Jurnal Ilmiah
TELSINAS

Volume 8, No. 2 September 2025
e-ISSN 2621-5276 (online)

Study on Improving Clean Water Distribution System Using the Epanet 2.0 Application in Tiara Regency Housing Limbangan

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DOI:	Received:	Accepted:	Publish:
https://doi.org/10.38043/telsinas.v8i2.6837	23 June 2025	12 August 2025	25 September 2025

ABSTRACT: Tiara Regency Limbangan Housing is located in Limbangan village, Sukaraja District, Sukabumi Regency. This housing is one of the areas that is growing rapidly. As the number of residents and activities in the area increases, the need for an effective and efficient clean water distribution system is very important. However, the clean water distribution system at Tiara Regency Limbangan Housing is still uneven at several points. This research aims to simulate the clean water distribution system in the Epanet 2.0 application to find out the problems and solutions so that they run optimally. This study uses population data to determine the amount of discharge needed. Water discharge data from the reservoir to determine water availability. Existing data and pipeline details are used to analyze Epanet 2.0 so that the pressure value, and energy loss in each connection and pipeline can be known. The availability of main pipeline water 1 is 444,096 liters/day and the availability of mains pipeline water 2 is 425,952 liters/day. The water demand in main pipeline 1 reaches 321,595 liters/day while the water demand in main pipeline 2 reaches 284,335 liters/day. The results of the existing analysis showed that there were 88 connections with negative pressure at peak usage hours. Optimization is carried out by changing the diameter of the main pipe 1 from 3 inches to 4 inches.

Keyword: *Water Distribution System; Epanet 2.0; Optimalization*

I. INTRODUCTION

Water is one of the most vital sources of livelihood for all living things on earth. In modern economic life, water has a big role as a parameter of environmental balance[1]. Water resources are very vital resources for human survival. Various activities carried out by humans are highly dependent on their availability [2]. The need for water in an area will increase along with the development of the region and the growth of the population [3]. The provision and development of clean water is an activity that directly touches one of the basic needs of the community in addition to the needs of clothes and boards that are used as sources of drinking water, bathing, washing and other activities [4]. If the distribution system that occurs is not good, it will cause various kinds of problems, including lack of water pressure so that the water flow is not evenly distributed[5].

A clean water supply system must be planned and built in such a way that in its operation it can meet the purpose of providing sufficient quantities of water with quality that meets the requirements of drinking water. A clean water distribution system is a piping network consisting of existing pipe, pump, reservoir and distribution systems. Clean water supply systems often experience problems in terms of discharge and pressure related to the hydraulic criteria that must be met in the clean water drainage system [6]. Water distribution is carried out by closed channels or by piping with the intention of preventing contamination of the water flowing in it. In addition, with a piping system, water is easier to flow because of the water pressure. The components of the distribution system are reservoirs and piping systems [7].

Water resource management is an effort to plan, implement, monitor and evaluate the implementation of water resource conservation, water resource utilization and water damage control [8]. In line with the increasing population, the need for clean water has also increased, both in quality and quantity. Water is no longer an item that is available in abundance and free to use, but has become an increasingly scarce economic commodity, so proper management is needed [9]. Clean water distribution system is a system that is directly related to consumers, which has the main function of distributing water that has qualified to all service areas [10]. The clean water distribution system in Tiara Regency Limbangan Housing uses a gravity flow system with a combination system network pattern where the piping network system is a combination of a branched network system and a circular network system.

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e-ISSN 2621-5276 (online)

The clean water distribution system at Tiara Regency Housing uses 2 main pipes with different water availability. However, the distribution of clean water in Tiara Regency Limbangan Housing is still not running well, where the distribution of clean water at some points is still uneven. The level of clean water demand is calculated from domestic and non-domestic needs in Tiara Regency Limbangan Housing. The analysis of improving the clean water distribution system was carried out using the Epanet 2.0 application.

Based on this description, this study was analyzed for clean water needs in Tiara Regency Limbangan Housing and analysis of improving the clean water distribution system using the Epanet 2.0 Application in Tiara Regency Limbangan Housing.

II. THEORETICAL FRAMEWORK

Clean Water Needs

The water need for an area is the amount of water needed to meet the components in the area, plus water leakage due to pipe leaks [11]. Water needs are categorized into 2 types, namely domestic activities and non-domestic activities. Domestic activities are activities carried out in the household while non-domestic activities are urban support activities, which consist of commercial activities in the form of industry, offices, and others as well as social activities such as schools, hospitals and places of worship [12]. The standards of domestic and non-domestic water needs are:

1. Urban Domestic : 120 – 150 Liters/person/day
2. Rural Domestic : Minimum 60 – 80 Liters/person/day
3. Non domestic : 15% – 30% x Domestic needs or adjusted to the specifications of location or regional needs.

Epanet 2.0 Applications

Epanet is a computer program that describes the simulation of hydraulics and the trend of water quality flowing in a pipeline. EPANET performs simulations of hydraulic and water quality behavior within pressurized pipe networks, such as a city water supply system. A network can consist of pipes, pipe junctions, pumps, valves, storage tanks, and reservoirs [13]. E is designed as a tool to achieve and realize an understanding of the movement and fate of drinking water content in the distribution network. It can also be used for various analyses of various distribution network applications. Epanet uses the Hazen Williams equation so that manual calculations must be carried out to correct and verify the accuracy and correctness of the analysis carried out in the Epanet 2.0 application [14].

To calculate the headloss in the epanet application using the Hazen Williams equation as follows

$$HL = (10.666 \times Q^{1.85})/(C^{1.85} \times D^{4.85}) \times L \quad (1)$$

Information:

HL = Loss of energy (m)
Q = Water discharge (m3/sec)
C = Hazen Williams coefficient
D = Pipe diameter (m)
L = Pipe length

The following is the value of the coefficient C in the Hazen Williams equation.

Table 1. Hazen Williams C value

Pipe Type	Grade C Planning
Asbes Cement (ACP)	120
UPVC	120
Medium DPE	130
High HDPE	130
Ductile (DCIP)	110
Cast Iron (CIP)	110
GIP	110
Steel	110
Pre – streems (PSC)	120

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III. METHODS

The research method used in this study to conduct optimization analysis is a quantitative method to determine the need for clean water in Tiara Regency Housing and review the discharge ability from spring water sources and reservoirs. The research steps carried out can be seen in the following research flow diagram:

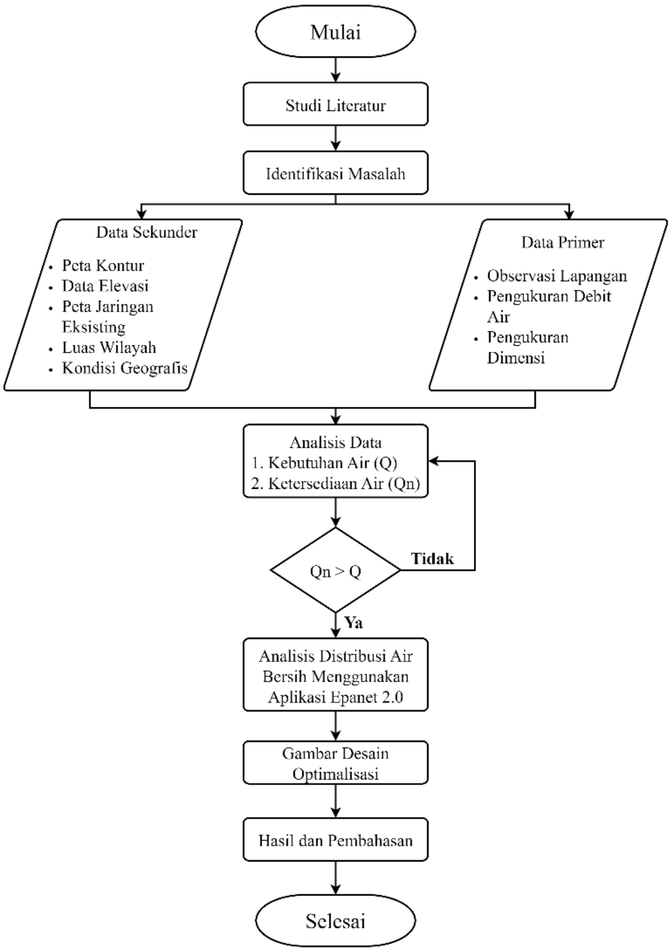

Figure 1. Research Flow Diagram

Literature studies are carried out for research by collecting data from various literature sources regarding previous studies that are in accordance with the research to be conducted. Problem identification is carried out to find out the field conditions and how the problems exist in the research object. Problems that occur in the object of research. Data collection was carried out through literature studies and using data owned by clean water managers in Tiara Regency Limbangan Housing. The data collected is relevant data. The data collection techniques used in this study are:

Primary Data

Conducting direct reviews and observations in the research area to obtain direct data. The data obtained is data on water discharge measurement in the reservoir which is measured using the container method using a bucket with a capacity of 20 liters for the container and a stopwatch to measure the time it takes for water to fill the bucket. The experiment was carried out 5 times and the average of the experiment was taken and the length measurement data and pipe diameter data were carried out by tracking the existing pipeline path.

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Secondary Data

Secondary data collection is data obtained from related agencies and also clean water managers in Tiara Regency Limbangan Housing. The data obtained were the Tiara Regency Limbangan Housing Site Plan, research location data, population data, existing network map data and elevation data obtained through the google earth application.

Data Analysis

After the necessary data is collected, a calculation of water availability and water needs will be carried out as well as an analysis of the clean water distribution system using the Epanet 2.0 application.

IV. DISCUSSION

The following is a picture of the pipeline network in Tiara Regency Limbangan Housing using the Epanet 2.0 application.

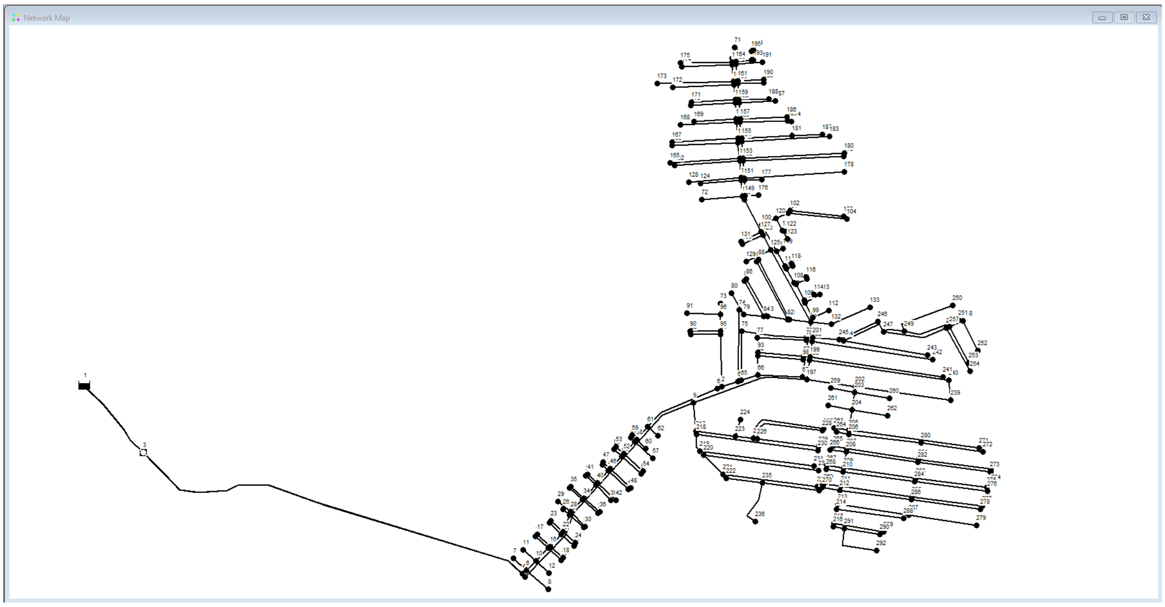

Figure 2. Map of the Existing Network of Tiara Regency Housing

The type of pipe used in the Tiara Regency Limbangan Housing is PVC (polyvinyl chlodide) pipe. The pipe diameters used are 1 inch, 1.5 inch, 2 inch, 3 inch and 4 inch pipes. The distribution network used in Tiara Regency Limbangan Housing is a combination network system. That is a combination of a branch system and a circular system. The distribution network in Tiara Regency Housing Limbangan uses 2 main pipes that flow from the same reservoir. Main pipeline 1 is flowed for the construction of phase 1, namely blocks A to block F with a total of 819 SR. Mainline 2 is flowing for the construction of phase 2, namely block G to block K with a total of 725 SR. Both pipes are drained from the same reservoir resulting in the same quality of water.

Clean Water Needs (Q)

The data obtained from the calculation of the number of clean water provider customers in Tiara Regency Limbangan Housing in 2025 is 1,544 House Connections (SR) with 3,659 customers divided into 2 main pipes. Tier 1 development customers totaled 819 home connections (SR) with 1,942 customers and level 2 development customers totaled 725 home connections (SR) with 1,717 customers. The need for clean water is divided into 2 parts, namely the need for clean water for the main pipe 1 and the clean water need for the main pipe with the calculation of the need for clean water as follows.

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Clean Water Needs of Main Pipe 1

1. Domestic Needs (Q_D)
   QD = Number of Inhabitants x Average Water Demand
   QD = 1,942 x 120 liters/person/day
   QD = 233.040 liters/day
   QD = 2,697 liters/sec
2. Non-Domestic Needs (QN)
   QN = 15% x Domestic Needs
   QN = 15% x 439,080 liters/day
   QN = 34,956 liters/day
   QN = 0.405 liters/sec
3. Water Loss (QA)
   QA = 20% x (QD + QN)
   QA = 20% x (439,080 + 65,862)
   QA = 53,599 liters/day
   QA = 0.620 liters/second
4. Total Water Requirement (QR)
   QR=QD+QN+QA
   QR = 439.080 + 65.862 + 87.816
   QR = 321.595 liters/day
   QR = 3,722 liters/sec

Clean Water Needs of Main Pipe 2

1. Domestic Needs (QD)
   QD = Number of Inhabitants x Average Water Demand
   QD = 1,717 x 120 liters/person/day
   QD = 206,040 liters/day
   QD = 2,385 liters/second
2. Non-Domestic Needs (QN)
   QN = 15% x Domestic Needs
   QN = 15% x 439,080 liters/day
   QN = 30,906 liters/day
   QN = 0.358 liters/sec
3. Water Loss (QA)
   QA = 20% x (QD + QN)
   QA = 20% x (439,080 + 65,862)
   QA = 47,389 liters/day
   QA = 0.548 liters/second
4. Total Water Requirement (QR)
   QR=QD+QN+QA
   QR = 439.080 + 65.862 + 87.816
   QR = 284,335 liters/day
   QR = 3,291 liters/second

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Table 2. Recapitulation of Clean Water Needs of Main Pipe 1

Yes	Description	Unit	Sum
1	Number of Home Connections	SR	819
2	Number of Customers	Soul	1.942
3	Domestic water needs	Lt/dt	2,697
4	Non-domestic water needs	Lt/dt	0,405
5	Water loss (with 20% leakage)	Lt/dt	0,620
6	Total water requirement (Q)	Lt/dt	3,722

Table 3. Recapitulation of Clean Water Needs of Main Pipes 2

	Description	Unit	Sum
1	Number of Home Connections	SR	725
2	Number of Customers	Soul	1.717
3	Domestic water needs	Lt/dt	2,385
4	Non-domestic water needs	Lt/dt	0,358
5	Water loss (with 20% leakage)	Lt/dt	0,548
6	Total water requirement (Q)	Lt/dt	3,291

Availability of Clean Water (Qn)

The discharge of water availability is measured by the container method by measuring 5 times on a container with a volume of 20 liters as shown in the following table.

Table 4. Main Pipeline Reservoir Discharge Calculation 1

Main Pipe Reservoir 1		
Measurement	**Vol.Tampung (liter)**	**Time (seconds)**
1	20	3.51
2	20	4.18
3	20	3.88
4	20	3.66
5	20	4.21
Average	-	3.888
Q=	**5.14**	**lt/dt**

Table 5. Main Pipe Reservoir Discharge Calculation 2

Main Pipe Reservoir 2		
Measurement	**Vol.Tampung (liter)**	**Time (seconds)**
1	20	4.18
2	20	3.96
3	20	4.27
4	20	4.05

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5	20	3.81
Average	-	4.054
Q=	**4.93**	**lt/dt**

From the calculation above, the water availability discharge in the main pipeline reservoir 1 is 5.14 liters/second or 444,096 liters/day with a water demand discharge of only 3,722 liters/second and the water availability in the main pipeline reservoir 2 is 4.93 liters/second or 425,952 liters/day with a water demand discharge of only 3,291 liters/second. With these results, the water availability discharge (Qn) is greater than the water requirement discharge (Q) or Qn>Q= OK so that the water availability discharge meets the standards for clean water distribution.

Analysis Using the Epanet 2.0 Application

The first step that must be taken is to form a distribution network model taken from pipeline tracking data in the Epanet 2.0 application by forming a master network model that has been drawn in the Epanet 2.0 application. Then enter the required data such as the elevation of the reservoir, the length of the pipe, the roughness of the pipe, and the diameter of the pipe. Next, run the program so that the output produced can be accessed in the form of a table and figure 3 as follows.

Based on figure 3, the simulation results at peak usage time, which is 17:00, there are 88 junctions with a negative pressure (red) which causes the water distribution system to be uneven. Negative pressure usually indicates that there is a problem with the network being created or operated [15]. The negative value of pressure is due to the size of the pipe that is not suitable or not optimal in distributing water in Tiara Regency Housing.

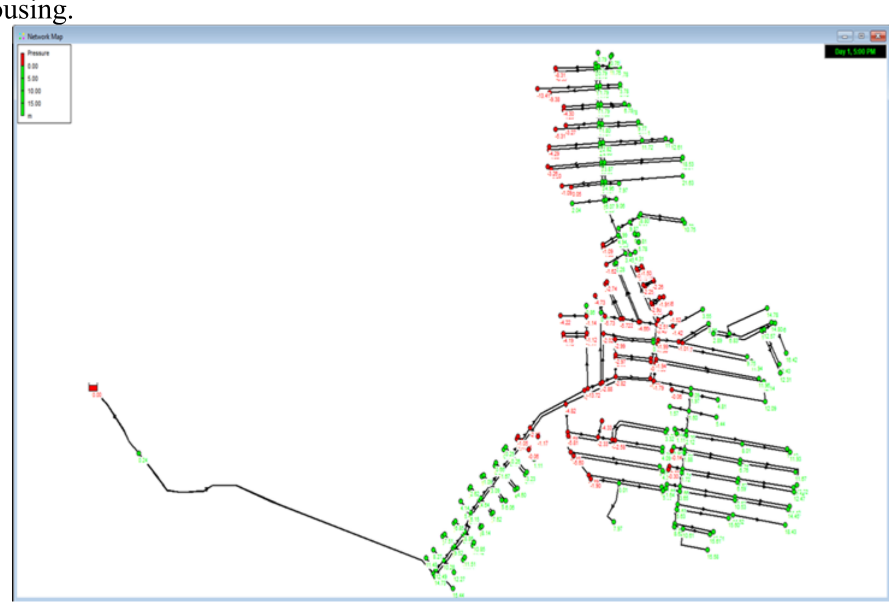

Figure 3. Results of Existing Simulations

With less than optimal results in figure 3, optimization must be increased by changing the diameter of the pipe. The optimization of the water distribution system in the epanet 2.0 program is carried out by changing the pipe diameter on the main pipe first. This is because the main pipe has a big impact on the overall water distribution system. In this study, the distribution system that is not optimal is only at the point flowed by the main pipe 1, therefore the diameter of pipe 1 was changed from 3 inches to 4 inches. The results of the optimization improvement can be seen in figure 3 as follows.

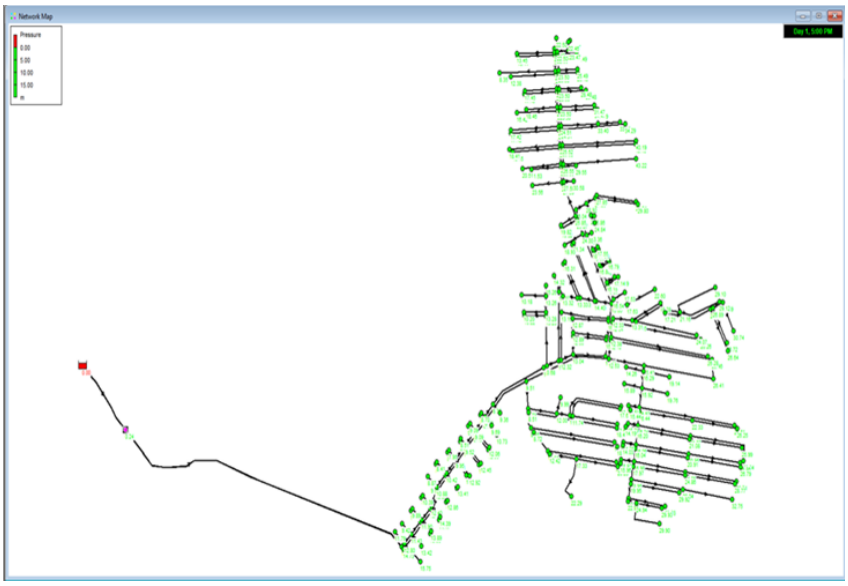

Figure 4. Optimization Simulation Results

Based on Figure 4, all junctions with negative pressure or junctions with uneven water distribution have been successfully optimized. This results from the change in the diameter of the pipe at the junction which has a negative value. The change of pipe diameter was carried out on 63 pipes out of a total of 288 existing pipes. Pipe change occurs in master pipe 1 which was initially 3 inches to 4 inches as shown in the following table.

Table 6. Pipe Diameter Change

Yes	Pipe ID	Existing Diameter		Diameter Optimization	
		(mm)	(inch)	(mm)	(inch)
1	Pipe 5	82.8	3	105.8	4
2	Pipe 8	82.8	3	105.8	4
3	Pipe 9	82.8	3	105.8	4
4	Pipe 12	82.8	3	105.8	4
5	Pipe 15	82.8	3	105.8	4
6	Pipe 18	82.8	3	105.8	4
7	Pipe 21	82.8	3	105.8	4
8	Pipe 24	82.8	3	105.8	4
9	Pipe 27	82.8	3	105.8	4
10	Pipe 30	82.8	3	105.8	4
11	Pipe 33	82.8	3	105.8	4
12	Pipe 36	82.8	3	105.8	4
13	Pipe 39	82.8	3	105.8	4
14	Pipe 42	82.8	3	105.8	4
15	Pipe 45	82.8	3	105.8	4
16	Pipe 48	82.8	3	105.8	4
17	Pipe 51	82.8	3	105.8	4
18	Pipe 54	82.8	3	105.8	4

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Yes	Pipe ID	Existing Diameter		Diameter Optimization	
		(mm)	(inch)	(mm)	(inch)
19	Pipe 57	82.8	3	105.8	4
20	Pipe 60	82.8	3	105.8	4
21	Pipe 62	82.8	3	105.8	4
22	Pipe 65	82.8	3	105.8	4
23	Pipe 66	82.8	3	105.8	4
24	Pipe 67	82.8	3	105.8	4
25	Pipe 68	82.8	3	105.8	4
26	Pipe 69	82.8	3	105.8	4
27	Pipe 70	82.8	3	105.8	4
28	Pipe 71	82.8	3	105.8	4
29	Pipe 72	82.8	3	105.8	4
30	Pipe 73	82.8	3	105.8	4
31	Pipe 74	82.8	3	105.8	4
32	Pipe 75	82.8	3	105.8	4
33	Pipe 76	82.8	3	105.8	4
34	Pipe 77	82.8	3	105.8	4
35	Pipe 78	82.8	3	105.8	4
36	Pipe 79	82.8	3	105.8	4
37	Pipe 80	82.8	3	105.8	4
38	Pipe 84	82.8	3	105.8	4
39	Pipe 117	82.8	3	105.8	4
40	Pipe 134	82.8	3	105.8	4
41	Pipe 135	82.8	3	105.8	4
42	Pipe 136	82.8	3	105.8	4
43	Pipe 137	82.8	3	105.8	4
44	Pipe 143	82.8	3	105.8	4
45	Pipe 144	82.8	3	105.8	4
46	Pipe 145	82.8	3	105.8	4
47	Pipe 146	82.8	3	105.8	4
48	Pipe 147	82.8	3	105.8	4
49	Pipe 148	82.8	3	105.8	4
50	Pipe 149	82.8	3	105.8	4
51	Pipe 150	82.8	3	105.8	4
52	Pipe 151	82.8	3	105.8	4
53	Pipe 152	82.8	3	105.8	4
54	Pipe 153	82.8	3	105.8	4
55	Pipe 154	82.8	3	105.8	4
56	Pipe 155	82.8	3	105.8	4
57	Pipe 156	82.8	3	105.8	4

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Yes	Pipe ID	Existing Diameter		Diameter Optimization	
		(mm)	(inch)	(mm)	(inch)
58	Pipe 157	82.8	3	105.8	4
59	Pipe 158	82.8	3	105.8	4
60	Pipe 159	82.8	3	105.8	4
61	Pipe 160	82.8	3	105.8	4
62	Pipe 161	82.8	3	105.8	4
63	Pipe 162	82.8	3	105.8	4

Results Discussion

The existing condition of the clean water distribution network in Tiara Regency Limbangan Housing according to the analysis of the Epanet 2.0 application is still not optimal, especially during peak usage hours, which is at 17:00. There are 88 junctions with negative pressures so that the water distribution is uneven at these points.

The junction with uneven water distribution is located in block B, block C, block D, and block E. This is in accordance with the problems that exist in the clean water distribution network in the Tiara Regency Limbangan Housing shown by the management where the water distribution is uneven in the block.

Junctions with negative pressure are also caused by the energy loss factor (headloss) that occurs in the pipeline network, so the main solution for a clean water distribution system that uses gravity is to change the size of the pipe starting with the replacement of the main pipe. However, if the replacement of the main pipe does not result in a change, it will be continued with the replacement of the secondary pipe.

Energy loss (headloss) in the epanet 2.0 application can be done by manual calculation to see how accurate the results of the simulation carried out in the Epanet 2.0 application are. The energy loss (headloss) used in the epanet 2.0 application uses the Hazen Williams equation. The pipe tested with manual calculation is pipe 8 at normal time of use, which is at 00:00 with the results on the eparena as follows.

Table 7. Pipe Headloss Unit 8

Yes	Pipe ID	Long	Diameter	Roughness	Flow	Velocity	Unit Headloss
		(m)	(mm)		lt/dt	m/d	m/km
8	Pipe 8	351.67	82.8	120	0.69	0.13	0.39

The energy loss (headloss) from the analysis of the Epanet 2.0 application on the existing clean water distribution network in Tiara Regency Housing Limbangan is 0.44 m/km with a pipe length = 0.35167 km or the value of energy loss (headloss) of pipe 8 is 0.44 x 0.35167 = 0.137 m. Meanwhile, the energy loss (headloss) with manual calculations is as follows.

$$HL = x\ L\ \frac{10{,}666\ x\ Q^{1{,}85}}{C^{1{,}85}\ x\ D^{4.85}}$$

Information:
HL = Loss of energy (m)
Q = 0.69 liters/sec = 0.00069 m^3/second
C = 120 (PVC pipe)
D = 82.8 mm = 0.0828 m
L = 351.67 m

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$$HL = x\ 351.67\ \frac{10{,}666\ x\ (0.00069)^{1{,}85}}{(120)^{1{,}85}\ x\ (0.0828)^{4.85}}$$

HL = 0.134 m

The result of the manual calculation for energy loss (headloss) in pipe 8 is 0.134 m while the results of the existing simulation in the Epanet 2.0 application are 0.137 m/km so that the difference between the calculations is 0.003 (OK) so that the Epanet 2.0 application runs quite accurately.

V. CONCLUSION

Tiara Regency Limbangan Housing distributes clean water using 2 distribution main pipes from reservoirs. The results of the calculations that have been carried out can be concluded that the water requirement for main pipe 1 (Q) is 3.722 liters/second while the availability of mains pipe water 1 (Qn) is 5.14 liters/second and the water requirement for mains pipe 2 (Q) is 3.291 liters/second while the availability of mains pipe water 2 (Qn) is 4.93 liters/second or Qn>Q = OK. So that the water availability discharge meets the standards for clean water distribution. However, based on the manager's report and the author's survey, the water distribution is uneven, which causes water shortages in several house connections (SR).

The distribution is uneven because the main pipe does not have an optimal size. The results of the simulation of the Epanet 2.0 application in the existing Epanet 2.0 application have 88 negative values due to the inappropriate pipe size which causes uneven water distribution in the pipe that is connected (junctiuon). The results of optimizing water distribution were carried out by changing the diameter of pipes in 63 pipes out of a total of 288 existing pipes. Pipe replacement occurs in the master pipe from 3 inches to 4 inches in size.

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