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Analysis of Clean Water Demand and Availability in Prambon Village using F.J Mock Method and Direct Testing in Tugu District, Trenggalek Regency

Wieke Pramesthy Artha Amalia[1], **Vita Ayu Kusuma Dewi**[2]✉

[1, 2] Department of Civil Engineering and Planning, Faculty of Engineering, Universitas Negeri Malang, Indonesia

✉ **Corresponding Author :** Vita Ayu Kusuma Dewi (e-mail: vita.ayu.kusuma.ft@um.ac.id)

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ABSTRACT

Drought frequently occurs in Trengalek Regency, with Prambon Village being one of the affected areas. The prolonged droughts in Prambon Village cause the water sources to dry up. As the population increases, so does the water demand. This study used arithmetic methods to project the population size until 2032. To assess the availability of water, the study used the F.J. Mock method and direct testing. According to the F.J. Mock method, the water balance indicated a surplus, projecting that the available water supply would meet the villagers' needs through 2032. However, the water balance based on data from the PKPLH Department and direct testing shows a deficit, insufficient to meet the population's needs until 2032. To address this issue, the conservation of water resources is necessary, involving the construction of spring protections, tree planting, and rainwater harvesting to ensure that the water needs of Prambon Village residents are met. This research serves as a reference for clean water utilization in Trenggalek Regency.

INTRODUCTION

The issue of water availability in a region has become a primary focus today as water is a crucial component for human survival (Riani et al., 2020). An abundance of water sources can facilitate meeting human needs. However, regions with plentiful water can face limitations due to natural disasters such as drought seasons (Sudarti & Puspitasari, 2021). One of the villages affected is Prambon Village. Prambon Village is located in the Tugu District of Trenggalek Regency, East Java Province. The village covers an area of 16.28 km² and primarily thrives on agriculture. Prambon experiences a lack of access to clean water during the dry season (Utama & Nurjani, 2021). The drought leads to the drying up of existing water sources, consequently making it difficult for villagers to access clean water. Assistance from the BPBD of Trengalek Regency proves insufficient to meet the water needs of all residents of Prambon Village. As the population continues to grow, the water demand also increases significantly (Sophocleous, 2024).

Minimal rainfall prevents water from being absorbed into the ground or flowing on the surface. This naturally affects the availability of water at the sources, making them unable to serve the needs of the villagers (Mishra, 2023). Consequently, Prambon Village is facing a clean water crisis due to the lack of supply to meet daily demands.

In the existing conditions, the villagers utilize springs and wells as their water sources. Therefore, the onset of the dry season directly impacts the availability of water the villagers use. The water source utilized by the villagers is named Sumber Lebak, located at Mount Lebak. Both spring and well water are used by the villagers to meet their daily needs, such as bathing, drinking, cooking, washing, and other requirements.

The previous study on water demand and availability in Prambon Village using the F.J. Mock method only focused on theoretical calculations and did not incorporate direct field testing to validate the actual water quality, leaving a gap in the understanding of the water's potability. This study aims to determine the demand and availability of clean water in Prambon Village for the next ten years. It is hoped that this research will provide alternatives or solutions to address the issue of insufficient clean water supply in the area.

RESEARCH METHODS

Research Design

This study on the analysis of clean water demand and availability in Prambon Village used a descriptive research methodology with a quantitative approach involving the collection of both primary and secondary data. Descriptive research is a method that describes or depicts a phenomenon occurring, specifically the shortage of clean water in Prambon Village, based on the collected data. Quantitative research is a method where the primary data to be analyzed are numerical. The stages in conducting this research were carried out systematically with the following steps:

- Conducting field observations and requesting data needed for the research
- Calculating the population projection of Prambon Village for the next 10 years
- Calculating the water requirements of Prambon Village residents for the next 10 years
- Calculating Potential Evapotranspiration (ET0) using the Blaney Criddle Method
- Calculating the reliable flow rate using the F.J. Mock Method
- Evaluating the results of the flow rate calculations and the water needs of the residents
- Recommendations for solving the problem of clean water limitations
- Results and discussion

Research Location

The research was conducted in Prambon Village, Tugu District, Trenggalek Regency, which is geographically located at 111.6685°E longitude and 8.0225°S latitude, with a mountainous topography. A map of the research area can be seen in the following figure:

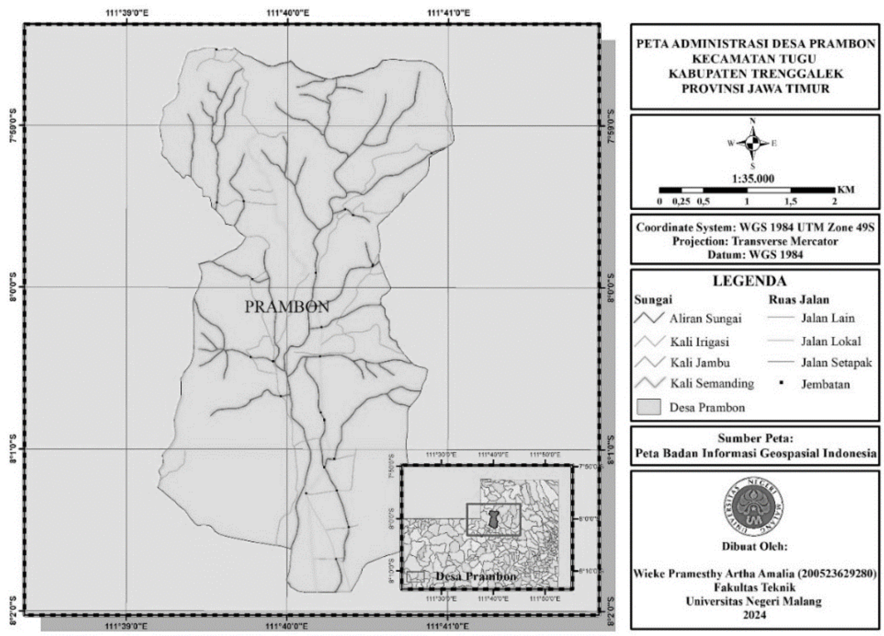

Figure 1. Research area of Prambon Village

Data Collection Techniques

Data collection techniques are essential steps in research to obtain the necessary data throughout the study. The types of data used in this study are primary and secondary data. Primary data is data obtained directly from its source and can also be referred to as new and original data. In this study, primary data collection was conducted through observations at water sources in Prambon Village and interviews with local residents knowledgeable about the field conditions.

Observations were conducted to understand the actual field conditions and to analyze issues in the research area. Observations took place at the spring water sources in Prambon Village, used to meet the residents' needs. The observations revealed that the water source in Prambon Village originates from a mountain spring located at Mount Lebak, hence locally named Sumber Lebak. Sumber Lebak is situated in the middle of a forest densely populated with bamboo trees. The Lebak water source is equipped with a Spring Box to protect the spring underneath from contamination and environmental damage.

Interviews were conducted with local residents who were familiar with the actual conditions of the water sources in Prambon Village. The interviews involved asking several questions necessary for the research needs of the local population. The interviews indicated that residents struggle to obtain clean water for daily needs during the dry season. The residents have to wait for water flow from the source or wells for 1-2 days before they can access clean water.

Secondary data is data obtained from other parties or sources related to the research. The secondary data collected in this study includes population data from 2018 to 2022, available on the website of the Central Statistics Agency of Trenggalek Regency, and daily standard water needs for rural areas obtained based on the Indonesian National Standard (SNI) 67281 of 2015 concerning Water Resources. Additionally, secondary data required includes rainfall and temperature data for analysis using the F.J. Mock method.

Data Analysis

Data analysis involves selecting, processing, and organizing data to make it easily interpretable. The collected data was analyzed as follows:

Population Projection Calculation. To calculate the future clean water needs, it is crucial to consider the current population growth rate. The analyses that can be performed include calculating the average population growth in Prambon Village up to a planned 10 years in the future, based on population data from previous years. Predicting the population of Prambon Village up to 10 years in the future using the following calculation method, they are a arithmetic method, geometric method, and least Square Method. Then, calculating the standard deviation for each method used. The method with the smallest standard deviation among the three is considered the most accurate.

Water Demand Calculation. To determine the clean water needs in Prambon Village, an estimation close to the actual daily water requirement is necessary. The estimation of daily water needs is based on the current population conditions. In the analysis, clean water needs are calculated according to the Public Works' Directorate General of Human Settlements Planning Criteria for each category (Angga et al., 2022).

Water Availability Calculation. The calculation of clean water availability is conducted using the F.J. Mock Method. The F.J. Mock calculation involves determining the Potential Evapotranspiration (ET0) using the Blaney Criddle Method, followed by the calculation of actual evapotranspiration, and the subsequent step is the water balance calculation.

RESULTS AND DISCUSSION

Population Projection Analysis

The data required for this analysis included secondary data in the form of population data from 2018 – 2022, which was obtained from the Central Statistics Agency of Trenggalek Regency, as shown in Table 1. Based on this data, the population for the next 10 years, up to the year 2032, was projected. The results of the population projection calculations are presented in the following table 1.

Tabel 1. Population data in Prambon Village and parameters Ka, r, a, b

Population Data (people)		Population Growth	
		Ka	**r**
2018	7873	-	-
2019	7860	-13	-0,17
2020	7851	-9	-0,11
2021	8296	445	5,36
2022	8316	20	0,24
Total		443	5,32
Average		111	1,33
a		8039	
b		132	

The standard deviations of these three methods were then calculated, and the method with the smallest standard deviation was chosen.

Tabel 2. Standard Deviation Results of Arithmetic, Geometric and Least Square Methods

Year	Arithmetic	Geometric	*Least Square*
2032	9424	9492	9626
Standard Deviations	**166,1**	525,9	438,4

The arithmetic method had the smallest standard deviation at 166.1. Therefore, the population in 2032 is determined to be 9424 people.

Water Demand Analysis

Following the population projections up to the year 2032, the calculation of clean water demand based on regulations was conducted. The results of the clean water demand calculations for the population in 2032 are shown in the following Table 3. From the analysis, the total water demand for Prambon Village in 2032 is projected to be 7329 l/s, with a maximum demand of 9675 l/s.

Tabel 3. Water demand in 2032

Data	Rumus	Result (l/s)
Domestic demand	$q_D = (JP \times (pl\%) \times S)/86400$	6108
Non domestic demand	$q_{nD} = q_D \times (nD\%)$	1222
Total water demand	$q_T = q_D + q_{nD}$	7329
Water loss	$q_{HL} = q_T \times (K_t\%)$	1466
Average water demand	$q_{RH} = q_T + q_{HL}$	8795

Data	Rumus	Result (l/s)
Maximum water demand	$q_m = C1 \times q_{RH}$	9675
Peak hour water demand	$q_{jp} = C2 \times q_m$	14512

Water Availability Analysis

Water availability assessment was conducted by obtaining data from the Trenggalek Regency Environmental Services and Public Hygiene Department (Dinas PKPLH), performing direct surveys at the source, and using calculations with the F.J. Mock Method. The amount of water available in Prambon Village was calculated using a rainfall-runoff model approach, requiring climatological data, potential evapotranspiration, and rainfall data.

Potential Evapotranspiration Calculation

The potential evapotranspiration was calculated using the Blaney-Criddle method, and tje results are listed in Table 4 as follows:

Tabel 4. Potential evapotranspiration (ET_0)

Month	ET_0 (mm/month)
January	167,1
February	147,2
March	164,1
April	153,7
May	152,9
June	146,9
July	151,8
August	156,7
September	151,4
October	165,4
November	159,2
December	168,7

Flow Rate Based on the F.J. Mock Method

The calculation of water availability in Prambon Village was performed using the F.J. Mock Method. The data required for the calculation included rainfall data from 2013 to 2022 and climatological data. The results of the monthly flow rate calculations from 2013 – 2022 using the F.J. Mock method are presented in Table 5 below:

Tabel 5. Monthly Discharge using F.J. Mock method 2013 – 2022

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Okt	Nov	Des
2013	1105,5	1495,3	1224,7	863,6	201,9	127,4	79,5	11,9	0,0	0,0	219,7	400,5
2014	845,4	622,7	300,7	388,1	194,9	0,0	0,0	0,0	0,0	0,0	0,0	497,8
2015	233,0	219,4	796,1	1604,6	745,4	0,0	0,0	0,0	0,0	0,0	0,0	132,7
2016	219,3	1284,3	1387,8	589,2	35,4	310,3	217,9	245,0	786,6	791,8	1481,6	854,3
2017	978,9	1201,5	850,5	1041,2	849,4	0,0	0,0	0,0	0,0	0,0	628,6	974,4
2018	821,3	1044,9	364,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	686,5	697,1

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Okt	Nov	Des
2019	750,9	457,9	1171,9	1308,0	285,7	0,0	0,0	0,0	0,0	0,0	0,0	454,1
2020	608,2	1249,6	1284,7	530,1	50,6	54,8	0,0	0,0	0,0	42,9	341,8	340,5
2021	579,5	701,9	426,8	148,2	50,7	216,4	219,7	0,0	0,0	0,0	876,8	1030,6
2022	976,6	742,8	451,2	128,5	41,2	344,6	304,5	0,0	0,0	1175,0	2370,3	1579,3

Flow Rate Based on Data from PKPLH Trenggalek and Direct Calculation

The flow rate data for the spring was obtained from PKPLH Trenggalek. They measured the spring's flow rate in 2018, a year marked by an extended drought period over the last few years according to (Soimah et al., 2024). The flow rate of the spring according to PKPLH Trenggalek is 0,15 l/s.

The testing of the spring water flow rate yielded the following result:

$$Q = V/t$$
$$= 0.0015/14.72$$
$$= 0.000102 \text{ m3/s}$$
$$= 0.102 \text{ l/s}$$

Thus, the calculated flow rate from the Lebak spring in Prambon Village is 0.102 l/s.

Water Balance Results

The results of the water balance from the F.J. Mock method, data from PKPLH, and direct testing can be viewed in Table 6 below:

Tabel 6. Water Balance using F.J. Mock method

F.J. Mock (Surplus)		PKPLH Data (Defisit)		Direct Calculation (Defisit)	
Month	Water Balance (l/s)	Year	Water Balance (l/s)	Year	Water Balance (l/s)
January	781,3	2023	-8,501	2023	-8,550
February	992,6	2024	-8,615	2024	-8,663
March	908	2025	-8,729	2025	-8,777
April	723,8	2026	-8,843	2026	-8,891
May	263,1	2027	-8,956	2027	-9,004
June	107,4	2028	-9,070	2028	-9,118
July	81,6	2029	-9,184	2029	-9,232
August	18,9	2030	-9,297	2030	-9,345
September	77,7	2031	-9,411	2031	-9,459
October	213,6	2032	-9,525	2032	-9,573
November	724,3	-9,013		-9,061	
December	763,8				
471,3					

Clean Water Needs in Prambon Village

Clean water is crucial for human life. As the population increases, so does the water demand (Jaya et al., 2022). The future water demand must take into account the population size (Mutiara et al., 2023). The population for the next 10 years can be projected using previous years' population data. The method used to project the population is the arithmetic method. The calculations indicate that the population of Prambon Village in 2032 will be 9,424 people, with an average growth rate of 1.33% per year. The calculated average water demand for Prambon Village in 2032 is approximately 8,795 l/s, with a maximum water demand of 9,675 l/s and a peak hour demand of 14,512 l/s.

Clean Water Availability in Prambon Village

This study used the F.J. Mock Method to assess the availability of clean water in Prambon Village. The F.J. Mock Method is applied when river flow data are not available. Flow data information relies on rainfall data based on approximation calculations (Tunas, 2007). The flow calculation involves computing potential evapotranspiration using the Blaney-Criddle Method. The data required to calculate potential evapotranspiration with the Blaney-Criddle Method includes average monthly temperatures (Samsuar, Mubarak & Lestari, 2022).

The results revealed that the highest evapotranspiration occurred in December at 168.7 mm/month, and the lowest in June at 151.8 mm/month. The F.J. Mock Method calculations continued to determine the reliable flow rate. These calculations were based on rainfall data in Prambon Village from 2013 to 2022. The flow rate calculations using the F.J. Mock Method provided the average reliable monthly flow rate. The analysis found that the flow rates from June to September tend to be lower due to the dry season occurring in these months. Conversely, from October to April, the flow rates tend to be higher due to the rainy season.

In addition to the F.J. Mock Method, flow rate data was also obtained from PKPLH Trenggalek, which surveyed the spring source in 2018. To determine the existing condition flow rate, direct flow testing was conducted at the water source in Prambon Village. Using the F.J. Mock Method, the water balance in Prambon Village shows a surplus, indicating that the existing water supply can meet the needs of the population until 2032. However, according to data from PKPLH and direct testing, the water balance experiences a deficit because the flow rate data measured during the dry season when rainfall in Prambon Village is low.

The differences in calculations between the F.J. Mock Method and direct testing can be attributed to various factors. The F.J. Mock calculations are based on a series of relationships between rainfall, evaporation, and surface runoff that may not always align with actual field conditions (Mayavani et al. 2024). The F.J. Mock Method heavily relies on historical data, including rainfall, temperature, evapotranspiration, etc., to estimate water components such as runoff and infiltration for indirect flow calculation. Therefore, inaccuracies in the input data can create discrepancies between the F.J. Mock results and direct testing. Moreover, the analysis within the F.J. Mock Method is used over long time scales (annually), does not fully consider changes in the environment or new land use, and may not always reflect the worst-case scenarios present in the field. The F.J. Mock Method is typically used for larger areas with limited access to direct measurements. The variability in climate and broad soil conditions cannot capture the complexities of local hydrology in detail. On the other hand, direct testing involves measuring the actual flow rate in the field, which reflects the current or actual condition of the water source, not based on historical data, and uses a short time scale (daily). This reflects the actual water flow conditions at the time of measurement. Direct testing relies on results from actual observations, making it more representative of the field conditions at the time. Additionally, environmental changes significantly influence the results of direct testing, such as soil type, vegetation cover, and the topography of the area (Anggraini, 2024).

Solutions to Existing Water Scarcity Issues in Prambon Village

One of the measures to address the scarcity of clean water is through the conservation of water resources. Water resource conservation involves efforts to maintain the existence, sustainability, condition, properties, and functions of water resources to ensure their availability and adequacy to meet the needs of the population both now and in the future (Fakhrudin et al., 2023). As time progresses and the water demand continually increases, it becomes crucial to engage in water resource conservation efforts to ensure water availability. To address the scarcity of clean water, the Prambon Village government has constructed two bore wells, one in each of the hamlets Pakel and Krajan, to meet the clean water needs of its residents. For homes utilizing wells, whether boreholes or dug wells, increasing the well depth can enable access to deeper groundwater layers, ensuring the wells function effectively.

Additionally, the development of a sustainable PAMSIMAS system (Community-Based Drinking Water and Sanitation Service) allows for active community involvement in its implementation. Maximizing the use of PAMSIMAS facilities and bore wells provided by the village government ensures that the water needs of the population are met. Improvements to the piping infrastructure are also critical to making water distribution more efficient.

Recommendations for Addressing Clean Water Issues

According to (Palguna et al., 2023), water resource conservation can be achieved by constructing Spring Water Catchments (SWC) at various points with potential water sources. SWCs function to capture water flow directly from the source, preventing it from spreading and being wasted. They are made from concrete, which is durable against climate change, and the interior is lined with waterproof material to prevent water from seeping out through the concrete. Fakhrudin et al. (2023) suggest that water conservation can also be implemented through tree-planting activities. This initiative can involve the participation of the local community. Planting trees helps rainwater to be absorbed by the soil and minimizes erosion. Additionally, planting trees around water sources can help prevent contamination at these points. Regular implementation of tree planting activities can aid areas frequently experiencing droughts by improving water availability, soil quality, and ecosystem stability. However, these activities will not succeed without the awareness and participation of the community, highlighting the need for education to maximize the impact of tree-planting efforts. Utomo et al. (2023) discuss rainwater harvesting as a simple water resource conservation technique that involves collecting and storing rainwater for reuse. This technology operates by capturing rainwater, which is then channeled through pipes and gutters to storage systems. Before entering storage, the water passes through filters to remove leaves, dirt, and other large particles. Rainwater harvesting is defined as the process of collecting rain flow for domestic needs and environmental management (Ramadhayanti & Helda, 2021). These recommendations for addressing water scarcity are based on various aspects including the availability of water resources, distribution infrastructure, supportive policies, and, most importantly, the participation of the village community in implementation. With these recommendations, it is hoped that the issue of limited access to clean water in Prambon Village can be resolved. High participation from both the village government and the community is crucial for overcoming this issue. Therefore, education on water resource conservation must be communicated to the residents of Prambon Village to ensure the smooth execution of conservation activities.

CONCLUSION

The population of Prambon Village in 2032 will be 9,424 people, with an average water requirement of 8,795 l/s, a maximum water need of 9,675 l/s, and a peak hour demand of 14,512 l/s. Water availability according to the F.J. Mock Method shows a surplus which will meet the water needs of Prambon Village's population until 2032. Conversely, water availability according to the flow rate data from PKPLH Trenggalek and direct testing indicates a deficit which will not meet the population's needs by 2032.

Recommendations for resolving the water availability issue in Prambon Village include water resource conservation through the construction of spring catchment structures, engaging in tree planting activities, and implementing rainwater harvesting technology.

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