Volume 2, No. 10 October 2023 - (1179-1195)
p-ISSN 2980-4868 | e-ISSN 2980-4841
https://ajesh.ph/index.php/gp

WATER DISTRIBUTION SYSTEM MANAGEMENT IN DISTRICT METERED AREA (DMA) KALIPURO 5

[1*] Irma Rahmania Mahardini, [2] Bieby Voijant Tangahu
[1,2] Department of Environmental Engineering, Institut Teknologi Sepuluh Nopember
Emails: mahardini.ir@gmail.com

ABSTRACT:
Water supply system is an important infrastructure that needs improvement in water distribution networks efficiency, along with energy consumption and water losses. DMA Kalipuro 5 is formed to improve the management of water distribution system by monitoring the water flows into the district. This program is supported by pressure management, repairs, active leakage control, and asset management. Water balance is the first step to reduce the water losses. From the water balance of DMA Kalipuro 5 calculated in January and September 2022, the percentage of water losses decreases 7,02%, from 62,55% to 55,53%. The percentage of physical water losses also decreases 7,06%, from 62,32% to 55,26%. Pressure management is conducted in order to reduce the physical water losses by installing pressure reducing valve (PRV). From the simulation of existing water distribution network, installing PRV can reduce the highest pressure from 108,82 meters to 58,42 meters.

Keywords: District Metered Area, EPANET, Non Revenue Water, Pressure Management, Water Losses

INTRODUCTION

Water supply system is an important infrastructure that provide water to residents, industry, and other public utilities. The management and maintenance of the water distribution network is increasing attention on environmental issues and sustainable development strategies. The complexity of the system is because of many factors such as large size (up to thousand pipes), the hydraulic function and asset condition from the original installation. The urban area expansion and information growth on water distribution system are increasing the complexity of analysis, management and planning (Laucelli et al., 2016). The greatest interest nowadays is the improvement of water distribution networks efficiency, along with energy consumption reduction and water losses. Water loss is the difference between the overall amount of water supplied in the network and the water volumes to the customer consumption recorded by the flow meters (Galdiero, 2015).

Based on Regional Regulation of Banyuwangi Regency Number 2 Year 2018 about Perusahaan Umum Daerah Air Minum Kabupaten Banyuwangi, Perumda Air Minum Kabupaten Banyuwangi is a regional public company that conducts business in drinking water field or other business for public benefit for regional economy development and obtaining profits. It has six branches, including central Banyuwangi which service area including Kalipuro Sub-district. In Kalipuro Sub-district has been made five District Metered Area (DMA) supplied by Kalipuro Reservoir.

DMA is a technique to improve the management of water distribution system. To make the disctrict, we put isolation valves to disconnect one DMA to another and place a flow meter in the DMA entrance. From the measured inflow and outflow of the DMA, we can determine the water balance of the DMA and monitor the minimum night flows. The information obtained is used to identify the leakage within the district and to locate and repair the leakage more efficiently (Alvisi & Franchini, 2014); (Diao et al., 2013).

Water losses is influenced by many factors depends on water supply companies. Density of connections, age of pipe network, length and layout of the water distribution network, the type of distribution network (gravity or pumping), time detection and removal of the leakage (Ociepa et al., 2019).

Water balance is the first step of water losses reduction program. Water balance can be used to know the water losses conditions by knowing the details of water components using WB-EasyCalc program. This program expressing the equation of the water coming in and out of the system (Setianingsih & Karnaningroem, 2019). WB-EasyCalc is not only ask for physical data, but also the accuarcy of that data. Using this estimates, the software calculates its various components in addition to the accuracy of these components. The standard water balance by International Water Association (IWA) is possible to monitor the real water loss and its components, including NRW. However, fulfilling the water balance table needs detailed data which in most developing countries the data is estimated (Yilmaz et al., 2021).

Water loss is a gap between system input volume and authorized consumption. Water loss is the amount of non-physical (commercial) water loss and physical water loss (Azwar et al., 2021). NRW indicates the efficiency of a water supply system. The physical losses is affected by the total amount of water used, system pressure, and the continuity of water supply. Meanwhile commercial losses or non-physical water losses is affected by illegal connections and meter accuracy (Mulay et al., n.d.). Non-revenue water (NRW) is water entered the system but not billed. The important component of NRW is the leakages occur based on reported and unreported incidents. In the water distribution system where the rates of old pipe are high, the leakages are genereally high, which increases the system operating cost (Durmuşçelebi et al., 2020).

The four pillars of leak management strategies are pressure management, repairs, active leakage control, and asset management. These factors influence how leakage is managed. Active leakage control is important to cost effective and efficient leakage management. The concept is monitoring flows into zones or DMA where leak location should be undertaken. The quicker we can analyse DMA flow data, the quicker leaks can be located. This strategy along with speedy repair limits the total volume of water lost (Farley et al., 2008).

Pressure management is a basic method to manage water losses in water distribution system. The most used method to reduce pressure is using a time-modulated or flow-modulated pressure reducing valve (PRV) in a selected network zone to control upstream and downstream pressures (Mathye et al., 2022).

Establishing DMA is not only for reducing NRW, but also improve the water pressure within DMA. Improved presssure control can reduce leakages and stabilize system pressures which increase asset life. Most pipe bursts occur not because of high pressure, but due to ongoing pressure fluctuations that force pipe to continually expand and contract. Installing PRV helps to reduce pressure through the day, stabilize fluctuations, and reduce pipe stress. The main benefits of water losses reduction are reducing water treatment cost, increasing revenue water, postponing investment for new water distribution infrastructure, protecting water quality, reducing pipe leakage, extensing pipe service life, and improving customer satisfaction (Selek et al., 2018).

To evaluate the water distribution system, we use a mathematical simulation that represents the real system. Using simulations, problems can be anticipated and solutions can be proposed to evaluate before time, money, and materials are invested in a real project. The type of simulations can be steady-sate or extended-period. Steady-state simulation is used to determine the operating behavior of a system in a static conditions. The extended-period simulation is used to evaluate system performance over time. This simulation lets the user to model valve regulation, pressures and flow rate changing in the system to know the varying conditions and formulating the strategies (Walski et al., 2003).

One of the most used software to analyse water distribution system is EPANET, because of its open source program that can simulate static and dynamic simulation of network models, presenting the behavior, and let the users know about the water consumption to help choosing the best operating condition for the system (Marques et al., 2023).

The decision to solve the problem must be decided after conducting studies that can improve the existing condition. The decision have to consider the optimal hydraulic design based on pressure head at nodes and flow velocity in the links. To optimalize the network, further studies can be done by conducting analysis using various parameters (Ajaz & Ahmad, 2023).

The hydraulic simulation of existing network is evaluated with design criteria based on Regulation of Minister Od Public Works Number 27 Year 2016 about Operation of Water Distribution System. Based on the regulation, design criteria for pressure is set in a minimum value of 10 meters or 1 bar up to 60 meters or 6 bar, and a minimum flow velocity with a value of 0,30 m/s up to 3 m/s. The percentage of water losses also being evaluated based on this regulation, that maximum leakage rate in primary distribution network is not more than 20%. When the pressure criteria is sufficient for water distribution based on government regulation, it is generally become an efficient water distribution network (Vasudevan, 2018).

RESEARCH METHODS

A. Study Location

The location taken for this research is DMA Kalipuro 5 in Kalipuro Sub-District. It is belong to Central Banyuwangi service area of Perumda Air Minum Kabupaten Banyuwangi and administratively located in Klatak Village, Kalipuro Sub-District. This village is a lowland with average elevation is 7 meters above sea level (Central Bureau of Statistic, 2016). This DMA is supplied by Kalipuro Reservoir in Kalipuro Village with elevation of 142 meters above sea level. Service area boundaries of DMA Kalipuro 5 shown in Figure 1.

Figure 1. DMA Kalipuro 5 Service Area

B. Methods

The first step of this research is collecting the primary and secondary data. The primary data needed is pressure measurement in field using manometer, meanwhile the secondary data needed are administration map of DMA Kalipuro 5, existing water distribution network map of DMA Kalipuro 5, water supply data from Kalipuro Reservoir to DMA Kalipuro 5, water consumption pattern of DMA Kalipuro 5, pressure in existing water distribution network using pressure logger, number of customers in DMA Kalipuro 5, and number of water consumption by customer in DMA Kalipuro 5.

Table 1
Number of Customer, Customer Water Consumption, and Volume of Distributed Water

Month	Number of Customer	Volume of Customer Water Consumption	Volume of Distributed Water
Jan'22	663	11.391	30.444
Peb'22	689	9.664	28.456
Mar'22	690	14.141	28.320
Apr'22	687	15.451	25.645
Mei'22	687	12.880	26.789
Jun'22	683	13.953	28.358
Jul'22	688	14.795	28.988
Agt'22	685	15.301	29.601
Sep'22	683	12.669	28.510

The data obtained from data collection will be processed to calculate the difference between water distributed and water consumed by customer using water balance software called WB EasyCalc. Then, evaluating the existing water distribution system using EPANET 2.2 to know the velocity and pressure through simulation and calibrate it with data taken in the field. The data needed for this analysis are length of pipe, diameter of pipe, pipe material, elevation, and base demand.

RESULTS AND DISCUSSION

A. Water Balance Calculation

Water balance is the first step in water losses reducing program. Water balance can be used as a framework for assesing water losses condition. The water balance calculated in 2 month, January and September 2022 to know the effect of making DMA and efforts done to reduce water losses within DMA from January untuk September 2022. The water balance can be seen in Figure 2 and 3 below.

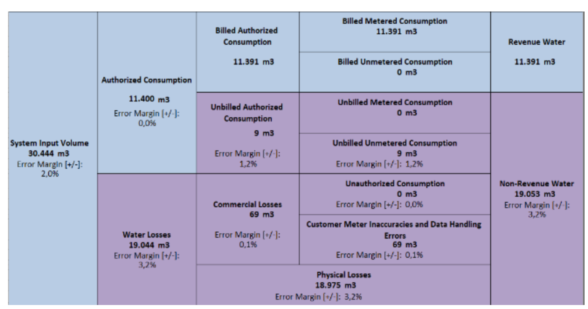

Figure 2. Water Balance of DMA Kalipuro 5 in January 2022

The water balance for January 2022 is described as follows:

1. The volume of water input into the system is the monthly volume input into the water supply system. System input volume in January 2022 is 30.444 m^3/month.

2. Authorized consumption is the monthly volume of metered and unmetered water taken by registered customers, water suppliers, and others, for example water used in fire hydrants and others. The authorized consumption for January 2022 is 11.400 m^3/month.

3. Water losses is the input volume of the system minus the authorized consumption. Water losses consists of physical losses and commercial losses. Water losses in January 2022 is 30.444 m^3/month – 11.400 m^3/month = 19.044 m^3/month. If converted in percentage, it is 62,55%.

4. Billed authorized consumption is the monthly metered or unmetered volume of water used by registered customers. Billed authorized consumption in January 2022 is 11.391 m^3/month.

5. Unbilled authorized consumption is the authorized consumption minus the billed authorized consumption. So the calculation of unbilled authorized consumption in January 2022 is 9 m^3/month.

6. Billed metered consumption is commonly referred as customer subscription of 11.391 m^3/month.

7. Billed unmetered consumption is billed authorized consumption minus billed metered consumption. So the calculation for billed unmetered consumption is 11.391 m^3/month – 11.391 m^3/month = 0 m^3/month.

8. Revenue water is billed metered consumption plus unbilled metered consumption. So the calculation for revenue water in January 2022 is 11.391 m^3/month + 0 m^3/month = 11.391 m^3/month.

9. Non revenue water is the system input volume minus revenue water. So the calculation for non revenue water in January 2022 is 30.444 m^3/month – 11.391 m^3/month = 19.053 m^3/month.

10. Unbilled metered consumption is the use of water for customers who have meters installed but the Perumda Air Minum Kabupaten Banyuwangi policy does not charge a fee fot water usage or it is free. Currently, in the DMA Kalipuro 5 there is no unbilled metered consumption, so the unbilled metered consumption in January 2022 is 0 m^3/month.

11. Unbilled unmetered consumption is all authorized consumption that is neither billed nor metered. This component usually used for the operation of Perumda Air Minum Kabupaten Banyuwangi such as pipe washing, pipe testing, and so on. The calculation of unbilled unmetered consumption is the unbilled authorized consumption minus unbilled metered consumption of 9 m^3/month.

12. Unauthorized consumption is known as illegal connections or water theft, meter bypasses, use of unofficial hydrants, and so on. Unofficial consumption in January 2022 is 0 m^3/month.

13. Customer meter inaccuracies and data handling errors are non-physical (commercial) water losses due to customer meter inaccuracies and meter readinf errors. Meter inaccuracy and data handling error in January 2022 is 69 m^3/month.

14. Non-physical water losses (commercial losses) are unauthorized consumption added with meter inaccuracies and data handling errors. So the calculation of non-physical water losses in January 2022 is 69 m^3/month. If converted into a percentage, it is 0,22%.

15. Physical losses are the volume of water losses thriugh all kind of leaks, explosions and overflows in pipes, and so on. The calculation of physical water losses is water losses minus non-physical water losses. So the calculation of physical water losses in January 2022 is 19.044 m^3/month – 69 m^3/month = 18.975 m^3/month. If converted into a percentage, it is 62,32%.

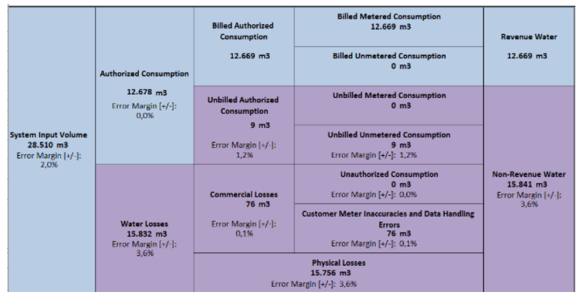

Figure 3. Water Balance of DMA Kalipuro 5 in September 2022

The water balance in September 2022 is described as follows:

1. System input volume in September 2022 is 28.510 m^3/month.
2. Authorized consumption in September 2022 is 12.678 m^3/month.
3. Water losses in September 2022 is 28.510 m^3/month – 12.678 m^3/month = 15.832 m^3/month. If converted into a percentage, it is 55,53%.
4. Billed authorized consumption in September 2022 is 12.669 m^3/month.
5. Calculation for unbilled authorized consumption in Septmber 2022 is 12.678 m^3/month – 12.669 m^3/month = 9 m^3/month.
6. Billed metered consumption in September 2022 is 12.669 m^3/month.
7. Billed unmetered consumption in September 2022 is 12.669 m^3/month – 12.669 m^3/month = 0 m^3/month.
8. Calculation for revenue water in September 2022 is 12.669 m^3/month + 0 m^3/month = 12.669

m^3/month.

9. Calculation for non revenue water in September 2022 is 28.510 m^3/month – 12.669 m^3/month = 15.841 m^3/month.
10. Unbilled metered consumption in September 2022 is 0 m^3/month.
11. Unbilled unmetered consumption in September 2022 is 9 m^3/month.
12. Unauthorized consumption in September 2022 is 0 m^3/month.
13. Customer meter inaccuracies and data handling errors in September 2022 is 76 m^3/month.
14. Calculation for non-physical water losses in September 2022 is 76 m^3/month.
15. Calculation for physical water losses in September 2022 is 15.756 m^3/month. If converted into a percentage, it is 55,26%.

From the water balance calculated in January and September 2022, we can know that the water losses percentage decreases 7,02%, from 62,55% to 55,53%. The physical water losses percentage is also decreases 7,06%, from 62,32% to 55,26%. Although the water losses is far from maximum criteria design of 20%, we can conclude that forming DMA is useful for reducing water losses because we can monitor the water usage by customer, simplify the searching of pipe leakage, and optimize the water distribution system.

Physical water losses is known bigger than the non-physical water losses (commercial losses), so we can focused in evaluating and improve it by pressure management.

B. Evaluation of Existing Water Distribution Network

In this study, consumption fluctuations were recorded every hour of the day. This is to determine the customer's daily water consumption pattern. The data used is the result of recorded data from main water meter every hour for 3 months, then the average is calculated to get the customer's average hourly water consumption pattern in a day. The average water consumption and consumption factor of DMA Kalipuro 5 can be seen in Table 2.

Table 2

Average Water Consumption and Consumption Factor of DMA Kalipuro 5

Time	Average Water Consumption (m^3/hour)	Consumption Factor
00.00 - 01.00	34,3	0,88
01.00 - 02.00	34,18	0,88
02.00 - 03.00	34,31	0,88
03.00 - 04.00	35	0,90
04.00 - 05.00	38,6	0,99
05.00 - 06.00	42,89	1,10
06.00 - 07.00	43,32	1,11
07.00 - 08.00	43,47	1,12
08.00 - 09.00	42,19	1,08

Time	Average Water Consumption (m^3/hour)	Consumption Factor
09.00 - 10.00	40,87	1,05
10.00 - 11.00	39,82	1,02
11.00 - 12.00	40,23	1,03
12.00 - 13.00	39,78	1,02
13.00 - 14.00	38,89	1,00
14.00 - 15.00	38,69	0,99
15.00 - 16.00	41,55	1,07
16.00 - 17.00	43,23	1,11
17.00 - 18.00	43,77	1,12
18.00 - 19.00	39,75	1,02
19.00 - 20.00	37,22	0,96
20.00 - 21.00	36,38	0,93
21.00 - 22.00	36,12	0,93
22.00 - 23.00	35,37	0,91
23.00 - 24.00	34,55	0,89

Source: Calculation, 2022

From the table above, we can know that the highest water consumption in DMA Kalipuro 5 occurs in the period of 07.00 – 08.00 and 17.00 – 18.00 with the consumption factor of 1,12. The hydraulic simulation of existing network in DMA Kalipuro 5 is evaluated with design criteria based on Regulation of Minister of Public Works Number 27 Year 2016, pressure with a minimum value of 10 meters or 1 bar up to 60 meters ir 6 bar, and a minimum flow velocity with a value of 0,30 m/s up to 3 m/s. The data used for EPANET analysis are length of pipe, diameter of pipe, pipe material, elevation, and base demand. Number of base demand is calculated based on average water consumption divided by number of customer. From the calculation, we can know that the average water consumption in DMA Kalipuro 5 is 19,54 m^3/bulan.

In calibrating the results of EPANET simulation, we use pressure measurement data in the field using manometer and pressure logger with the following results.

Table 3
Pressure Measurement in DMA Kalipuro 5

Node	Time	Pressure
J28	10.00	50,00
J28	11.00	40,00
J28	12.00	40,00
J28	13.00	30,00
J31	11.00	40,00
J31	12.00	40,00
J32	01.00	31,04
J32	02.00	31,34
J32	03.00	30,84
J32	04.00	27,66
J32	05.00	18,49

Node	Time	Pressure
J32	06.00	14,35
J32	07.00	16,00
J32	08.00	14,90
J32	09.00	18,64
J32	10.00	21,15
J32	11.00	21,62
J32	12.00	20,79
J32	13.00	21,82
J32	14.00	23,30
J32	15.00	19,71
J32	16.00	15,42
J32	17.00	14,45
J32	18.00	15,39
J32	19.00	23,20
J32	20.00	26,07
J32	21.00	26,90
J32	22.00	27,88
J32	23.00	29,82
J32	24.00	30,64

Source: Primary Data, 2022

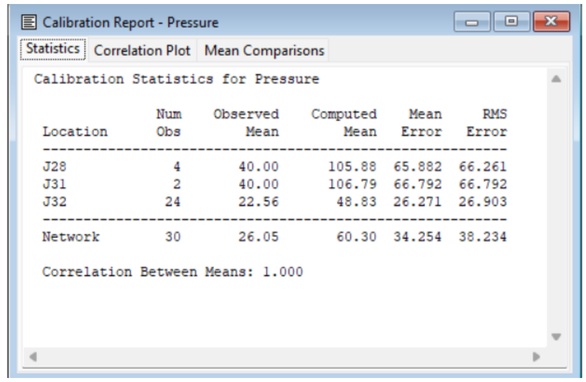

Figure 4. Pressure Calibration Results in DMA Kalipuro 5

From calibration results, a correlation value of 1,000 is obtained. These results concluded that the EPANET simulation is close to the actual situation in the field. The simulation results of existing water distribution system in DMA Kalipuro 5 can be seen in Figure 5, Table 4 and Table 5.

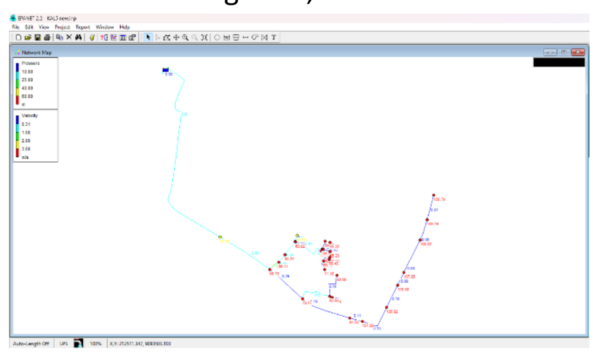

Figure 5. EPANET Simulation Results of Existing Water Distribution System in DMA Kalipuro 5

Table 4

EPANET Simulation Results of Each Nodes of Existing Water Distribution System in DMA Kalipuro 5

	Elevation	Base Demand	Demand	Head	Pressure
Node ID	**m**	**LPS**	**LPS**	**m**	**m**
Junc J32	82	0	0	130,83	48,83
Junc J23	58	0,05	0,05	124,11	66,11
Junc J24	57	0,05	0,05	121,37	64,37
Junc J25	30	0,1	0,1	127,02	97,02

	Elevation	**Base Demand**	**Demand**	**Head**	**Pressure**
Node ID	**m**	**LPS**	**LPS**	**m**	**m**
Junc J26	25	0,1	0,1	126,99	101,99
Junc J27	21	0,05	0,05	126,92	105,92
Junc J28	21	0,05	0,05	126,88	105,88
Junc J29	19	0,05	0,05	126,86	107,86
Junc J30	18	0,05	0,05	126,82	108,82
Junc J31	20	0,5	0,5	126,79	106,79
Junc J1	142	0	0	141,99	-0,01
Junc J2	26	0,1	0,1	126,79	100,79
Junc J3	59	0,5	0,5	127,75	68,75
Junc J4	58	0,1	0,1	116,89	58,89
Junc J5	56	0	0	116,9	60,9
Junc J6	56	0	0	116,82	60,82
Junc J7	47	0,2	0,2	115,59	68,59
Junc J8	49	0,1	0,1	115,63	66,63
Junc J9	49	0,2	0,2	115,41	66,41
Junc J10	49	0	0	115,41	66,41
Junc J11	51	0,25	0,25	115,35	64,35
Junc J12	49	0	0	115,42	66,42
Junc J13	50	0,1	0,1	115,22	65,22
Junc J14	49	0,15	0,15	115,23	66,23
Junc J15	47	0,3	0,3	115,18	68,18
Junc J16	44	0,25	0,25	115,42	71,42
Junc J17	46	0	0	115,48	69,48
Junc J18	46	0,25	0,25	115,43	69,43
Junc J19	48	0,1	0,1	127,17	79,17
Junc J20	37	0,6	0,6	122,84	85,84
Junc J21	37	0,3	0,3	122,93	85,93
Junc J22	39	0,3	0,3	122,69	83,69
Resvr R1	142	#N/A	-4,8	142	0

Table 5
EPANET Simulation Results of Each Links of Existing Water Distribution System in DMA Kalipuro 5

	Length	Diameter	Roughness	Flow	Velocity
Link ID	**m**	**mm**		**LPS**	**m/s**
Pipe L50	2279,75	100	130	4,8	0,61
Pipe L51	629,65	100	130	4,8	0,61
Pipe L31	128,46	50	130	2	1,02
Pipe L33	101,46	50	130	1,95	0,99
Pipe L34	173,76	50	130	1,9	0,97
Pipe L35	542,03	100	130	1	0,13
Pipe L37	139,47	100	130	0,9	0,11
Pipe L39	383,07	100	130	0,8	0,1
Pipe L41	262,33	100	130	0,75	0,1
Pipe L43	149,18	100	130	0,7	0,09
Pipe L45	386,11	100	130	0,65	0,08
Pipe L47	224,31	100	130	0,6	0,08
Pipe L48	268,13	100	130	0,1	0,01
Pipe L49	2,49	100	130	4,8	0,61
Pipe L5	3,4	50	130	1,8	0,92
Pipe L7	93,81	50	130	0,1	0,05
Pipe L10	367,67	75	130	1,8	0,41
Pipe L11	76,14	75	130	0,7	0,16
Pipe L12	88,5	50	130	0,25	0,13
Pipe L14	5,51	50	130	0,2	0,1
Pipe L16	27,08	50	130	1	0,51
Pipe L17	7,8	50	130	0,45	0,23
Pipe L18	59,85	50	130	0,3	0,15
Pipe L19	74,94	50	130	0,55	0,28
Pipe L20	93,11	50	130	0,1	0,05
Pipe L22	85,72	50	130	0,25	0,13
Pipe L23	51,47	50	130	0,5	0,25
Pipe L24	102,53	50	130	0,25	0,13
Pipe L26	464,18	100	130	2,3	0,29
Pipe L28	293,25	50	130	0,3	0,15
Pipe L29	385,23	50	130	1,2	0,61
Pipe L30	29,72	50	130	0,6	0,31

From the simulation results, we can know that lowest pressure occurs at junction J32 of 48,83 m and teh highest pressure occurs at junction J30 of 108,82 m. Also known that the lowest flow velocity occurs at pipe L48 of 0,01 m/s and the highest flow velocity occurs at pipe L31 of 1,02 m/s. To reduce the high pressure, a PRV installation simulation was carried out between junctions J32 and J3 (pipe L51) with a 4 inches diameter and PRV setting pressure of 3 meters. The simulation results can be seen in Figure 6, Table 6 and Table 7.

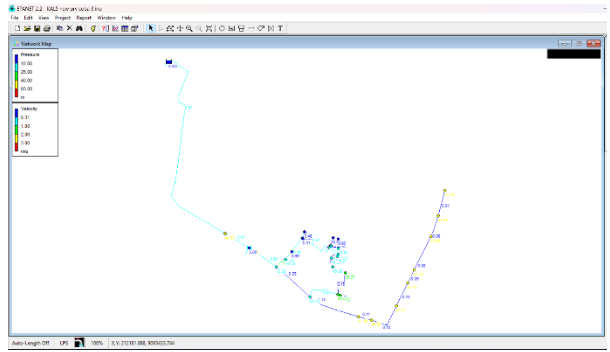

Figure 6. EPANET Simulation Results using PRV in DMA Kalipuro 5

Table 6

EPANET Simulation Results of Each Nodes using PRV in Water Distribution System of DMA Kalipuro 5

	Elevation	Base Demand	Demand	Head	Pressure
Node ID	**m**	**LPS**	**LPS**	**m**	**m**
Junc J33	71	0	0	129,42	58,42
Junc J34	71	0	0	74	3
Junc J32	82	0	0	130,83	48,83
Junc J23	58	0,05	0,05	68,7	10,7
Junc J24	57	0,05	0,05	65,96	8,96
Junc J25	30	0,1	0,1	71,61	41,61
Junc J26	25	0,1	0,1	71,58	46,58
Junc J27	21	0,05	0,05	71,51	50,51
Junc J28	21	0,05	0,05	71,47	50,47
Junc J29	19	0,05	0,05	71,45	52,45
Junc J30	18	0,05	0,05	71,4	53,4
Junc J31	20	0,5	0,5	71,38	51,38
Junc J1	142	0	0	141,99	-0,01
Junc J2	26	0,1	0,1	71,38	45,38
Junc J3	59	0,5	0,5	72,33	13,33
Junc J4	58	0,1	0,1	61,48	3,48
Junc J5	56	0	0	61,49	5,49
Junc J6	56	0	0	61,41	5,41
Junc J7	47	0,2	0,2	60,18	13,18
Junc J8	49	0,1	0,1	60,22	11,22

	Elevation	Base Demand	Demand	Head	Pressure
Node ID	**m**	**LPS**	**LPS**	**m**	**m**
Junc J9	49	0,2	0,2	59,99	10,99
Junc J10	49	0	0	59,99	10,99
Junc J11	51	0,25	0,25	59,94	8,94
Junc J12	49	0	0	60,01	11,01
Junc J13	50	0,1	0,1	59,8	9,8
Junc J14	49	0,15	0,15	59,81	10,81
Junc J15	47	0,3	0,3	59,76	12,76
Junc J16	44	0,25	0,25	60	16
Junc J17	46	0	0	60,06	14,06
Junc J18	46	0,25	0,25	60,01	14,01
Junc J19	48	0,1	0,1	71,75	23,75
Junc J20	37	0,6	0,6	67,43	30,43
Junc J21	37	0,3	0,3	67,52	30,52
Junc J22	39	0,3	0,3	67,27	28,27
Resvr R1	142	#N/A	-4,8	142	0

Table 7
EPANET Simulation Results of Each Links using PRV in Water Distribution System of DMA Kalipuro 5

	Length	Diameter	Roughness	Flow	Velocity
Link ID	**m**	**mm**		**LPS**	**m/s**
Pipe L52	288,3	100	130	4,8	0,61
Pipe L53	340,36	100	130	4,8	0,61
Pipe L50	2279,75	100	130	4,8	0,61
Pipe L31	128,46	50	130	2	1,02
Pipe L33	101,46	50	130	1,95	0,99
Pipe L34	173,76	50	130	1,9	0,97
Pipe L35	542,03	100	130	1	0,13
Pipe L37	139,47	100	130	0,9	0,11
Pipe L39	383,07	100	130	0,8	0,1
Pipe L41	262,33	100	130	0,75	0,1
Pipe L43	149,18	100	130	0,7	0,09
Pipe L45	386,11	100	130	0,65	0,08
Pipe L47	224,31	100	130	0,6	0,08

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s
Pipe L48	268,13	100	130	0,1	0,01
Pipe L49	2,49	100	130	4,8	0,61
Pipe L5	3,4	50	130	1,8	0,92
Pipe L7	93,81	50	130	0,1	0,05
Pipe L10	367,67	75	130	1,8	0,41
Pipe L11	76,14	75	130	0,7	0,16
Pipe L12	88,5	50	130	0,25	0,13
Pipe L14	5,51	50	130	0,2	0,1
Pipe L16	27,08	50	130	1	0,51
Pipe L17	7,8	50	130	0,45	0,23
Pipe L18	59,85	50	130	0,3	0,15
Pipe L19	74,94	50	130	0,55	0,28
Pipe L20	93,11	50	130	0,1	0,05
Pipe L22	85,72	50	130	0,25	0,13
Pipe L23	51,47	50	130	0,5	0,25
Pipe L24	102,53	50	130	0,25	0,13
Pipe L26	464,18	100	130	2,3	0,29
Pipe L28	293,25	50	130	0,3	0,15
Pipe L29	385,23	50	130	1,2	0,61
Pipe L30	29,72	50	130	0,6	0,31
Valve V1	#N/A	100	#N/A	4,8	0,61

After installing PRV, there is a pressure reduction with the lowest pressure occurs at junction J4 of 3,48 m and highest pressure occurs at junction J33 of 58,42 m.

CONCLUSION

Based on the analysis that has been done, we can conclude that the water losses percentage decreases 7,02%, from 62,55% in January 2022 to 55,53% in September 2022. The physical water losses percentage is also decreases 7,06%, from 62,32% in January 2022 to 55,26% in September 2022. Although the water losses is far from maximum criteria design of 20%, we can conclude that forming DMA is useful for reducing water losses because we can monitor the water usage by customer and make it easier to find the pipe leakage. Physical water losses is known bigger than the non-physical water losses (commercial losses), so we can focus in evaluating and improve it by pressure management. From the simulation of existing water distribution system, we can know that lowest pressure occurs at junction J32 of 48,83 m and the highest pressure occurs at junction J30 of 108,82 m. To reduce the high pressure, a PRV installation simulation was carried out between junctions J32 and J3 (pipe L51) with a 4 inches diameter and PRV setting pressure of 2,5 meters. The results are the lowest pressure occurs at junction J4 of 3,48 m and highest pressure occurs at junction J33 of 58,42 m. The result of installing PRV is the pressure decreases in the range of pressure design criteria between 10 and 60 meters.

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First publication right:

Asian Journal of Engineering, Social and Health (AJESH)

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