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Analysis of Water Loss in the District of Meter Area (DMA) Bumi Kepongongan Indah Regency, Cirebon for Civilization

Adam Safitri[1], Slamet Imam Wahyudi[2], Soedarsono[3], Mahmud Yunus[4], Nono Carsono[5], Lia Amaliah[6]

[1,2,3]*Faculty of Engineering – Islamic University of Sultan Agung Semarang*

[1,4,5,6]*Civil Engineering Study Program – Academy of Technology Cirebon*

adam@sttcirebon.ac.id

Abstract

Based on the calculation of Non-Revenue Water/Un-billed Water (NRW/ATR), it is known that the value of NRW (Non-Revenue Water/Unbilled Water) in the Meter Area (DMA) District of Perum Bumi Kepongpongan Indah, Cirebon Regency with 204 SR subscribers, in February 2020 was relatively high, at 50.92%. The purpose of this study was to determine the level of water loss by looking for causes arising from water leaks, knowing the location of water loss both physically and non-physically, and knowing how to control Non-Revenue Water (NRW) water loss. The methodology used is to collect secondary data and primary data. Secondary data were obtained from the Cirebon City Water Supply Corporation, including images of the DMA distribution network and monthly customer water usage data taken from February to April 2020. Primary data was obtained by means of surveys and direct field observations by testing the steptest in one test. DMA. The result of controlling and decreasing NRW/ATR is that it can reduce the value of NRW/ATR from 50.92% in June 2020 down to 46% based on (WB 0) and in August 2020 down to 25% based on the results of simultaneous readings (WB 1). Pressure also needs to be considered, because pressure that is too high can also increase water loss. So that the Pressure Reducing Valve (PRV) is installed which can reduce excess pressure, from the PRV installation reducing the water loss rate from 25% in August 2020 to 20% in February 2021.

Keywords

PDAM Cirebon city; NRW/ATR; DMA; steptes; pressure reducing valve

I. Introduction

Number of Non-Revenue Water (ATR)/Non Revenue Water (NRW) is one indicator that affects the performance and services of PDAM/BUMD Drinking Water [1] [2]. According to the 2018-2019 PDAM Performance Book data source, BPPSPAM (Agency for Improvement of the Implementation of the Drinking Water Supply System) Indonesia's average non-billed water rate (ATR) is 33.16% [3].

Water loss (Non Revenue Water) can be interpreted as the recorded difference or the difference between the water produced and entered into the system with the amount of water recorded on the customer meter [4]. With this understanding, the loss of a number of water that can occur due to leaving the system without being used or not recording water use for various reasons. PERUMDA Drinking Water Tirta Giri Nata Cirebon City has a water loss rate of more than 30%. In Perum Bumi Kepongpongan Indah, Cirebon Regency, Perumda Water Drinking Tirta Giri Nata, Cirebon City, with 204 SR subscribers, in February 2020 was relatively high, at 50.92%. For this reason, one of the efforts to reduce Non Revenue Water (NRW) is the establishment of a Meter Area District (DMA), so that

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the zone within the Bumi Kepongpongan Indah area of Cirebon, the area of the Tirta Giri Nata Drinking Water Company, Cirebon City, can be easily evaluated for the level of water loss.

Water loss control (NRW) in the area of Bumi Kepongpongan Indah Regency, Cirebon, the level of water loss by looking for causes that arise due to water leaks[5]

Figure 1. *Bumi Kepongpongan Indah Regency, Cirebon in 2021 (Cirebon City PDAM, 2021)*

II. Review of Literature

Water balance is a method or method of calculating water loss issued by the International Water Association (IWA), which makes it easy to analyze water loss [6]. Calculation of water loss can be done by two methods, namely:

1. Percentage method
   Water loss in percentage can be calculated by the formula:
   $H = \frac{S-D}{S} X\ 100$................................(1)
   In which:
   H : Water loss in percent (%).
   S : The amount of water distributed in (m3).
   D : The amount of water recorded in the billing account (m3).
2. Infrastructure Leakage Index (ILI) Method Infrastructure Leakage Index (ILI) is a water loss performance value compared to physical leakage. ILI is calculated by weighing the CAPL from the results on the Water Balance with MAAPL on the distribution pipeline infrastructure [7].
   ILI = CAPL / MAAPL ....(2)
   In which:
3. CAPL : (Current Annual Physical Losses) MAAPL: (Minimum Achievable Annual Physical Losses). To determine the CAPL value which is a leak in the service pipe up to the customer meter, it can be known through the water balance [8]. Meanwhile, to determine the MAAPL value, the steps that need to be considered are as follows:
   a. Define system characteristics
   b. Determine the number of service pipe connections.
   c. Determine the length of the main pipe.
   d. Determine (or estimate) the mean pressure.

e. Calculating MAAPL using a formula (empirical)

MAAPL (ltr/day) = (18 x LM + 0.8 x NC + 25 x LP) x P ....(3)

In which:

LM = Main pipe length (km)

NC = Number of house connections or tapping

LP = Average length of service pipe from house connections in customer parcels multiplied by the number of SR (km)

P = Average pressure (m3)

III. Research Methods

Data collection, then the data collection technique can be done by interview (interview), questionnaire (questionnaire), observation (observation), and a combination of the three of them:

- The flow data and input volume of this system are carried out for 1 x 24 hours, these activities are carried out to determine fluctuations in customer water usage and determine the water cubic distributed for the measured area for 24 hours. Readings are carried out using an Ultrasonic Flow Meter (UFM) [9].
- Map or As-Built Drawing from the planning section

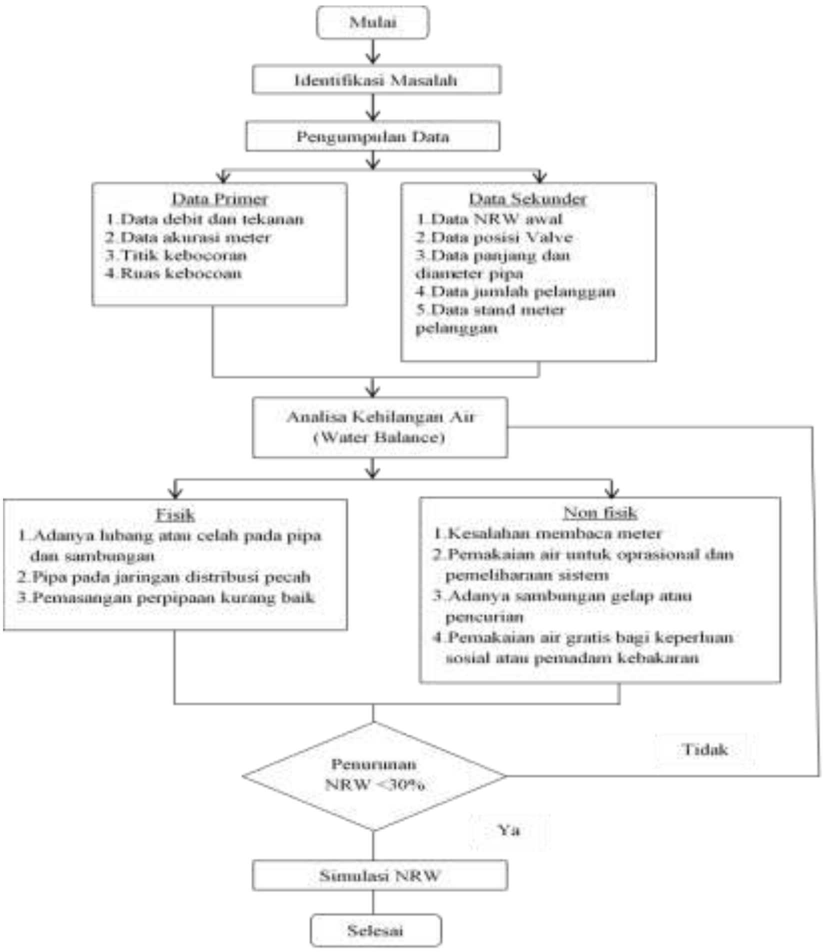

Figure 2. *Research Flowchart*

The loss of clean water in the process of distribution and service of clean water to customers which is not shown by the existence of a physical flow out of the distribution and service network system, including:

1. Improper use on customers.
   In the use of water by customers, there is often an unreasonable use of water. Due to the lack of customer awareness of water meter ownership, whether the water is used or not.
2. Water meter inaccuracy
   The number of meters of water needed in each customer area of PDAM Tirta Giri Nata, Cirebon City. Which causes the water meter stock is not adequate to be paired with each other with the same brand or type. However, the level of accuracy must be in accordance with SNI and function properly.
3. Meter reader error.
   Meter reader errors occur due to poor water meter conditions, such as the water meter is dewy and it is difficult to read the water meter numbers.
4. Illegal connection
   It is an act that is considered a violation of criminal law because the water used or used by the customer is water from the theft, which causes illegal connections in the field is an economic factor, when water needs must be met every day but cannot afford to pay, resulting in illegal connections that can occur harm the customer.

IV. Results and Discussion

The research location is Bumi Kepongpongan Indah Regency, Talun, Cirebon, West Java Province. The choice of research location was because PERUMDA for Drinking Water Tirta Giri Nata, Cirebon City had a water loss rate of more than 30%. In Bumi Kepongpongan Indah Regency, Cirebon, the area of Perumda Water Drinking Tirta Giri Nata, Cirebon City with a distribution pipe length of 100mm or 4” along 895 meters originating from the edge of the 225 mm pipe, the number of customers is 204 SR, and is a customer whose flow is not 24 hours, in February 2020 was relatively high, which was 50.92%.

Figure 3. *Map of Bukepin Regency DMA Network*

4.1 District Meter Area (DMA) Establishment Process

In the implementation of the reduction of Non Revenue Water (NRW) at Bumi Kepongpong Indah Regency, Cirebon, Tirta Giri Nata Drinking Water Company, Cirebon City, preparations were made, including:

- Prepare a detailed work plan.
- Collect and analyze secondary data.
- Drilling search and valve installation.
- Carry out a field survey.

Figure 4. *Installation of pressure logger data*

Installation of a Pressure Data Logger to measure water pressure in the distribution network for 24 hours to find out the pressure pattern that exists in the distribution network. In addition, from the pressure measurements made, it can also be seen the AMM (Minimum Night Flow) time in the distribution network. In this step, the pressure measurement is carried out for ± 24 hours spreading to several points, either upstream, middle, downstream or random distribution. The pressure measurement is read every 15 minutes by the data logger.

Figure 5. *Map of Bukepin Regency DMA Network*

Customer Verification to find out active customer data contained in the DMA of Bumi Kepongpong Indah Regency, Cirebon, Perumda Air Drinking Tirta Giri Nata, Cirebon City, as many as 204 SRs and there are 9 SRs of non-active customers.

4.2 Handling Non-Physical Water Loss

Water meter accuracy is an activity to measure the accuracy level of the main water meter and registered customers. In the main water meter accuracy activity, it is carried out using a portable test bench, while for meter accuracy the customer uses a measuring vessel to compare the volume recorded by the customer's water meter with the volume of water accommodated from the faucet.

Table 1. Description of water meter accuracy and replacement

Detail	Total SR	Additional Information
Main Meter		Inaccurate because the water that came out did not match the measured numbers, replaced on June 12, 2021
Customer Meter	203	
Accurate number of customer meters	174	
Accurate number of meters	140	
The inaccurate number of meters	34	
The number of meters in which the water comes out is more than the meter reading	4	Disadvantage PDAM. Suggested to be replaced.
The number of meters in which the water comes out is less than the meter reading	30	Profitable PDAM. Suggested to be replaced.
Inaccurate number of customer meters	29	Many house fences are locked and cannot be accurate because the meter in cement or ceramic and the meter is broken

Source: PDAM Cirebon City, 2021

During the meter accuracy activity, 1 SR was found with the status unplugged but there were still meters and service pipes installed. After being traced, the customer has a history of being uprooted in 2011 with a lift stand of 2,586 m3. Stand meter as of 19 June 2020 6,770 m3 (used 4,184 m3 for 9 years).

Customer data:
Name : Denjaya
Brand of Tool : Lianly
No samb/lang : 1917150140/051892
Long time the meter is not billed : 9 tahun
No Meter/ factory : O/00000333/09515092
The next process is carried out by changing the status on the master (from unplug active), the amount of the bill for 9 years is Rp. 23,938,430,-

4.3 Handling Physical Water Loss

Isolation of a leakage control area is intended to prepare a certain area (DMA) so that the level of leakage can be monitored and measured. The implementation of DMA isolation includes:

1. Provide map As – Built drawing network complete with consumer maps and consumer data. Includes a map of pipe diameters and lengths.
2. Fixed As-Built drawing map drawing if new network/pipe is found.
3. Check the condition of the isolation and recirculation valves.
4. Determine the location and length of the pipe and the location of the isolation and circulation valves.
5. Checking the number of house connections within the district.
6. Monitoring equipment installation and repair:
   a. Repair/replace broken valve.
   b. Installing a new valve
   c. Installing a replacement pipe
   d. Making/installing protective boxes for district meters.
7. Reviewing the district boundaries in more detail and carefully.
8. Installing district water meter/leakage meter.
9. Install a manometer measuring water pressure in certain places.

Step test is a technique to find the location or area with the largest amount of water loss in the District Meter Area (DMA). Steptest is a method that is applied as a network scoping step in an effort to narrow the area / area of water flow to estimate the location and magnitude of water leaks.

Table 2. Steptest activity results

STEP	VALVE STATUS	MONITORED PIPE LEAKS	EXECUTION TIME		VOLUME	DEBIT	DEBIT DIFFERENCE (dQ)	TOTAL SR	dQ/dSR	LEVEL OF LEAK
			TIME	(dtk)	(L)	(L/dt)	(L/dt)	dSR		
0	ALL OPEN	ALL	01.02	42,31	100	2,364	2,364	183	0,013	MEDIUM
1	CLOSE V10	GREEN	01.22	26,96	50	1,855	0,509	38	0,013	MEDIUM
2	CLOSE V18	CYAN	01.37	73,66	100	1,358	0,497	55	0,009	MEDIUM
3	CLOSE V19	RED	01.52	65	50	0,769	0,588	5	0,118	HIGH
4	CLOSE V27	PURPLE	02.32	75	50	0,667	0,103	29	0,004	LOW
5	CLOSE V36	YELLOW	02.55	24	10	0,417	0,250	34	0,007	MEDIUM
6	CLOSE V3	BLUE	03.00	34	10	0,294	0,123	22	0,006	MEDIUM
7	CLOSE V1	DARK YELLOW				0	0,294	0	0,294	HIGH
7	OPEN V1	DARK YELLOW				0,294	0,294	0,000	0,294	HIGH
6	OPEN V3	BLUE	03.31	26	10	0,385	0,091	22	0,004	LOW
5	OPEN V36	YELLOW	03.51			0,926	0,541	34	0,016	MEDIUM
4	OPEN V27	PURPLE	4:12			2,009	1,083	29	0,037	HIGH
3	OPEN V19	RED	4:28			2,344	0,335	5	0,067	HIGH
2	OPEN V18	CYAN	4:40			2,879	0,535	55	0,010	MEDIUM
1	OPEN V10	GREEN	04.55			3,564	0,685	38	0,018	MEDIUM

Source: Processed Data, 2021

With standard dQ/dSR that is:

• 0,001 – 0,004 = Low Water Loss

• 0,005 – 0,01 = Moderate Water Loss

• > 0,02 = High Water Loss

4.4 Simultaneous Meter Reading

Water Balance Zero (WB 0) is the water balance before the program is implemented. WB 0 is carried out to determine the amount of water distributed from the inlet pipe and the amount of water consumed by customers at a time where the difference between the two is an indication of leakage. The method used in this Water Balance activity is simultaneous meter reading on the main meter and customer meter. This method is done by comparing the readings on the Main Meter with the customer meter readings

Table 3. Water meter reading

Meter reading	**Usage (m3/day)**	**NRW (m3)**	**Percent**
Main WM	408,532		
Read customer WM (140 SR)	121,5889		
Estimated water usage 64 SR	55,5834	188,1596	46%
Estimated Water Loss Due to Leaks	43,2		

Source: PDAM Cirebon City, 2021

$$x\%\ water\ loss = \frac{(Vol.\ \ Main\ WM - Vol.\ Customer\ WM)}{Vol.\ Main\ WM}$$

$$x\%\ water\ loss = \frac{(408{,}532 - 220{,}3723)}{408.532} = 46\%$$

From the results of the handling of non-physical water loss that has been carried out, it is known that the percentage of NRW in DMA Bumi Kepongpongan Indah Regency is still high (> 30%). For this reason, the activities of handling water loss at DMA Bukepin Regency are still continuing with the handling of physical water loss.

4.5 Pressuring Reducing Valve (PRV) Instrument Installation

Activities to reduce Non-Reducing Water (NRW) in the Meter Area (DMA) District of Bumi Kepongpongan Indah Regency, Cirebon, both physical and non-physical with a water loss rate that was originally 46% in June 2020 to 25% in August 2020. With a decrease in Non-Reducing Water RevenueWater (NRW) that happened is certainly not the end of implementation of Non-RevenueWater (NRW) reduction. In order for the implementation of the reduction of Non-Revenue Water (NRW) to be sustainable, it is necessary to measure pressure to be able to determine the level of water loss in the future. For pressure measurement, a Pressure Reducing Valve (PRV) tool is needed which functions to regulate a gas or liquid fluid pressure system from a high pressure source system, so as to produce a lower pressure according to the needs of a system. From the data obtained before and after the installation of Pressure Reducing Valve (PRV) in various areas such as upstream, middle, and downstream areas.

The pressure before the Pressure Reducing Valve (PRV) was installed reached a maximum of 27.5 m or 2.75 bar and a minimum of 5.2 m or 0.52 bar. This can lead to very high leakage rates. It can be seen in table 4 upstream below.

Table 4. Upstream part of the PRV installation

Date	Time	Before Pressure (M)	After Pressure (M)
19-May-20	14:15	5,2	4,097
19-May-20	15:15	13	2,898
19-May-20	16:15	19	2,898
19-May-20	17:15	20	2,698
19-May-20	18:15	22,7	2,498
19-May-20	19:15	24,4	2,498
19-May-20	20:15	26	2,498
19-May-20	21:15	26,6	2,398
19-May-20	22:15	27,5	2,398
19-May-20	23:15	26,7	2,398
20-May-20	0:15	27,1	2,298
20-May-20	1:15	27,5	2,298
20-May-20	2:15	28	2,298
20-May-20	3:15	23,7	2,198
20-May-20	4:15	21,6	2,198
20-May-20	5:15	21,4	3,897
20-May-20	6:15	5,1	4,097
20-May-20	7:15	5,5	4,797

Source: Processed, 2021

The pressure drop that occurred before the installation of the PRV instrument upstream in Block T.14 Bumi Kepompongan Indah Housing with a decrease during normal hours was relatively the same, which was about 2.9 meters.

Table 5. Center of PRV installation

Date	Time	Before Pressure (M)	After Pressure (Bar)
19-May-20	14:15	5,5	2,598
19-May-20	15:15	12,5	7,295
19-May-20	16:15	19,7	11,292
19-May-20	17:15	20,8	20,786
19-May-20	18:15	22,7	13,391
19-May-20	19:15	24,2	14,49
19-May-20	20:15	26,2	15,489
19-May-20	21:15	26,7	12,791
19-May-20	22:15	27,4	13,291
19-May-20	23:15	26,9	12,991
20-May-20	0:15	27,3	13,291
20-May-20	1:15	23,7	13,391
20-May-20	2:15	28,2	13,691
20-May-20	3:15	25,4	12,292
20-May-20	4:15	20,7	10,393
20-May-20	5:15	21,3	19,187

20-May-20	6:15	5,2	-0,5
20-May-20	7:15	5,7	-0,4

Source: processed, 2021

The pressure drop that occurred before the installation of the PRV instrument in the middle of Block T.14 Bumi Kepompongan Indah Regency with a decrease during normal hours was relatively the same, which was about 12.9 meters.

Table 6. Downstream of PRV installation

Date	Time	Before Pressure (M)	After Pressure (Bar)
19-May-20	14:15	5	-0,1
19-May-20	15:15	12,2	4,1
19-May-20	16:15	19,5	10,7
19-May-20	17:15	19,9	10,9
19-May-20	18:15	21,9	10,5
19-May-20	19:15	23,2	11,4
19-May-20	20:15	25,2	11,6
19-May-20	21:15	25,7	11,6
19-May-20	22:15	26,6	11,6
19-May-20	23:15	25,8	11,7
20-May-20	0:15	26,2	11,7
20-May-20	1:15	26,6	11,8
20-May-20	2:15	27,1	11,8
20-May-20	3:15	24,4	11,8
20-May-20	4:15	20,8	11,2
20-May-20	5:15	20,6	9,8
20-May-20	6:15	4,5	-0,1
20-May-20	7:15	4,7	4,1

Source: processed, 2021

The pressure drop that occurred before the installation of the PRV instrument in the middle of Block T.14 Bumi Kepompongan Indah Regency with a decrease during normal hours was relatively the same, which was about 11.8 meters.

Table 7. Decreased water loss resulting from NRW activities and PRV installation

Water Loss Data Period	Cubic (m3) / day	%
Water loss (m3) June 2021	188,16	46%
Water loss (m3) August 2021	50,08	25%
Water loss (m3) February 2021	41,32	20%

Source: processed, 2021

Decrease in water loss by 20% in February 2021 or around 41.32 m3 per day.

4.6 NRW Decrease Simulation

Simulation of NRW reduction can be done by using the EPANET 2.0 application which uses the basic Hazen-Williams formula. Simulations and analyzes were carried out at the research location in the DMA Bumi Kepongpongan Indah Regency, Cirebon district, including:

a. The flow conditions in the study area are the flow conditions at the beginning of the flow, peak hours, and minimum night flow hours.
b. The peak hour factor used is 1 based on fluctuations in water usage from the main meter reading data x 18 hours.
c. The minimum pressure in the network is 0.7 bar.
d. The average discharge fluctuation is 3.23 l//s with a total cubic of 209.376 m3/day.
e. Other technical standards in hydraulic analysis refer to the Minister of Public Works Regulation No. 18 of 2007

Flow conditions in the study area during the initial hours of flow Conditions of flow during the initial hours of flow, because the Bumi Kepongpong Indah Regency area is a customer with a flow of less than 24 hours, so the flow starts at 14:00 WIB.

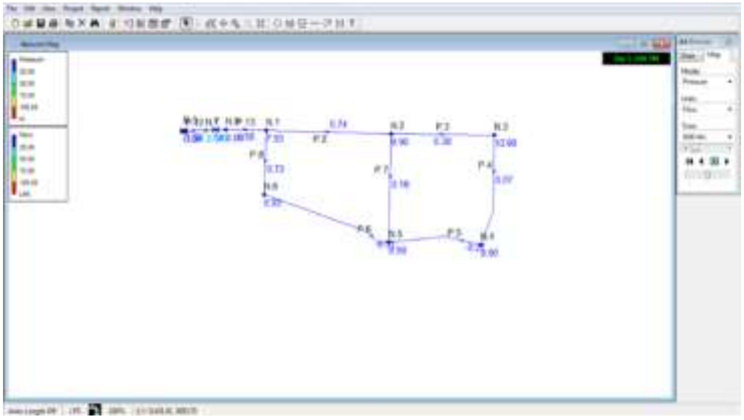

Figure 6. *Flow conditions at the initial hour of flow*
Source: Data processed, 2021

Figure 6 above can be seen in starting the flow simulation, we can do the settings on the PRV section because the function of the PRV is to regulate a gas or liquid pressure system from a high pressure source system, so as to produce a lower pressure according to the needs of a system. So that it is set to a pressure of 8 meters or 0.8 bar accordingly (Ministerial Decree No. 18 of 2007), from the flow simulation above shows that the initial flow hour is at 14.00 WIB with a maximum pressure of 1.09 bar, and a minimum pressure of 0.793 bar.

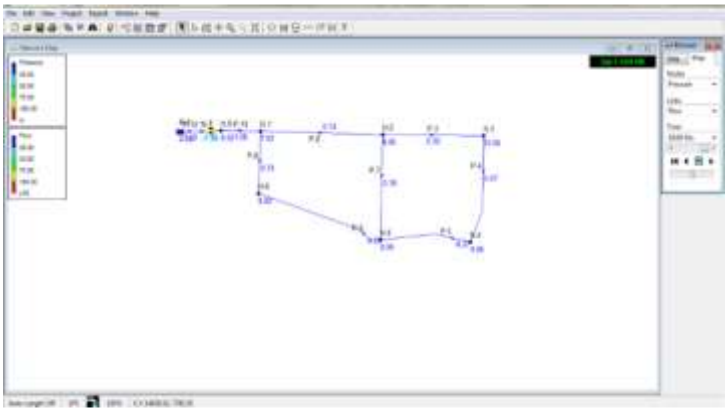

Figure 7. *Flow conditions at peak hours*
Source: Data processed, 2021

Figure 7 shows that the flow conditions at the time of peak flow are at 05.00 WIB with a maximum pressure of 1.090 bar, and a minimum pressure of 0.793 bar. Due to the flow in this area < 24 hours, so that the pressure during peak hours is still quite large, this is done so that after the flow is complete the customer can still collect water in the reservoir.

The average discharge fluctuation is 18 hours, so the water pressure in Bumi Kepongpongan Indah Regency, Cirebon district, decreases. Water pressure that is too high can also increase the rate of water loss, with lower water pressure it can also reduce water loss in Bumi Kepongpongan Indah Regency, Cirebon district.

Table 8. Debit Measurement Data

No	Time	Stand Meter	Difference Cubic	L/s	Fluktuasi
1	14:15:00	243502,00	11,52	3,2	0,9903
2	15:15:00	243513,52	12,6	3,5	1,0832
3	16:15:00	243526,12	13,32	3,7	1,1451
4	17:15:00	243539,44	15,552	4,32	1,3370
5	18:15:00	243554,99	13,32	3,7	1,1451
6	19:15:00	243568,31	12,384	3,44	1,0646
7	20:15:00	243580,70	11,88	3,3	1,0213
8	21:15:00	243592,58	12,24	3,4	1,0522
9	22:15:00	243604,82	10,44	2,9	0,8975
10	23:15:00	243615,26	9	2,5	0,7737
11	0:15:00	243624,26	10,08	2,8	0,8665
12	1:15:00	243634,34	8,28	2,3	0,7118
13	2:15:00	243642,62	8,64	2,4	0,7427
14	3:15:00	243651,26	10,8	3	0,9284
15	4:15:00	243662,06	12,24	3,4	1,0522
16	5:15:00	243674,30	12,6	3,5	1,0832
17	6:15:00	243686,90	12,96	3,6	1,1141
18	7:15:00	243699,86	11,52	3,2	0,9903
	Total Cubic		**209,376**	**M3/Hr**	

Source: Data processed, 2021

The average discharge fluctuation for 18 hours is 3.23 l/sec with a total cubic of 209.376 M3/day, it is known that the flow fluctuation for 18 hours at Bumi Kepongpongan Indah Regency is a maximum discharge of 4.32 l/sec, a minimum flow of 2.4 l/s , and an average discharge of 3 l/s.

V. Conclusion

Based on Simultaneous Meter Readings (WB 1), it was found that the water loss in the DMA was 25%, the NRW value was relatively low (<30%) from the original 50.92% water loss. The installation of a Pressure Reducing Valve (PRV) can help reduce the level of Non-Revenue Water (NRW) which was originally 46% to 20% which was analyzed from the activities of the Non-Revenue Water (NRW) team for Drinking Water Local Residence. The research area is the flow conditions at the beginning of the flow, peak hours, and minimum night flow hours. The peak factor used is 1 based on Ministerial Decree No. 18 of 2007. The maximum pressure is 1.090 bar and the minimum pressure in the network is 0.7 bar. The average discharge fluctuation is 3.23 l//s with a total cubic of 209.376 m3/day.

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