

## Rule Curve of Meninting Reservoir in West Lombok Regency, West Nusa Tenggara

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### ABSTRACT

Meninting Reservoir in West Lombok Regency is essential for addressing uneven water distribution on Lombok Island. It reallocates water from the Sesaot, Penimbung, and Ketapang Irrigation Areas, covering 1,490 hectares, and supplies 150 liters/second of raw water while generating 2×0.4 MW of electricity. To ensure equitable water distribution, an optimal rule curve is needed. This study analyzes water demand and availability using the continuity equation. Water availability was assessed based on discharge data from the Orong Atas AWLR station, while demand was evaluated under various scenarios, including different planting schedules and Micro Hydro Power Plant (MHP) integration. Results show that irrigation demand ranges from 1,082,648.92 m<sup>3</sup> to 1,496,415.21 m<sup>3</sup> per half-month period, while raw water and MHP demands are 197,100 m<sup>3</sup> and 2,857,950 m<sup>3</sup>, respectively. The optimal rule curve is achieved with the October II planting schedule without MHP, ensuring 100% reliability. However, with MHP, the best rule curve occurs under the November I schedule, reducing reliability to 54.2% and increasing failure risk to 45.8% in dry years. These findings emphasize the need for strategic planting schedules and reservoir management to balance irrigation, raw water supply, and hydropower generation. The study provides a scientific basis for optimizing reservoir operations to ensure sustainable water use in West Lombok Regency.

**Keywords:** Meninting Reservoir, Rule Curve, Water Balance.

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### INTRODUCTION

Water resources play a crucial role in human life and survival, as nearly all human activities require water (Ardana et al., 2021); (Pratama Nataniel, 2022). Without water, humans cannot survive. Over time, the use of water resources for daily needs has increased alongside population growth and its associated activities (Ardana et al., 2021); (Rosandi et al., 2023). Therefore, efforts in water management are necessary to ensure its optimal utilization.

A policy to ensure the sustainability of water resources is the development of water infrastructure, such as reservoir construction (Mulyawati & Fazhar, 2020). In principle, a reservoir functions as a place to store and hold water during the rainy season when rainfall is high, so that it can be used during the dry season when rainfall is low (Shiamah, 2020); (Farida & Andajani,

2019). It is expected that the water stored in the reservoir can meet various needs, including irrigation water, raw water, hydroelectric power generation, or other uses, depending on whether the reservoir serves a single or multiple purposes in accordance with competing interests (Swastika et al., 2022).

The Ministry of Public Works and Housing is currently completing the construction of Meninting Reservoir. Meninting Reservoir is located in West Lombok Regency and is part of the Meninting River Basin. The construction of Meninting Reservoir was motivated by the uneven distribution of water on Lombok Island. The western part of Lombok Island, which includes the Meninting River Basin, has sufficient water potential to meet its own needs. However, the southern part of Lombok Island, particularly the Mujur Complex area, which has significant agricultural potential, faces water scarcity. To balance water potential and agricultural potential on Lombok Island, Meninting Reservoir will supply water to the southern part of Lombok Island by reallocating some of the water from the Sesaot Irrigation Area, covering 1,000 hectares. The Meninting Reservoir will also irrigate the Penimbung Irrigation Area and Ketapang Irrigation Area, covering 450 hectares and 40 hectares, respectively, with a planting intensity of 300% for each irrigation area (1, 2017).

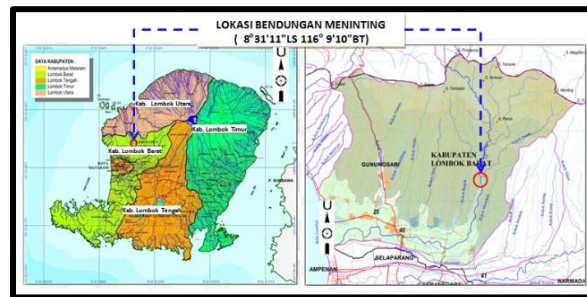
In addition, the decreasing discharge of springs and the increasing demand for drinking water due to population growth have exacerbated the water balance crisis. Therefore, with the presence of Meninting Reservoir, the supply of raw water to the northern part of West Lombok Regency, amounting to 150 liters/second, will be more secure. The outflow from Meninting Dam for irrigation water supply to southern Lombok Island and for drinking water supply to northern West Lombok Regency can also be used to generate electricity with a capacity of  $2 \times 0.4$  Megawatts (Wiyasri et al., 2022).

Reservoir management and operational guidelines are essential not only during the construction phase but also after completion (Anggraheni et al., 2017). In addition to the increasing demand for water, inefficient water use and fluctuations in Meninting River discharge contribute to the instability between water availability and demand, especially during the dry season. Therefore, the rule curve of Meninting Reservoir is crucial to ensure that the water stored and held in the reservoir can be distributed accurately, meeting all water needs fairly and equitably.

In this study, water distribution is conducted using a simulation method, by simulating the reservoir rule curve based on its storage capacity. This aims to determine the water demand and availability based on the continuity equation or mass balance equation. The continuity equation relates inflow, outflow, and changes in storage across three conditions: wet year, normal year, and dry year. For the outflow, several alternatives were tested in this study, including MHP sharing a channel with irrigation or MHP on a separate channel from irrigation, which were also simulated at different planting schedules. This way, the optimal reservoir rule curve be determined, ensuring its role as both a water storage and supply system.

## RESEARCH METHOD

The research location is the Meninting Reservoir, situated in West Lombok Regency. It lies within the Meninting River Basin, covering a river basin area of 32.77 km<sup>2</sup> and an inundation area of 53.60 hectares. The reservoir has a maximum water surface elevation of 198.72 meters and a minimum elevation of 169 meters. Its gross volume is 9.91 million m<sup>3</sup>, with an effective storage volume of 8.19 million m<sup>3</sup>.



**Figure 1. Map of Meninting Reservoir location**

The Meninting Reservoir plays a critical role in water resource management on Lombok Island and requires a rule curve for effective use. Reservoir operation refers to the control of water flow from a river into a reservoir and the subsequent release of stored water for various purposes. The rule curve acts as a reference point to maintain the reservoir's water levels according to the design, ensuring that outflow meets demand (Soetopo, 2010).

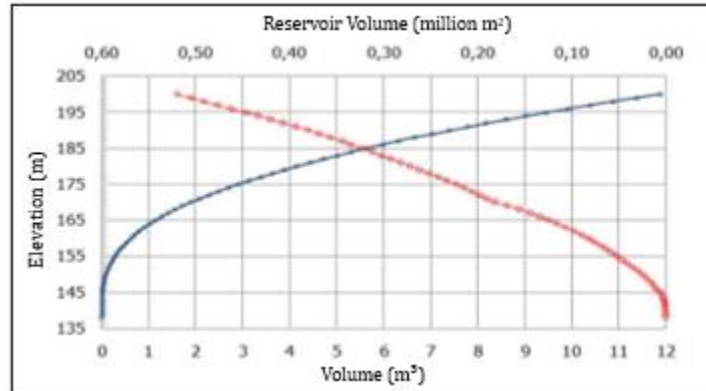
One commonly used method for reservoir operations is the continuity equation, which links inflow, outflow, and changes in reservoir storage. This simulation model, known as behavior analysis, calculates water availability and demand based on mass balance principles. The continuity equation expresses the relationship between inflow, outflow, and changes in storage, as shown in the following equation (McMahon, 1978):

$$St+1 = St + Qt + Dt - Et - Lt$$

$$\text{For } 0 \leq St+1 \leq C$$

Where  $t$  is the time period,  $St+1$  is the reservoir storage at the end of period  $t$  (m<sup>3</sup>),  $St$  is the reservoir storage at the beginning of period  $t$  (m<sup>3</sup>),  $Qt$  is the inflow during period  $t$  (m<sup>3</sup>),  $Dt$  is the demand during period  $t$  (m<sup>3</sup>),  $Et$  is evaporation during period  $t$  (m<sup>3</sup>),  $Lt$  is represents water losses due to leakage and seepage during period  $t$  (which can be neglected) (m<sup>3</sup>),  $C$  is the reservoir's active storage capacity (m<sup>3</sup>).

The reservoir's storage capacity can be determined from the reservoir capacity curve, which depicts the curve relationship between water surface area, storage volume, and water surface elevation (Susanto & Yosanto, 2017).



**Figure 2. Capacity curve of Meninting Reservoir**

The inflow to the reservoir, as outlined in the Reservoir Operation Module from the Water Allocation Training Module 8 by the Training Center for Water Resources and Construction of the Ministry of Public Works and Housing, is classified into three reliability conditions: a wet year with 35% reliability, a normal year with 50% reliability, and a dry year with 65% reliability (Kementerian, 2017).

The water requirements are aligned with the functions of the reservoir, including raw water, irrigation water, and MHP generation. This study explores several alternatives, including integrating the MHP with the irrigation system and separating it from the irrigation system, while also considering the reservoir's function as a source of raw water. These scenarios are simulated across different planting schedules.

The irrigation water requirements for paddy and secondary crops, according to Planning Criteria, are based on the principle of water balance, which can be expressed using the following equations (Sudirman et al., 2021):

$$\mathbf{NFR_{paddy} = Etc + WLR + LP + Pe - Reff}$$

$$\mathbf{NFR_{secondary\ crops} = Etc - Reff}$$

Where NFR is the net field water requirement (mm/day), Etc is the crop evapotranspiration (mm/day), LP is land preparation (mm/day), WLR is water loss replacement (mm/day), Pe is percolation (mm/day), and Reff is effective rainfall (mm/day).

One of the most important factors in calculating irrigation water requirements is evapotranspiration, which represents the amount of water lost through evaporation from land surfaces and transpiration by plants. Evapotranspiration is equivalent to the consumptive water requirement, defined as the total evaporation from the land and the water needed by the plants. In this calculation, evaporation and transpiration are considered simultaneously (Triatmodjo, 2009). To determine the evapotranspiration value, the Penman method, modified by the FAO, is used. This method involves extensive use of climatological data, making the calculations more accurate and logical. The Penman equation (FAO modification) is expressed as follows (Strahler & Chow, 1964):

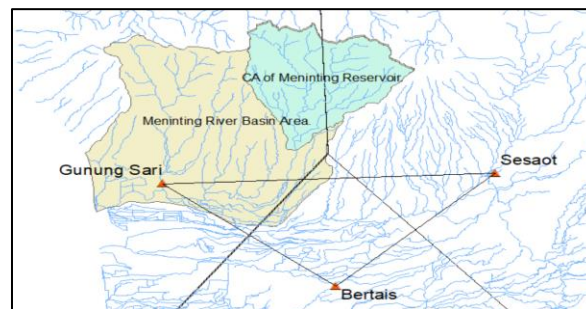
$$E_{To} = C_f (W \cdot R_n + (1-W) \cdot f(u) \cdot (e_a - e_d))$$

Where  $E_{To}$  is the reference crop evapotranspiration (mm/day),  $C_f$  is the wind speed and humidity correction factor,  $W$  is the temperature and altitude factor,  $R_n$  is net radiation (mm/day),  $f(u)$  is the wind speed function,  $e_a$  is saturated vapor pressure (mbar),  $e_d$  is actual vapor pressure (mbar).

To determine water demand at the intake, the net field requirement (NFR) is converted from mm/day to liters/second/hectare using a factor of 0.116 and divided by irrigation efficiency. Additionally, water loss due to evaporation is a significant factor in reservoir operations. Evaporation refers to the loss of water from the surface of the water body, land, or plant surfaces (interception). It is influenced by solar radiation, temperature, humidity, and wind speed. Various methods can be used to measure evaporation, including evaporation pans, water balance in the reservoir, mass transfer methods, and energy balance techniques (Triatmodjo, 2009).

## RESULT AND DISCUSSION

To determine the average rainfall over the area affecting the catchment of the Meninting Reservoir, the Thiessen Polygon method is employed, which requires a minimum of three Automatic Rainfall Recorder (ARR) stations to create the polygon. The rainfall stations impacting the catchment area of the Meninting Reservoir are the ARR Gunung Sari, with an influence area of 18.95 km<sup>2</sup>, and the ARR Sesaot, with a sequential influence area of 13.82 km<sup>2</sup>.



**Figure 3. Map of the catchment area, location of rainfall stations, and Thiessen polygon for the Meninting Reservoir**

Based on the Thiessen polygon above, the average rainfall in the catchment area of the Meninting Reservoir can be analyzed by multiplying the area of each influential rainfall station by the respective rainfall data from each Automatic Rainfall Recorder (ARR). The resulting average rainfall for the Meninting Reservoir is presented in the following table:

**Table 1. Half-Monthly Rainfall Data in the Catchment Area of Meninting Reservoir (mm)**

Year	Jul		Aug		Sep		Oct		Nov		Dec	
	I	II	I	II	I	II	I	II	I	II	I	II
2013	104.57	10.24	1.89	10.93	1.75	0.51	16.37	149.98	116.55	111.26	262.21	244.04
2014	29.80	14.88	7.23	1.14	1.01	0.42	5.69	12.55	183.26	76.75	111.51	223.48
2015	0.88	1.79	0.42	1.10	0.00	0.47	9.87	0.93	37.41	66.90	113.68	149.71

Year	Jul		Aug		Sep		Oct		Nov		Dec	
	I	II	I	II	I	II	I	II	I	II	I	II
2016	50.14	47.24	43.56	22.70	93.70	117.50	191.95	108.23	197.01	229.44	300.10	133.44
2017	25.71	15.76	6.89	1.99	1.43	34.33	260.00	93.10	167.92	156.95	50.36	177.01
2018	1.56	6.25	0.13	21.22	16.58	31.51	1.43	1.35	259.11	49.86	72.17	55.13
2019	2.60	0.00	0.00	2.08	0.00	0.29	0.00	0.00	33.53	170.08	176.28	149.94
2020	60.46	1.69	53.16	19.52	22.12	50.99	88.77	226.55	139.80	134.73	192.27	34.48
2021	23.83	0.00	123.10	86.60	74.18	54.48	122.51	165.18	316.20	148.46	295.59	130.67
2022	48.18	1.14	23.00	9.44	218.46	132.21	280.70	190.70	209.46	114.26	114.53	234.90

Subsequently, an analysis of effective rainfall was conducted. Effective rainfall refers to the portion of precipitation that falls in a specific area and is utilized by plants for their growth. The analysis of effective rainfall aims to determine the effective precipitation for rice and secondary crops. In this study, the calculation of dependable rainfall employs the basic month method, using data spanning a period of 10 years.

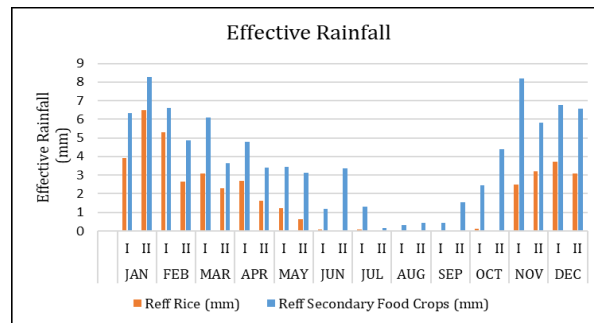


Figure 4. Curve of effective rainfall in Meninting catchment area

After analyzing effective rainfall, the next step is to analyze evapotranspiration using the Modified Penman method, employing average climatological data from 2013 to 2022 obtained from the West Nusa Tenggara Meteorology, Climatology, and Geophysics Agency (BMKG) station located in Kediri, West Lombok. This climatological data encompasses information on temperature, wind speed, humidity, and solar radiation. The recap of water requirements for evapotranspiration using the Modified Penman method for the Meninting Reservoir can be seen in the curve in Figure 5 below.

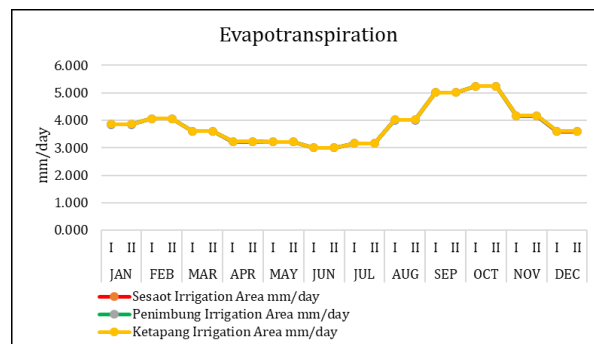
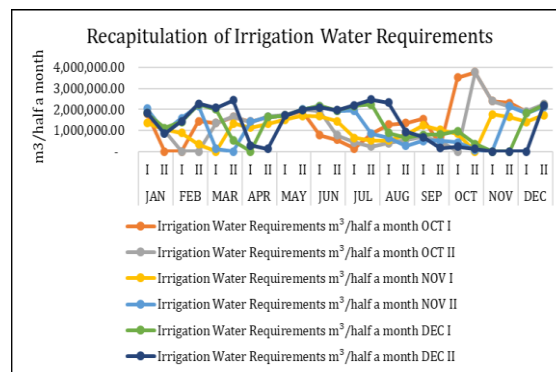


Figure 5. Evapotranspiration curve for the Meninting Reservoir

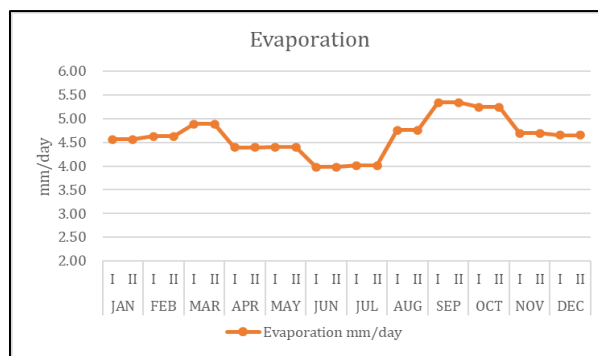
This information helps determine the irrigation water requirements in the irrigation areas of Meninting Reservoir, which include the Sesaot, Penimbung, and Ketapang irrigation regions. The cropping patterns used in this analysis are rice, rice-corn, and corn for the Sesaot irrigation area, and rice, rice, and rice-corn for the Penimbung and Ketapang areas, which reflect the existing cropping patterns. The planting intensity in the Meninting Reservoir irrigation area is set at 300%, with each planting schedule allocated equally at 100%. The beginning of the planting schedule is evaluated with several alternatives, specifically in the first and second weeks of October (Oct I and Oct II), the first and second weeks of November (Nov I and Nov II), and the first and second weeks of December (Dec I and Dec II). Based on the analysis results, the irrigation water requirements in Meninting Reservoir for different planting schedules can be seen in the curve in Figure 6 below.



**Figure 6. Curve of the total irrigation water requirements for Meninting Reservoir at the beginning of different planting schedules**

Meanwhile, the requirements for raw water and MHP generation from the Nusa Tenggara 1 River Basin Center are 150 liters per second for raw water and 2.175 cubic meters per second for the MHP, with a capacity of 2 x 0.4 MW.

In addition to the water requirements for the reservoir functions, evaporation data is also needed to determine water loss due to evaporation in the reservoir. For Meninting Reservoir, the evaporation value is based on the data recorded at the West Nusa Tenggara Meteorology, Climatology, and Geophysics Agency Station located in Kediri, West Lombok Regency.



**Figure 7. Evaporation value curve**

Another important factor for simulating reservoir rule curves is the analysis of water availability. In this study, the discharge data used is the semi-monthly discharge data from the Automatic Water Level Recorder station at Orong Atas from 2013 to 2022. To obtain the inflow for the catchment area of Meninting Reservoir, routing needs to be performed using the area ratio between the catchment area of the Automatic Water Level Recorder at Orong Atas and the catchment area of Meninting Reservoir. The inflow discharge data for Meninting Reservoir can be seen in Table 3 below.

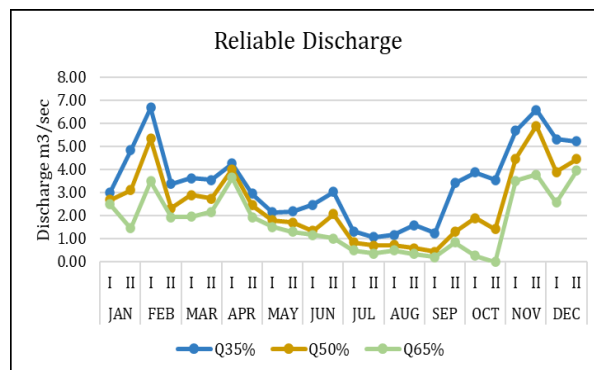
**Table 2. Inflow discharge of Meninting Reservoir (m<sup>3</sup>/s)**

YEAR	JAN		FEB		MAR		APR		MAY		JUN	
	I	II	I	II	I	II	I	II	I	II	I	II
2013	2.59	3.82	6.26	2.91	2.53	2.61	3.07	2.30	1.18	1.31	1.18	2.12
2014	6.87	4.82	4.92	1.10	0.56	1.41	0.97	1.92	1.41	0.87	0.43	0.25
2015	2.19	0.62	1.56	1.96	3.28	2.88	4.64	4.60	2.06	0.90	2.64	0.34
2016	2.04	2.38	5.77	2.13	2.03	2.17	4.20	1.40	1.37	1.82	1.03	2.01
2017	0.66	1.47	9.32	1.19	1.42	2.03	3.91	2.60	3.13	4.09	3.08	2.63
2018	3.12	17.45	2.09	2.50	1.54	2.09	3.03	2.88	1.52	2.03	0.17	1.05
2019	3.00	1.33	1.67	1.79	3.43	3.23	3.76	3.44	2.65	1.59	1.34	8.39
2020	2.80	1.26	3.74	6.01	4.78	5.95	6.75	1.88	2.03	3.06	2.44	0.76
2021	8.67	8.96	30.21	9.19	7.63	6.95	4.13	1.93	1.57	1.18	1.33	5.54
2022	2.54	4.97	9.14	9.35	6.33	5.31	6.38	9.50	3.31	3.62	4.05	5.29

YEAR	JUL		AUG		SEP		OCT		NOV		DEC	
	I	II	I	II	I	II	I	II	I	II	I	II
2013	0.69	0.47	4.47	3.94	3.42	3.25	0.00	0.00	5.42	5.69	11.38	11.30
2014	0.12	0.03	0.26	0.02	0.03	0.08	0.02	0.00	0.17	1.03	1.98	4.05
2015	0.15	0.02	0.02	0.02	0.02	0.00	0.00	0.00	1.38	3.79	6.86	5.38
2016	1.27	3.89	0.53	0.67	0.52	6.15	5.60	11.33	7.29	3.72	2.59	1.20
2017	1.61	0.93	0.65	0.53	0.25	0.89	3.60	2.63	4.18	6.57	1.47	5.19
2018	0.50	0.33	0.35	0.39	0.33	0.51	0.31	0.19	4.78	6.91	3.92	1.74
2019	0.49	0.37	0.81	0.00	0.00	1.66	2.45	0.00	0.50	2.12	2.55	4.54
2020	0.98	1.10	0.97	1.18	1.08	0.93	5.40	3.21	3.90	6.10	5.05	5.38
2021	4.86	1.06	2.33	4.82	2.21	4.92	1.34	5.54	16.70	6.76	7.59	4.39
2022	2.05	1.18	2.57	4.43	2.53	4.36	12.96	13.38	7.94	6.83	3.87	3.46

After obtaining the inflow discharge of the reservoir, the reliability discharge is then calculated using the basic month method. The reliability used in this study is 35% for wet years, 50% for normal years, and 65% for dry years. The selection of these reliability conditions is based on Module 8 of Reservoir Operations. The results of the reliability discharge calculation using the basic month method for Meninting Reservoir can also be seen in the curve in Figure 8 below.



**Figure 8. Curve of reliable discharge for Meninting Reservoir using the basic month method**

Simulation of reservoir operation is conducted to review the reliability levels or failures that occur in the operational behavior of the reservoir system in meeting its service needs. In this study, the rule curve simulation uses a 15-day period, experimenting with several alternatives based on different planting schedule starts, namely in October I, October II, November I, November II, December I, and December II. The simulations include a MHP in a single channel with an irrigation channel (simulation without a MHP) or a MHP in a different channel from the irrigation channel (simulation with a MHP).

Example of reservoir operation simulation calculation with planting patterns used for rice, rice-secondary crops, and secondary crops with a planting intensity of 300%, planting schedule in October, first week of January, 2013, with one channel between the mhp and the irrigation channel as follows:

1. Initial Reservoir Storage (Effective)  
= 8,190,000.00 m<sup>3</sup>
2. Inflow  
= 2.59 m<sup>3</sup>/second  
= 3,357,750.01 m<sup>3</sup>/half-month
3. Water Availability  
= Initial storage + inflow  
= 8,190,000 + 3,357,750.01  
= 11,547,750.01 m<sup>3</sup>/half-month
4. Irrigation Water Demand  
= 1,813,585.96 m<sup>3</sup>/half-month
5. Raw Water Demand  
= 0.15 m<sup>3</sup>/second  
= 194,400.00 m<sup>3</sup>/half-month
6. Total Water Demand  
= Irrigation demand + raw water demand  
= 1,813,585.96 + 194,400.00  
= 2,007,985.96 m<sup>3</sup>/half-month
7. Evaporation  
= 4.56 mm/day  
= 36,662.40 m<sup>3</sup>/half-month
8. Total Outflow  
= Total water demand + evaporation  
= 2,007,985.96 + 36,662.40  
= 2,044,648.36 m<sup>3</sup>/half-month
9. Final Reservoir Storage (Effective)  
= Water availability – total outflow

$$= 11,547,750.01 - 2,044,648.36$$

$$= 9,503,101.65 \text{ m}^3$$

10. Since the final reservoir storage exceeds the reservoir's capacity, spillover occurs from the spillway, commonly referred to as spillout. As a result, the final reservoir storage equals the maximum reservoir capacity, which is 8,190,000.00 m<sup>3</sup>.

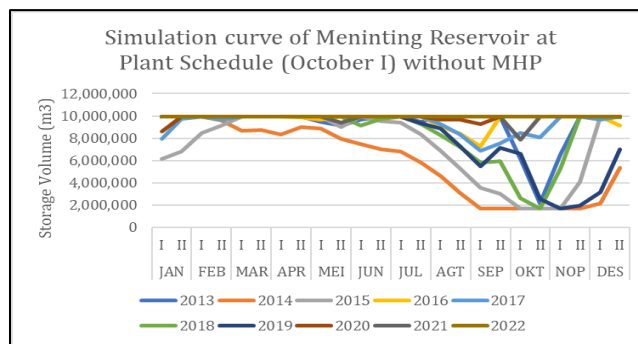
11. Spillover  
 = 9,503,101.65 - 8,190,000.00  
 = 1,313,101.65 m<sup>3</sup>

12. Remarks  
 = Successful

The results of the reservoir storage simulation analysis for the year 2013, at the beginning of the planting schedule in October I, without the need for the MHP, are presented in Table 3 and figure 9-10 below.

**Table 3. Reservoir Simulation of Meninting in 2013 at plant schedule October I without MHP (m<sup>3</sup>)**

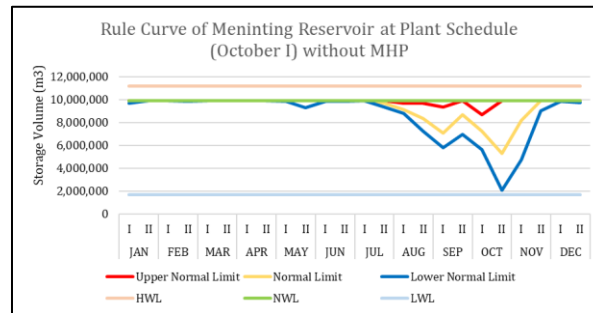
No.	Month		Initial Reservoir Storage		Inflow		Water Availability	Irrigation Water Demand	Raw Water Demand		Total Water Demand
			Total (m3)	Effective (m3)	m3/sec	m3/half a month	m3/half a month	m3/half a month	m3/sec	m3/half a month	m3/half a month
1	JAN	I	9,910,000.00	8,190,000.00	2.59	3,357,750.01	11,547,750.01	1,813,585.96	0.150	194,400.00	2,007,985.96
		II	9,910,000.00	8,190,000.00	3.82	5,285,201.38	13,475,201.38	-	0.150	207,360.00	207,360.00
2	FEB	I	9,910,000.00	8,190,000.00	6.26	7,569,793.98	15,759,793.98	-	0.150	181,440.00	181,440.00
		II	9,910,000.00	8,190,000.00	2.91	3,776,594.55	11,966,594.55	1,448,029.37	0.150	194,400.00	1,642,429.37
3	MAR	I	9,910,000.00	8,190,000.00	2.53	3,276,090.24	11,466,090.24	1,364,577.62	0.150	194,400.00	1,558,977.62
		II	9,910,000.00	8,190,000.00	2.61	3,611,710.35	11,801,710.35	1,653,286.59	0.150	207,360.00	1,860,646.59
4	APR	I	9,910,000.00	8,190,000.00	3.07	3,976,962.45	12,166,962.45	1,419,955.78	0.150	194,400.00	1,614,355.78
		II	9,910,000.00	8,190,000.00	2.30	2,987,206.46	11,177,206.46	1,642,664.96	0.150	194,400.00	1,837,064.96
5	MAY	I	9,910,000.00	8,190,000.00	1.18	1,526,682.46	9,716,682.46	1,710,668.13	0.150	194,400.00	1,905,068.13
		II	9,501,148.74	7,781,148.74	1.31	1,812,934.78	9,594,083.51	1,931,886.13	0.150	207,360.00	2,139,246.13
6	JUN	I	9,143,247.10	7,423,247.10	1.18	1,530,903.82	8,954,150.93	771,166.74	0.150	194,400.00	965,566.74
		II	9,682,468.09	7,962,468.09	2.12	2,744,810.40	10,707,278.49	570,272.40	0.150	194,400.00	764,672.40
7	JUL	I	9,910,000.00	8,190,000.00	0.69	890,199.20	9,080,199.20	147,577.22	0.150	194,400.00	341,977.22
		II	9,910,000.00	8,190,000.00	0.47	646,218.68	8,836,218.68	836,228.66	0.150	207,360.00	1,043,588.66
8	AUG	I	9,483,013.76	7,763,013.76	4.47	5,789,815.63	13,552,829.39	1,277,312.46	0.150	194,400.00	1,471,712.46
		II	9,910,000.00	8,190,000.00	3.94	5,440,678.12	13,630,678.12	1,363,762.48	0.150	207,360.00	1,571,122.48
9	SEP	I	9,910,000.00	8,190,000.00	3.42	4,432,586.67	12,622,586.67	1,555,208.25	0.150	194,400.00	1,749,608.25
		II	9,910,000.00	8,190,000.00	3.25	4,213,504.55	12,403,504.55	292,544.94	0.150	194,400.00	486,944.94
10	OCT	I	9,910,000.00	8,190,000.00	0.00	0.00	8,190,000.00	3,517,249.74	0.150	194,400.00	3,711,649.74
		II	6,162,068.50	4,442,068.50	0.00	0.00	4,442,068.50	3,774,640.95	0.150	207,360.00	3,982,000.95
11	NOV	I	2,151,766.69	431,766.69	5.42	7,018,436.93	7,450,203.61	2,410,263.64	0.150	194,400.00	2,604,663.64
		II	6,551,641.01	4,831,641.01	5.69	7,372,202.06	12,203,843.06	2,309,687.85	0.150	194,400.00	2,504,087.85
12	DEC	I	9,910,000.00	8,190,000.00	11.38	14,753,015.41	22,943,015.41	1,883,727.63	0.150	194,400.00	2,078,127.63
		II	9,910,000.00	8,190,000.00	11.30	15,626,564.42	23,816,564.42	2,219,667.44	0.150	207,360.00	2,427,027.44



**Figure 9. Simulation curve of Meninting Reservoir at plant schedule October I without MHP**

## Rule Curve of Meninting Reservoir in West Lombok Regency, West Nusa Tenggara

To calculate the conditions for wet, normal, and dry years, reliability levels of 35% for wet years, 50% for normal years, and 65% for dry years were used. These reliability conditions were chosen based on Module 8 of Reservoir Operation (14).



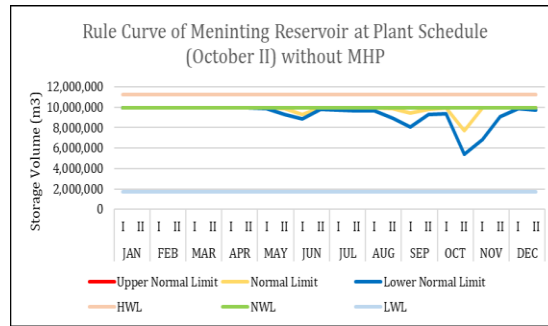
**Figure 10. Rule curve of Meninting Reservoir at planting schedule on October I without MHP**

The same process was also carried out for the planting schedules of October II, November I, November II, December I, and December II, resulting in the following rule curve:

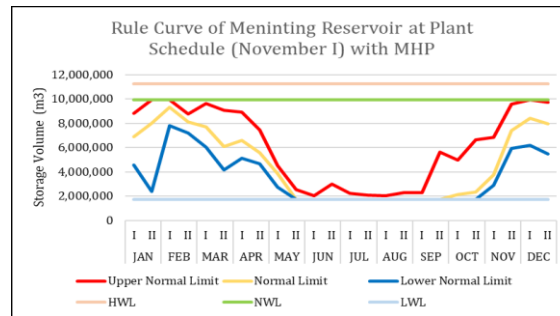
**Table 4. Recapitulation rule curve of Meninting Reservoir**

Alternatives and Conditions			Start of Planting Season											
			Oct I		Oct II		Nov I		Nov II		Dec I		Dec II	
			Failure	Reliability	Failure	Reliability	Failure	Reliability	Failure	Reliability	Failure	Reliability	Failure	Reliability
Without Hydropower Plant (PLTMH)	Wet Year (35% Reliability)	PS I	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		PS II	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		PS III	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		Raw Water	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
	Normal Year (50% Reliability)	PS I	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		PS II	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		PS III	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		Raw Water	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
	Dry Year (65% Reliability)	PS I	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		PS II	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		PS III	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		Raw Water	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
With Hydropower Plant (PLTMH)	Wet Year (35% Reliability)	PS I	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%
		PS II	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	4.2%	95.8%	8.3%	91.7%	8.3%	91.7%
		PS III	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	4.2%	95.8%	0.0%	100.0%
		Raw Water	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	4.2%	95.8%	12.5%	87.5%	8.3%	91.7%
		Hydropower Plant	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	4.2%	95.8%	12.5%	87.5%	8.3%	91.7%
	Normal Year (50% Reliability)	PS I	8.3%	91.7%	4.2%	95.8%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	4.2%	95.8%
		PS II	8.3%	91.7%	8.3%	91.7%	12.5%	87.5%	16.7%	83.3%	20.8%	79.2%	25.0%	75.0%
		PS III	33.3%	66.7%	29.2%	70.8%	25.0%	75.0%	20.8%	79.2%	16.7%	83.3%	12.5%	87.5%
		Raw Water	50.0%	50.0%	41.7%	58.3%	37.5%	62.5%	37.5%	62.5%	37.5%	62.5%	41.7%	58.3%
	Dry Year (65% Reliability)	PS I	16.7%	83.3%	8.3%	91.7%	0.0%	100.0%	0.0%	100.0%	4.2%	95.8%	8.3%	91.7%
		PS II	8.3%	91.7%	12.5%	87.5%	12.5%	87.5%	20.8%	79.2%	20.8%	79.2%	29.2%	70.8%
		PS III	33.3%	66.7%	29.2%	70.8%	33.3%	66.7%	29.2%	70.8%	25.0%	75.0%	20.8%	79.2%
Raw Water		58.3%	41.7%	50.0%	50.0%	45.8%	54.2%	50.0%	50.0%	50.0%	50.0%	58.3%	41.7%	
		Hydropower Plant	58.3%	41.7%	50.0%	50.0%	45.8%	54.2%	50.0%	50.0%	50.0%	58.3%	41.7%	

The simulation results show that the optimal rule curve occurs at the planting schedule of October II without MHP and November I with the MHP.



**Figure 12. Rule curve of Meninting Reservoir at planting schedule on October II without MHP**



**Figure 13. Rule curve of Meninting Reservoir at planting schedule on November I with MHP**

The results of this study show that the optimal rule curve at Meninting Reservoir is achieved with the October II planting schedule without MHP, with reservoir reliability reaching 100%. In contrast, in the presence of MHP, the best planting schedule was November I, although the reliability decreased to 54.2% with a 45.8% risk of failure in a dry year. These results are in line with previous research showing that planting schedules and reservoir operation patterns play an important role in maintaining the balance of water availability and demand (Sari et al., 2012). In addition, research by (Sutrisno & Hamdani, 2019) confirms that optimizing reservoir operation patterns can increase the efficiency of irrigation water distribution and reduce the risk of water deficits in the dry season. Thus, the management strategy of Meninting Reservoir must consider the interaction between irrigation needs, raw water, and micro-hydro power generation to achieve sustainable utilization of water resources.

## CONCLUSION

The conclusion of this study based on the results of the analysis, the water demand for irrigation, raw water, and Micro Hydro Power Plant (MHP) varies depending on the planting schedule and annual conditions. The highest irrigation discharge is 1,496,415.21 m<sup>3</sup> and the lowest is 1,082,648.92 m<sup>3</sup> per half month, while the raw water discharge is 197,100 m<sup>3</sup> and the MHP discharge is 2,857,950 m<sup>3</sup> during rainy, normal, and dry years. Reservoir operation simulations show that the optimal rule curve occurs in the October II planting schedule without MHP, with reservoir reliability reaching 100%. In contrast, the best rule curve with MHP occurs in the November I planting schedule, with reservoir reliability decreasing to 54.2% and failure increasing to 45.8% during dry years.

Future research should explore more advanced reservoir optimization models incorporating climate change scenarios to improve water resource management strategies. In addition, integrating real-time hydrological data and machine learning approaches can improve forecast accuracy and operational efficiency. Further studies could also consider the socio-economic impacts of different water allocation strategies, to ensure sustainable water distribution for agriculture, households and energy needs. Investigating alternative water storage and conservation methods, such as groundwater recharge or inter-watershed water transfers, could provide additional resilience to fluctuating hydrological conditions.

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