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RESEARCH PAPER

Water supply network with zonation system in Golo Wua dan Golo Watu Village, Manggarai District

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Abstract. Drinking water sources in Manggarai Regency are mostly supplied from springs. Golo Wua and Golo Watu are two villages in Manggarai Regency that utilize springs. About 12.06 liters/second of drinking water is needed by residents in those villages. This study addresses to forecast the demand of drinking water. This study found that pressure values in manual calculations range from 1.85 meters to 84.22 meters. The minimum pressure requirements from BPP-SPAM is 7 meters (0.7 bar). While the simulation results using the EPANET program, the pressure value is at 1.90 meters up to 84.22 meters. Therefore, the pipe diameter selection is appropriate and the pressure meets the requirements of the BPP-SPAM. The difference between pressure values less than 5% indicates that the selection is the right pipe diameter. Choosing the right pipe diameter will optimize the distribution network in the villages of Golo Wua and Golo Watu. The selected pipe is the high density polyethylene type. Selected pipe diameter 1½"; 2"; 2½"; 3"; 4 and 5". The pipe has a pressure resistance of up to 125 meters.

Keywords: water; distribution; pressure; EPANET

1. Introduction

Water is a necessity of life for the community. Water is used for daily activities such as drinking, bathing, and washing. Efforts to meet drinking water needs can be planned in the form of a drinking water supply system. The drinking water supply system can be managed by a community institution or run by a water company. Community-based drinking water management is called PAMSIMAS. Meanwhile, the management of drinking water by professional institutions is part of the PDAM (Suhono, 2016).

In the Sustainable Development Goals program, clean water and sanitation programs are efforts to ensure access to clean water and sanitation for all (United Nations, 2019). In general, water sources in rural areas can be obtained from wells, springs, and streams. The availability of

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this water depends on the condition of each region. For areas in the highlands and mountains, water can be obtained from springs and wells. Meanwhile, in the lowlands and urban areas, water is obtained from drinking water treatment and drinking water distribution networks from mountain springs (Karnadi, 2010).

Manggarai Regency is an area located in East Nusa Tenggara Province (see Figure 1). This regency has an area of 2,094 km². Manggarai Regency has 12 Districts. Ruteng District is the Capital of this Regency (Zamimiluny, 2020). The drinking water needs in Manggarai are mostly obtained from water sources. The drinking water supply system is in the form of pipelines and public hydrants. The springs are spread in Manggarai Regency. The southern part of the Regency is a mountain range that has elevations above 1000 above sea level. The piped water supply system has been managed professionally by PDAM Tirta Komodo (Tim Konsultan Barn Cita Laksana, 2016).

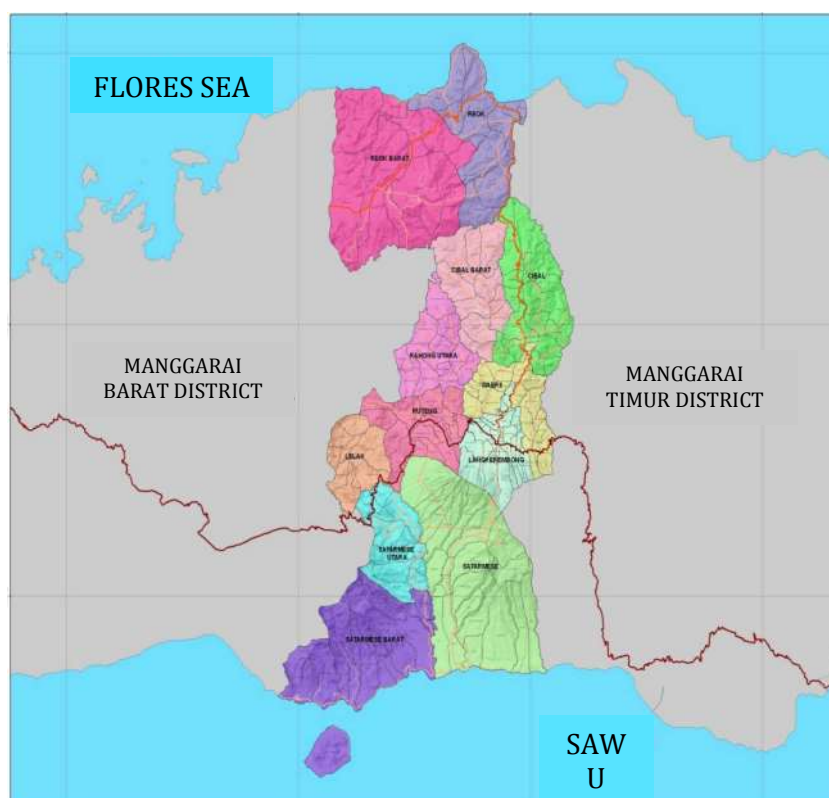


Figure 1. Administrative map of Manggarai Regency (Tim Konsultan Barn Cita Laksana, 2016)

Wae Ri'i and Langke Rembong sub-districts are part of the Manggarai Regency. These two districts have been served by PDAM Tirta Komodo. The clean water supply comes from springs. Water sources are easy to find because these two sub-districts are located at an elevation of 1.000 meters above sea level. One source of spring in this area is called Wae Decer Spring. The Wae Decer spring has an effective elevation of 1,100 meters above sea level. This spring has a reliable discharge of 150 liters/second. As much as 30 Liters per second is pumped to Carep, Satar Tacik, and Mbaumuku village, respectively. The remaining of the spring flow is still large enough for drinking water supply. Therefore, PDAM Tirta Komodo wants to increase the reach of drinking water services by utilizing the remaining capacity of this spring (Utama et al., 2018).

The villages of Golo Wua and Golo Watu are two villages located in the Manggarai Regency. Golo Wua village has a population of 1,017 people and Golo Watu has a population of 2,240 people in 2019 (BPS Kabupaten Manggarai, 2019). The population of each village is projected to increase according to the current year. The population in the village of Golo Wua will increase in 2022, 2027, 2032, and 2036 in a row of 1,172 people, 1,298 people, 1,439 people, and 1,562 people. Meanwhile, the population in Golo Watu Village will increase in 2022, 2027, 2032, and 2036 in a row of 2,491 people, 2,760 people, 3,059 people, and 3,320 people (Barn Cita Laksana, 2016). Based on the projection results, drinking water needs in Golo Wua Village in 2020, 2025, 2030, and 2035 were 5.88 Lps, 6.48 Lps, 7.13 Lps, 7.86 Lps, and 8.20 Lps, respectively. Whereas drinking water needs in Golo Watu Village in 2020, 2025, 2030, and 2035 are 2.77 Lps, 3.05 Lps, 3.35 Lps, 3.70 Lps, and 3.86 Lps (Utama et al., 2018).

Therefore, planning for drinking water distribution networks is needed for these two villages. This will support the improvement of drinking water services in the Manggarai Regency. The two villages will be planned area-based system with one reservoir. The amount of water distributed will adjust to the DMA system (Alvisi & Franchini, 2014).

2. Planning Method

2.1. Wae Decer Spring Survey

Wae Decer Springs is in Carep Village. Carep Village is included in Langke Rembong District. The elevation of this spring is at 1,120 meters above sea level. Measured spring discharge of 150 Lps. This data was obtained from the Drinking water division of the Manggarai Regency Public Works and Spatial Planning Office. The coordinates of these springs are located at 0.80 ° 36 '16,934 South Latitude and 120 ° 28' 54,566 East. At, this spring, the Manggarai Regency Government built a broncapturing. This broncapturing serves to accommodate a part of the spring discharge. As much as 30 Lps is pumped to Carep, Satar Tacik, and Mbaumuku village, respectively. 40 Lps is distributed to Bangka Kenda, Golo Wua, Golo Watu, and Poco Village. The remain of debit 80 Lps is flowed into natural channels and agricultural irrigation channels (Tim Konsultan Barn Cita Laksana, 2016).

2.2. Analysis of Population Data

Population data were obtained from the Central Statistics Agency of the Manggarai Regency. Population data was taken ten years ago. Data is projected for the next 20 years. The projection model uses three commonly used methods. From the results of these projections, the population in the nth year will be multiplied by the amount of drinking water needs. The results of this multiplication will produce the value of water needs in liters per second. The population projection method is as follows:

2.2.1. Arithmetic Method

The arithmetic projection model is population growth which is assumed to be the same every year. The consequence of this model is population growth at a certain time duration will always be constant. The population arithmetic formula is as follows:

$$P_n = P_o + K_a(T_n - T_o) \quad (1)$$

$$K_a = \frac{P_a - P_1}{T_2 - T_1} \quad (2)$$

Where:

P_n = total population in year n

P_o = population in the initial year

T_n = N-year

T_0 = base year

K_a = arithmetic constant

P_1 = number of residents known in year 1

P_2 = total population known in the last year

T_1 = known 1st year

T_2 = known 2nd year

2.2.2. Geometric method

The geometric projection model is population growth that follows arithmetic. Population growth with a geometric model increases gradually in accordance with a large number of the population without regard to the rate of population reduction. The population formula geometrically as follows:

$$P_n = P_o(1 - r)^n \quad (3)$$

Where r is population growth rate, and n is number of year intervals

2.2.3. Least-square method

The least-square projection model is population growth in an area with a high growth rate. This population growth is suitable to be applied in rapidly developing urban areas. The population formula geometrically as follows:

$$y = a + bx \quad (4)$$

$$a = \frac{\sum y \sum x^2 - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \quad (5)$$

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \quad (6)$$

Where y is value of the variable based on regression, x is independent variable, a is a constant, and b is a slope.

2.3. Analysis of Drinking Water Needs

2.3.1. Domestic Water Demand

Domestic water demand is the amount of water needed by households (Makawimbang et al., 2017). Domestic water demand is calculated in the form of house connections. At present, the

planning for drinking water does not include water demand for public hydrants. Household connections are more reliable and precise data to describe the number of base demand nodes. Domestic water demand can be formulated:

$$Q_d = y + S_d \quad (7)$$

Where:

Q_d = household drinking water needs (liters/day)

S_d = Standard drinking water needs of each person (liter/person/day)

y = total population (people)

2.3.2. Non-domestic Water Demand

Non-domestic water demand is the amount of water needed for public facilities and infrastructure (Makawimbang et al., 2017). Public facilities and infrastructure for drinking water supply are houses of worship, schools, and small shops. This happens because the Manggarai Regency is not yet a big city. The availability of public facilities and infrastructure is still in the form of social, public, and small trade facilities. Non-domestic drinking water needs can be formulated:

$$Q_n = Q_d + S_n \quad (8)$$

Where:

Q_n = Non-domestic drinking water needs (liters/day)

Q_d = Domestic water needs (liters/day)

S_n = Non-domestic water requirements (%)

2.3.3. Water loss

Water loss is a leak in the distribution system. This leak can be caused by technical and non-technical factors. Technical leakage is a loss of water due to meter reading errors and physical leakage in the pipe connection. Non-technical leaks are losses of water due to account arrears, water theft, illegal connections, and errors in the recapitulation of water volume in customers. Permissible water loss is a maximum of 20% of the standard (Hadimuljono et al., 2016). Water loss can be formulated:

$$Q_a = (Q_d \times Q_n) \times R_a \quad (9)$$

Where:

Q_a = water loss (liters/day)

Q_d = non-domestic drinking water needs (liters/day)

Q_n = domestic water needs (liters/day)

R_a = water loss percentage (%)

2.3.4. Base Demand for Clean Water

The base demand for clear water is total water needs both domestic and non-domestic plus water losses (Makawimbang et al., 2017):

$$Q_t = (Q_d + Q_n + Q_a) \quad (10)$$

Where:

Q_t = total base demand (liters/day)

Q_d = domestic water needs (liters/day)

Q_n = non-domestic drinking water needs (liters/day)

Q_a = water loss (liters/day)

2.4. Pipe Dimensions

The determination of the dimensions of the pipe is done by technical calculations. The dimensions of this pipe are closely related to the discharge that is flowed in the pipe. In the distribution of drinking water in the villages of Golo Wua and Golo Watu, the distribution system is planned in the form of a drinking water zone. The drinking water zone is chosen because the application is easier in the field. Calculation of pipe dimensions, construction and operation, and maintenance can be simple. The two villages are planned to be a distribution reservoir with two main meters. Water meters are installed at reservoir outlets and water meters at inter-village branching pipes. The distribution reservoir will receive water from the Wae Decer Spring transmission system. The piping dimension calculation is:

$$Q = \frac{1}{4} \pi D^2 \quad (11)$$

Where:

Q = discharge flow in the pipe (Lps)

D = distribution pipe diameter (mm)

After obtaining the dimensions of the pipe, the next step is choosing for the diameter of the pipe, the diameter of the pipe is chosen which is close to the calculation results. Flow rates in distribution pipes range between 0.6 - 1.2 meters/second (Karnadi, 2010). Headloss calculations include major headloss and minor headloss. Major headloss is caused by the friction factor between the flow of water in the pipe. The roughness coefficient of the pipe depends on the material of the pipe (see Table 1). Meanwhile, a minor headloss is a pressure loss due to accessories of pipe, such as gate valve, check valve, curves, reducer and etc (Mays, 2000). Headloss can be calculated with:

$$Q = 0.2785CD^{2.63}S^{0.54} \quad (12)$$

$$\Delta h = K \frac{v^2}{2g} \quad (13)$$

Where:

Q = discharge flow in the pipe (Lps)

C = pipe roughness coefficient

D = distribution pipe diameter (mm)

S = major headloss (meters)

Δh = minor headloss (meters)

K = headloss coefficient of accessories

v = velocity in the pipe (m/sec)

g = gravitational acceleration (9.81 m²/sec)

Table 1. Relative Roughness Coefficient of the Pipe

Materials	C	Materials	C
Brick Sewer	100	Galvanized iron	120
Brass	130 - 140	Plastic	140 - 150
Cast Iron		Steel	
New, unlined	130	New unlined	140 - 150
Cement, lined	130 - 150	Corrugated	60
Concrete	130 - 140	Glass	140
Copper	130 - 140	Tin	130

Sources: Lin and Lee (2007)

Table 2. Minor headloss of accessories

Type	K	Type	K
Bend ^[1]		Check valve ^[1]	2,0 - 2,5
Angle 22,5°	0,11	Gate Valve ^[1]	0,12
Angle 45°	0,19	Tee ^[2]	1,8
Angle 60°	0,25	Reducer ^[2]	0,04 - 0,08
Angle 90°	0,33		

Sources: Mays (2000) and SUEZ (2007)

EPANET V2.0 is used to validate the results of manual calculations. EPANET V2.0 is a software released by US-EPA (Rossman, 2000). Validation is done to ensure that the dimensions of the selected distribution pipe are the optimal dimensions. Optimal dimensions will reduce the potential for distribution errors. Error analysis of distribution can be too slow and over-dimensional. Flow rates that do not meet the over-dimensional standard can occur if the calculation of this dimension has been wrong from the beginning of the plan (Utama et al., 2018). Error tolerance between manual calculation and EPANET V2.0 is planned not more than 5%.

3. Results and Discussion

The determination of the dimensions of the pipe is done by technical calculations. The dimensions of this pipe are closely related to the discharge that is flowed in the pipe. In the distribution of drinking water in the villages of Golo Wua and Golo Watu, the distribution system is planned in the form of a drinking water zone (see Figure 2). The drinking water zone is chosen because the application is easier in the field. Calculation of pipe dimensions, construction and operation, and maintenance can be simple. The two villages are planned to be a distribution reservoir with two main meters. Water meters are installed at reservoir outlets and water meters at inter-village branching pipes. The distribution reservoir will receive water from the Wae Decer Spring transmission system.

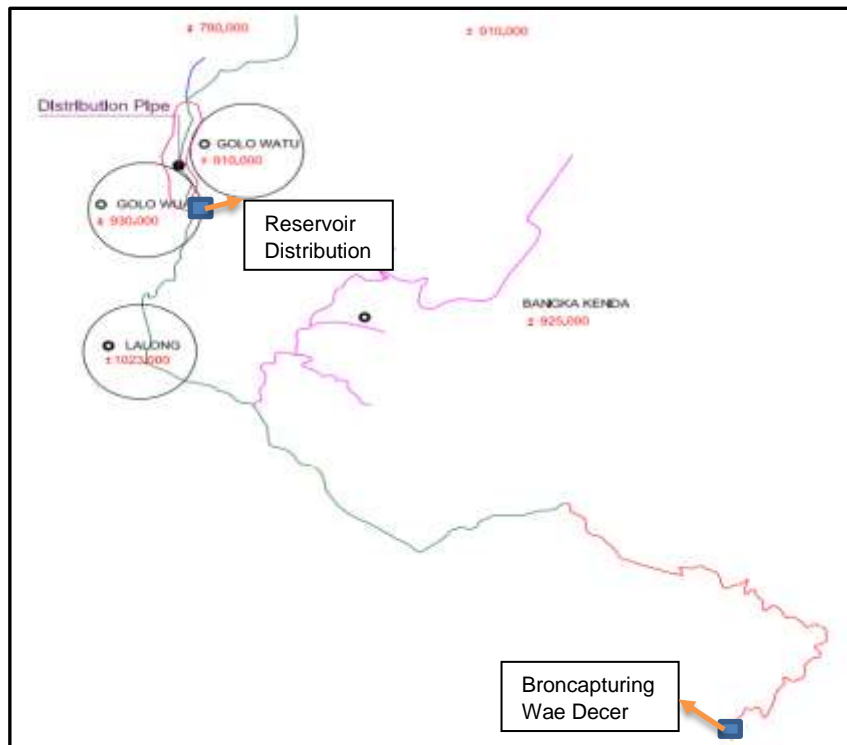


Figure 2. Plan of distribution pipe of Golo Wua and Golo Watu Village

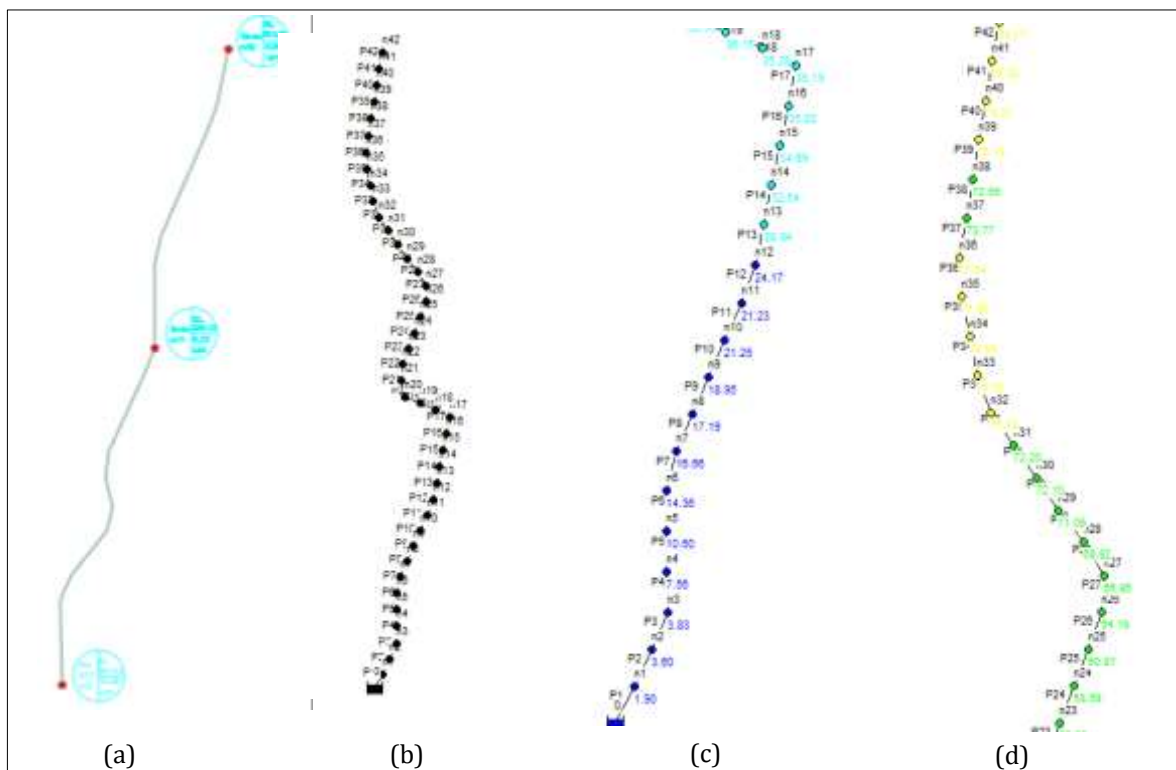


Figure 3. Plan of distribution pipe of Golo Wua and Golo Watu Village. (a) Plan of distribution network, (b) The distribution network on EPANET, (c) Output EPANET of Golo Wua System, (d) Output EPANET of Golo Watu System

The need for drinking water in these two villages is projected based on population. The discharge of water distributed follows the projection results. The water needs of the analysis results are taken from 2020 to 2037. This year's period is listed in the Manggarai Regency SPAM Master Plan. The results of the projected water needs until 2037 is figured in Figure 3.

The need for drinking water in these two villages is projected based on population. The discharge of water distributed follows the projection results. The water needs of the analysis results are taken from 2020 to 2037. This year's period is listed in the Manggarai Regency SPAM Master Plan. Figure 3 shows the results of the projected water needs until 2037.

Table 3. Projection of drinking water needs

Village	Year's				
	2020	2025	2030	2035	2037
Golo Wua	5.88 Lps	6.48 Lps	7.13 Lps	7.86 Lps	8.20 Lps
Golo Watu	2.77 Lps	3.05 Lps	3.35 Lps	3.70 Lps	3.86 Lps

Source: Utama et al. (2018)

In the mainline distribution zone, this pipeline is the main distribution pipe of the reservoir. Water is divided into each village. In the main lane, residents of Golo Wua and Golo Watu villages also live there and build houses so that the main lane is also given drinking water needs. The distribution reservoir is placed at the entrance of the Golo Wua village road and reservoir with a capacity of 577 m³. The dimensions of the reservoir are 15 meters long, 15 meters wide, and 2.6 meters high, with a 0.4-meter freeboard. Reservoirs are built on land without towers. The initial elevation of the reservoir is 961,523 meters. Table 4 shows a summary of the results of network calculations.

The distribution analysis results show that the percentage of errors is less than +5% (Berthouex & Brown, 2002). This error value indicates that the diameter of the pipe is correct. Distribution network pressure is affected by water friction with the pipe material, the type of pipe accessories. The friction of water with the high density polyethylene (HDPE) pipe is a major headloss. The calculation of pipe dimensions uses the Hazen-Williams formula. The results of this planning analysis are in line with the planning of drinking water supply systems in Surat City, India (Lungariya et al., 2016). The results of the analysis of drinking water distribution networks using EPANET modeling also produce very satisfying pressure values (Jumanalmath & Shivapur, 2017).

EPANET modeling is often used in drinking water planning. This software is an advancement in distribution network analysis technology. In general, EPANET modeling also requires supporting software such as ArcGIS, AutoCAD, and EPACAD (Desai & Pathan, 2018). ArcGIS can translate coordinate data. These coordinate data are validated by theodolite measurements. Meanwhile, AutoCAD will produce a distribution network plan. Finally, EPACAD will convert CAD drawings to coordinates on EPANET. EPANET software needs to be filled with input data in the field. Input data in the form of land elevation, distance, base demand, and pipe diameter. The determination of input data will determine the results of the simulation. Simulation results can be cross-tested with manual calculations (Mays, 2000).

Table 4. Distribution analysis results

No. Node	Length of pipe (m)	Flow (Lps)	Ø of pipe (Inch)	Total Headloss (m)	Pressure (m)	EPANET V.2.0 (m)	Errors (%)
n.1	25,00	12,06	5"	0,053	1,85	1,90	-2,68
n.2	25,00	11,60	5"	0,049	3,55	3,60	-1,45
n.3	24,76	11,15	5"	0,041	3,79	3,84	-1,18
n.4	25,00	10,69	5"	0,044	7,52	7,56	-0,56
n.5	25,00	10,24	5"	0,056	10,55	10,60	-0,49
n.6	25,00	9,78	5"	0,051	14,32	14,37	-0,37
n.7	24,48	9,33	5"	0,051	16,62	16,67	-0,32
n.8	25,00	8,87	5"	0,046	17,15	17,20	-0,28
n.9	25,00	8,42	5"	0,038	18,92	18,96	-0,19
n.10	25,00	7,96	4"	0,057	21,20	21,25	-0,25
n.11	25,00	7,50	4"	0,051	21,19	21,24	-0,23
n.12	24,89	7,05	4"	0,045	24,14	24,18	-0,18
n.13	25,00	6,59	4"	0,043	28,81	28,85	-0,13
n.14	25,00	6,14	4"	0,034	32,51	32,55	-0,11
n.15	25,00	5,68	4"	0,029	34,67	34,70	-0,08
n.16	25,00	5,23	3"	0,057	34,98	35,03	-0,15
n.17	25,00	4,77	3"	0,048	35,16	35,20	-0,12
n.18	23,52	4,32	3"	0,050	35,25	35,29	-0,13
n.19	25,00	3,86	3"	0,031	36,13	36,16	-0,08
n.20	24,98	3,70	2 ½"	0,062	39,06	39,12	-0,16
n.21	25,00	3,54	2 ½"	0,068	47,22	47,29	-0,15
n.22	23,85	3,38	2 ½"	0,056	52,45	52,50	-0,10
n.23	25,00	3,22	2 ½"	0,051	55,19	55,25	-0,10
n.24	25,00	3,06	2 ½"	0,043	58,57	58,62	-0,08
n.25	25,00	2,90	2 ½"	0,038	60,86	60,90	-0,06
n.26	25,00	2,73	2"	0,034	64,19	64,22	-0,05
n.27	22,44	2,57	2"	0,073	66,82	66,89	-0,11
n.28	25,00	2,41	2"	0,067	68,79	68,85	-0,09
n.29	25,00	2,25	2"	0,049	71,07	71,12	-0,07
n.30	25,00	2,09	2"	0,042	72,09	72,13	-0,05
n.31	25,00	1,93	2"	0,036	72,20	72,24	-0,05
n.32	25,00	1,77	2"	0,031	75,14	75,17	-0,05
n.33	24,52	1,61	1 ½"	0,073	75,98	76,05	-0,09
n.34	25,00	1,45	1 ½"	0,059	75,92	75,98	-0,08
n.35	25,00	1,29	1 ½"	0,044	77,68	77,72	-0,05
n.36	24,64	1,13	1 ½"	0,036	77,04	77,08	-0,05
n.37	25,00	0,96	1 ½"	0,027	73,78	73,81	-0,03
n.38	25,00	0,80	1 ½"	0,017	72,59	72,60	-0,02
n.39	25,00	0,64	1 ½"	0,011	75,22	75,23	-0,01
n.40	25,00	0,48	1 ½"	0,006	78,11	78,11	0,00
n.41	25,00	0,32	1 ½"	0,003	83,42	83,43	-0,01
n.42	25,00	0,16	1 ½"	0,001	84,22	84,22	0,00

4. Conclusion

Distribution network planning in the villages of Golo Wua and Golo Watu produces water pressure between 1,85 meters and 84,22 meters. These values are still within the pressure range required by BPP-SPAM. The minimum pressure at the end of the distribution network is 7 meters. The maximum pressure of water is 100 meters. The maximum pressure from the

calculation results is still below the HDPE pipe pressure with a nominal PN12 (125 meters). The distribution network can function optimally in flowing water from the source to the customer.

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