River Basin. *International Research Journal of Advanced Engineering and Science*, *4*(2), 393–398. http://chrsdata.eng.uci.edu/

Nugroho, A. P., & Sachro, S. S. (2024). Analisis Regresi Untuk Penentuan Faktor Koreksi Data Hujan Satelit (Studi Kasus Daerah Tangkapan Air Bendungan Way Apu). *TEKNIK*, *45*(1), 59–68. https://doi.org/10.14710/teknik.v45i1.60335

Ramadhan, R., Muharsyah, R., Marzuki, Yusnaini, H., Vonnisa, M., Hashiguchi, H., Suryanto, W., & Sholihun. (2022). Evaluation of GPM IMERG Products for Extreme Precipitation over Indonesia. *Journal of Physics: Conference Series*, *2309*(1). https://doi.org/10.1088/1742-6596/2309/1/012008

Sosrodarsono, S., & Takeda, K. (1985). *Hidrologi Untuk Pengairan*.

Sudjarwadi. (1979). *Pengantar Teknik Irigasi*. Fakultas Teknik UGM.

doi: 10.14710/teknik.v46i2.67856