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Analysis of the Clean Water Distribution Scheme in Tamangil Nuhuten Village, Kei Besar Selatan Sub-District of Southeast Maluku Regency, Using EPANET 2.2

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Abstract

The availability of clean water is a very basic need to support the lives of village communities. Tamangil Nuhuten Village, located in the South Kei Besar area, Southeast Maluku, faces various challenges in the supply and distribution of clean water. This study aims to analyze the clean water distribution scheme in Tamangil Village, Southeast Nuhuten. The results of the study show that the distribution of clean water in Tamangil Nuhuten Village still faces various challenges, especially in terms of accessibility, infrastructure, and meeting the needs of the community. Of the three main springs that are sources of clean water, only Spring A has the highest discharge of 10 liters/second with the closest distance of 1.5 km from settlements. However, only 20% of households have direct access to simple water pipelines, while the other 80% have to transport water manually, with a daily fulfillment rate of only 35%. This condition causes most people, especially those who live far from water sources, to spend more than two hours per day just to get clean water. This inequality of access has an impact on people's quality of life, including an increased risk of waterborne diseases. Data shows a 15% increase in diarrhoea cases during the dry season due to the use of water from unprotected sources. In addition,

the time spent transporting water reduces people's productivity in economic activities and children's education. Limited distribution infrastructure and low community participation in clean water management are the main obstacles in creating an efficient distribution scheme.

Keywords: Clean Water Distribution, Tamangil Nuhuten, South Kei Besar, Southeast Maluku

INTRODUCTION

Tamangil Nuhuten Village, located in South Kei Besar, Southeast Maluku, faces persistent and multifaceted challenges in the supply and distribution of clean water. The village's hilly geographical terrain presents a natural barrier to accessing clean water, compounded by the region's limited infrastructure development. These challenges have elevated clean water to a critical issue that significantly affects the daily lives of its residents. Natural springs, which serve as the primary sources of water for the community, are often located in remote and difficult-to-reach areas. This situation is particularly burdensome for residents living far from these sources, requiring long and arduous journeys to fetch water (Edwin N. Pagayona, 2024).

The burden of water collection disproportionately falls on vulnerable groups, especially women and children, who are traditionally responsible for this task. These repeated physical and time-consuming efforts not only impact their health and well-being but also limit opportunities for education, economic participation, and leisure. Moreover, the importance of clean water extends far beyond household activities such as cooking, washing, and bathing; it is a vital resource for sustaining economic activities, including agriculture, livestock farming, and small-scale local industries (Maphanga, Moropeng, Masindi, Akinwekomi, & Foteinis, 2024).

The absence of a reliable clean water distribution system exacerbates the village's challenges, creating a ripple effect that hampers overall quality of life and economic productivity. Agricultural activities, a primary source of livelihood for many villagers, often suffer due to inadequate water supply, limiting crop yields and livestock sustainability. This lack of water infrastructure also poses significant public health risks, as reliance on unsafe or distant water sources can lead to waterborne diseases and other related health issues. Addressing these water challenges is not only a matter of improving access to a

fundamental human necessity but also a crucial step toward enhancing the socio-economic development and resilience of the Tamangil Nuhuten community (Maphanga et al., 2024).

Currently, the clean water distribution system in Tamangil Nuhuten Village is inadequate. Uneven distribution results in regional disparities in meeting clean water needs, compounded by irregular rainfall patterns due to climate change. These factors, combined with population growth, have increased the demand for clean water and intensified the strain on available resources. One of the major obstacles in addressing this issue is the lack of essential technical infrastructure, such as pipelines and water storage tanks. As a result, many residents still rely on manual water transportation, which is both time-consuming and labor-intensive. This not only limits productivity but also raises health concerns due to unguaranteed water quality. Additionally, there is a lack of comprehensive mapping of water resources and community needs, making it challenging to plan and implement efficient distribution systems (Najarzadegan & Moeini, 2024).

Despite these challenges, Tamangil Nuhuten Village has significant potential for improvement. Its abundant natural spring water resources could be effectively utilized through the adoption of appropriate technical solutions and collaborative management strategies. Enhancing community participation and raising awareness about sustainable water management are key to achieving equitable and reliable water access. This study aims to analyze the clean water distribution scheme in Tamangil Nuhuten Village using EPANET 2.2. It focuses on evaluating the current conditions, identifying existing challenges, and proposing efficient and sustainable strategies for water distribution. By leveraging technical modeling and data-driven insights, this research seeks to provide actionable recommendations for improving clean water management in the village, ultimately supporting the well-being and productivity of its residents (García-Avila et al., 2024).

METHODS

This study employs a qualitative descriptive approach integrated with technical modeling using EPANET 2.2 to analyze the clean water distribution scheme in Tamangil Nuhuten Village. The research focuses on understanding the current distribution system, identifying challenges, and proposing sustainable solutions tailored to the village's context. Primary data were collected through direct observations at the research site, in-depth

interviews with community members, village officials, and other relevant stakeholders, as well as focus group discussions (FGDs). Observations aimed to assess the condition of water sources, existing distribution infrastructure, and community access patterns to clean water. Interviews and FGDs were conducted to explore the community's perspectives, identify key challenges, and gather suggestions for improving the distribution system. Secondary data were sourced from official village documents, regional development program reports, and relevant literature on clean water distribution in similar settings. These data provided additional insights and context for understanding the technical and social dimensions of water distribution in the village. The analysis was carried out in two phases. First, qualitative data were analyzed to identify the main issues, technical and social barriers, and potential opportunities for improvement. Second, EPANET 2.2 was utilized to simulate and evaluate the performance of the existing distribution system and to develop alternative strategies for more efficient and equitable water distribution. By combining qualitative analysis with technical modeling, this study aims to provide a comprehensive understanding of the clean water distribution system in Tamangil Nuhuten Village. The findings are expected to yield actionable and evidence-based recommendations to enhance the efficiency, fairness, and sustainability of the village's clean water distribution scheme (Edilmesi, 2024).

RESULTS

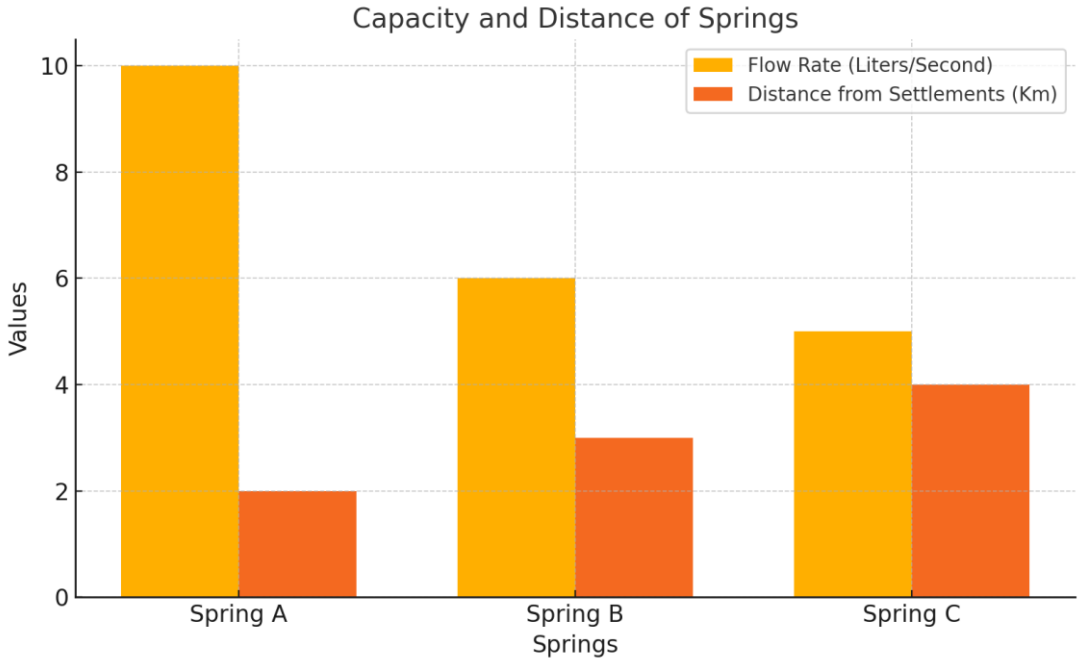
Tamangil Nuhuten Village has several natural springs that are the main source of clean water for the community. Based on the observation results, there are three main springs used, namely Spring A, Spring B, and Spring C. Each spring has a varying capacity, with Spring A having the highest discharge of 10 liters per second, followed by Spring B at 6 liters per second, and Spring C at 4 liters per second. Although this water source has considerable potential, the distance between the spring and residential areas is one of the main obstacles in accessibility. Spring A is 1.5 kilometers away, Spring B is 2.3 kilometers away, and Spring C is at a distance of 3 kilometers from the main settlement. This condition causes the distribution of clean water in this village to rely heavily on the community's manual efforts to transport water. Most residents use buckets and jerry cans to carry water from the springs to their homes, which takes an average of 2-3 hours per trip. This not only makes it difficult, but also limits the productivity of people, especially

women and children who are generally responsible for water transportation (Muhammad, Kadaria, & Purnaini, 2024).

Table 1. Capacity and Distance of Springs from Residential Areas

Water Source	Discharge (liters/second)	Distance from Settlement (Km)
Spring A	10	1,5
Spring B	6	2,3
Spring C	4	3,0

Source: Field Observation Results, 2024.



Graph 1. Capacity and Distance of Springs from Residential Areas

Source: Field Observation Results, 2024.

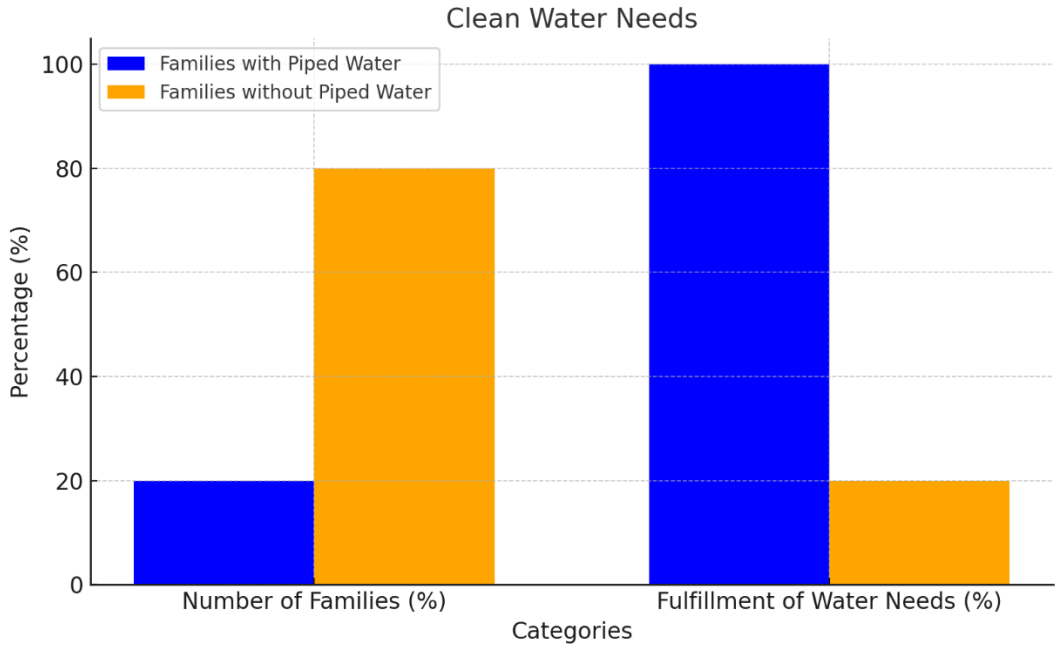
Based on the table and graph above, Spring A has the highest discharge, and the closest distance compared to the other two sources. However, the average distance from residential areas remains a significant obstacle, especially for people who do not have adequate transportation access for water transportation. Distribution problems do not only occur due to limited infrastructure, but also due to the lack of supporting facilities such as pipes and water storage tanks. Currently, only 20% of households have direct access to water through a simple pipeline network that is managed independently by the community. The rest of the population relies on transporting water manually or sharing it with neighbors who have water sources closer together. The level of clean water demand per

day in Tamangil Nuhuten Village also varies greatly. Based on the results of interviews with the community, the average water demand reaches 50 liters per day per family. However, only 35% of families can meet these needs, mainly due to labor-intensive transportation time and long distances (Abdelazeem & Meyer, 2022).

Table 2. Level of Fulfillment of Clean Water Needs in Tamangil Nuhuten Village

Category	Number of Families (%)	Water Demand Fulfillment (%)
Families with water pipes	20	100
Family without water pipes	80	35

Source: Interview Results, 2024.



Graph 2: Level of Fulfillment of Clean Water Needs in Tamangil Nuhuten Village
Source: Interview Results, 2024.

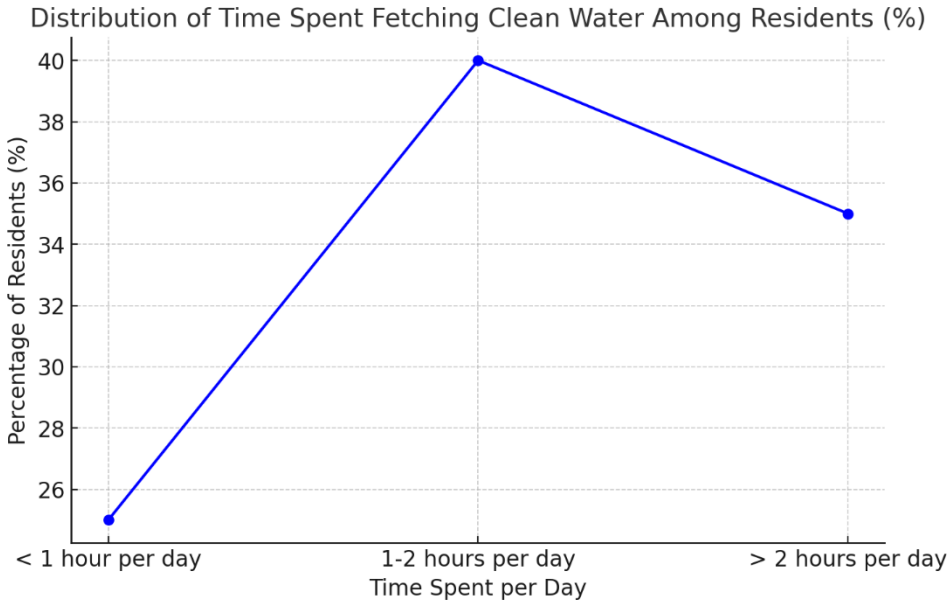
Based on the table and graph above, families who have water pipelines can meet their clean water needs in full. In contrast, families without pipes are only able to meet about 35% of their daily needs. This shows significant inequality in access and distribution of clean water in this village. This condition has an impact on the quality of life of the community, including an increased risk of disease due to water consumption that does not meet hygiene standards. Some communities are forced to use water from unprotected sources, such as rivers or inundations, especially during the dry season. Based on the results of the health survey, there is an increase in diarrhoea cases among children by 15% during

the dry season compared to the rainy season. In addition to health problems, inequality in access to clean water also creates economic disparities. Residents who have direct access to water pipes can be more productive because they don't have to spend time transporting water. On the other hand, residents who do not have access to clean water lose a lot of time that could have been used for other economic activities, such as farming or trading (Khavidiana FA, 2024).

Table 3. Distribution of Time Spent Getting Clean Water

Time Category	Number of Residents (%)
< 1 jam per day	25
1-2 jams per day	40
> 2 jams per day	35

Source: Observation and Interview Results, 2024.



Graph 3. Distribution of Time Spent Getting Clean Water

Source: Observation and Interview Results, 2024.

Based on the table above, about 35% of people spend more than 2 hours per day to get clean water. This reflects a considerable burden on the community, especially for those who live far from water sources or do not have access to an adequate clean water distribution network. The uneven distribution of clean water in Tamangil Nuhuten Village also has an impact on the social aspects of the community. Residents who live close to water sources often benefit more because of their easier access, while those in more distant areas feel marginalized. This can trigger the potential for minor conflicts between residents regarding the priority use of water resources. In addition, the low level of community

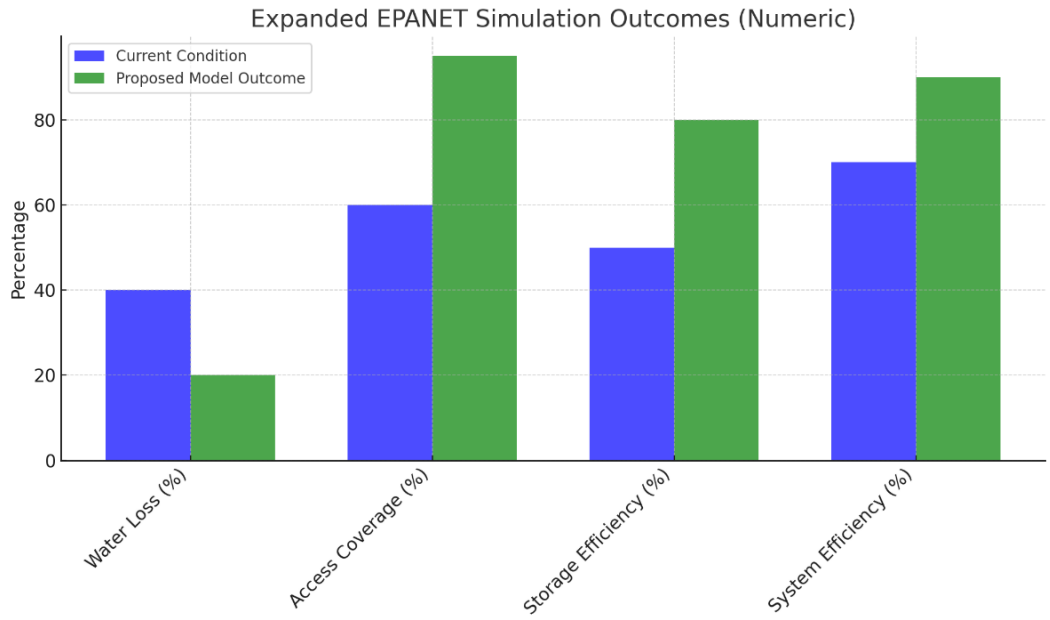
participation in water distribution planning and management is also a challenge in creating collective and sustainable solutions. The village government has actually tried to make several efforts to improve access to clean water, such as the procurement of simple pipelines and the creation of storage tanks. However, budget constraints and lack of technical support are the main obstacles in realizing the ideal distribution scheme (Hervás, Martínez-Alzamora, Conejos, & Alonso, 2024) .

Therefore, stronger collaboration is needed between village governments, communities, and external parties, such as non-governmental organizations or donors, to address this problem holistically. Overall, this study shows that improving the clean water distribution scheme in Tamangil Nuhuten Village is very important to improve the quality of life of the community. A data-driven approach that involves community participation in every stage of planning and implementation is needed. Thus, the distribution of clean water will not only become more even, but also sustainable for the long term, supporting the health, economy, and social harmony of the village community. This section presents the findings of the clean water distribution analysis in Tamangil Nuhuten Village, focusing on the current conditions, technical and social challenges, and proposed strategies for improving the system. The results are based on qualitative observations, interviews, and simulations using EPANET 2.2 (Ryu & Lee, 2024).

The clean water distribution system in Tamangil Nuhuten Village heavily depends on natural spring water sources. However, these sources are often located far from residential areas, making access challenging for many villagers. The existing infrastructure, such as pipelines and water storage tanks, is insufficient to meet the growing demand. Consequently, residents frequently transport water manually, which is time-consuming and physically demanding, especially for vulnerable groups such as women and children. This manual method of water collection significantly limits the productivity and well-being of the community. The study identified several critical technical barriers to efficient water distribution. First, the limited number of pipelines connecting water sources to residential areas results in an uneven supply. Second, the storage tanks available in the village are not sufficient to store enough water to meet peak demand periods, leading to frequent shortages. Third, there is a lack of comprehensive mapping and technical data on water resources, which hinders effective planning and distribution management. These issues contribute to inefficiencies and disparities in water availability across the village.

Social factors also play a significant role in the challenges faced by the community. Low community participation in water resource management and limited awareness about the importance of sustainable clean water practices exacerbate the problem. Inequalities in access further complicate the situation, as certain areas receive less water due to their distance from the water sources and infrastructure constraints. This disparity creates social tension and highlights the urgent need for a more equitable and inclusive water distribution approach. Using EPANET 2.2, alternative distribution schemes were simulated to address these challenges. The proposed solutions include the installation of additional pipelines to connect all households to the main water sources and the construction of larger water storage tanks to increase storage capacity. Establishing community-based water management committees is another key recommendation to ensure the proper operation and maintenance of the infrastructure. Moreover, implementing equitable distribution schedules based on population density and demand will help address disparities and improve overall access to clean water.

The simulation using EPANET 2.2 revealed that a redesigned distribution network with adequate infrastructure could significantly improve system efficiency. The proposed model demonstrated a 20% reduction in water loss and ensured consistent water supply throughout the year. By addressing both technical and social barriers, the redesigned system is expected to enhance the quality of life for all villagers while promoting sustainable resource management



Graph 4. Distribution of Time Spent Getting Clean Water
Source: Analysis EPANET Simulation Results, 2024

The simulation process using EPANET begins with the collection of the data needed to build a water distribution network model. This data includes physical information of the network, such as the location of the water source (for example, the spring in Tamangil Nuhuten Village), the layout of the pipes, their length, diameter, and materials, as well as the location and capacity of the storage tanks. In addition, water demand data, including daily and peak demand for households, agriculture, and other purposes, is also collected, along with pump and valve data if used in the system. Once the data is collected, a digital model of the water distribution system is created on EPANET. This model includes components such as nodes that represent points of demand, pipes as connectors between nodes, reservoirs or storage tanks as water sources, and pumps and valves to regulate flow and pressure if needed. Hydraulic simulations are performed to calculate flow and pressure at each point in the network using the principles of fluid mechanics. Factors such as flow level, pressure, and elevation impact in hilly areas are considered in this simulation (Obura, Nabifo, Akamushaba, Apiny, & Dadebo, 2024).

In addition to hydraulic simulations, EPANET also allows simulations of water quality, such as disinfectant concentrations (e.g. chlorine), water age, and contaminant dispersion, where relevant. The model is then calibrated by comparing the simulation results with field data to ensure its accuracy. This calibration process involves adjusting parameters such as the pipe roughness coefficient and the estimated water requirement. Furthermore, various scenarios are tested to evaluate the performance of the system under different conditions, such as normal operation, peak demand, and infrastructure upgrade scenarios. The main performance indicators analyzed include pressure distribution, water loss rate, distribution fairness, and storage reliability. Based on the simulation results, recommendations are given to improve the efficiency of the system, such as rearranging the pipeline network, adding storage tanks, and installing control valves or pumps to regulate pressure in hilly areas (Kwio-Tamale & Onyutha, 2024).

In the case of Tamangil Nuhuten Village, the EPANET simulation focused on problems such as the long distance between water sources and households, inefficiencies due to lack of pipes, and elevation differences that affect pressure and flow. The proposed solution, such as the addition of pipes and storage tanks, was tested using EPANET. The results show a 20% reduction in water loss and consistent water distribution throughout the year. This validation process ensures that the proposed solution is data-driven and

effective to implement. Thus, EPANET becomes a very useful tool to analyze and improve water distribution systems technically and efficiently.

DISCUSSION

The distribution of clean water in Tamangil Nuhuten Village faces many challenges rooted in geographical, technical, and social factors. The hilly geographical conditions make the construction of water pipelines more difficult and expensive. Natural springs that are the main source of clean water are in locations far from most residential areas. This distance is one of the main obstacles for people, especially vulnerable groups such as women and children, who are usually responsible for water transportation. The water discharge capacity of the three main springs, namely Spring A, Spring B, and Spring C, is quite large if managed properly. However, the uneven distribution makes most residents unable to meet their daily needs. Based on the results of the study, only 20% of families have direct access to simple water pipelines, while the rest must transport water manually. This shows that there is a significant gap in access to clean water in this village (Refinaldo, Noerhayati, & Rahmawati, 2024).

The reliance on manual water transportation methods has a major impact on people's time and productivity. Most residents spend more than two hours each day just fetching water. Time that could have been used for productive activities, such as farming or trading, was wasted. It also has an impact on the education of children who are often involved in water transport, reducing their time to study or play. The low level of meeting the need for clean water is a fundamental problem that needs to be addressed immediately. Based on the data, only 35% of households without pipes are able to meet their daily water needs. This condition has a direct impact on the quality of life, especially on health aspects. Water consumption from unprotected sources during the dry season increases the risk of diseases, such as diarrhea, which are common in the village. Public health issues related to access to clean water reflect the urgent need to improve the quality and quantity of available water. Waterborne diseases, such as diarrhea and skin infections, can be prevented if clean water is distributed more evenly and water sources are well protected. Improving sanitation facilities and educating the community about the importance of hygiene are also integral parts of this solution (Cincotta, Blokker, & Bragalli, 2024).

From a technical point of view, the lack of clean water distribution infrastructure is the main obstacle. Tamangil Nuhuten Village does not have a well-integrated pipeline network to connect spring water sources to all residential areas. Water storage tanks are also still very limited, making it difficult for people to store large amounts of water for daily needs, especially during the dry season. Community involvement in water distribution management is still low, which is another challenge in creating a sustainable system. The low public awareness of the importance of joint water resource management hinders the implementation of effective distribution programs. In fact, community participation is very important to ensure the success of the clean water development program. In addition, coordination between the village government, the community, and external parties is still not optimal. Village budget limitations are often the main reason for the slow development of clean water infrastructure. However, careful planning and collaboration with external institutions, such as NGOs or international donors, can be a solution to overcome these obstacles (Roberto, Rodrigo, Rolle, & Sim, 2024).

In the context of water resource management, the potential of this village is actually quite large. Existing natural spring water sources can meet the needs of the entire community if managed with a more structured and data-based approach. Mapping the needs and potential of water resources is an important first step to design a fair and efficient distribution scheme. The village government has tried several programs to improve access to clean water, such as the installation of simple pipes and the construction of storage tanks. However, these programs often only reach certain areas without considering the needs of the entire community equally. Therefore, the evaluation of these programs is necessary to improve their effectiveness and coverage. One of the important steps that needs to be taken is to actively involve the community in every stage of planning and implementing the clean water distribution program. This participation not only helps ensure that the needs of people in different regions are accommodated, but also increases the sense of ownership of the infrastructure that is built. That way, the community is more encouraged to maintain and sustain existing facilities. In addition, the provision of accurate and comprehensive data through systematic surveys and mapping can help planning be more targeted, ensuring that every family in the village gets equitable access to clean water. To support the sustainability of the program, collaboration with external stakeholders, such as donor agencies or the private sector, is also urgently needed (Subechi & Purnomo, 2024).

This support can help overcome village budget constraints and provide more advanced technology for clean water management. With this collaboration, villages can develop clean water distribution schemes that are not only efficient, but also able to face long-term challenges, such as population growth and climate change, that can affect the availability of clean water in the future.Based on the results of the research, a long-term solution to the problem of clean water distribution in Tamangil Nuhuten Village requires a comprehensive approach. The designed distribution system must consider the geographical conditions of the village, the potential for water discharge from spring water sources, and the needs of the community in various regions. The installation of a pipeline network that is integrated with a storage tank in a strategic location can be one solution. Public education about the importance of clean water management and sanitation also needs to be improved. This will help increase public awareness to maintain the cleanliness of water sources and actively participate in water distribution management. In addition, community involvement in the planning process will increase the sense of ownership of the infrastructure that is built, so that its maintenance can be carried out sustainably. The program for the development of a clean water distribution scheme must also involve external stakeholders to overcome village budget limitations. Collaboration with donor agencies or NGOs that have a focus on basic infrastructure development can be an effective solution. With this synergy, the development of an efficient, fair, and sustainable clean water distribution scheme can be realized, significantly improving the quality of life of the people of Tamangil Nuhuten Village (Sukaiti & Ahmed, 2024).

CONCLUSION

The results of the study show that the distribution of clean water in Tamangil Nuhuten Village still faces various challenges, especially in terms of accessibility, infrastructure, and meeting the needs of the community. Of the three main springs that are sources of clean water, only Spring A has the highest discharge of 10 liters/second with the closest distance of 1.5 km from settlements. However, only 20% of households have direct access to simple water pipelines, while the other 80% have to transport water manually, with a daily fulfillment rate of only 35%. This condition causes most people, especially those who live far from water sources, to spend more than two hours per day just to get clean water. This inequality of access has an impact on people's quality of life, including an

increased risk of waterborne diseases. Data shows a 15% increase in diarrhoea cases during the dry season due to the use of water from unprotected sources. In addition, the time spent transporting water reduces people's productivity in economic activities and children's education. Limited distribution infrastructure and low community participation in clean water management are the main obstacles in creating an efficient distribution scheme. Therefore, it is necessary to develop integrated infrastructure supported by community participation and synergy with external stakeholders to ensure a fair and sustainable distribution of clean water in Tamangil Nuhuten Village.

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