Simulation of Transmission of Drinking Water Sources to Reservoirs: Case Study PDAM Tirta Jati, Cirebon, Indonesia

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Abstract: Population dynamics have very important effects on ecosystems, including those related to water availability. The availability of clean water is closely related to the condition of the population in an area. Every human being must drink 8 (eight) glasses of water per day. Plants and animals also need water. So it can be said that water is one source of life. Regional Water Supply Company (PDAM) is a company whose ownership is held by the regional head as the operator of drinking water supply for the community. Companies are encouraged to utilize developing technology to manage their drinking water assets effectively and efficiently so they can improve services to the community. EPANET 2.0 is one tool that is suitable for connecting piping network models. Quantum Geographic Information System (QGIS) is a model simulating hydraulics which parameters can be launched through a processing stage. The master network system model created in QGIS was included in EPANET 2.0 for rasterization. Then enter the required data such as pipe length, height of each node, water flow per tapping, pipe roughness coefficient, and peak hour factor. The results of the analysis in the form of pipe hydraulics, such as pipe speed and pressure from each node are used as a basis for network development plans. The ratio of the total population per family in Sumber District in 2018 is 6 people / head of the family. The population in the administrative area served by PDAM is 22,560 people. Domestic water needs can be calculated based on data on average water usage per month recorded at PDAM Tirta Jati, Cirebon Regency. The number of domestic customers was 2,446 in August 2019 with an average monthly water consumption of 15.02 m\(^3\) / unit. Based on analysis using Epanet and QGIS, parameter data for pipe flow rates are 0.63 - 1.05 meters / second. While the result for water pressure in the pipe is 140.95 meters at node 274.

1. Introduction
High population growth resulted in not all components of the community can enjoy clean water. Provision of water to meet community needs is one of the important agendas in ensuring the basic needs of the community. Of all the liquids, consisting of 95% ground water, 2% water content, and 3% are rivers, lakes, and other flows [1]. The availability of clean water is closely related to the condition of the population in an area. With rapid population growth and demands for quality of life in Cirebon, it requires a sustainable supply of water for household needs. To ensure a safe supply of drinking water, it is necessary to evaluate the performance of water transmission and distribution from water sources from rivers to reservoirs and households.

For this reason, analytical methods are needed to improve the efficiency and control of the transmission network from water sources to reservoirs so that water distribution is guaranteed. Among the pipeline system analysis methods is to use the EPANET 2.0 program [2] and the Geographic Information System (GIS) as well as creating an information monitoring model related to the quantity.
and continuity of water [3]. Utilize technology related to the quantity and sustainability of services so that the PDAM can distribute water accurately. Water loss is the problem most often faced by each PDAM [4]. Based on the problem of the level of water loss in the water distribution network. Non-Revenued Water (NRW) is strongly associated with pressure loss in pipes [5]. Geographic Information Systems (GIS) can be defined as a means of providing up-to-date information for planning and operational tasks.

To facilitate water distribution, stages of the planning and design process, resource management, operations and exploitation, reconditioning areas, customer relations, etc. are required. Process stages are based on Geographic Information Systems [6].

Geographic Information Systems (GIS) provide significant improvements in terms of quality of work and efficiency and optimization of resources, and also contributed to manage database manager drinking water [7]. In addition, it is also very useful for integrating water networking tools are ready to run on the simulator [8]. Some trends have been made to integrate GIS with hydraulic models. The new developments presented in this paper, by using Q-GIS 2.18 as Geographic Information Systems (GIS).

PDAM Tirta Jati Cirebon has a drinking water supply system from Cigusti spring which has a discharge capacity of 45 liters / second, then sent through a transmission pipe with a diameter of 250 mm / 10 inches along 7,000 meters to the reservoir with a gravity flow system. The height of the water source is located at surface height 198 m and the height of the reservoir is 95 m, from the difference in surface height required instruments that reduce the speed and pressure of water so that the speed and air pressure in the transmission pipeline is adjusted to the pipe specifications.

1.1. Theory
Geographic Information System is a system for the management, storage, processing (manipulation), analysis and delivery of data are spatially associated with the earth [9]. Epanet is a computer program that describes the simulation hydraulic and water quality trends flowing in the pipeline. The network itself consists of pipes, nodes (connection points), pump, valve and tank or reservoir [10]. One parameter that is measured is the pressure. Pressure measuring devices such as pressure gauge (pressure indicator or manometer), mounted on a pipe which shows a pressure indicator [11]. Epanet is a software developed by the Drinking Water Research Division of EPA (Environmental Protection Agency) United States which simulates the hydraulic modeling and water quality in a distribution network system. The distribution network consists of points / node / junction pipes, pumps, valves and reservoirs. In the water distribution network modeling, the first step put these data above, then the initial conditions, the estimated water use and an operating system set the desired water distribution. Furthermore Epanet program will predict the direction and flow in each pipe, the pressure at each node, the water level in the tank and the concentration of chemicals in the whole network during the simulation period [12].

1.2. Study locations
The most potential surface water source for services in Sumber Regency Cirebon Regency is the Cigusti spring with a height of 275 in Kuningan District. Data from PDAM Tirta Jati Cirebon for service areas in Sumber Regency shows that in 2019 in August, there were 2,446 housing connections. Generally one house connection unit serves one family head. Based on data from the Cirebon Central Statistics Agency (BPS), the number of household connections in the Sumber District area in 2019 in August was 2,446 house connections.

Figure 1 and 2 present map of District and Housing service. Sumber Regency is part of Cirebon Regency, 85.7% of the topography is lowland, the rest is a hill with an altitude of less than 500 meters above sea level with an area of 25.65 km². Geographically, Sumber District is bordered by the West by Dukupuntang District, in the north it is bordered by Weru and Plumbon Districts, in the east it is bordered by Talun District, and in the South it is bordered by Kuningan Regency.
Figure 1. Map of the District Sources.

Figure 2. Map of Housing Services TTI.

The relationship graph in Figure 3 is a comparison between the number of customers for one year 2017-2019 with 24-hours service. Figure 3 are determined from January 2017 to August 2019 with a total of 152 connection units. Reading with this chart facilitates analysis in assessing flow during peak hours or water usage during normal hours so that the results of field survey data are carried out in 24 (twenty four) clean air congestion services in housing.

Figure 3. Number of customer 2017-2019.
The relationship graph in Figure 4 is the level of water consumption comparison between 2017-2019 and 24-hour service. The results bearing in mind the number of customers has fluctuated increasing and decreasing in the graph, the level of water consumption is strongly influenced by the number of customers. This makes it easy to read graph analysis to assess water flow during peak use hours or water consumption during normal hours so that field survey data are conducted for 24 (twenty four) hours of clean water in a Taman Tukmudal Indah residential.

![Figure 4. Water Consumption 2017-2019.](image)

The chart in Figure 5 present the calculation results between the number of customers with the level of water consumption in 2018 fluctuated in the months running. It can be seen in January 2018, the number of customers amounted to 2,333 units by the amount of water consumption of 33 183 m³/month so that the average customer spends 14.22 m³/month. Water consumption category present in Table 1.

![Figure 5. Usage data on average years of 2017-2019.](image)
### Table 1. Water consumptions category.

| Description                                      | City Category Based on Population (person) |
|-------------------------------------------------|-------------------------------------------|
| House Connection Unit (SR) consumption (liters / person / day) | Metropolis City 1 >1,000,000 500,000 s/d | 2 150 |
|                                                 | Big city 3 1,000,000 100,000 s/d | 3 150-120 |
|                                                 | Medium city 4 500,000 s/d | 4 90-120 |
|                                                 | Small town 5 200,000 s/d | 5 80-120 |
|                                                 | Village 6 <20,000 | 6 60-80 |
| Hydrant Unit (HU) consumption (liters / person / day) | 20-40 | 20-40 |
| Non-domestic unit consumption                    | a Small Trade (liters / units / day) | 600-900 |
|                                                 | b Wholesale trade (liters / units / day) | 1,000-5,000 |
|                                                 | c Large Industry (liters / units / day) | 0.2-0.8 |
|                                                 | d Tourism (liters / units / day) | 0.1-0.3 |
| Water loss (%)                                   | 20-30 | 20-30 |
| Maximum daily factor                             | 1,15-1,25 * daily | 1,15-1,25 * daily |
|                                                 | * daily | 1,15-1,25 * daily |
| Peak Hour Factor                                  | 1,75-2,0 * Max daily | 1,75-2,0 * Max daily |
| Number of Souls per Home Connection (person)     | 5 | 5 |
| Number of Souls per Home Connection (community)  | 100 | 100 |
| The customer's remaining pressure (meter)        | 10 | 10 |
| operating hours (hours)                          | 24 | 24 |
| Volume Reservoir (% Max Day Demand)              | 15-25 | 15-25 |
| SR:HU                                           | 50:50 s/d | 50:50 s/d |
|                                                 | 80:20 | 80:20 |
| Service Coverage (%)                             | 90 | 90 |

#### 1.3. Domestic Water Needs

Cirebon Sumber District as a whole in 2018 amounted to 11,962 inhabitants. By comparing the number of families and the number of residents in the District of source, may be obtained ratio of the number of people per household. The calculation of the ratio of the number of residents per household is as follows.

The ratio of people / head of household = (Total Population District of Source) / (Number of Head of Family)

= (11,962 inhabitants) / (2,934 families)

= 4.08 ~ 4 Head of the Family

The ratio of the number of residents per household Source subdistrict in 2018 was 6 person/household. The population of the region served by PDAM administration as much as 22,560 inhabitants. Percentage of PDAM Cirebon service levels can be calculated as follows.
n population served = Number SR (August 2019) x Ratio n per resident KK
SR = 2,446 units x 6 life
= 14,676 inhabitants.

Percentage of service = (n Population served) / (n region served) X 100%
= (14,676 inhabitants) / (22,560 inhabitants) X 100%
= 65.05%

Based on the above calculation known taps on the service level Sumber District Kabupaten Cirebon by 65.05%. This value is still less than the government's target of piped water supply services category of the city is at 100% so that the necessary efforts to improve service coverage of drinking water distribution systems. Domestic requirement is meant to meet the needs of clean water for domestic purposes is done through House Connection (SR) [13].

Then discharge (Q) domestic water requirement in liters / second can be calculated as follows:

Q = Number SR x average consumption
= 2,446 units of SR x 15.91 m³/unit/month
= 38,928 m³/month or equivalent to 79.57 liters/person/day

When considered within one month there are 30 days, then the water needs to be, as follows:

Q = (Q in m³/month) / (n days per month x 86,400) X 1000 liters/m³
= (38,928 m³ / month) / (30 days x 60x60x24) X 1000 liters/m³
= 15.02 liters/sec

Water discharge at the springs Cigusti which has a production capacity of 40 liters / sec if calculated as follows:

Q = 40 liters/sec is equivalent to 103.680 m³/month
= Water Production - Water Distribution = Water Leakage production
= 103.680 m³/month - 75.168 m³/month = 28.512 m³/month or equivalent to 11 liters/sec
= Air Distribution - Air Sold = Leakage Distribution
= 75.168 m³/month - 38.928 m³/month = 36.240 m³/month or equivalent to 13.98 liters/sec

The level of water loss can be expressed as the ratio between the loss of water and the amount of water that is distributed into the water piping network. Water loss can be calculated based on physical loss minus non-technical loss. The high leakage causes damage to the company because there is an imbalance between the amount of water that is distributed to the company's revenue from the sale of water [14].

2. Research method
In this study used secondary data combined with the primary data. Primary data is needed to verify the present (up to date) data. Secondary data regarding water resources are generally issued by the relevant agencies, such as PDAM Tirta Jati Cirebon, Office of Human Settlements and Spatial Planning Agency. The process of creating a systematic water distribution network and Optimal Use of GIS and EPANET [15]. The stages of research presented in Figure 6.
Data collection is done by holding a large direct measurement of water pressure a number of 6 (six) survey point on the pipe bridge. Water pressure was observed and recorded every hour, 24 times or 24 hours per day with the instrument "manometer". Total points survey taken for sample = 7 (seven) points survey (Sampling) carried out in connection with research on the main distribution line pipe network can be seen in Figure 7.
3. Results and Discussion

Measurement of flow velocity directly in the field at some point represents the state of the entire network, Epanet 2.0 Model simulation was conducted to determine the accuracy of measured data field. Table 2 and 3 presents the results of a simulation using a pressure manometer and simulation program and G-Hydrolc Epanet. To show the trend of simulation results with field measurements following Figure 8 presented the comparative results.

From Figure 8 we can see trends from water pressure graphs using G-Hydrolc simulation, EPAnet 2.0 and Manometer (pressure gauge in the field). The black line shows the results of the G-Hydrolc simulation which shows that node 182 has a water pressure of 124.9 meters which is quite high, while the black dotted line is the trend of the EPAnet 2.0 simulation model that illustrates the water pressure node, there are differences in the number of 2 simulation models between G-hydrolc and EPAnet 2.0 ie at the highest node the difference is j18 no. 7.47 m. Unlike the case with manometer readings in the field placed at nodes 50,98,107,182,274 and 284, the water pressure on the manometer tends to be below the numbers in G-hydrolc and EPAnet 2.0 simulations. This situation shows that the piping network system using simulation models is only limited to reference planning. This requires prevention efforts that have to be made by the PDAM Cirebon to overcome this problem. Various efforts such as network modification, addition of pumps, and others can be alternative solutions to the problem. However, pipe replacement in design modification needs to be designed in an economical way. In addition, all aspects that will affect the cost should be considered as a whole.

Factors that influence the difference between the results of the EPANET model simulation with direct measurements on the transmission pipeline simulation are: Effect of pipe type factors that influence the Hazen-Williams coefficient. The possibility of leakage in the transmission pipe that produces water pressure when the pressure measurement becomes small (both leakage is good and large enough). The effect of the air valve installed on the bridge bridge becomes smaller so that the process of exhausting the air in the pipe is not optimal, it is necessary to regulate the regulating valve is much smaller than the valve regulating data obtained.

Pressure is one of the factors that support people's satisfaction with the service taps, in a piping system we know the static pressure and the dynamic pressure or hydraulic pressure. Static pressure (static pressure) is the pressure when liquid water is not flowing and dynamic pressure (dynamic pressure) pressure at cait substance flowing[16], Water is supplied to consumers through transmission pipes and distribution pipes are designed to be able to serve customers to the farthest place, with a minimum water pressure of 10 MKA or 1 atm. In the distribution of water, to be able to reach all areas of service and to maximize the level of service, then the mandatory thing to note is the rest of the water pressure. The remainder of the low water pressure is 5 MKA (meter water column) or 0.5 atm (one atm=10 m) and the highest is 8 atm or equivalent to 80 m [17].
Figure 6. Flowchart Methods.
**Figure 7.** Total points survey

**Table 2.** Simulation of high pressure in meters of water (in meter).

| dc_id  | elevation | G-Hydrolic | Epanet  | Manometer |
|--------|-----------|------------|---------|-----------|
| Node 50| 182       | 7.00       | 6.97    | 2.79      |
| Node 98| 144       | 44.98      | 43.51   | 17.40     |
| Node 107| 134      | 54.97      | 51.44   | 20.58     |
| Node 182| 64       | 124.96     | 119.53  | 47.81     |
| Node 274| 48       | 140.95     | 134.68  | 53.87     |
| Node 284| 79       | 109.95     | 102.76  | 41.10     |

Source: Calculated using data from field survey

**Figure 8.** Result of pressure test.

**Table 3.** Flow speed of transmission pipeline (m/s).

| dc_id  | elevation | G-Hydrolic | Epanet  | Manometer |
|--------|-----------|------------|---------|-----------|
| Node 50| 182       | 30.00      | 33.00   | 28.71     |
| Node 98| 144       | 30.00      | 33.00   | 28.71     |
| Node 107| 134     | 30.00      | 33.00   | 28.71     |
| Node 182| 64       | 30.00      | 33.00   | 28.71     |
| Node 274| 48       | 30.00      | 33.00   | 28.71     |
| Node 284| 79       | 30.00      | 33.00   | 28.71     |

Source: Calculated using data from field survey
Flow velocity in pipes is also limited by certain values (see Figure 9). Flow rates that are too high can cause scouring on the pipe surface, while very low surfaces can cause deposition on the pipe so that the flow rate limits on the pipe that can be used are as follows:

- maximum speed = 2-3 m/sec
- The minimum speed = 0.3 m/sec.

From Figure 9, it can be seen from the graph the trend of water pressure using a simulated G-Hydrolic, Epanet 2.0 and flowmeter (flow velocity measuring field). The black line shows the simulation results that show the G-Hydrolic that the node 182 has a high enough pressure, amounting to 124.9 meters of water, while the dashed line is the trend of black color EPANET 2.0 simulation model that describes nodes water pressure, there is a difference in the numbers of two simulation models between G-hydrolic and Epanet 2.0 i.e the highest node is no j98 difference of 0.15 m/d. Unlike the case with the reading of the flowmeter instruments in the field are placed at the nodes 50,98,107,182,274 and 284, the flow velocity in the flowmeter are likely to be below the number on the simulated G-hydrolic and Epanet 2.

4. Conclusion

Water pressure measurements directly in the field at some point which is considered to represent the condition of the entire network, it should also be proven by way of data validation 2.0 Epanet calculation results with field measurements to obtain results closer to the real situation in the field. The results of the validation of the simulation model of Epanet 2.0 was conducted to determine the accuracy of the simulation results Epanet 2.0 with measurable data field. In the calculation results Epanet 2.0 with data measured in the field comparison is approaching.

Discharge of domestic water demand can be calculated based on the data the average - average water consumption per month was recorded in PDAM Tirta Jati Cirebon. The number of subscribers/SR domestic amounted to 2,446 units of a connection with the average usage per month is 14.22 m$^3$/units in August 2019.

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