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DESIGN AND FLOW ANALYSIS OF FRESHWATER PIPELINE IN THE ARCHIPELAGO

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Abstract: *As population growth increases, so does the need for clean water. Many areas do not have clean water sources. Due to the geographical location of small islands bounded by the ocean, The development of clean water infrastructure must be carried out in accordance with the needs of the community and its geographical conditions and potential. This research aims to get an alternative inter-island water supply system with new technology that is more efficient for operational costs, water supply systems that can be operated by local residents so that the existence of a clean water supply system can bring impact on the economy of the local community. This research was conducted by direct observation at the location to obtain the data needed for the analysis and design. The data used in the analysis are water demand data and pipeline topography data. Hydraulic analysis is carried out with the help of Epanet 2.2 software with reference to Permen PU No.18 of 2007 and SNI 7509: 2011. From the results of the analysis carried out, it was found that the HDPE pipe diameter used was 200 mm diameter, 150 mm diameter, and 100 mm diameter. The length of the pipeline is 23.37 km. The minimum pressure obtained from the analysis is 0.94 bar and the maximum water pressure is 4.69 bar. The minimum flow velocity in the pipe is 0.35 m/s and the maximum flow velocity is 0.93 m/s. The research contribution is can be used as a reference and consideration in the selection of inter-island clean water supply systems that are more efficient and easy to operate.*

Keywords: *epanet 2.2, freshwater, Indonesian water, pipeline, water demand*

https://doi.org/

Abstrak: Semakin bertambahnya pertumbuhan penduduk semakin besar pula kebutuhan akan air bersih. Banyak wilayah yang tidak terdapat sumber air bersih. Karena letak geografis yang berada di pulau – pulau kecil dan di batasi oleh lautan. Pembangunan infrastruktur air bersih harus dilakukan sesuai dengan kebutuhan masyarakat serta kondisi dan potensi geografisnya. Penelitian ini bertujuan untuk mendapatkan alternatif sistem penyediaan air bersih antar pulau dengan teknologi baru yang lebih efisien dari segi biaya dan operasional, sistem penyediaan air bersih juga dapat dioperasikan oleh warga. sehingga keberadaan sistem penyediaan air bersih dapat memberikan dampak terhadap perekonomian masyarakat sekitar. Penelitian ini dilakukan dengan peninjauan langsung di lokasi untuk memperoleh data yang di butuhkan dalam analisis dan desain. Data yang gunakan dalam analisis berupa data kebutuhan air dan data topografi jalur pipa. Analisis hidrolis dilakukan dengan bantuan softwere Epanet 2.2 dengan mengacu pada Permen PU No.18 Tahun 2007 dan SNI 7509:2011. Dari hasil analisis yang dilakukan didapatkan diameter pipa HDPE yang digunakan yaitu diameter 200 mm, diameter 150 mm, dan diameter 100 mm. Panjang jalur pipa sejauh 23,37 km. Tekanan minimum yang didapatkan dari hasil analisis sebesar 0,96 dan Tekanan air maksimum sebesar 4,79 Atm. Kecepatan aliran didalam pipa minimum sebesar 0,35 m/s dan Kecepatan aliran maksimum sebesar 0,93. Kontribusi penelitian ini dapat digunakan sebagai referensi dan pertimbangan dalam pemilihan sistem penyediaan air bersih antar pulau yang lebih efisien dan mudah dioperasikan.

Kata kunci : epanet 2.2, air bersih, air Indonesia, sistem perpipaan,kebutuhan air

INTRODUCTION

One essential element for human life is water. It is essential for everyday tasks such as drinking, cooking, cleaning, sanitation, farming, and industrial operations. The demand for safe and clean water increases in accordance to population growth (Pranoto & Suyono, 2018;Suyono et al., 2022;Harisman et al., 2018;Makawimbang & Lambertus Tanudjaja, 2017). Existing water resources are being severely constrained by a rapid growth in the human population, particularly in urban and developing regions. Unfortunately, some locations has access to clean water sources and the others are limited to it. Due to economic, infrastructural, or natural limitations, many places—especially rural or isolated ones have limited access to clean water. In areas with challenges geographic conditions, this issue is even more prevalent. Many small islands, for example, lack adequate freshwater sources such rivers or subterranean aquifers despite being surrounded by ocean water. Seawater's high salinity renders it unfit for domestic or direct consumption without the necessary desalination treatment, which is frequently expensive and energy-intensive. As a result, local communities frequently struggle to meet their daily water needs and may have to rely on water transportation from the mainland or seasonal rainwater harvesting. This circumstance emphasizes the urgency of creative and sustainable solutions to guarantee how every region has adequate accessibility to clean water (Suyono et al., 2023;Dundu & Mandagi, 2012).

Access to clean water is remained a challenge worldwide, especially in areas with difficult topography and inadequate infrastructure. In developing nations, where water distribution systems are frequently inadequate and dispersed unevenly, this issue is particularly severe. As a sizable archipelagic country, Indonesia has comparable difficulties. Many rural and isolated places, particularly those on small islands, remain challenged by severe water scarcity, even though urban areas may have comparatively easier access to clean water. Local water sources are unable for human consumption in these regions since they frequently lack natural freshwater sources and are susceptible to seawater intrusion. One such location is Kayoa City, which is in the North Maluku Province's South Halmahera Regency. The city offers an interesting case study because of its remote location and the significant obstacles its citizens face in accessing dependable and safe sources of clean water.

Several Kayoa's villages are located on tiny islands without access to potable water. Seawater intrusion frequently degrades the quality of water, rendering it unsafe for human consumption, even in villages with access to water sources. Residents are consequently compelled to order potable water from nearby islands that have set up water supply systems. They have to travel on a boat across the ocean to reach this clean water, which comes with extra costs such as fuel. As a result, providing the local community with clean water on a daily basis becomes extremely expensive.

In addition to the community's needs, the region's potential and geographic circumstances require to be considered in designing drinking water facilities. Population density, long-term sustainability, local environmental factors, and available water sources must all be thoughtfully considered into attention when designing infrastructure (Suyono et al., 2019). Since freshwater is scarce and vulnerable to seawater intrusion, these challenges are even more severe in isolated or remote areas, especially small islands. Constructing inter-island water distribution systems with submarine pipelines is a practical and widely used approach to meet the clean water demands of these regions (Suyono et al., 2022;Hardi & Suyono, 2016). These pipelines enable it to be possible to deliver clean water to islands without access to centralized treatment facilities or enough water resources. In archipelagic areas especially Indonesia, where inter-island distances are short and maritime conditions enables underwater infrastructure, submarine piping systems perform particularly efficient. However, to ensure resistance against environmental factors such as ocean currents, corrosion, and seismic activity, the implementation of such systems necessitates a substantial investment, technical ability, and continuous maintenance.

Three requirements have to be approached for the supply of clean water: continuity, quantity, and quality. Implementing a subsea clean water piping system requires thorough preparation and adherence to essential technical specifications in order to reach these standards (Harisman et al., 2018). Freshwater supply system design and development ought to consider into account important technical aspects while also considering the target community's social and economic circumstances into consideration. The system's chances of acceptance and long-term sustainability are significantly increased by designing it to the socioeconomic circumstances of the local community. This alignment ensures the clean water infrastructure's efficient and ongoing application by reducing resistance connected with its operation and maintenance (Makawimbang & Lambertus Tanudjaja, 2017;J. enniver . S. S & Horvath, 2009).

In the supply of freshwater from one island to another there are several problems that occur. Each region has a different topographic shape. With the existing topography in an area, how to design a drinking water supply that is appropriate and in accordance with the design criteria (Suyono et al., 2023). Rainwater Harvesting System is a system of pipes that used to collect rainwater so that can be utilized (Dundu & Mandagi, 2012;Fatikasari et al., 2023;Suprayogi et al., 2017). However, rainwater harvesting systems still depend on rainfall at the local location. In addition, rainwater systems are only still on an individual use scale so that the development of rainwater systems still depends on the economy of the local community. The existing technology for providing clean water on islands that do not have a raw water source is Photovoltaic Sea water Reverse osmosis (PV-SWRO). PV-SWRO technology is technology for processing seawater into fresh water by utilizing solar energy (A. S et al., 2024). However, PV-SWRO technology is quite expensive, and not everywhere are there sales of PV-SWRO equipment at the time of maintenance, so it takes a long time, and the production process must stop. Besides being expensive, PV-SWRO also requires professional personnel for its operation.

In the supply of freshwater from one island to another, several challenges may arise due to variations in regional topography. Each area has unique geographical and elevation characteristics, which influence the planning and design of an appropriate drinking water supply system. Therefore, the development of such systems must consider topographic conditions to ensure they meet established design criteria and function effectively in the local context (Suyono et al., 2023). One alternative for freshwater provision is the Rainwater Harvesting System (RHS), which utilizes a network of pipes to collect and store rainwater for domestic use (Dundu & Mandagi, 2012;Fatikasari et al., 2023;Suprayogi et al., 2017). However, the effectiveness of RHS is highly dependent on the local rainfall pattern, making it unreliable in areas with low or inconsistent precipitation. Moreover, most existing RHS implementations are limited to individual household use and are often constrained by the economic capacity of the local community, which hinders large-scale adoption. Another existing technology used in island regions without natural freshwater sources is the Photovoltaic Seawater

Reverse Osmosis (PV-SWRO) system. PV-SWRO converts seawater into potable water using solar energy as its power source (A. S et al., 2024). While this method is environmentally sustainable, it presents several limitations. The technology is relatively expensive, and the availability of equipment and spare parts is limited, often causing prolonged downtime during maintenance. Additionally, the system requires skilled personnel for operation and technical support, which may not be readily available in remote island communities.

The objective of this research is to obtain a design for a freshwater supply system in the archipelago that complies with the design criteria. In addition, The purpose of this research is to get an alternative inter-island water supply system with new technology that is more efficient for operational costs, in addition to saving on operational water supply systems that can be operated by local residents so that the existence of a clean water supply system can bring impact on the economy of the local community. As explained in Ministerial Regulation of the Ministry of Public Works and Housing No. 27 of 2016, article 2 point 2, which contains ministerial regulations aimed at providing drinking water services in order to guarantee the people's right to drinking water, the realization of quality drinking water management and services at affordable prices, achieving balanced interests between customers and organizers, achieving effective and efficient implementation of drinking water to expand the coverage of drinking water services (Menteri Pekerjaan Umum, 2016).

DESIGN CRITERIA

To obtain a freshwater supply design that is in accordance with the design criteria, this research refers to Permen PU No. 18 of 2007 concerning the implementation and development of drinking water supply systems and SNI 7509: 2011 (Peraturan Menteri Pekerjaan Umum Nomor: 18/PRT/M/2007 Tentang Penyelenggaraan Pengembangan Sistem Penyediaan Air Minum, 2007)(Badan Standartisasi Nasional, 2011). Design criteria for distribution pipes are as follows:

a. Flow Plan (Qpeak)
Q_{peak} : F_{peak} x Q_{avg}
b. Peak hour factor
- Main distribution pipe : 1,15 – 1,7
- Carrier distribution pipe : 2
- Divider distribution pipe : 3

c. Velocity of water flow in the pipe
- Minimum velocity (Vmin) :
  Vmin: 0,3 – 0,6 m/det
- Maximum velocity (Vmax) :
  Vmax : 3 – 4,5 m/det

d. Water pressure at the end of pipe
- Minimum pressure (h_{min})

hmin : 0,5 – 1 Bar (at farthest point)
- Maximum pressure (h_{max})
  h_{max} : 12,4 Bar

The design criteria above are used as validation of the analysis results in this research.

HYDRAULIC ANALYSIS

Hydraulic analysis is carried out in accordance with the Permen PU No.18 Year 2007 with the following provisions:

1. If the pipe network is not more than four loops, the calculation with the Hardy cross method is still permitted manually. If more than 4 loops must be analyzed with the help of a computer program. A computer program often used for distribution piping analysis is epanet(Rossman, 2000;Jayanti et al., 2019;APRITAMA et al., 2020).
2. Calculation of pressure loss in the pipe can be calculated with the Hazen -William equation (Badan Standartisasi Nasional, 2011). The Hazen -William equation can be seen below :

$$Hf = S.L \qquad (1)$$

$$Hf = \left(\frac{Q}{0{,}2783CD^{2{,}63}}\right)^{1{,}85}.L \qquad (2)$$

Where,

Hf : *Headloss* (m/km)
Q : Flow (m^3/det)
C : Pipe roughness coefficient
D : Diameter of Pipe (m)
L : Pipe length (m)

In the Hazen-Williams pressure loss equation, it is calculated based on the flow rate, the pipe roughness coefficient depending on the type of pipe used, the pipe diameter, and the length of the pipe used. Pressure loss is calculated in meters per kilometer(Jamil, 2019;Hashemi et al., 2020).

3. Velocity of flow

The flow velocity in the pipe can be calculated by the following equation:

$$V = 0{,}38464C.D^{0{,}63}S^{0{,}54} \qquad (3)$$

Where,

V : Velosity of flow (m/s)
A : Cross-sectional area (m^2)
Q : Flow (m^3/det)

4. Flow discharge in the pipe

$$Q = 0{,}2783CD^{2{,}63}S^{0{,}54} \qquad (4)$$

Where,

Q : Flow (m^3/det)
C : Pipe roughness coefficient
D : Diameter of Pipe (m)
S : Sloope

METHODOLOGY

This research was conducted in South Halmahera Regency, North Maluku Province. South Halmahera Regency is an area consisting of several islands. In this study, the freshwater supply system serves Tawabi Village with a water demand of 2 Lps, Pasir Putih Village with a water demand of 2 Lps, Laluin Village with a water demand of 7.4 Lps, Arumakurunga Village, Posi - Posi Village and Sagawele Village with a water demand of 3 Lps. Where the freshwater supply system crosses 2 (two) islands in the South Halmahera district.

Figure 1. Research Location

Figure 1 above is the research location located in kayoa sub-district, south halmahera district, north maluku province, Indonesia. This research was taken at that location because there are several small islands that have not had access to drinking water from the local government because there are no raw water sources.

In completing this research, there are several stages that we do to make it easier to do research and write. The stages carried out can be seen in the form of a flowchart and also accompanied by an explanation of each stage. The flowchart can be seen in Figure 2.

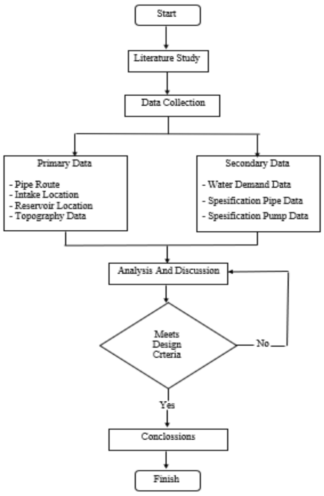

Figure 2. Flowchart

The explanation of the flowchart is as follows:

1. Literature Study

Literature studies are used to find out research that has existed and is similar to the current research. With the literature study, it can be used to explore things that need to be improved with research that has already been done.

2. Data collection.

Data collection consists of primary data and secondary data. Primary data is data obtained from direct measurement. While secondary data is data obtained from related agencies. Primary data includes pipeline topography data. While the secondary data used is water demand data and properties data, that will be used.

a. Pipe specification data

The specifications of the pipes used in the research can be seen in table 1.

Table 1. Pipe specification data

No.	Pipe Type	Pipe Diameter (mm)
1	HDPE	200
2	HDPE	150
3	HDPE	100

b. Pump Specification Data

The selection of pump specifications used in this research is based on water elevation and discharge. The following pump specifications are used from the analysis results.

Table 2. Pump Specification Data

Pump	Flow (Lps)	Head (m)
1	20	40
2	3	30
3	5	60

c. Topography data

Topographic measurements are carried out using GPS. Measurements are carried out to obtain elevations and pipelines that will be designed. The results of the topographic measurements can be seen in Figure 3 and Figure 4.

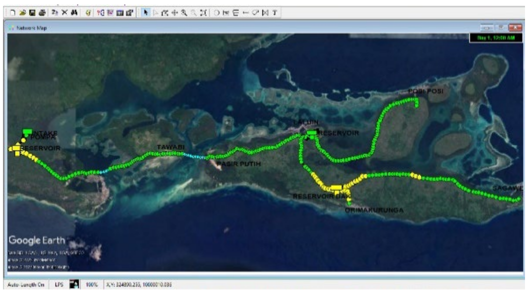

Figure 3. Pipeline route map

Figure 3 above is the route of the freshwater pipeline system. Where water is distributed from one island to another by crossing the sea. The length of the pipe from the measurement results is 23,370 meters (23.37 km).

3. Analysis and Discussion

Data analysis and simulation in this study used Epanet 2.2 software. Epanet is a software for simulating clean water distribution networks that is quite complex and flexible because it can be used without internet access with a fairly complete formulation and a high level of accuracy. After the simulation is carried out, the results are obtained, which will be adjusted to the existing design criteria. In this case, namely Permen PU No. 18 of 2007 and SNI 7509: 2011. The criteria that must be adjusted are the water pressure in the pipe, the flow velocity, and the pipe diameter configuration used as the output of this study.

4. Conclusion

The results of the analysis carried out are then made conclusions as the final result obtained from this research. Writing conclusions can be in the form of important points that can be taken from this research.

ANALYSIS AND DISCUSSION

1. Topography data

In the analysis using Epanet 2.2 software, the data that must be collected are pipe specification data, pumps, and topographic data.

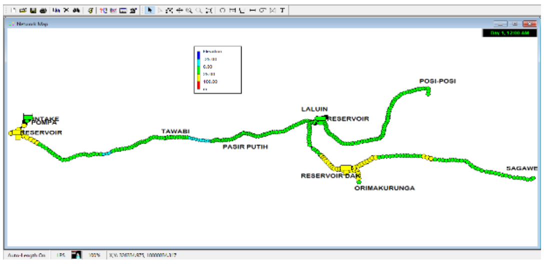

Figure 4. Elevation of pipe route

Figure 4. shows the elevation of the freshwater network system. Elevation at the raw water source is at an elevation of 19 meters. The elevation at the production unit is at an elevation of 60 meters. The deepest seabed is at a depth of 24 meters. Distribution reservoir elevations are at elevations of 16 meters and 63 meters. For the elevation of the service area, the elevation is 7 meters and 23 meters.

2. Pipe Design Configuration

The use of pipes in this research is arranged from the largest, namely pipes with a diameter of 200 mm used in the raw water unit to the production unit. A pipe with a diameter of 150 mm was used for the main distribution pipe. Pipes with a diameter of 100 are used for distribution pipes.

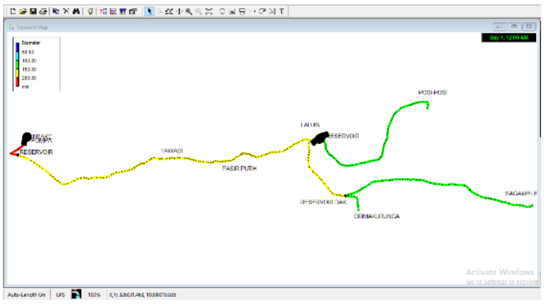

Figure 5. Pipe diameter

The figure above shows the configuration of pipe usage. A 200 mm diameter pipe with a length of 810 meters is shown in red. Pipe diameter 150 mm with a length of 10,780 meters is shown in yellow. A 100 mm diameter pipe with a length of 11,722 meters is shown in green.

3. Pressure and Velocity of flow

The analysis of pressure at the end of the pipe and flow velocity refers to government regulation No.18 of 2007. Regarding the minimum and maximum limits of pressure at the end of the pipe and flow velocity.

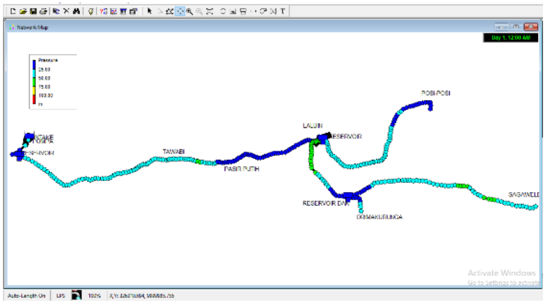

Figure 6. Water pressure at the Pipe end

The figure above shows the results of the water pressure analysis at the pipe nodes. From the analysis, the maximum water pressure at the end of the service area pipe is 4.76 bar and the minimum pressure is 0.94 bar.

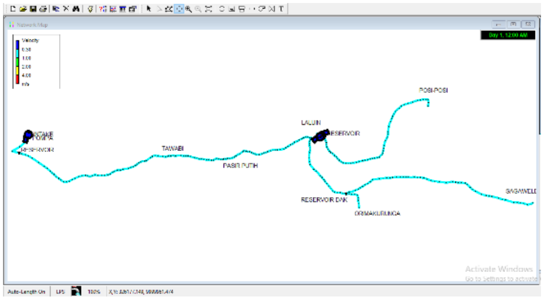

Figure 7. Water velocity in the pipe

Figure 7 shows the results of the flow velocity analysis in the pipe. The maximum flow velocity was found to be 0.93 m/s, while the minimum velocity was 0.35 m/s.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions :

The results of the analysis and design of freshwater pipes in the islands can be concluded as follows:

1. The designed freshwater supply system of this research uses a gravity flow system and a pump.
2. The type of pipe used is HDPE pipe
3. The pipe diameters used are pipe diameters of 200 mm, 150 mm, and 100 mm..
4. The pump used from the design results is to use 3 pumps. For raw water to the production unit reservoir, 1 (one pump) is used and 2 (two) pumps have functioned as boosters to the service reservoir.
5. The water pressure in the pipe at the farthest end in all service areas meets the design criteria. From the design results, the minimum pressure in the service area is 0.94 Bar. The maximum pressure at the end of the pipe is 4.79 Bar.

6. The water velocity in the pipe meets the design criteria from the analysis of the minimum velocity of 0.35 m/s and the maximum velocity of 0.93 m/s.

Recommendation :

1. In the freshwater supply system in the archipelago, further analysis can be carried out regarding the stability of the pipe on the seabed (On Bottom Stability).

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