Analysis Of Clean Water Distribution Pipe Network PDAM Way Rilau Using Epanet 2.2 Software (Case Study: District Meter Area G26)

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Abstract

As the population continues to grow, the demand for clean water has risen significantly, requiring Regional Drinking Water Companies (PDAMs) to ensure optimal service by maintaining quality, quantity, and continuity. This study focuses on projecting the clean water demand for PDAM Way Rilau in the DMA G26 service area of Kelurahan Sukabumi over the next 20 years, based on current customer data, while also evaluating the adequacy of its production capacity through 2044. Additionally, the research includes a simulation and assessment of the existing water distribution network in 2024 using Epanet version 2.2. The methodology involves projecting customer growth using arithmetic, geometric, and exponential models, followed by calculations of future water demand and analysis of the pipeline system. Results indicate that the projected maximum daily water demand in 2044 will reach 603,245 liters per day (6.982 L/s), while the current production capacity of 1,143,936 liters per day (13.24 L/s) is adequate for long-term needs. However, Epanet simulations identified several technical issues, such as low pressure at nodes J372 and J370, high headloss in pipe Pi356, and below-standard flow velocity in 13 pipes. These issues were addressed by adjusting pipe diameters and increasing reservoir head, resulting in improved network performance under both normal and peak conditions.

Keywords: *Epanet 2.2, Water Demand, Distribution Network, Piping, PDAM.*

I. INTRODUCTION

As the population increases, the demand for clean water also increases, but its availability is often insufficient due to weak management and lack of water resources infrastructure [1]. This challenge is exacerbated by rapid development and land use change without regard to environmental sustainability, which ultimately disrupts the balance of ecosystems and worsens water supply conditions in various regions [2].

Bandar Lampung City, the capital city of Lampung Province with an area of 183.77 km², consists of 20 sub-districts and 126 villages, and plays a strategic role as a National Activity Center (PKN) in the fields of government, trade, logistics, tourism, and higher education. With a population of 1,100,109 people in 2023 and an average growth of 0.655% per year (2021-2024), the city faces a high demand for clean water to support household activities, industry and public services [3].

The fulfillment of clean water needs is a basic development priority in Bandar Lampung City. The local government actively strives for equitable, affordable and stable access to clean water through the development of the Drinking Water Supply System (SPAM). SPAM management is carried out by PDAM Way Rilau which is tasked with providing clean water services in a fair and sustainable manner. Currently, the system covers eight sub-districts, including Sukabumi Sub-district, with the focus of the study on Sukabumi Village within the G26 DMA service area. This area receives water supply from the main distribution reservoir located in Rajabasa.

One of the main challenges in PDAM Way Rilau's water distribution system is the fluctuation of water pressure and the high level of non-revenue water (NRW), which results in financial losses as lost water cannot be collected even after it has been produced. This problem is prevalent throughout the service area, including in DMA G26 of Sukabumi Village, Sukabumi Sub-district, the gravity distribution area with the largest number of customers. With a population of 2,792 in 10 sub-areas, a technical evaluation of the condition of the pipeline network was required, whether it was still viable, needed repair, or replacement. For this analysis, Epanet 2.2 software was used, which supports hydraulic simulation of water distribution systems in an effective and easy-to-use manner.

The increase in population and the expansion of the water distribution network have a direct impact on storage capacity in meeting clean water needs, especially in the DMA G26 area of Sukabumi Village, Sukabumi Subdistrict. To ensure that the distribution system remains optimal until 2044, a comprehensive evaluation of water demand projections is needed. This study is entitled "Analysis of PDAM Way Rilau's Clean Water Distribution Pipe Network Using Epanet 2.2 Software" to formulate effective solutions in planning and managing sustainable clean water distribution in the area.

Based on the background and problem identification, this study formulates four main questions: (1) what is the projected total water demand of PDAM Way Rilau's customers in the DMA G26 area from 2024 to 2044; (2) how does the demand match with PDAM Way Rilau's water supply capacity over the same period; (3) what is the condition of the pipeline distribution network in the area based on simulations using Epanet 2.2 for the year 2024; and (4) what are the results of the technical performance evaluation of the distribution network for the same year.

This study aims to estimate the water demand of PDAM Way Rilau customers in the DMA G26 area of Sukabumi Village from 2024 to the next 20 years, and analyze the suitability between the projected demand and the available supply capacity. In addition, this study simulated the existing water distribution network in 2024 using Epanet 2.2 software, and evaluated the performance of the distribution system based on technical problems identified in the area.

This research is expected to provide a comprehensive picture of PDAM Way Rilau's clean water availability in the DMA G26 area, both for the 2024 condition and projections for the next 20 years. In addition to being an analytical reference for water distribution system planning and development, the results are also academically useful as a source of learning for students, especially at the University of Lampung. Practically, the findings of this research can be a technical consideration for PDAM Way Rilau in dealing with water distribution problems in the area.

This research draws on previous studies that provide theoretical and methodological foundations, as well as helping to broaden the scope of the analysis and identify research gaps. These include studies on water distribution network evaluation and projection by [4] [5] [6] [7] [8] [9] [10] [11] [12] [13]. This research focuses on PDAM Way Rilau's water distribution system in the DMA G26 area, with a hydraulic simulation approach using EPANET 2.2. Its uniqueness lies in the study location, the use of customer projection data for 20 years, and the analysis of network adequacy and efficiency based on the comparison of water demand and production capacity.

Figure 1. Epanet 2.2 software logo.

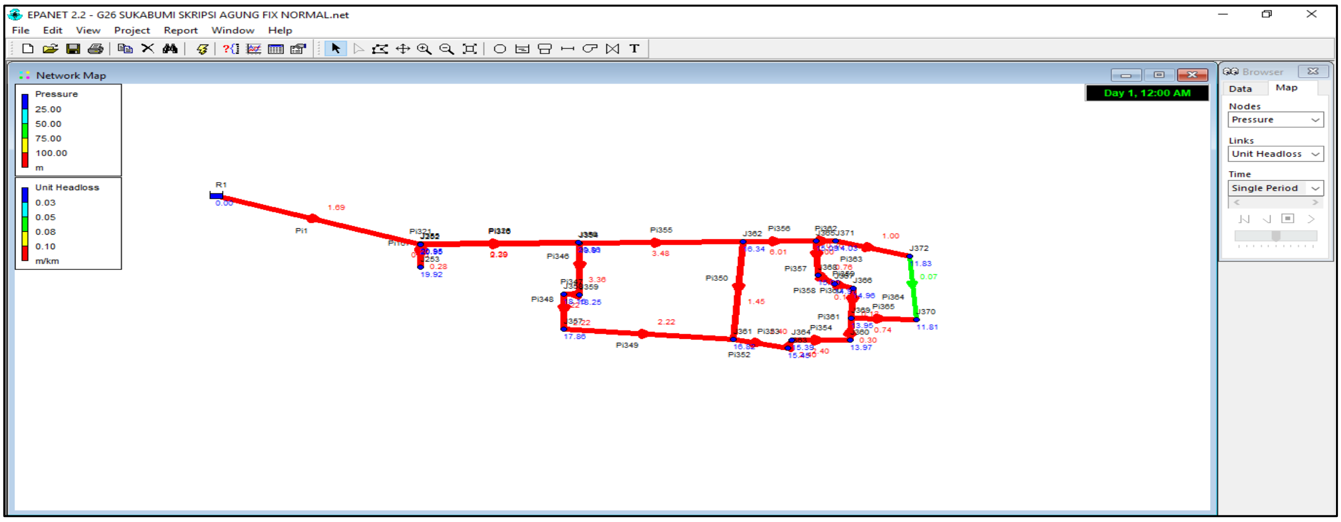

Figure 2. Simulation display on Epanet 2.2 software.

This research uses Epanet 2.2 Software as a simulation tool to analyze hydraulic data in water distribution network systems. Epanet, developed by the USEPA, is capable of modeling the flow and quality of water in closed networks such as pipes, nodes, tanks, and reservoirs. By dynamically accounting for technical variables, the program allows monitoring of water flow in a given period. To run the simulation accurately, Epanet 2.2 requires inputs such as water demand at each node, elevation, pipe length and diameter, and roughness coefficient, so that the results can be close to real conditions and form the basis for proper technical analysis [14].

II. Materials and Methods

This study used a quantitative approach as the main method to analyze the demand for clean water in DMA G26, Sukabumi Village. This approach focuses on numerical data obtained through systematic measurements, with the aim of evaluating the adequacy of clean water services and assessing the ability of the distribution system to optimally meet community needs from 2024 to the next two decades. This approach differs from qualitative, which is descriptive in nature, but both can complement each other in scientific studies [15] [16].

This research focuses on analyzing water demand and evaluating the distribution system of PDAM Way Rilau in DMA G26, Sukabumi Village, Bandar Lampung City. The methodological approach used was organized systematically to ensure the efficiency and validity of the research process. The objectives were to assess the condition of the existing network, design a more efficient distribution strategy, and manage the community's water needs in a sustainable manner with projections until 2044.

This research was conducted in the even semester of 2024/2025 at the Department of Civil Engineering, University of Lampung, as a continuation of the author's Practical Work program on the Bandar Lampung City Distribution Network and House Connection (SR) Development Project in 2024. The case study focused on Sukabumi Sub-district, with a population of 22,606 in three RWs, and specifically highlighted the DMA G26 area covering 2,792 people in ten sub-areas. The sub-district has an area of 3.58 km² and is bordered by Sukarame (north), Sukabumi Indah and Nusantara Permai (west), South Lampung (east), and Campang Raya and Campang Jaya (south) [17].

Figure 3. Map of DMA G26 research location in sukabumi urban village, sukabumi sub-district, bandar lampung city [18].

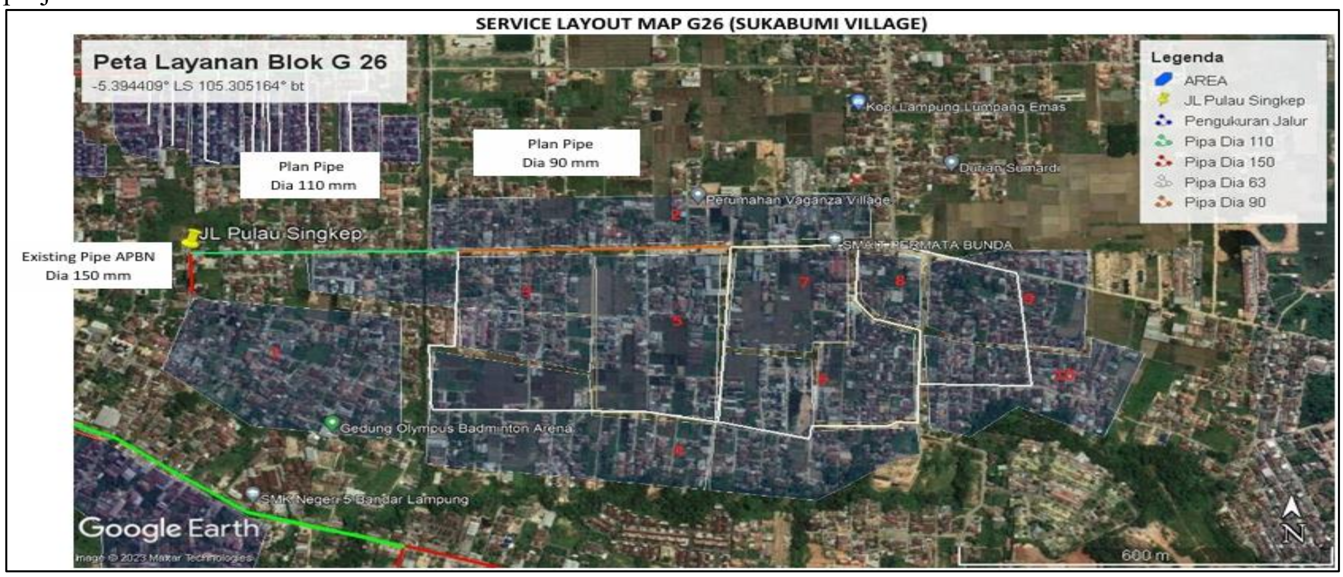

Figure 4. Layout map of DMA G26 service in sukabumi urban village, sukabumi sub-district, bandar lampung city [18].

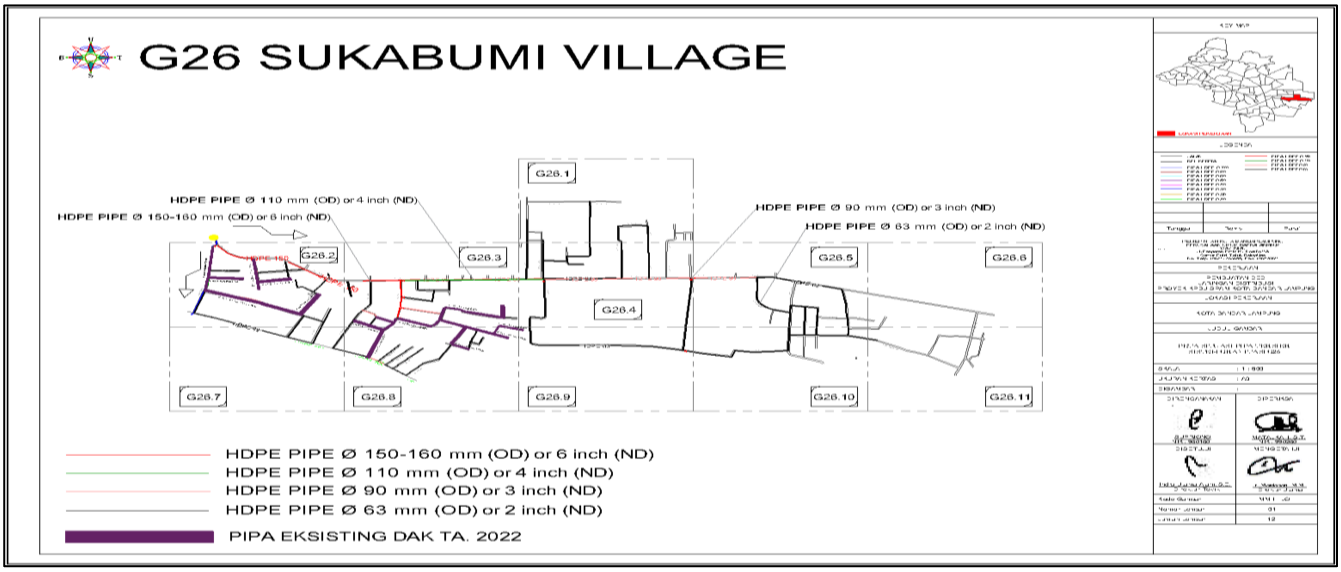

Figure 5. Situation map of DMA G26 pipeline in sukabumi urban village, sukabumi sub-district, bandar lampung city [18].

In the preparation of this final project, data was systematically collected according to the type and characteristics required to support the overall analysis. Primary data was obtained through surveys and direct observation in the DMA G26 area of Sukabumi Village, while secondary data was collected from relevant agencies as a complement. Secondary data included network maps and pipe dimensions, pipe elevations and coordinates, number of customers in 2024, base demand, water production capacity, and fluctuations in customer water consumption in the study area.

The data analysis stage in this study was carried out quantitatively to describe the water demand in the DMA G26 area, Sukabumi Village. The process began with the collection, grouping, and systematic preparation of data, then analyzed to evaluate both existing and projected long-term water demand. The stages include: (1) projection of the number of customers using arithmetic, geometric, and exponential methods; (2) calculation of water demand until 2044, including domestic, non-domestic, leakage, and peak demand aspects; (3) comparison between demand and supply capacity; (4) network simulation using Epanet 2.2; (5) evaluation of simulation results based on technical standards of [19]; and (6) identification and preparation of technical solutions if discrepancies are found to improve distribution system efficiency.

According to [20], the equation for calculating population projections (P_n) is as follows:

(a) Arithmetic Method

$$P_n = P_0\ (1 + r\ n)$$

P_n= Total population at the end of the n^{th} year (people)
P_0= Total population in the initial year of projection (people)
r = Population growth rate per year (%)
n = Number of projection years (year)

(b) Geometry Method

$$P_n = P_0\ (1 + r)^n$$

P_n= Total population at the end of the nth year (people)
P_0= Total population in the initial year of projection (people)
r = Population growth rate per year (%)
n = Number of projection years (year)

(c) Exponential Method

$$P_n = P_0\ e^{r\,n}$$

P_n= Total population at the end of the nth year (people)
P_0= Total population in the initial year of projection (people)
r = Population growth rate per year (%)
n = Number of projection years (year)
e = Natural logarithm (e = 2,718281828)

According to [21], there are six main aspects that can be used as a basis in calculating the estimation of future clean water demand, as follows:

(a) Domestic Water Demand

$$qD = Pn \times (pl\%) \times S$$

qD = Domestic water demand (lt/sec)
P_0= Total population in the initial year of projection (people)
$pl\%$ = Percentage of services to be served
S = Average water demand standard (lt/ people/day)

(b) Non-Domestic Water Demand

$$qnD = qD \times nD\%$$

qnD = Non-domestic water demand (lt/sec)
qD = Domestic water demand (lt/sec)
$nD\%$ = Percentage of non-domestic demand (%)

(c) Total Water Demand

$$qT = qD + qnD$$

qT = Total water demand (lt/sec)
qD = Domestic water demand (lt/sec)
qnD = Non-domestic water demand (lt/sec)

(d) Water Leakage or Loss

$$qHL = qT \times (Kt\%)$$

qHL = Leakage or water loss (lt/sec)
qT = Total water demand (lt/sec)
$Kt\%$ = Percentage of loss or leakage (%)
(e) Kebutuhan Air Rata-Rata

$$qRH = qT + qHL$$

qRH = Average water demand (lt/sec)
qT = Total water demand (lt/sec)
qHL = Leakage or water loss (lt/sec)
(f) Maximum Daily Water Demand

$$qmax = F \times qRH$$

$qmax$ = Maximum daily water demand (lt/sec)
qRH = Average water demand (lt/sec)
F = Maximum daily factor
g) Peak Hour Water Demand

$$qpeak = F \times qRH$$

$qpeak$ = Peak hour water demand (lt/sec)
qRH = Average water demand (lt/sec)
F = Peak hour factor

Table 1. Clean Water Planning Criteria [22]

URAIAN	**CITY CATEGORY BY POPULATION (PEOPLE)**				
	>1.000.000	**500.000 to 1.000.000**	**100.000 to 500.000**	**20.000 to 100.000**	**<20.000**
	Metropolitan City	**Large City**	**Medium City**	**Small City**	**Village**
1	**2**	**3**	**4**	**5**	**6**
1. House Connection Unit (SR) Consumption (Liter/people/day)	190	170	130	100	80
2. Hydrant Unit (HU) Consumption (Liter/people/day)	30	30	30	30	30
3. Non-domestic unit consumption (%)	20 - 30	20 - 30	20 - 30	20 - 30	20 - 30
4. Water Loss (%)	20 - 30	20 - 30	20 - 30	20 - 30	20 - 30
5. Maximum Daily Factor	1,1	1,1	1,1	1,1	1,1
6. Peak Hour Factor	1,5	1,5	1,5	1,5	1,5
7. Number of people per SR (people)	5	5	5	5	5
8. Number of people per HU (people)	100	100	100	100	100
9. Remaining Press in Distribution Provision (Meter)	10	10	10	10	10
10. Operation Hours (Hours)	24	24	24	24	24
11. Reservoir Volume (% Max Day Demand)	20	20	20	20	20
12. SR : HU	50 : 50 s/d 80 : 20	50 : 50 s/d 80 : 20	80 : 20	70 : 30	70 : 30
13. Service Coverage (%)	*) 90	90	90	90	**) 70

The design criteria of the piping network refers to [19], among others: (1) Pressure 5.16 - 82.6 m; (2) Headloss 0 - 10 m/km; (3) Velocity 0.3 - 4.5 m/s.

In order for the preparation of this research report to run systematically and in accordance with the plan, a flow chart is made that describes the stages of analysis in the research. This chart serves as a guide to map the workflow starting from the problem identification process to determining the right solution. A visual representation of the study flow can be seen in Figure 6.

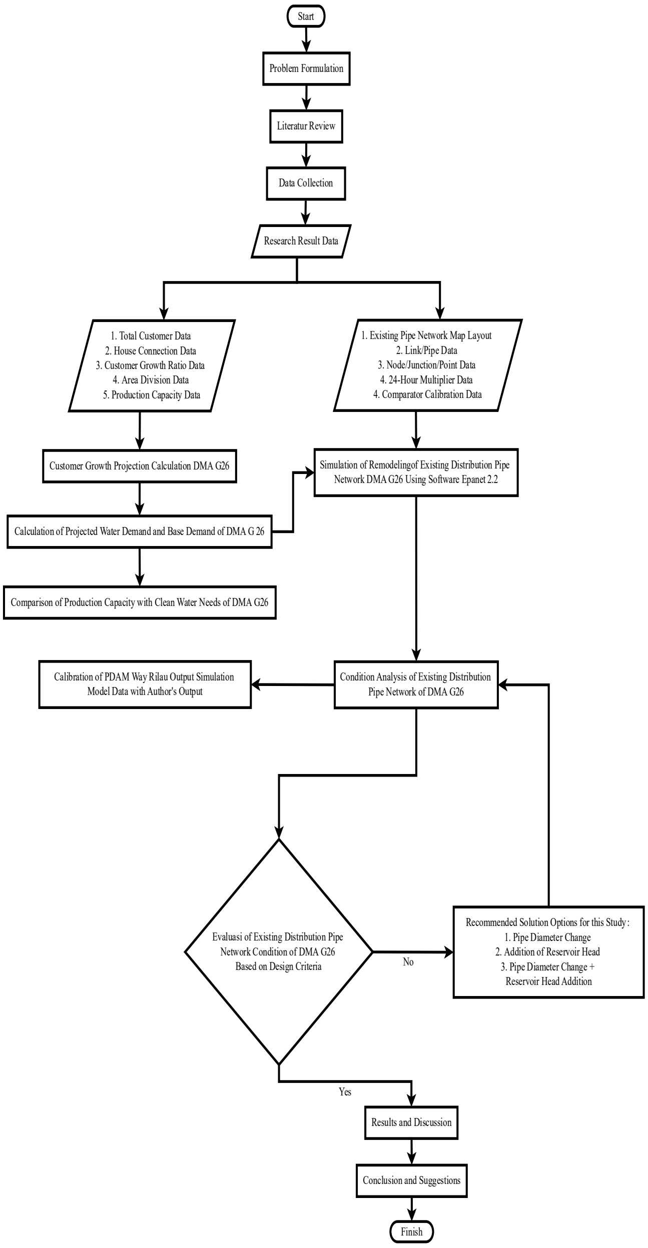

Figure 6. Research flow chart.

III. RESULTS AND DISCUSSIONS

A. Calculation of Water Demand and Base Demand

Based on the calculation results, the demand for clean water in the DMA G26 area in 2024 was recorded at an average of 5,119 liters/second, the daily maximum demand was 5,631 liters/second, and at peak hours it reached 7,678 liters/second. Projections to 2044 show an increase, with an average demand of 6,347 liters/second, a daily maximum of 6,982 liters/second, and a peak hour of 9,521 liters/second. All of these values are still below the supply capacity of 13.24 liters/second, so the distribution system is still considered capable of meeting demand. A detailed recapitulation is shown in Tables 2 and 3.

In planning the clean water pipeline network, determining the base demand at each junction is based on the estimated average daily water demand at that point. The calculation of discharge is carried out by referring to the water demand (Qaverage) according to the position and function of each junction. To obtain accurate data, a field survey was conducted in the form of tracking existing pipe lines and collecting data on the number of house connections (SR) in the DMA G26 area, Sukabumi Village. This data was used to determine the distribution of water demand at each point, which is summarized in Table 4.

Table 2. Recapitulation of Calculation of Clean Water Needs in DMA G26 Kelurahan Sukabumi Current Conditions (2024)

CALCULATION OF CLEAN WATER DEMAND FOR EACH USAGE AREA DMA G26 SUKABUMI VILLAGE BANDAR LAMPUNG CITY CURRENT CUSTOMER CONDITIONS (YEAR 2024)												
No	Area	House Connection (SR)		Water Demand		Q Domestic	Q Non Domestic	Q Total Demand	Q Leakage	Q Average	Q Max	Q Peak
		Family	People	lt/people/day	lt/day	lt/sec	lt/sec	lt/sec	lt/sec	lt/sec	lt/sec	lt/sec
		a	b	c	d=(bxc)	e=d/(24x60x60)	f=(ex20%)	g=(e+f)	h=(gx20%)	i=(g+h)	j=(ix1,1)	k=(ix1,5)
1	Area 1	178	712	110	78320,00	0,906	0,181	1,088	0,218	1,305	1,436	1,958
2	Area 2	70	280	110	30800,00	0,356	0,071	0,428	0,086	0,513	0,565	0,770
3	Area 3	25	100	110	11000,00	0,127	0,025	0,153	0,031	0,183	0,202	0,275
4	Area 4	75	300	110	33000,00	0,382	0,076	0,458	0,092	0,550	0,605	0,825
5	Area 5	75	300	110	33000,00	0,382	0,076	0,458	0,092	0,550	0,605	0,825
6	Area 6	70	280	110	30800,00	0,356	0,071	0,428	0,086	0,513	0,565	0,770
7	Area 7	50	200	110	22000,00	0,255	0,051	0,306	0,061	0,367	0,403	0,550
8	Area 8	35	140	110	15400,00	0,178	0,036	0,214	0,043	0,257	0,282	0,385
9	Area 9	50	200	110	22000,00	0,255	0,051	0,306	0,061	0,367	0,403	0,550
10	Area 10	70	280	110	30800,00	0,356	0,071	0,428	0,086	0,513	0,565	0,770
Total	**10 Area**	**698**	**2792**	**110**	**307120,00**	**3,555**	**0,711**	**4,266**	**0,853**	**5,119**	**5,631**	**7,678**

Table 3. Recapitulation of Calculation of Clean Water Needs in DMA G26 Kelurahan Sukabumi Condition for The Next 20 Years (2044)

CALCULATION OF CLEAN WATER DEMAND FOR EACH USAGE AREA DMA G26 SUKABUMI VILLAGE BANDAR LAMPUNG CITY CUSTOMER CONDITION 20 YEARS IN THE FUTURE (YEAR 2044)															
No	Area	House Connection (SR)		% Customer	Planning	20 Year	Water Demand		Q Domestic	Q Non Domestic	Q Total Demand	Q Leakage	Q Average	Q Max	Q Peak
		Family	People	Growth	Year	Projection	lt/people/day	lt/day	lt/sec	lt/sec	lt/sec	lt/sec	lt/sec	lt/sec	lt/sec
		a	b	c	d	e=b(1+cxd)	f	g=(exf)	h=g/(24x60x60)	i=(hx20%)	j=(h+i)	k=(jx20%)	l=(j+k)	m=(lx1,1)	n=(lx1,5)
1	Area 1	178	712	1,2%	20	883	110	97116,80	1,124	0,225	1,349	0,270	1,619	1,780	2,428
2	Area 2	70	280	1,2%	20	347	110	38192,00	0,442	0,088	0,530	0,106	0,637	0,700	0,955
3	Area 3	25	100	1,2%	20	124	110	13640,00	0,158	0,032	0,189	0,038	0,227	0,250	0,341
4	Area 4	75	300	1,2%	20	372	110	40920,00	0,474	0,095	0,568	0,114	0,682	0,750	1,023
5	Area 5	75	300	1,2%	20	372	110	40920,00	0,474	0,095	0,568	0,114	0,682	0,750	1,023
6	Area 6	70	280	1,2%	20	347	110	38192,00	0,442	0,088	0,530	0,106	0,637	0,700	0,955
7	Area 7	50	200	1,2%	20	248	110	27280,00	0,316	0,063	0,379	0,076	0,455	0,500	0,682
8	Area 8	35	140	1,2%	20	174	110	19096,00	0,221	0,044	0,265	0,053	0,318	0,350	0,477
9	Area 9	50	200	1,2%	20	248	110	27280,00	0,316	0,063	0,379	0,076	0,455	0,500	0,682
10	Area 10	70	280	1,2%	20	347	110	38192,00	0,442	0,088	0,530	0,106	0,637	0,700	0,955
Total	**10 Area**	**698**	**2792**	**1,2%**	**20**	**3462**	**110**	**380828,80**	**4,408**	**0,882**	**5,289**	**1,058**	**6,347**	**6,982**	**9,521**

Table 4. Data on Node/Junction Position and Base Demand in DMA G26 Distribution Network of Sukabumi Village

No	DMA	Network Table - Nodes				
		Node ID	Elevation (m)	SR		Base Demand (lps)
				(kk)	(people)	
1	G26	Junc 354	100	0	0	0
2	G26	Junc 355	100	0	0	0
3	G26	Junc 356	100	70	280	0,637
4	G26	Junc 357	101	0	0	0
5	G26	Junc 358	101	0	0	0
6	G26	Junc 359	101	25	100	0,227
7	G26	Junc 360	103	70	280	0,637
8	G26	Junc 361	101	75	300	0,682
9	G26	Junc 362	102	75	300	0,682
10	G26	Junc 363	102	0	0	0
11	G26	Junc 364	102	0	0	0
12	G26	Junc 365	102	50	200	0,455
13	G26	Junc 366	102	0	0	0
14	G26	Junc 367	102	35	140	0,318
15	G26	Junc 368	102	0	0	0
16	G26	Junc 369	103	0	0	0
17	G26	Junc 370	105	70	280	0,637
18	G26	Junc 371	103	0	0	0
19	G26	Junc 372	105	50	200	0,455
20	G26	Junc 252	100	0	0	0
21	G26	Junc 253	101	178	712	1,619
22	G26	Reservoir 1	122	-	-	-

B. *Comparison of Clean Water Availability (Qavailable) with Clean Water Demand (Qneed)*

The projection of water demand for 2024-2044 aims to assess whether the Sukabumi Village DMA G26 area is in surplus or deficit supply. The aim is to ensure that the PDAM distribution capacity is sufficient to meet future demand. If there is a deficit, an increase in supply capacity is required. The evaluation was conducted using the Demand Supply Ratio (DSR) approach, which is a comparison between water supply and demand. A ratio > 1 indicates sufficient supply, while a ratio < 1 indicates the need for increased capacity. The full results of the DSR analysis are presented in Table 5.

Table 5. Demand Supply Ratio Analysis in DMA G26 of Sukabumi Village

Year	Suppy (liter/sec)	Demand (liter/sec)	Ratio	Surplus/ Deficit	Description
	a	b	c = (a/b)	d = (a-b)	
2024	13,24	5,631	2,351	7,609	Surplus (+)
2044	13,24	6,982	1,896	6,258	Surplus (+)

The results of the water balance analysis show that in 2024, the water supply capacity in the DMA G26 area of Sukabumi Village is still very sufficient, with a surplus of 7,609 liters/second and a ratio of availability to demand of 2,351. In the 2044 projection, although demand increased and the surplus margin decreased to 6,258 liters/second, the ratio remained at 1.896. The ratio value remaining >1 indicates that the distribution capacity of PDAM Way Rilau is still adequate until 2044 without the need for significant capacity additions in the near future.

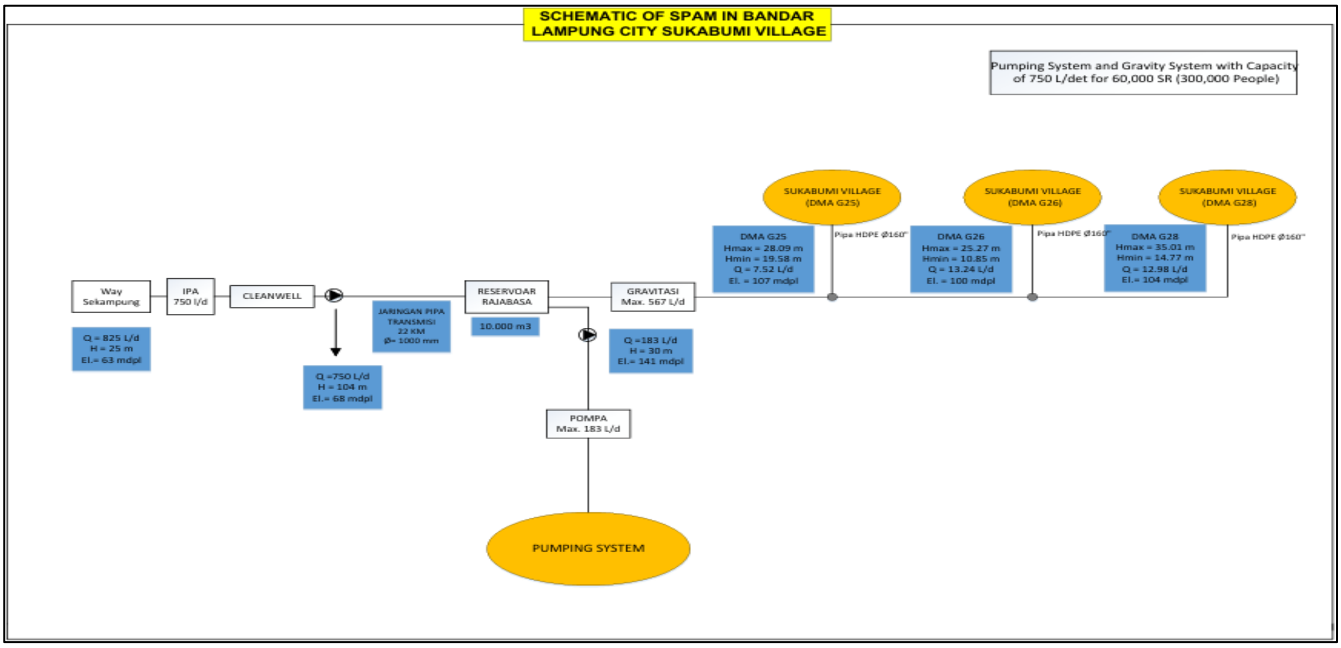

Figure 7. Schematic of clean water production/availability capacity in DMA G26 of sukabumi village [18].

C. *Condition Analysis of Existing Distribution Pipe Network in 2024*

Simulation of the water distribution network in DMA G26 of Sukabumi Village was conducted for 24 hours, from 00.00 to 24.00, using actual consumption data from PDAM Way Rilau. The data was averaged to determine the hourly water demand. Next, a demand multiplier was calculated by comparing consumption at a particular hour to the hourly average. This value is used in Epanet 2.2 to realistically depict daily consumption fluctuations, covering low to peak load conditions.

Table 6. 24-Hour Water Usage Fluctuation in DMA G26 of Sukabumi Village

Water Usage Per Hour (liter/hour)	Time (hour)	Production Capacity (liter/hour)
22860	01.00 - 02.00	47664
22860	02.00 - 03.00	47664
22860	03.00 - 04.00	47664
25128	04.00 - 05.00	47664
27432	05.00 - 06.00	47664
29700	06.00 - 07.00	47664
27432	07.00 - 08.00	47664
25128	08.00 - 09.00	47664
22860	09.00 - 10.00	47664
27432	10.00 - 11.00	47664
25128	11.00 - 12.00	47664
22860	12.00 - 13.00	47664
22860	13.00 - 14.00	47664
22860	14.00 - 15.00	47664
27432	15.00 - 16.00	47664
29700	16.00 - 17.00	47664
29700	17.00 - 18.00	47664
25128	18.00 - 19.00	47664
25128	19.00 - 20.00	47664
22860	20.00 - 21.00	47664
22860	21.00 - 22.00	47664
22860	22.00 - 23.00	47664
22860	23.00 - 24.00	47664
22860	24.00 - 01.00	47664

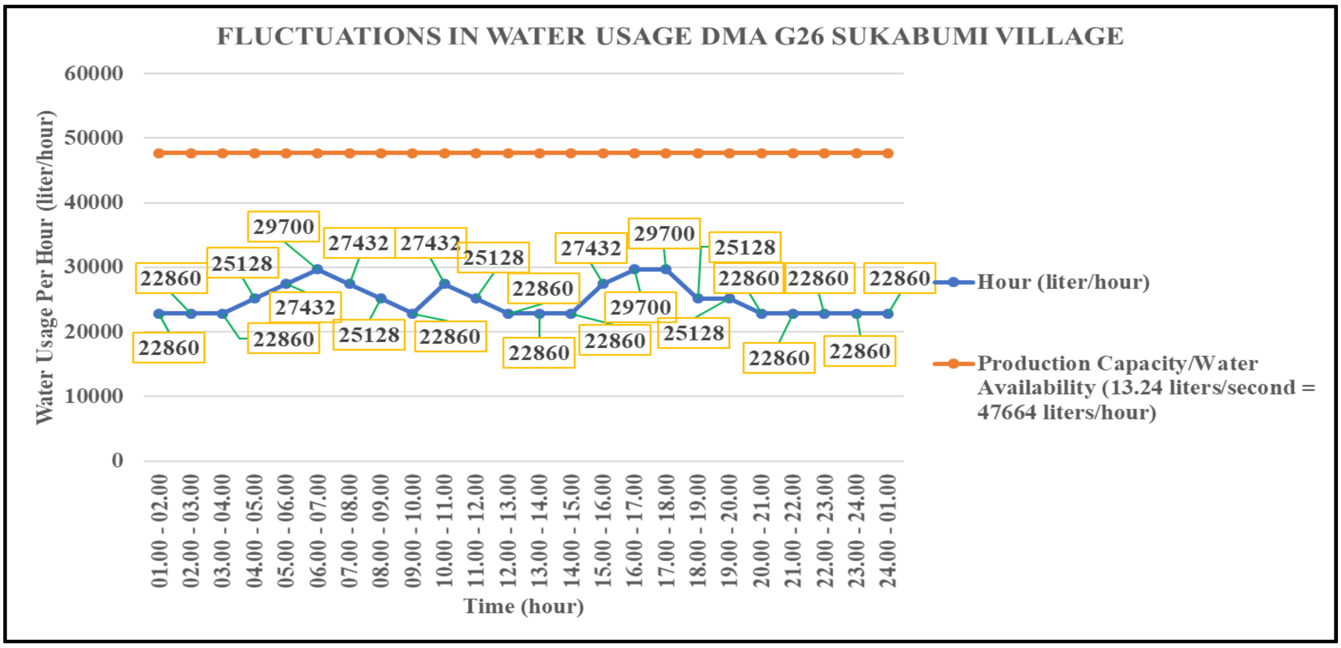

Figure 8. Fluctuation chart of 24 hour water usage in DMA G26 sukabumi village.

Based on Table 6 and Figure 8, the peak hours of water consumption occurred at 06.00-07.00 and 16.00-18.00, with the highest discharge reaching 29,700 liters per hour or 1.3 times the average usage. Meanwhile, the lowest consumption was recorded at 20:00-04:00 and 09:00-10:00 and 12:00-15:00, with a discharge of 22,860 liters per hour and a multiplier factor of 1, indicating near-average conditions. This information is important in hydraulic analysis to assess the performance of the distribution system in dealing with daily demand fluctuations.

After the data is entered into the Epanet 2.2 software, the program produces outputs that reflect the performance of the distribution network based on hydraulic parameters such as water demand, pressure, head, energy loss (headloss unit), flow, and velocity. The simulation results are presented in Figures 9 - 11, which form the basis for technical evaluation and reference for distribution system improvements to make it more optimal.

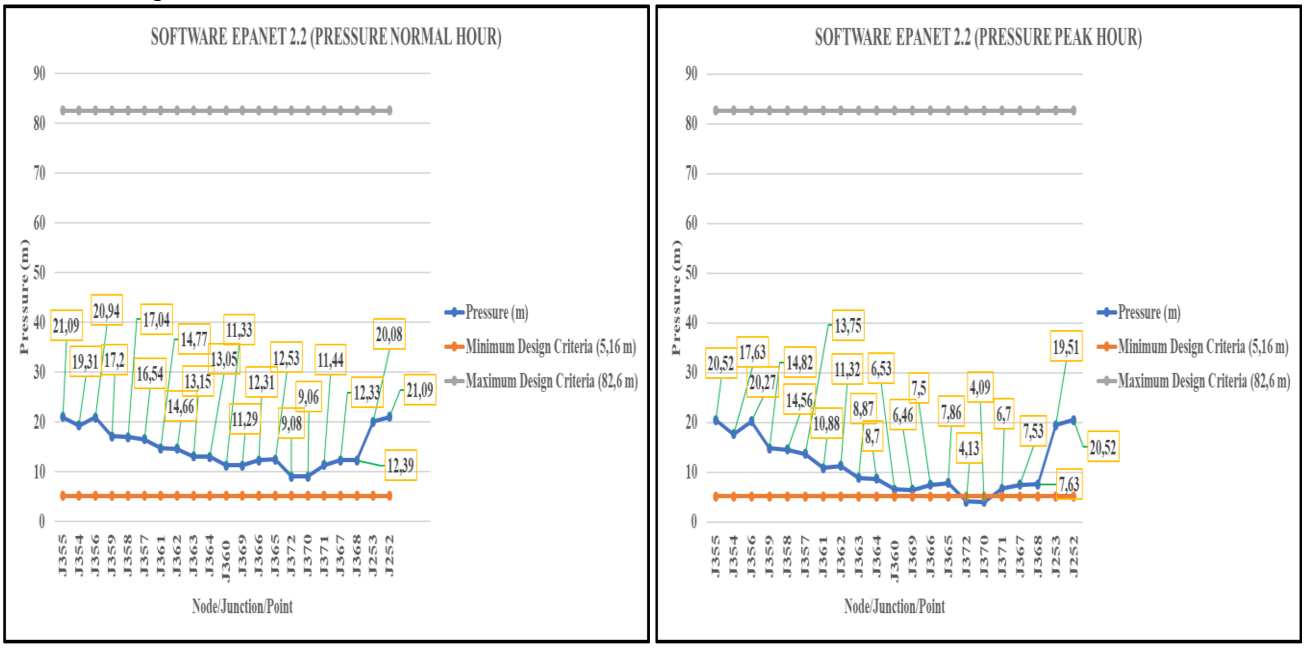

Figure 9. Pressure graph of each node/junction at normal hours and peak hours compared to design criteria (existing).

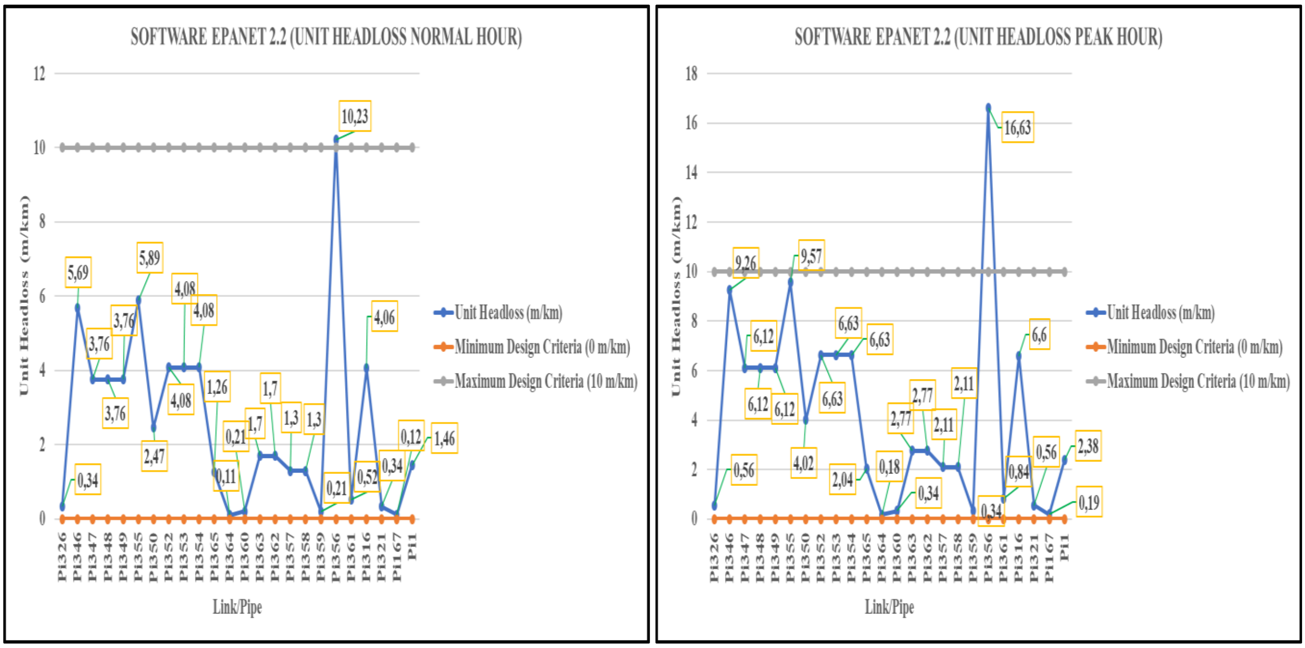

Figure 10. Graph of headloss unit for each link/pipe at normal hours and peak hours compared to design criteria (existing).

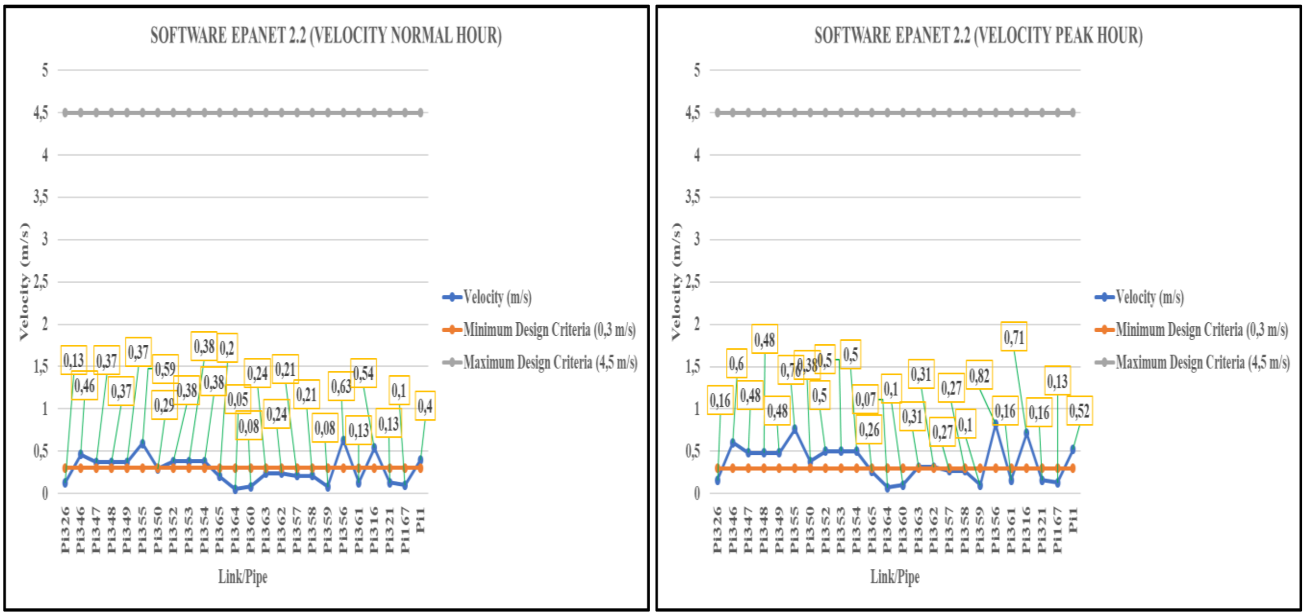

Figure 11. Velocity graph of each link/pipe at normal hours and peak hours compared to design criteria (existing).

Based on the graphical analysis in Figures 9 to 11, the simulation results with Epanet 2.2 show that most of the distribution network components are in compliance with technical standards. For the pressure parameter, most of the nodes are within the allowable limits (5.16-82.6 meters), both during normal and peak hours. However, two nodes, J370 and J372, recorded pressures below the minimum limit during peak hours.

For the headloss unit parameter, almost all pipes in the network meet the design standard of 0-10 m/km under both operational conditions. However, there is one pipe, Pi356, that does not meet these criteria during both normal and peak hours.

The flow velocity parameter needs to be considered, as there are 13 pipes in the Sukabumi Village DMA G26 distribution network that have velocities below the minimum limit of <0.3 m/s, both during normal and peak hours. These low velocities can reduce flow quality and lead to sediment formation in the pipes.

The list of nodes and pipes with substandard flow velocities is detailed in Tables 7, 8, and 9. This data serves as a reference in the preparation of technical recommendations to improve the efficiency and performance of the distribution system in the study area.

Table 7. Nodes/Points with Pressure below Design Criteria for DMA G26 Sukabumi Village

No	Node/ Junction	Elevation (m)	Pressure Normal Hour (m)	Pressure Peak Hour (m)	Design Criteria (m)
1	J372	105	9,08	4,13	5,16 - 82,6
2	J370	105	9,06	4,09	5,16 - 82,6

Table 8. Links/Pipes with Unit Headloss above Design Criteria for DMA G26 Sukabumi Village

No	Link/Pipe	Length (m)	Nominal Diameter (inch)	Headloss Normal Hour (m/km)	Headloss Peak Hour (m/km)	Design Criteria (m/km)
1	Pi356	438	Ø 2”	10,23	16,63	0 - 10

Table 9. Links/Pipes with Velocity below Design Criteria for DMA G26 Sukabumi Village

No	Link/Pipe	Length (m)	Nominal Diameter (inch)	Velocity Normal Hour (m/s)	Velocity Peak Hour (m/s)	Design Criteria (m/s)
1	Pi326	438	Ø 3”	0,13	0,16	0,3 - 4,5
2	Pi350	360	Ø 2”	0,29	0,38	0,3 - 4,5
3	Pi365	183	Ø 2”	0,2	0,26	0,3 - 4,5
4	Pi364	231	Ø 2”	0,05	0,07	0,3 - 4,5
5	Pi360	110	Ø 2”	0,08	0,1	0,3 - 4,5
6	Pi363	207	Ø 2”	0,24	0,31	0,3 - 4,5
7	Pi362	58	Ø 2”	0,24	0,31	0,3 - 4,5
8	Pi357	113	Ø 2”	0,21	0,27	0,3 - 4,5
9	Pi358	46	Ø 2”	0,21	0,27	0,3 - 4,5
10	Pi359	80	Ø 2”	0,08	0,1	0,3 - 4,5
11	Pi361	78	Ø 2”	0,13	0,16	0,3 - 4,5
12	Pi321	10	Ø 3”	0,13	0,16	0,3 - 4,5
13	Pi167	81	Ø 6”	0,1	0,13	0,3 - 4,5

D. Evaluation of the Condition of the Existing Distribution Pipe Network in 2024

It should be emphasized that all simulation results must be evaluated according to the technical standards listed in [19]. This standard is the main reference for assessing the feasibility of distribution network performance, especially HDPE pipes. Parameters that must be met include flow velocity between 0.3-4.5 m/s, headloss units of 0-10 m/km, and pressure in the range of 0.5-8 atm (5.16-82.6 meters). These three indicators serve as benchmarks for system efficiency and compliance with clean water service standards.

The main problem with PDAM Way Rilau's clean water distribution network in the DMA G26 area of Sukabumi Village is water loss, which is characterized by flow not reaching the customer. This is triggered by technical factors such as low pressure, headloss units that exceed the limit, and substandard flow velocity. Simulation results with Epanet 2.2 show that there are several nodes and pipes that do not meet the technical criteria, so they are considered not feasible to support optimal distribution.

Low pressure at some junction points is caused by headloss due to friction of water flow with pipe walls and high topographic elevation in certain areas. This condition makes the pressure insufficient, especially during peak hours, resulting in non-optimal water flow. A workable solution is to add head to the reservoir to increase the distribution pressure in the system.

Pipes with headloss values and flow velocities outside the standards of [19] need to be technically adjusted. Too low velocity and high headloss can reduce distribution efficiency and trigger sediment in the pipe. An effective solution is to change the diameter of the pipe to a larger diameter, which can reduce headloss and increase flow velocity. Although surface roughness also has an effect, adjusting the pipe size is considered more efficient. Therefore, diameter redesign in problematic segments is recommended to ensure water distribution according to technical standards.

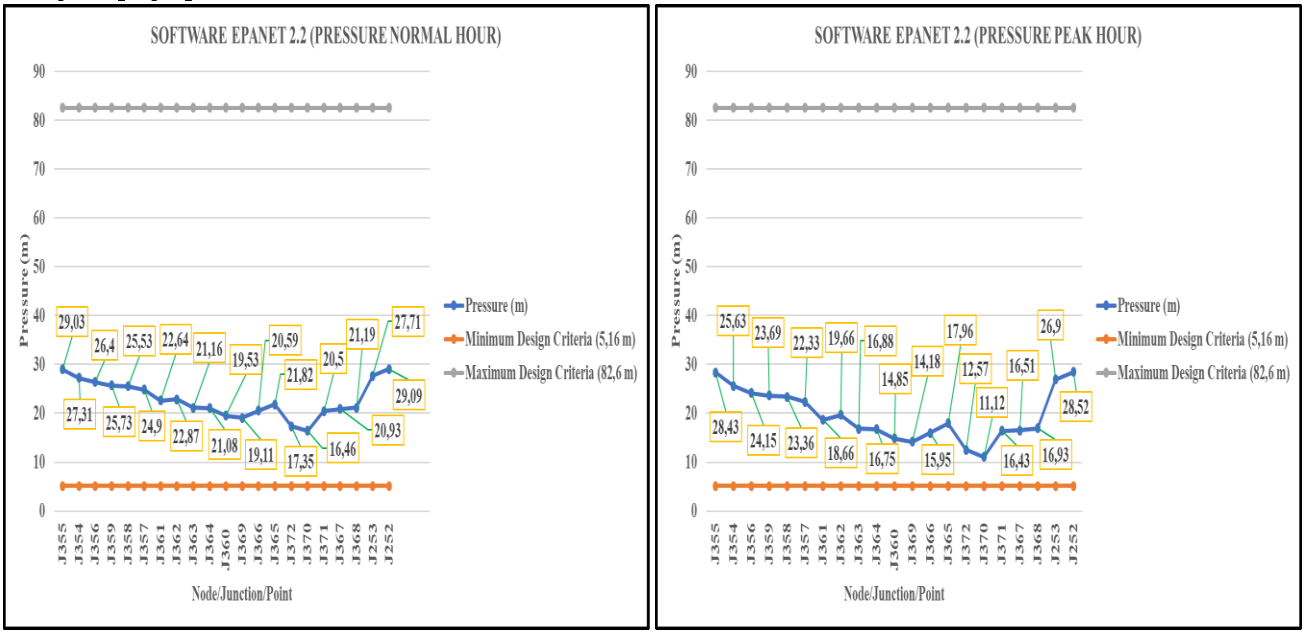

Figure 12. Pressure graph of each node/junction at normal hours and peak hours compared to design criteria (evaluation).

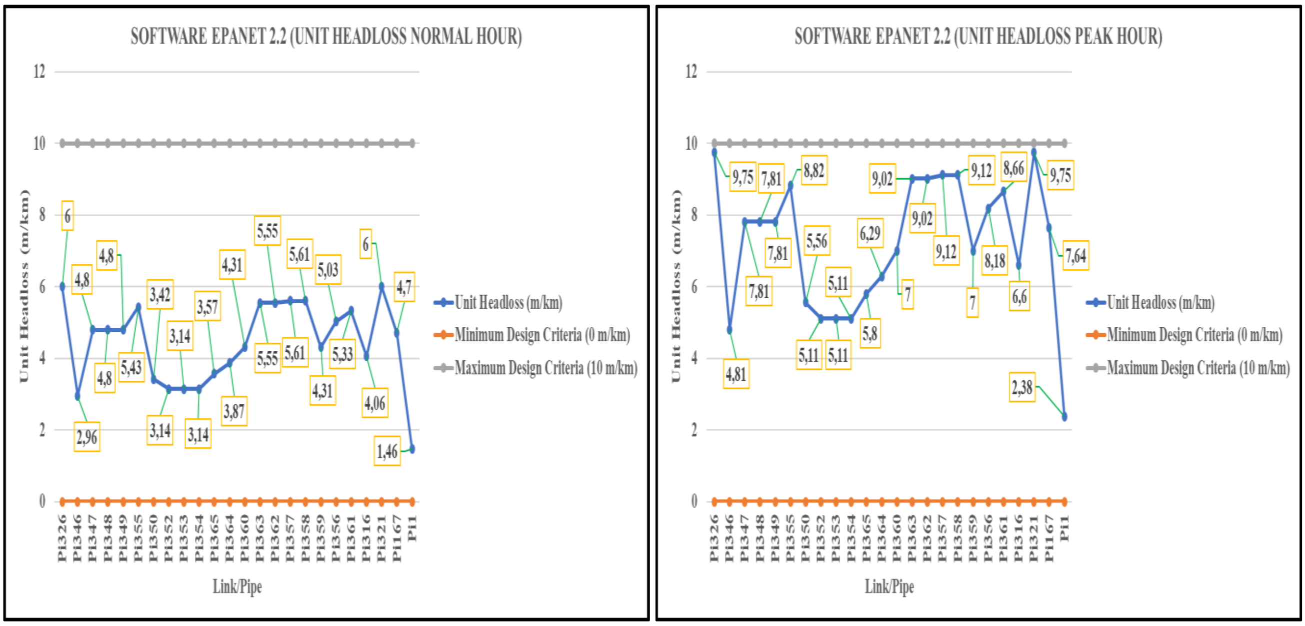

Figure 13. Graph of headloss unit for each link/pipe at normal hours and peak hours compared to design criteria (evaluation).

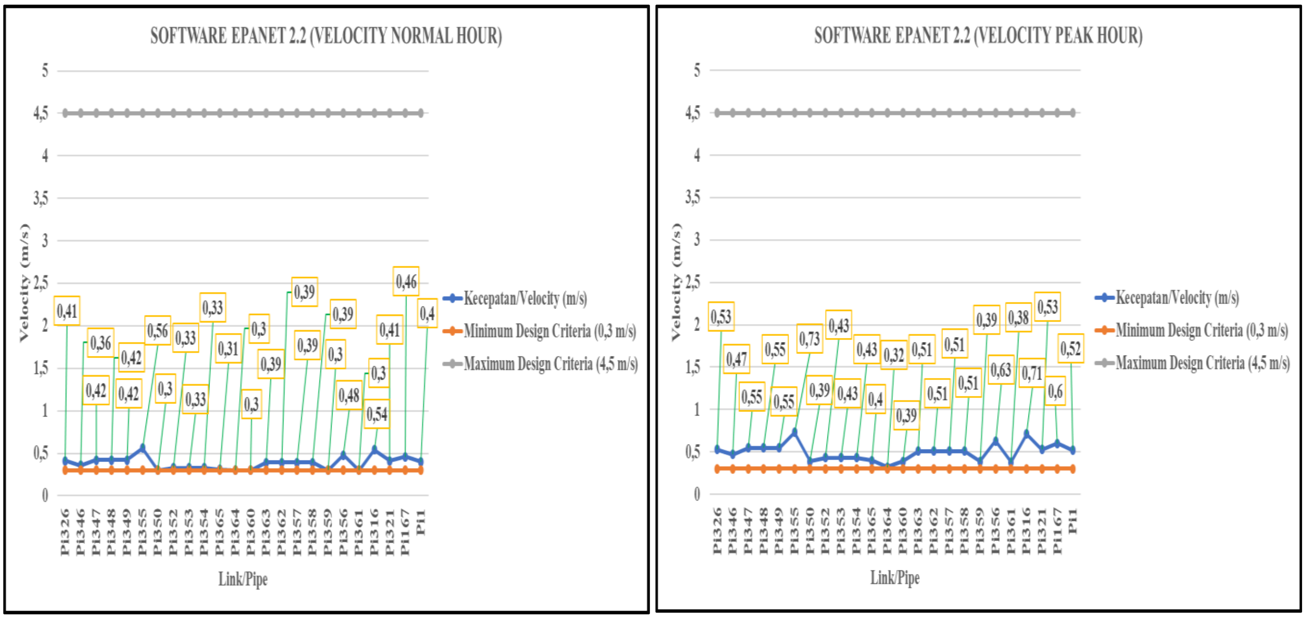

Figure 14. Velocity graph of each link/pipe at normal hours and peak hours compared to design criteria (evaluation)

All evaluation results are in accordance with the design standards in [19], namely flow velocity of 0.3-4.5 m/s, headloss unit of 0-10 m/km, and pressure of 0.5-8 atm or 5.16-82.6 meters.

A comparison of pipe diameters before and after the evaluation is listed in Table 10, while changes in reservoir head are shown in Table 11. These results indicate that the improvement efforts undertaken have successfully improved the performance of the clean water distribution system in DMA G26 of Sukabumi Village to technical standards.

Table 10. Pipe Diameter Before and After Evaluation

No	Link/Pipe	Nominal Diameter (inch)	
		Existing	Evaluation
1	Pi326	Ø 3”	Ø 1½”
2	Pi346	Ø 2”	Ø 2½”
3	Pi347	Ø 2”	Ø 2”
4	Pi348	Ø 2”	Ø 2”
5	Pi349	Ø 2”	Ø 2”
6	Pi355	Ø 3”	Ø 3”
7	Pi350	Ø 2”	Ø 1½”
8	Pi352	Ø 2”	Ø 2”
9	Pi353	Ø 2”	Ø 2”
10	Pi354	Ø 2”	Ø 2”
11	Pi365	Ø 2”	Ø 1½”
12	Pi364	Ø 2”	Ø 1”
13	Pi360	Ø 2”	Ø 1¼”
14	Pi363	Ø 2”	Ø 1½”
15	Pi362	Ø 2”	Ø 1½”
16	Pi357	Ø 2”	Ø 1½”
17	Pi358	Ø 2”	Ø 1½”
18	Pi359	Ø 2”	Ø 1¼”
19	Pi356	Ø 2”	Ø 2½”
20	Pi361	Ø 2”	Ø 1”
21	Pi316	Ø 4”	Ø 4”
22	Pi321	Ø 3”	Ø 1½”
23	Pi167	Ø 6”	Ø 2½”
24	Pi1	Ø 6”	Ø 6”

Table 11. Reservoir Head Before and After Evaluation

No	Node/Junction/Point	Total Head (m)	
		Existing	Evaluation
1	Reservoir 1	122	130

Tables 10 and 11 show the results of the distribution network evaluation, specifically the changes in pipe diameters indicated by colored numbers. The red color indicates pipes whose diameters were reduced to increase the flow velocity, conforming to the minimum limit as per the design standard.

Pressure adjustment at the nodes is done by increasing the pressure head in the reservoir, indicated by the green numbers in the table. This step aims to increase the pressure at points that were previously below standard, especially in areas of high elevation or the end of the network.

Flow velocities that are too low not only affect hydraulic performance, but can also trigger deposits in the pipes, leading to reduced water quality and increased network maintenance requirements in the long run.

Information on the total length of pipes that underwent diameter changes, both smaller and larger adjustments, is provided in Table 12. This data provides a quantitative picture of the extent of intervention in the evaluation of the distribution system in DMA G26 of Sukabumi Village.

Table 12. Reservoir Head Before and After Evaluation

No	Nominal Pipe Diameter Evaluation (inch)	Total Length of Evaluation Pipe (m)
1	1”	309
2	1¼”	190
3	1½”	1415
4	2½”	485
Total		2399

IV. CONCLUSIONS

Based on the results and discussion in this study, it can be concluded that:

(1) The projection of clean water demand in the DMA G26 area of Sukabumi Village was designed until 2044. In 2024, the average demand was recorded at 5.119 liters/second, the maximum daily demand was 5.631 liters/second, and at peak hour 7.678 liters/second, with a fixed supply of 13.24 liters/second. Projections for 2044 show an increase to 6,347 liters/second (average), 6,982 liters/second (daily maximum), and 9,521 liters/second (peak hour). All of these demand values are still below the supply capacity, indicating that the existing distribution system is still adequate for the next 20 years.

(2) The water balance analysis in the DMA G26 area shows that the supply capacity of PDAM Way Rilau is still sufficient until 2044. In 2024, clean water production of 13.24 liters/second met the maximum daily demand of 5.631 liters/second, resulting in a surplus of 7.609 liters/second and a capacity to demand ratio of 2.351. In 2044, the projected demand increases to 6,982 liters/second, but still leaves a surplus of 6,258 liters/second with a ratio of 1.896. A ratio value above 1 indicates that the distribution system remains safe and reliable in the long term.

(3) Simulation of the clean water distribution network in the DMA G26 area using Epanet 2.2 shows that several components do not meet the technical standards based on [19]. In terms of pressure, two points (J370 and J372) recorded values below the minimum limit, which was only 4.09-4.13 meters during peak hours. For headloss, pipe Pi356 exceeded the maximum limit with a value of 16.63 m/km. In addition, there were 13 pipes with flow velocities below the standard of 0.3 m/s, both during normal and peak hours. This 24-hour simulation used HDPE PN 10 pipes with varying diameters (Ø 2“-6”), and the results showed the need for adjustments for the distribution system to function optimally as required.

(4) An evaluation of PDAM Way Rilau's water distribution system in the DMA G26 area revealed a major problem in the form of water loss due to non-optimal flow. Three hydraulic parameters did not meet the standards of [19], namely pressure below 5.16 meters, headloss exceeding 10 m/km, and flow velocity below 0.3 m/s. This condition reduces system efficiency and triggers leaks. To overcome this, it is recommended to increase the pressure by raising the reservoir elevation, replace the pipe to a larger diameter to reduce headloss, and reduce the pipe in the low-discharge segment to increase the flow velocity. Design adjustments were made by raising the total reservoir head to 130 meters and replacing 2,399 meters of pipe with Ø 1“ to Ø 2½” sizes, tailored to the technical needs of each segment.

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