RESEARCH ARTICLE OPEN ACCESS

Design and Analysis of a Sustainable Water Distribution Network for the Aeta Community in Brgy. Diaz, Porac, Pampanga

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Abstract:

This experimental research aimed to propose a conceptual design of sustainable water distribution network that addresses the current water system in the Brgy. Diaz, Porac, Pampanga. In the barangay, the main source of water is groundwater that came from manually operated pump that is located at the highest elevation of the barangay. Water samples were collected for physiochemical and microbiological testing in a laboratory. The water sample only failed the DOH standards for heterotrophic plate count, having a result of 2000 MPN. The software used to design the WDN was EPANET. Beforehand, collected data such as the difference in elevation, length, and the water demand for each station. The elevations and lengths were measured in actual by means of auto-level surveying. This study based the design of WDN with the future water demand, since the design that can accommodate the future demand, will and can also supply the current water demand. The total water demand in the barangay was distributed equally to the six stations. The design consists of pipes having a diameter of 100mm and 200 mm, one main storage tank, and a pump with 1.5 hp. The pressure and head loss were analyzed during normal hours and peak hours. The maximum and minimum pressure within the network were 22.63 m and 11.88 m, which are within 10 psi to 60 psi. Based on the output of EPANET, the design of WDN can fulfill the current and future water demand based on its water flow rate.

Keywords **—water, water distribution network, EPANET, pressure, water demand.**

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I. THE PROBLEM AND A REVIEW OF RELATED LITERATURES AND STUDIES

1.1 Introduction

Humans, consisting of 60% liquid, can only last for 2-4 days without consuming any water. It helps with digestion, circulation, and transportation of nutrients throughout the body [1]. However, there are times that water in today's time is being taken for granted, either for consumption or residential use. This valuable resource is being wasted by excessive use of water such as taking a bath for longer period of time or letting the faucet open while brushing teeth, and not fixing broken pipes resulting in leakage. Wasting water has its impact on neighboring communities, wherein it restricts water access specifically to the areas where water shortage is a prevalent issue. To have a sufficient and constant water supply has become a normal thing for most of the people in the world, but for some, it is already a privilege.

Even though the Earth consists of 71% of water, only 3% is fresh water and roughly around 0.5% is being accommodated by humans as potable water. It might not seem like it, but water scarcity is a worldwide problem [2]. Based on the statement of the World Health Organization in 2022, there are around 2.2 billion people globally who do not have access to safe drinking water. In line with this, around 300 million people around the world have only intermittent access to piped water supply [3]. Piped water is only available for a few hours per day or two or three days per week in some developing world cities in Asia, Africa, and Latin America. Furthermore, disturbances in water availability pose a serious public health risk, necessitating universal regular supply [4].

Deficits in water services, such as water supply shortage, are one of the main causes of illness and premature mortality for the urban poor in the world's fast-growing cities [5]. Those problems also make it difficult for the affected people to access school that leads to a reduction in livelihood security. Due to the inevitable growth of our planet, the water crisis cannot be avoided both in quantity and quality. In return, some people are forced to accommodate water that is only available. To have a sufficient amount of potable water has become a challenge for most of the people in the world. That is why it is critical to recognize sources of water, together with their conservation and optimum use. To ensure sufficient pressure and hygienically safe water, the network's structure and configuration must be properly planned [6]. In the study of Sunghun[7], it was stated that the necessary improvement of the national water supply system is needed as well as innovative reorganizing of the waterwork business structure, so that the people can use tap water without thinking of it running out.

Groundwater is the most prevalent source of water in towns, municipalities, and rural areas in the Philippines. 60% of families utilize groundwater, and in villages without the convenience of piped water supply from municipal or city water agencies, people use water from a local "poso" or deep well [8]. It is critical to have an adequate water supply; yet this is not the case throughout the country. The country's constantly growing population (2.3% per year) not only makes it more difficult for planners and water service providers to meet the ever-increasing demand, but it also has a significant impact on water quality. Among the 109 million Filipinos, 52% (57 million people) lack reliable access to a safely managed water source, and 39% (43 million people) lack access to properly managed household sanitation facilities [9]. Despite economic growth, the nation grapples with substantial issues related to water and sanitation access, particularly as urbanization accelerates. When the demand for water exceeds the supply, an uneven distribution of water resources occurs, resulting in water shortages. The expanding cities face difficulties in supplying sufficient water and sanitation services to the growing population [10]. The National Capital Region (NCR, Metro Manila), Central Luzon, Southern Tagalog, and Central Visayas are regarded to be in critical condition in terms of water quality and quantity [8].

This is quite similar in the case of the province of Pampanga. The growth of its human population and its industries are the main factors for the over-extraction of groundwater, which results in an uneven water supply [11]. Groundwater resources receive continuous replenishment from rainwater and seepage from water bodies such as rivers and lakes. However, the persistent issues of over-extraction and inadequate distribution pose ongoing threats to the usability and recharge of fresh water in groundwater aquifers [12].

When dealing with this type of problem, the engineering field related to it, which plays a vital role, is clearly water resources engineering. This engineering domain studies and manages the preservation of water [13]. It also deals with designing water infrastructure to manage and utilize water supply. Additionally, in a much smaller context, water resource engineer's major role is to regulate a population's water use and guarantee that water treatment is safe for human use [14].

When water is distributed unevenly, the high-density urban areas will become water-stressed, escalating issues between users, notably between the urban, agricultural, and industrial sectors. One of the ways to prevent or lessen this is the preservation of ecological flow and natural water bodies. Also, effective water distribution network restoration and management strategies can result in major economic, social, and environmental advantages [15]. A network of hydrologic and hydraulic components that have been specially designed to supply water is known as a water network. These are a system of pipes supplying the enough quality and quantity of water to a community. Improved administration and operation of home water distribution networks are required for urban water supply [16]. In order to address all concerns properly and in a timely manner, decision-making procedures should rely on credible information that characterizes system operation, such as flows, probable failures, losses, and/or other difficulties.

A regular supply of drinking water will benefit individuals and communities, as well as wider economic and social benefits. The most obvious advantage of safe and clean drinking water is improved health, well-being, and development [2]. Initially, safe drinking water and proper sanitation help to avoid the development of water-borne diseases including cholera, typhoid, and diarrhea. Access to safe drinking water benefits the economy as well [15]. Creating a fully operational drinking water system produces jobs for local inhabitants while also allowing corporations and social enterprises to invest in the local economy. Additionally, this also impacts the time saved by not having to collect water from sources. The number of hours every day spent worldwide to fetch water is around 200 hours. This will also result in more time for social activities such as spending time with family and friends or participating in other leisure activities [2].

The action of improving the water system is aligned with the sixth Sustainable Development Goal (SDG), also referred to as Clean Water and Sanitation, which aims to address various challenges associated with global access to safe drinking water, sanitation, and ensuring water availability. It focuses on improving the quality and sustainability of water resources on a worldwide scale [17]. In order to fulfill the increasing demand for water and provide a future supply that is both safe and environmentally sustainable, sustainable management of water resources is essential [18]. The term "sustainable water management" refers to the use of water resources to meet present-day water demand without compromising future water supply. In the Philippines, in year 2021, groundwater currently provides more than 50% of the potable water supply and 85% of the piped water supply [19]. Groundwater is the primary source of river flows during the dry season, which are then frequently used to produce drinking water. Groundwater is also strategically and economically significant to the present and future water supply. In order for the water network design to be sustainable, it should consider the following factors such as accessibility to clean water, availability of water which should supply the everyday demand of the residents, and the stability of the water source which in this paper, the main water source is a groundwater [20].

1.2 Literature Review

One of the factors that contributes to uneven water distribution is the inefficiency of the existing water network design at the given location [7]. This was the case in another study, it was emphasized that one of the main concerns in India is the water management problem [21]. It was also found out that there are numerous drawbacks when it comes to the earlier water supply system. The study suggested redesigning the water system distribution that was based on their CPHEEO manual and must meet the parameters for pipe material, velocity of flow in pipe, reservoir level and unit head-loss.

To meet the demands of the rapid expanding of population, water must be supplied across the planned pipeline network equally [22]. In order to do that, some studies utilized Environmental Protection Agency Network Evaluation Tool (EPANET), a software that is used worldwide mainly for water distribution system modeling. It was created as a tool for analyzing how drinking water elements move through distribution networks and what happens to them after that. However, it may be applied to a wide range of distribution systems analysis tasks. Currently, EPANET is used by engineers and consultants to plan and size new water infrastructure, adapt outdated infrastructure, improve the efficiency of tanks and pumps, save energy, look into issues with water quality, and get ready for emergencies. Additionally, it can be used to simulate contamination risks and assess a system's resilience to security risks or calamities. In addition, due to its software flexibility and accessibility, EPANET can become a standard tool for Water Distribution System quality modeling [23].

In the study of Awe et al., where various water distribution system (WDS) models were reviewed, EPANET is a free hydraulic analysis software for WDSs. Within pressurized WDSs, it fully simulates hydraulic and water movement [23, 22, 24]. It was created to help better understand how water moves through WDSs. EPANET is a robust and adaptable application that offers a workspace for hydraulic analysis of systems of any scale by modifying system input data, performing hydraulic and water quality simulations, and visualizing the results on several platforms of your choice. Although its primary function is as a research tool, it may also be used to design new WDSs and restore old ones.

The importance of water resources as a foundation of human life is emphasized due to the growing demands driven by economic development and population growth [25]. EPANET 2.0 software was used and incorporated various data such as land elevation, pipe distribution maps, population figures, and discharge rates. It was revealed that the existing water distribution design fell short of meeting availability, hydraulic analysis, and calibration standards, necessitating a redesign to fulfill all parameters [7, 21, 25]. The new design proposed a two-stage development process spanning 2015-2020 and 2020-2025 to enhance the water distribution system.

In the study of Sahu and Singh [26], it is focused on demonstrating how EPANET might be used to analyze a water distribution system, and it should be applied to evaluate non-revenue urban and rural water management. The study utilized EPANET to analyze and design a water distribution system in confined places in Jharkhand, India. In conclusion, a new design of the water system was integrated with gravity and pumping system.

Lingayat and Rai [27] discussed the importance of a water distribution network in providing urban areas with an adequate supply of high-quality drinking water, highlights the use of tools such as EPANET, the Hardy Cross method, and the Newton-Raphson method for efficient network analysis. EPANET is particularly emphasized for simulating hydraulic behavior in pressurized pipe networks. The study aimed to assess parameters like pressure, flow rate, and velocity to ensure sufficient water supply in the study area. By calculating residual head at nodes and considering elevation, it provides valuable insights into the performance of the pipeline system, with a specific focus on urban water distribution networks in developing countries.

Parmar and Patel [28] stated that to meet the water requirements for the continuous growth of population, it is critical to have a uniform quantity of water through the pipeline [25]. EPANET was utilized to design the new water network with the presence of water pump in Olpad village [26]. It was found out that the pressure in the newly designed water network is enough to provide uniform water throughout the Olpad village. The findings of their study were also the same in the case of an Aeta Community in Arayat, Pampanga [29].

The initial step of the system incorporates the recreation of the static and dynamic qualities of the WDN through EPANET programming. For this reason, verifiable guides of the WDN are utilized to consolidate network calculations and line distance across, length, and material. A spatio-transient reproduction of a WDN is carried out with the utilization of EPANET. To decouple the interest-driven and pressure-driven parts of SIV, spillage "valves" are utilized in each EPANET hub. The results of such an investigation can offer definitive knowledge to the administrator of the WDN with respect to the progression of the planning boundaries and KPIs of the organization. The created tool compartment can act as management support for the WDN or the premise for the development of a digital twin [30].

Having a main objective to assess the current water distribution arrangement of CUET, an improvement for the water circulation framework was done with the help of EPANET 2.0 and will foster an administration framework to supply the water with sufficient pressure [21, 28, 29]. After gathering all necessary data, various situations were assumed to test the new model of water network. The results showed that the water network can fulfill the present water demand in the area as well as the future demand since every node has sufficient pressure with appropriate diameter. The correctness of the software was also checked by performing manual pressure computation, and it was confirmed by having almost similar values [31, 32].

There is a vital role that water distribution network plays in ensuring and providing worthy life for the public [33]. To fulfill the population's growing water demand, it is essential to deliver an adequate and equal amount of water through a well-designed network of pipes [22]. The software EPANET and Loop were utilized to examine the water network in the long run. In the end, they were able to provide a design with appropriate pressure and velocities at all pipes.

In a study "Methodological approach for the compilation of a water distribution network model using Quantum Geographic Information System (QGIS) and EPANET", it introduces an innovative methodological approach that combines open-source software like QGIS and EPANET with engineering practices for water distribution network design. The integration of these tools with engineering expertise has proven to be a cost-effective and practical way to create water distribution network models in smaller developments or towns. By avoiding the expenses associated with commercial licensed software and providing process flow diagrams, this approach can save both time and money while assisting municipalities in southern Africa with outdated records and budget constraints. Ultimately, the methodology aims to enhance water infrastructure planning, design, and management, addressing critical challenges in the region, such as water scarcity and service delivery issues [34].

EPANET 2.2 software was used to try to simulate the water quality of the proposed distribution network for the University of Kashmir [35]. The study also sought to obtain the planned network's optimum performance in terms of water quality metrics. Additionally, the EPANET extension—WaterNetGen—has been used to carry out leakage modelling. In conclusion, the leakage discharge for their design was negligible with a value of 0.1% and 0.15%. It also obtained the maximum efficiency performance of the said water network in terms of water quality.

A study found out certain limitations regarding EPANET software. It is clearly the best and user-friendly software to use when modelling water network. However, it can only design pressurized water system and assumes pipes are pressurized. It is recommended to use other kinds of software when designing water systems with gravitational systems or with low pressure for transferring water along the waterline. It was stated that GOODwater software is the best partner of EPANET[36].

Given these various literatures, they all have similar problem, it is the improvement of the existing water network in their locale due to various drawbacks. Some of these problems are insufficient pressure, inappropriate diameters of pipes, and uneven distribution of water. In order to solve the problem, they proposed a design for the new water network wherein they utilized EPANET, a software mainly used for design and simulation of the water distribution system. Their proposed design was viable and has enough pressure, but before obtaining this result, the important parameters they gathered were the number of nodes, distance between each node, elevations, pressure and water demand. This study had utilized mostly the same approach.

1.3 Background of the Study

A worldwide concern regarding managing small community water supplies is present for developed and poorer countries. It is common that smaller community water supplies are more vulnerable to failures and pollution, which can result in the spread of waterborne illnesses and a gradual decline of their functionality and services. Having 71% of water across the world, yet the scarcity of water is still clear. With this in mind, the effects of water scarcity to a person's life are significantly great such as poor hygiene, bad sanitation, and of course, dehydration.

The main water source of this proposed water network will be groundwater and it is located near the working *poso* at the top elevation. The Philippines' 85% piped water and 50% of potable water is being supplied by groundwater. Groundwater is the primary source of river flows during the dry season, which are then frequently used to produce drinking water. Groundwater is also strategically and economically significant to the present and future water supply. This water source can be maximized by having a properly designed water distribution network [30].

In the Aeta Community in Brgy. Diaz, Porac, Pampanga, which is in uphill orientation, consists of four manually operated pumps (poso), but only one is working. This *poso* is located within the perimeter of the housing units but at higher elevation (refer to figure 1). To supply water using one mechanical pump (poso) for the 500 people residing in the barangay looks very underwhelming. Given this, some of the residents choose to fetch water in the place they call "sibol." They need to travel an estimated 1.5 kilometers on a sloping gradient road. In addition to this, fetching water plays significant challenge in a person's daily energy even though the distance they need to travel is more or less 1 kilometer. The energy consumption of fetching water is also affected by the age and gender of the fetcher, as well as the type of terrain and slope gradient of the road [37]. Even if the residents have another option to fetch water in another location, the lack of water supply is still present in the community. Ensuring water availability is one of the goals of SDG 6. That is why having a constant and sufficient potable water supply at any time of the day is the most ideal for every community, wherein it also promotes the overall well-being of everyone [17].

The people use the water they collect for agricultural and domestic purposes, as well as for consumption. With that, an initial test regarding the water quality was conducted to ensure if a water filtration system is still required for the whole water network. Water filtration is significant because it provides people with access to clean water that is free of impurities, has a pleasant flavor, and is a dependable source of hydration. There are various water filtration systems in today's time, and they all offer the fundamentals of water purification process [38]. Clean and safe drinking water is essential for human health and well-being.

Fig. 1 Geographical Location of the 79 Housing Units in Brgy. Diaz taken from Google Maps.

1.4 Statement of the Problem

In the Aeta community located in Brgy. Diaz, Porac, Pampanga, the uneven water distribution has been one of the main issues which is due to lack of well-designed water network. Within the perimeter of the housing units, there is one *poso* that is working out of four *posos*. However, before they can accommodate water, the residents mostly choose to fetch water from a groundwater source that is estimated to be one kilometer away from their houses, and this place is what they call "sibol." The significant inadequacy in access to clean and safe water sources not only poses a substantial health risk but also hinders the daily lives and overall welfare of the Aeta [39]. The energy and time needed to fetch water could be used to do other chores or recreational activities that can have a great impact on their lives. Additionally, the creation and implementation of a sustainable water distribution network acts as a resultant catalyst to develop essential skills and capacities of community members.

1.5 Research Objectives

General Objective:

The main goal of this study is to propose a design of sustainable water distribution network that addresses the current water system of the Aeta community in Brgy. Diaz, Porac, Pampanga.

Specific Objectives:

1. To identify the potability and needs of water filtration by testing the water's physical, chemical, and microbiological attributes.
2. To propose a design of new Water Distribution Network in the locale, using EPANET.
3. To perform a cost estimation regarding the proposed new water network.

1.6 Significance of the Study

The present study is significant because it affects many aspects, and it can contribute to the overall understanding and improvement of water distribution systems. Here are some important key points that highlight the significance of this study:

1. Improved Water Supply

Enhancing the water distribution network in Barangay Diaz can lead to improved water supply for the residents. This is particularly crucial for ensuring access to clean and sufficient water, which is essential for various domestic, and agricultural purposes.

2. Public Health and Safety

A well-structured water distribution system is important in maintaining public health and safety. An unplanned and improper structured of a water distribution can lead to waterborne diseases and other health hazards. Analyzing and optimizing the system in Barangay Diaz can contribute to a safer and healthier living environment for the community.

3. Efficiency and Sustainability

The study can contribute to the development of more efficient and sustainable water distribution systems. An optimization of the network design can reduce water losses, energy consumption, and operational costs, making the system more environmentally friendly and economically viable in future cases.

4. Government

The study can provide significant insight for the local government authorities. Recommendations and results from the analysis can be used to shape policies related to water infrastructure, ensuring that they are capable in providing the community's needs and priorities.

5. Community

Involving the community in the study can lead to increase the awareness and empowerment. Educating the residents about water conservation, proper usage, and the importance of a reliable distribution system can be a reminder for them to have a sense of responsibility and cooperation within the community.

6. Academic Contribution

This study can contribute to the academic field by providing a real-world case study that can be referenced by future researchers and students studying civil engineering, water resources management, or any other related courses. It can contribute and improve the existing knowledge in the field of water distribution network design and analysis.

1.7 Scope and Limitations

The primary scope of this study is to design a new water distribution network that was located within the perimeter of the 79 houses in the Aeta community situated in Brgy. Diaz, Porac, Pampanga. The water network was designed in a way that it accommodated the water demand of the current population, as well as the future population of the barangay. The design of the water network consisted of pipe lay-outing, determination of sizes of pipes, and the location of the water storage tank to be used in the water network. The groundwater potability had been tested by examining the water's physical, chemical, and microbiological attributes to identify if the water is safe for consumption. For the design, analysis, and simulation of the proposed water network, the software EPANET was utilized. One of the concerns for this study is the urban development in the barangay or the orientation of the houses that will be constructed in the future. With that, the WDN design was focused on the current population of the barangay. Auto level surveying was performed to determine the difference in elevations of each node as well as the location of the water source. Also, the head loss and pressure throughout the network was analyzed to ensure that there will not be any problem when supplying water during peak hours. Lastly, this study also presents the list of materials and the estimated cost of these materials for the possible implementation of the water distribution network.

This study only designed a water distribution network consisting of six stations which would be shared by several housing units per station. This method was chosen to minimize the cost of the proposed water network while being able to distribute water throughout the community. Also, taking into consideration the urban development in the barangay, the orientation of the future houses that will be constructed in the barangay cannot be identified accurately. As a result, it would yield to inaccurate or inappropriate design output. Given that, this study only designed the WDN for the current population. There are various pipes prepared in advance that will serve as the connecting pipes for the layout of the future WDN after several years. The main source of the water distribution network is groundwater. The water has been examined by AquaLab Center through various tests to identify its physical, chemical, and microbiological properties. Under the physiochemical analysis, the Arsenic (As), Cadmium (Cd), Lead (Pb), Nitrate (No3), Color (Apparent), Turbidity, pH level, Total Dissolved Solids, and Disinfectant Residual have been analyzed through atomic absorption spectrophotometer and ion-chromatography tests. On the other hand, the test for the microbiological properties of water were total coliform, thermotolerant coliform, heterotrophic plate count, and E-Coli have been examined through multiple tube fermentation technique and enzyme substrate coliform test. The mentioned examinations have been conducted in a laboratory. For the elevations, surveying was conducted to get the difference in elevation for each node of the water network. The elevations besides the nodes were not measured. The outputs of the study were limited in the EPANET only. Additionally, only the conceptual design of the water network study was provided, and the actual implementation is considered as beyond the scope of this study. Lastly, since there is no available data regarding the groundwater volume in the barangay, the design capacity of the network will be limited to 10 years.

1.8 Conceptual Framework

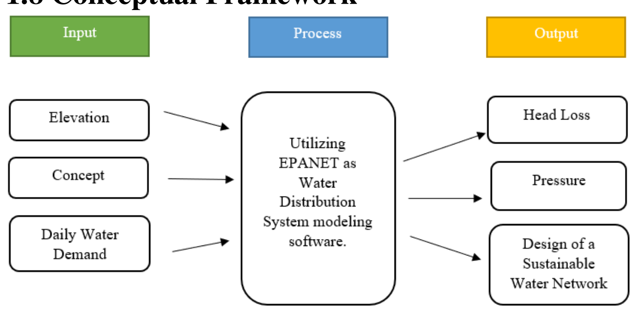

Fig. 2 Illustration Between the Connections of Data for Design Framework.

Figure 2 illustrates the design framework or the relationship between pieces of data. It starts with the input, which are collected data from the locale, and the community. These data served as the foundation for the water network design, yet these data can be manipulated to produce a sustainable water network. Later on, this input has been used in EPANET as the primary tool for modeling a water distribution network. EPANET then analyzes the concept to generate outputs. These outputs represent the factors that affect a water distribution network.

1.9 List of Terms and Abbreviations

1. Water Network - an arrangement of designed hydrologic and pressure driven parts that give water supply.
2. Groundwater - Water that has seeped into the earth to fill the voids left by sediments and rock fissures is known as groundwater. Rainfall supplies groundwater, which then rises to the surface to restock rivers, lakes, and streams.
3. Water Scarcity - lack of fresh water supplies to fulfill average water demand.
4.Water Demand **–** it is the precise estimate of the total water consumed by the population.
5. Nodes - the point of connection for network equipment that may send and receive data between endpoints, such as switches, routers, and printers.
6. Junctions - a point where two or more objects are connected for the combination or splitting of one or more incoming fluid streams into one or more exit pipes.
7. Discharge - volumetric flow rate in a stream.
8. EPANET (Environmental Protection Agency Network Evaluation Tool) -A software program called EPANET is used to model water distribution systems all around the world.
9. WDN – Water Distribution Network
10. WDS – Water Distribution System
11. MAL – Maximum Allowable Level
12. PPM – Parts Per Million
13. NTU – Nephelometric Turbidity Unit
14. AOC – Assimilable Organic Carbon
15. HPC – Heterotrophic Plate Count

II. METHODOLOGY

2.1 Methodological Framework

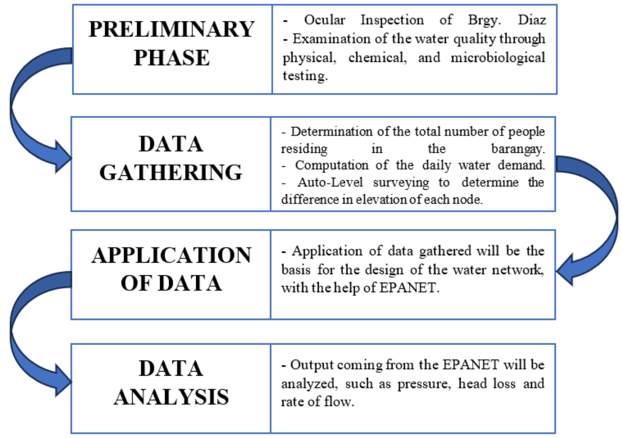

Fig. 3 Comprehensive Process of the Methodology of this Study.

Presented in Figure 3 is the methodological framework of this research. It consists of the preliminary phase where site visitation, and conducting of preliminary tests take place. Next is the determination of the total population and daily water demand of the barangay. Also, another data that is crucial for this study is the difference in elevation of each node. This will directly determine the design of the water network such as the sizes of pipes and the pressure within the pipes. To accumulate this data, auto-level surveying was conducted in the barangay. Lastly, these data play a vital role because they will be the basis for the proposed design of the water network in the locale.

2.2 Research Design

The study made use of experimental research design. This type of research design is conducted with a systematic and scientific approach to examine the relationship between the independent and dependent variables [40]. The independent variable is the one being manipulated or controlled to achieve desired results. On the other hand, the dependent variable is the one being measured or tested in the study. It is altered in response to the changes applied to the independent variable [41]. In this study, the independent variables are the elevations, diameter, and length of pipes, while the dependent variable is the design of sustainable water distribution network in the barangay. Additionally, the researchers have the power over the variables to gain specific results.

2.2.1 Water Testing

The assessment of water quality examines numerous parameters to identify its suitability for drinking water. Physical, chemical, and microbiological properties are the foundation of water quality evaluation. Physical properties involve various characteristics of water such as temperature, turbidity, odor, color, and taste. This test quantifies parameters like temperature fluctuations, suspended solids, and aesthetic qualities. Chemical properties analysis involves the concentration of different substances dissolved or suspended in water. Laboratory analysis of physiochemical properties includes arsenic, cadmium, lead, nitrate, pH, and disinfectant residual. Microbiological analysis aims to quantify the microorganisms present in water, mainly total and fecal coliform, heterotrophic plate count, and E-Coli test. These analyses are critical in assessing water potability and the risk of waterborne diseases.

According to the Department of Health[42], under the Philippine National Standards for Drinking Water of 2017:

TABLE I
STANDARD VALUES, METHODS OF DETECTION AND POINTS OF COMPLIANCE FOR MICROBIOLOGICAL QUALITY OF DRINKING-WATER

Parameter	**Standard Values**	**Methods of Analysis (SMEWW 22nd ed.)**	**Point of Compliance**
1 . Total Coliform	MTFT: < 1.1 MPN/ 100 mL	9221 Multiple Tube Fermentation Technique	Consumer's taps Water treatment works/plants Water refilling stations Water vending machines Mobile treatment devices Point of use treatment devices Water haulers Bulk Water
	EST: Absent or < I MPN/IOO mL	9223 Enzyme Substrate Coliform Test*	
	MFT: < I total coliform colonies / 100 mL	9222B Standard TotalColiform Membrane FilterTechnique 9222CDelayed Incubation Total Coliform Procedure* 9222H Simultaneous Detection of Total Coliform and E. coli by Dual-Chromogen Membrane Filter Technique*	.
2. Thermotolerant Coliform/E.coli	< 1.1 MPN/ 100	9221 Multiple TubeFermentationTechnique 9221 El Thermotolerant Coliform Test (EC medium) 9221 E2 Thermotolerant Coliform Test (A-I medium) *	Point sources Consumer's taps Water treatment works Water refilling stations Water vending machines Mobile treatment devices Point of use treatment devices Water haulers Bulk Water Food Establishments All buildings Ice Plants
	EST: Absent or < 1 MPN/IOO mL	9223 Enzyme SubstrateColiform Test*	
	MFT: < 1thermotolerant coliform colonies / 100 mL	9222B Standard TotalColiform Membrane FilterTechnique	
3. Heterotrophic Plate Count (HPC)	<500 CFU/mL	9215 B Pour Plate Method 9215 C Spread Plate Method 9215 D Membrane Filter Method	Consumer's taps Water treatment works Water refilling stations Water vending machines Mobile treatment devices Point of use treatment devices Water haulers Bulk Water Food Establishments All buildings Ice Plants

*MT FT: Multiple Tube Fermentation Technique, MPN: Most Probable Number*EST: Enzyme Substrate Test, CFU: colony Forming Units *M FT: Membrane Filter Technique, *should be verified and approved by the DOH

TABLE II
SUMMARY OF STANDARD VALUES AND METHODS OF ANALYSIS FOR INORGANIC CHEMICAL PARAMETERS OF DRINKING WATER

Parameters	Chemical Abstracts Service (CAS) No.	Maximum Allowable Level (MAL)	Methods of Analysis
1. Arsenic (As)	7440-38-2	0.01 mg/L	**A. Sample Preparation** - 3030 E. Nitric Acid Digestion - 3030 G. Nitric Acid-Sulfuric AcidDigestion - 3030 K. Microwave-Assisted Digestion **B. Instrumentation** - 3114 B. Manual Hydride - Generation/ Atomic AbsorptionSpectrometric Method - 3113 B. Electrothermal Atomic Absorption Spectrometric - 3120 B. Inductively Coupled PlasmaMethod - 3125 B. Inductively Coupled Plasma-Mass Spectrometry Method
2. Cadmium (Cd)	7440-43-9	0.003 mg/L	**A. Sample Preparation** - 3030 E. Nitric Acid Digestion - 3030 F. Nitric Acid-Hydrochloric Acid Digestion - 3030 K. Microwave-Assisted Digestion **B. Instrumentation** - 3113 B. Electrothermal Atomic Absorption Spectrometric - 3120 B. Inductively Coupled Plasma Method - 3125 B. Inductively Coupled Plasma-Mass Spectrometry Method
3. Lead (Pb)	7439-92-1	0.01 mg/L	A. Sample Preparation - 3030 E. Nitric Acid Digestion - 3030 K. Microwave-Assisted Digestion B. Instrumentation - 3113 B. Electrothermal Atomic Absorption Spectrometric - 3120 B. Inductively Coupled Plasma Method - 3125 B. Inductively Coupled Plasma-Mass Spectrometry Method
4. Nitrate (No3-)	C-005	50.00 mg/L	- 4110 B. Ion Chromatography with Chemical Suppression of Eluent Conductivity - 4110 C. Single-Column Ion Chromatography with Direct Conductivity Detection - 4500-NO3 B. Ultraviolet Spectrophotometric Screening Method 4500-NO3 E. Cadmium Reduction Method - 4500-NO3 I. Cadmium Reduction Flow Injection Method - 4140. Capillary Ion electrophoresis - 4500-NO3 D. Nitrate Electrode Method

TABLE III
SUMMARY OF STANDARD VALUES AND METHODS OF ANALYSIS FOR PHYSICAL AND CHEMICAL QUALITY FOR ACCEPTABILITY ASPECTS OF DRINKING WATER

Parameters	Chemical Abstracts Service (CAS) No.	Maximum Allowable Level (MAL)	Methods of Analysis
1.Color (Apparent)	N/A	10 CU	2120 B. Visual Comparison Method- for apparent color only
2. Turbidity	N/A	5 NTU	2130 B. Nephelometric Method
3. pH	N/A	6.5 – 8.5	4500-H+ B. Electrometric Method
4. Total Dissolved Solids	N/A	600 mg/L	2540 C. Total Dissolved Solids Dried at 180°C

2.2.2 Water Demand

It is the largest volume of water that may need to be delivered in a day within the community. Based on the statement of Philippine Institute for Development Studies, up to 48 to 108 liters of water per day a Filipino consumes in average [43]. On the other hand, according to Word Health Organization, a person needs 50 to 100 liters per day to ensure the most basic needs are met [44]. In this study, the value of 50 LPCD was chosen and set to minimum since the groundwater volume was not identified, and to make sure that the network will be sustainable in the long run. In order to design the WDN, the following were identified; the average day demand, maximum day demand, and the peak hour demand in liter per second or LPS with respect to the future population. The non-revenue water is the quantity of water that is produced but it is not consumed due to head loss, in which its value can be taken as 20%, according to the World Bank [45].

Water Demand Table

NODES	DOMESTIC		NON-REVENUE WATER (%)	AVERAGE DAY DEMAND (LPS)
	NO. OF INDIVIDUALS	WATER DEMAND (LPS)		

$$\textbf{Water Demand} = \textit{Total Population x Average Water Consumption per Individual}$$

$$\textbf{Non} - \textbf{Revenue Water} = 20\%$$

$$\textbf{Average Day Demand} = \frac{\textit{Water Demand}}{1 - NRW}$$

The presented table and formulas were all based on the volume one of the design manual for rural water supply in the Philippines by the World Bank [45].

2.2.3 Population Projection

As it was stated in the limitations of this study, the design limit was set to 10 years. With that, the researchers must design a water network that accommodates the water demand of the current population, as well as the population after 10 years.

$$GR = \frac{(\frac{P_f - P_i}{P_i}) \times 100}{N}$$

2.2.4 Elevation of each Node

One of the primary data needed to design the water network is the difference in elevationsbetween each node. After identifying the backsight (BS), foresight (FS) distances, and height of the instrument (HI) using auto-level surveying, the formulas were used to solve for the elevations on each node.

$$HI_A = Elev_A + BS_A$$

$$Elev_B = HI_A - FS_B$$

2.3 Research Locale

The research locale is located in Brgy. Diaz, Porac, Pampanga and it is estimated to be eight kilometers away from the municipal hall of Porac. The main location of the water distribution network is within the perimeter of the 79 housing units. There are also four manually operated water pumps (*poso*); unfortunately, only one is working. The working *poso* is located at a higher elevation compared to the housing units. Some of the residents get their water by fetching first in the place they call “sibol.” The water source in that place is also groundwater and it is estimated to be 1.5 kilometers away from the housing units.

2.4 Data Collection Method

Initially, water samples were collected to be tested for physiochemical and microbiological analysis. This was done to ensure the potability of the sample, aiding in the identification of potential requirements for water filtration. Before the design of the water distribution network, the daily water demand of the community was computed. In order to do that, first, the total number of people residing in the barangay must be identified. The number of individuals was then multiplied to the average liters per capita per day to solve the water demand. After that, auto level surveying was performed to get the difference in elevation for each node which is crucial for the network's design. Proceeding with the design of the water network, a computer or laptop equipped with EPANET software is needed and serves as the primary tool for designing the water network.

2.5 Data Analysis

In this study, EPANET software was utilized since it is a user-friendly computer program that simulates the behavior of hydraulic and water quality over extended periods of time in pressured pipe networks. EPANET has become the most popular and convenient tool for the effective design of complex pipe networks among all the computer tools available. These tools were developed to ensure that a sufficient quantity of high-quality water could be provided to different parts of the community in accordance with demand [21]. The data that were analyzed based on the output of the EPANET.

2.6 Ethical Considerations

Ethical factors were employed in the process of completing this study. Since the output of this study requires design and analysis, it was made sure that the preliminary data gathered are accurate and free of tampering. The results and analysis of the data were done with honesty. The researchers also respected intellectual property. In any portion of the dissertation, appropriate citation, and acknowledgement of the works of other writers concerning the data were also employed. Finally, openness, in which the investigator conducting the research will be able to recognize criticisms that have been provided and can use them to improve the paper [46].

III. RESULTS AND DISCUSSION

3.1 Water Quality Test

This research follows the SDG 6 as the indicator of sustainability, with that, safe consumption of water must also be considered. Groundwater samples were collected in the barangay and tested them for physiochemical, and microbiological test. The laboratory that conducted the said experiments is the AquaLab Center, a DOH accredited water testing laboratory located in San Fernando, Pampanga.

3.1.1 Collection of Water Samples

According to the standard guidelines of the Department of Health, for the water sample that was used for physical and chemical test, it was contained using PET bottle, it is simply a mineral water bottle that can be bought in any store and emptied it without drinking the water inside. The required volume of the water sample for physiochemical test is one liter. On the other hand, the researchers used a sterilized glass bottle to contain the sample for microbiological test. The required volume of the sample for this test is one hundred twenty milliliters[42].

3.1.2 Physiochemical Analysis Report

Groundwater mainly comes from rain and water runoffs that gathers various impurities. These impurities may include inorganic and organic soil particles, debris, microorganisms and chemicals [45]. Aligned with the goal of SDG 6, the population should be using potable water source that are free from any unhealthy substances. For example, the arsenic, lead and cadmium are known to be carcinogenic, or substances that can develop cancer. On the other hand, although the turbidity and color of water does not impose major health risk, it should still comply for the preference of the consumers[47]. As seen in the table 4, the water sample has passed all the critical parameters for physical and chemical aspects. The parameters stated directly can affect health through acute or chronic exposure. This means that the water source that the population uses which is located on the premises of the housing units, available when needed, is free of fecal and chemical contamination[42].

TABLE IV
PHYSICAL AND CHEMICAL ANALYSIS REPORT OF THE WATER SAMPLE.

PARAMETER	DESCRIPTION	METHOD	MAL	RESULTS
FREE CHLORTNE (RESIDUAL)	Excess Chlorine	DPD Colorimetric	**0.3** - 1.5***ppm**	**<0.05 ppm**
COLOR	Color due to dissolved particles	Visual Comparison	**10.0 cu**	**<5.0 CU**
NITRATE	"blue baby" syndrome	Ion Selective Electrode	**50.00 ppm**	**4.67 ppm**
LEAD	Carcinogenic when ingested	Graphite Furnace AAS	**0.01 ppm**	**<0.005 ppm**
ARSENIC	Occurs naturally in sulfide minerals as pyrite	HVG-AAS	**0.01 ppm**	**<0.001 ppm**
CADMIUM	Usually associated with zinc	Graphite Furnace AAS	**0.003 ppm**	**<0.0005 ppm**
pH	Measure of acidity or alkalinity	Electrometric Method	**6.5 - 8.5 @25°C 5.0 - 7.0***	**6.66**
TOTAL DISSOLVED SOLIDS	Total Dissolved Mineral Present	Gravimetric, dried at 180°C	**600.0 ppm <10.0 ppm***	**193.0 ppm**
TURBIDITY	Presence of Particles	Turbidimetry	**5.0 NTU**	**<1.0 NTU**

3.1.3 Microbiological Analysis Report

Presented in the figures 5 and 6, the microbiological test identifies the coliform, E. coli and heterotrophic bacteria content in the water sample. Under the total coliform test, using multiple tube fermentation, the standard value is less than 1.1, and the result showed less than 1.1. Next, the Escherichia coli test using also multiple tube fermentation conveyed a result of less than 1.1, which is within the range of the standard value of less than 1.1. With that, the water sample passed the DOH standards for drinking water regarding coliform and E-coli bacteria.

TABLE V
MICROBIOLOGICAL REPORT OF THE WATER SAMPLE ON COLIFORM AND E-COLI.

Test Performed	Methodology	No. of Positive Tubes (out of 5 tubes)	Results	Standards
Total Coliform *MPN/1OOml	Multiple Tube Fermentation	0	**< 1.1**	**< 1.1**
Thermotolerant (Fecal) Coliform *MPN/100ml	Multiple Tube Fermentation	0	**< 1.1**	**< 1.1**
Escherichia coli TEST	Multiple Tube Fermentation	0	**< 1.1**	**< 1.1**

Lastly, the sample was also tested for its heterotrophic plate count (HPC), using pour plate method, having a standard value of less than 500.Unfortunately, the sample yielded an estimated value of 2000, that means the sample failed the DOH standards for drinking water under heterotrophic bacteria.According to Health Canada, HPC in a water distribution system can be reduced by minimizing assimilable organic carbon (AOC), which is a portion of a carbon devoured by bacteria [48]. Aligned with this, activated carbon filtration is a possible solution to control AOC in a water network[49].

TABLE VI
MICROBIOLOGICAL REPORT OF THE WATER SAMPLE ON HPC.

Test Performed	Methodology	No. of Positive Tubes (out of 5 tubes)	Results	Standards
Heterotrophic Plate Count CFU/mL	Pour Plate Method	---	**Est. 2,000**	**< 500**

3.2 Beneficiaries' Average Water Consumption per Day

One of the data that directly affects the water network design is the water demand of the population.Given the design limit of the WDN for ten years, the design of the WDN must accommodate both the current and future water demand of the barangay. However, since the design focused on the current population, the future water demand will be used to identify the dimension of water storage tank needed.

The first step to determine the future water demand is to solve for the future population in the barangay. Based on the data given by the Rural Health Unit of Porac, thepopulation in Brgy. Diaz in year 2023 and 2018were 500 and 287, respectively. Using the formula for population projection, the growth rate was about 14.84%. This means that the population of the Aeta community increases for about 14.84% per year. This growth rate is high compared to the Philippines' population growth rate which is only around 1.51% from year 2023-2024 [50]. Using the same formula, the number of population after ten years was solved, and the result was 1,242 individuals. In continuation, the current water demand was solved by multiplying the 500 population with the set value of 50 LPCD. The water demand for the current population in the barangay was determined to be 25,000 LPCD or 0.294 LPS.

TABLE VII
COMPUTED WATER DEMAND PER STATION

NODE	DOMESTIC		NRW (%)	AVERAGE DAY (LPS)
	# POPULATION	DEMAND (LPS)		
STA A	84	0.049		0.0613
B	84	0.049		0.0613
C	84	0.049		0.0613
D	84	0.049		0.0613
E	84	0.049		0.0613
F	84	0.049		0.0613
TOTAL	504	0.294	20	0.368

After identifying thewater demand, it was equally divided to the six stations. This means that each of the station has the same water demand because considering the urban development in the barangay, the orientation of the houses cannot be determined precisely, and so the accurate and appropriate water demand per station. The base demand used per station on designing the WDN was the average day demand.

3.3 Elevations of each Nodes

The elevations of each node were measured by the researchers using auto-level surveying. The materials used were tripod, leveling rod, measuring tape, and the auto-level. Upon the arrival in the

Brgy. Diaz, the researchers planned the roles of each member, and identified the location of each station in the printed aerial view of the barangay. First, the distances of the stations from one another were measured. After that, the researchers proceeded on getting the backsight distance, foresight distance, and the height of the instrument for each node and station to solve for their elevations. First, the leveling rod was placed on BM1, which serves as our reference point having an assumed elevation of 100 meters. The height on the leveling rod that can be seen in the auto-level is noted as backsight distance. After that, the leveling rod was placed on node A' and the height measured was the foresight distance of A'. Next, the auto-level moved between node A' and A and took the backsight distance of A'. This process is repeated until the last node, which is node J where the main tank is located. The researchers were successful on identifying the elevations for each node, and the result showed that the location of the tank has the highest elevation, as which it should be. The differences in elevation of each node and station were then inputted in EPANET.

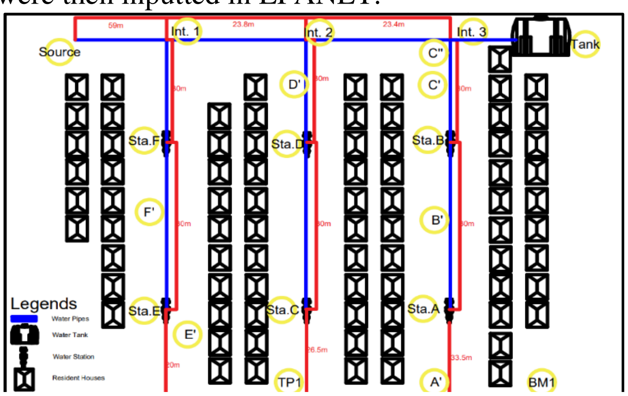

Fig. 4 Location and Distances Between Each Node of the Water Network.

TABLE VIII
ELEVATIONS ON EACH NODE

NODES	BS(m)	HI(m)	FS(m)	ELEVATION(m)
BM1	1.919	101.919		100
A'	2.95	104.584	0.285	101.634
STATION A	2.179	106.541	0.172	106.412
B'	2.11	108.551	0.15	106.441
STATION B	2.23	109.921	0.86	107.691
C'	3.619	112.876	0.664	109.257
C''	3.95	116.756	0.07	112.806
INT. 3	2.36	116.826	2.29	114.466
INT. 4	0.1	116.858	0.068	116.758
D'	0.199	113.257	3.8	113.058
STATION D	0.81	110.167	3.9	109.357
STATION C	0.335	105.587	4.915	105.252
TP1	2.81	104.485	3.912	101.675
E'	2.94	107.25	0.175	104.31
STATION E	3.405	109.92	0.735	106.515
F'	2.535	111.983	0.472	109.448
STATION F			0.695	111.288
INT. 4	4.35	121.108		116.758
INT. 1	2.52	123.041	0.587	120.521
PUMP			1.345	121.646

*Red – computed by the researchers
*Black – measured in actual surveying

3.4 Water Demand Pattern

The water demand pattern shows the peak hours that the WDNwill experience, as well as the water demand per station during peak and normal hours.It was set that the time of peak hours will be during 6:00AM – 8:00 AM, 11:00AM – 1:00PM, and 5:00PM – 7:00PM[51]. During peak hours, the peak hour demand will just be equal to the average water demand per station, which is 0.0613 LPS. This was the water demand per station that the WDN must supply during peak hours. On the other hand, during normal hours, a multiplier ranging 0.2, 0.3, 0.5 and 0.8 was applied to the average water demand per station. The WDN can accommodate these demand patterns if the flow of water inside the pipes is greater than or equal the demand in the station.

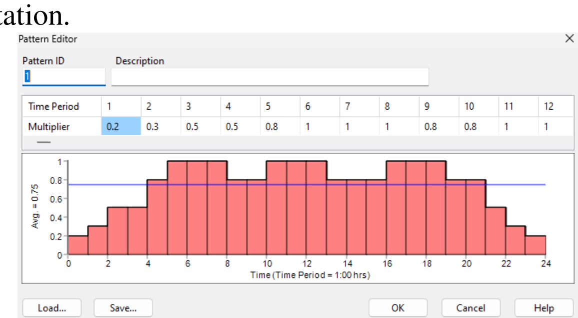

Fig. 5 Water Demand Pattern.

3.5 Design Parameters

The proposed water network design consists of Polyvinyl Chloride (PVC) pipes, having C Factor equal to 110-140, with common sizes of 50mm, 75mm, 100mm, 150mm, and 200mm. PVC pipes are commonly used in residential water networks in Philippines because it plays a crucial role in preserving the quality of drinking water thanks to their exceptional inertness and resistance to corrosioneven when exposed to chlorinated disinfectants. The main outlet of the network was hose bib, representing one of the most basic and prevalent types of outdoor faucetsavailable in various materials such as brass, galvanized steel, aluminum, cast iron, and plastic. Considering the community, it was best to make the design as plain and simple as possible. Additionally, the design parameters are based on the design manual of the World Bank for rural water supply, which are aligned with the plumbing code of the Philippines [45]:

- Maximum Head Loss: 10 m/km
- Minimum and Maximum Pressure: 7 psi to 60 psi (4.5 m to 40 m)

3.6 Water Distribution Network Design

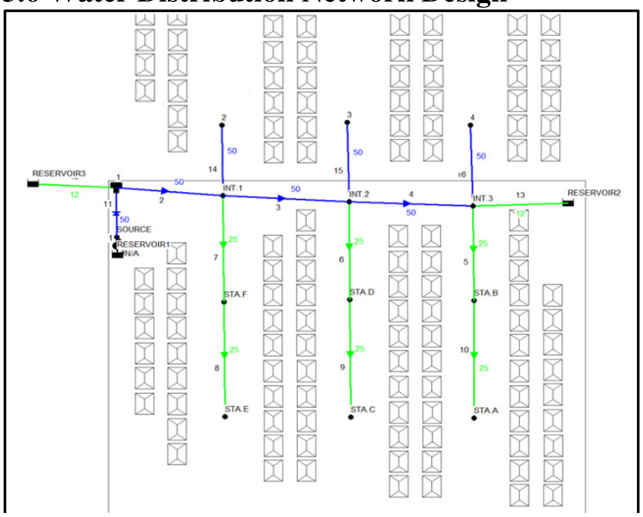

Fig. 6 Water Distribution Network Design taken from EPANET.

As seen in the Figure 6 above, it shows the overall design or layout of the water distribution network located within the perimeter of the 79 housing units. The output of the EPANET was based on all the data gathered such as the difference in elevations, length between the nodes, and the base water demand per station.

After inputting all the necessary data for each station, the diameter of each pipe was adjusted based on the results of the pressure and head loss within the network. After several adjustments, the final output produced with the help of EPANET is presented in figure above. The design consists mainly of 25 mm and 50 mm diameter pipes. The 50 mm pipe is used to transfer water from the source to the storage tank and from the tank to the stations. While the 25 mm diameter pipe was used to transfer water to the stations. The water network also consists of one booster pump, and a main storage tank with a capacity of 5,000 liters. The water tank is also located near the node labeled as INT. 3 to control the head loss within the pipes 2, 3 and 4. Also, pipes 12 and 13 were added next to the main water storage tank and INT 3 to act as connectors for the future water sources which maintains the sustainability of the water distribution network.

There is a possibility for the expansion of houses within the barangay, which made it hard to accurately produced a design accommodating the future population and complying with the orientation of the future houses. When the future population was used as the basis for computing the water demand, it resulted into pipes having a larger diameter. The sizes of pipes were not realistic since the water demand is for the 1,242 people. After careful considerations, it was decided to focus the design of the WDN for the current population, in which there are available data. Regarding the future orientation of the houses in the barangay, it was only assumed that those houses will be constructed above the 79 houses or will have a greater elevation than the current houses. Lastly, to answer the water demand of the future population, there are pre-prepared pipes connected on nodes INT 1, 2 and 3 that will link the pipes of the WDN to be constructed after several years.

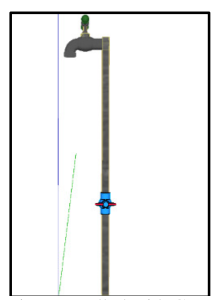

Fig. 7 Stations Installed with Gate Valves.

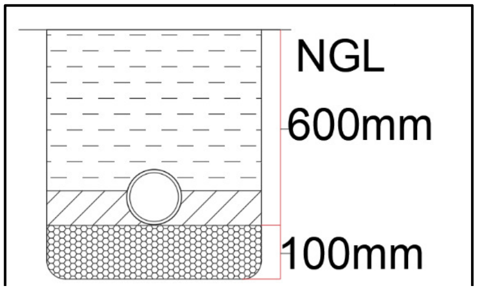

Fig. 8 Cross Section of the Pipes in Bed.

Additionally, as seen in Figure 7, gate valves were installed in each stations for the convenience when repairing any damages on each station or maintenance within the network [52]. Lastly, the pipes are design to be embedded 600mm below the natural grade line and 100 mm below the pipe is the gravel bedding to ensure that the pipe will have better foundation and support for loadings[53], as presented in Figure 8.

Presented in the Table 9 below was the various symbols or icons used in EPANET, which can be seen in the design of the WDN in Figure 6. Explanation of their functions and inputs were also stated.

TABLE IX
SYMBOL, FUNCTION, AND INPUTS OF WDN COMPONENTS IN EPANET.

SYMBOL	FUNCTION	INPUT
Reservoir	Reservoirs are nodes which provide the network access to an infinite external water supply.	Hydraulic head = Ground Elevation – Groundwater Surface Elevation Hydraulic head = 30meters.
Pump	Pumps are links that impart energy to a fluid thereby raising its hydraulic head.	Pump Curve - the combination of heads and flows that the pump can produce.
Tank	Tanks are nodes that have the ability to store water, and during a simulation, the amount of water in them can change over time.	Diamater = 1.7m Elevation = 121.646m Initial Level= 2m Minimum Level= 1m Maximum Level= 2.5m
Pipe	Pipes function as conduits that transport water between different points within a network. EPANET operates under the assumption that these pipes remain completely filled with water at all times.	Length Diameter = 50mm and 75mm Roughness Coefficient = 110 to 130, C Factor
Node	Nodes are junctions within the network where links converge and where water either enters or exits the system.	Elevation Base Demand = 0.15 liters per second Demand Pattern = a set of direct multipliers that applies to the base demand.

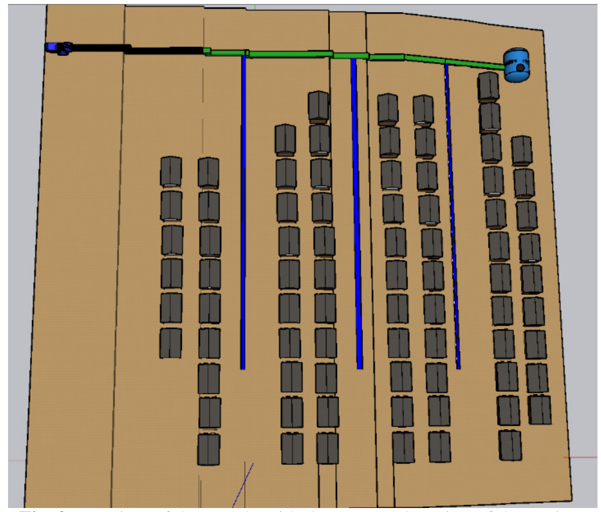

Fig. 9 Top View of the Locale with the Proposed Design of the Project

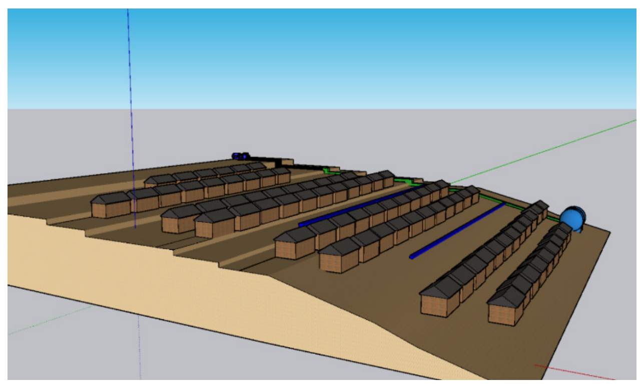

Fig. 10. Isometric View of the Locale with the Proposed Design of the Project

3.7EPANET Analysis Report

3.7.1 Pressure in Each Station

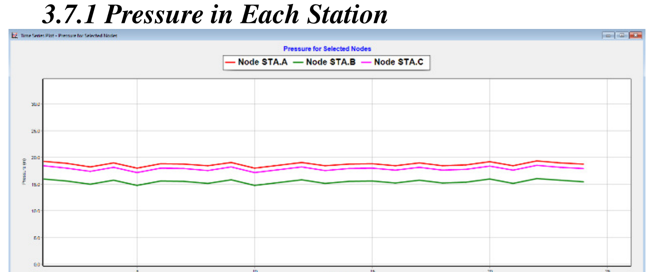

Fig. 11 Pressure Variation of Stations A, B, and C.

The Figure 11 shows the graphical representation of the pressure within station A, B and C with respect to the water demand pattern. The limiting values set for the pressure is between 7 psi to 60 psi. Since EPANET follows metric system, those values were converted to meter of head and are equal to 4.5 m to 40m. All of the values of pressure for stations A, B and C complied with the minimum and maximum limit. The highest pressure obtained between the three stations was 18.84 m in station A during peak hours, and the lowest pressure was 15.60 m in station B.

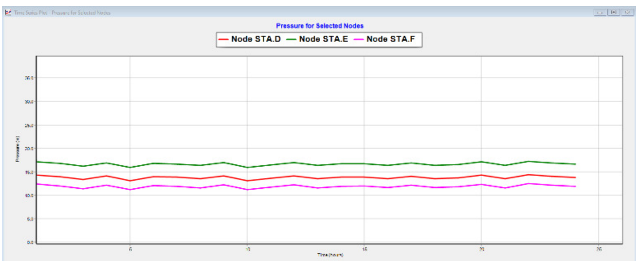

Fig. 12 Pressure Variation of Stations D, E and F.

On the other hand, for stations D, E and F, all of the pressure experienced by the WDN for the whole day is within the limiting values as shown in Figure 12. The highest pressure taken between the three stations was 16.76 m in station E during peak hours, and the lowest was 12.01 m in station F during normal hours. Overall, the attained values of pressure in all of the six stations were acceptable.

3.7.2 Head Loss in Each Pipe

In hydraulics, the change in head loss is due to the pipe friction and changes in velocity or direction of flow. Additionally, head loss is directly proportional to the length of pipe, while it is indirectly proportional to the pipe's diameter. These conditions were applied to the WDN to minimize the head loss in the pipes as low as possible.

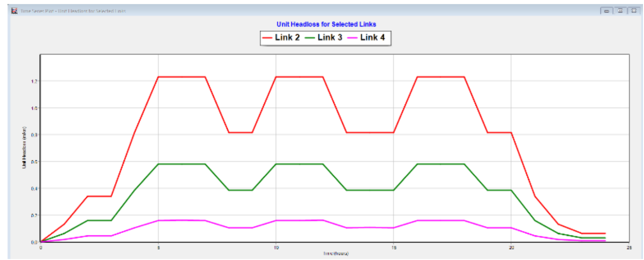

Fig. 13 Head Loss in Pipes 2, 3 and 4.

The values of head loss in pipes 2, 3 and 4 during peak hours were ranging between 1.23m/km, 0.58m/km, and 0.16m/km respectively. During normal hours, the head loss in these pipes were ranging between 0.19 to 0.81m/km. These pipes have a uniform diameter of 50 mm starting from the pump up to the tank. This was one of the reasons why the head losses in these pipes were low, since they have a larger diameter, and it was lengthy. The graph was presented in Figure 13 above.

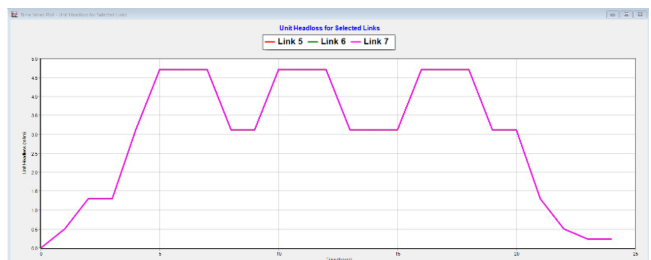

Fig. 14 Head Loss in Pipes 5, 6, and 7.

Compared to all of the pipes in the WDN, pipes 5, 6, and 7 experienced the largest head loss. As shown in Figure 14, during peak hours, the head loss was stable to be 4.71 m/km, while it was 3.1 m/km during normal hours. These pipes have the largest head loss since the flow of water changes its direction and velocity, from pipes 2, 3 and 4 and then to these pipes. Additionally, the sizes of pipes are smaller compared to earlier pipes of 50 mm, and with that, there was an additional head loss due to sudden contraction in the cross-sectional area of the pipes.

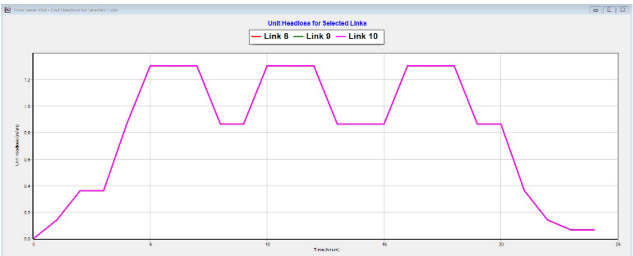

Fig. 15 Head Loss in Pipes 8, 9, and 10.

The pipes 8, 9, and 10 were located individually between the two stations. These pipes have a diameter of 25 mm and has a lower head loss compared to pipes 5, 6 and 7. This was understandable since the length increases while having a uniform diameter, and it was stated earlier that the head loss was directly proportional with the length of pipe. As shown in Figure 15, during peak hours, the head loss has a value of 1.30 m/km and 0.82 m/km during normal hours.

3.7.3 Flow of Water in Each Pipe

The flow of water in the pipe is simply the quantity of water passing through at any given time. In order to conclude that the design of WDNcan accommodate the water demand in the barangay, the flow of water passing through the stations must be greater than or equal its demand.

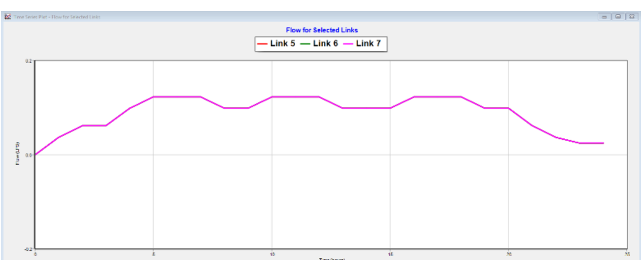

Fig. 16 Flow of Water inside pipes 5, 6, and 7.

Presented in Figure 16 is the flow of water passing through pipes 5, 6, and 7. These are the pipes that deliver water to stations B, D and F respectively. Additionally, the flow of water passing through those pipes is the total water demand for each two adjacent stations. It was shown in the graph that during peak hours, the water flow in the pipes is about 0.012 LPS. The excess water flow of 0.0613 LPS from those pipes will flow towards pipes 8, 9, and 10 and will supply the allocated average water demand for stations A, C, and E respectively.

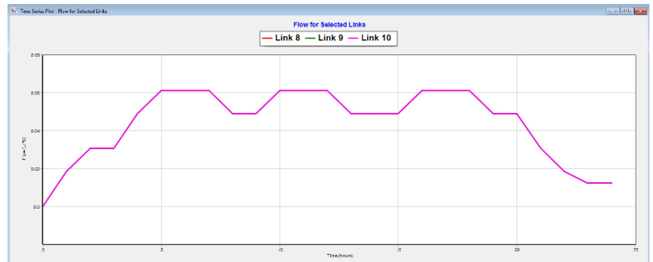

Fig. 17 Flow of Water inside the pipes 8, 9, and 10.

The graphical representation of the water flow inside pipes 8, 9, and 10 was presented in Figure 17. These pipes are responsible on supplying water to stations A, C and E respectively. The rate of water flow inside these pipes is the surplus quantity from the stations B, D and F. The peak hour demand in those stations is 0.0613 LPS and the value of water flow has an exact value with the demand. Overall, the flow of water throughout the network signifies that it was enough to supply the demand for each station.

3.8Water Network Components

MATERIALS	DESCRIPTION
Water Pump 	Water pumps are machines that help push water from one place to another by boosting its pressure.
Water Tank 	Water tank storage is a solution for storing water, serving domestic, agricultural, and industrial needs. Tanks come in various materials and sizes, primarily storing water for drinking, cleaning, and other purposes, but often serving additional functions.
Float Valve 	A float valve is a type of valve that allows liquid to enter or exit a tank, controlled by a float on the liquid's surface to keep the liquid level consistently stable.

Water Outlet (Hose Bibb) 	A faucet is a tool used to manage the flow of a liquid or gas from a pipe or container. Faucets operate based on the principles of fluid flow in engineering. They need to stop water flow when closed and control the flow when opened.
Polyvinyl Chloride (PVC) Pipes 	Polyvinyl Chloride (PVC) pipes are widely utilized in producing sewage pipes, water mains, and irrigation systems. Known for their durability, PVC pipes are lightweight, strong, easy to install, and can be recycled, making them both cost-effective and environmentally friendly.

3.9 Estimation of Materials

After looking through and canvassingvarioushardware and double checked on the internet to survey for the most economical materials that can be used for the project. The quantity, sizes, and specifications of each material were also indicated. The estimated cost presented below only includes the primary materials needed for the WDN.

TABLE X
ESTIMATED COST OF THE PROPOSED WATER DISTRIBUTION NETWORK.

QTY.	DESCRIPTION	LENGTH	PRICE	TOTAL COST
1	1.5 HP Water Pump	N/A	20,400	20,400
1	5K L Galvanized Water Tank (1.7m Ø × 2.52m height)	N/A	105,400	105,400
1	Float Valve	N/A	335	335
60	PVC Pipes, 50 mm Ø (2”)	3 m	151	9,060
36	PVC Pipes, 25 mm Ø (1”)	3 m	100	3,600
6	Hose Bibb	N/A	170	1,020
TOTAL COST				**139,815**

IV. SUMMARY, CONCLUSION, RECOMMENDATION

4.1 Summary of Findings

The water in the barangay was tested under physical, chemical, and microbiological analysis. Under physiochemical analysis, the properties of water sample met the DOH standards for drinking water. However, when it comes to heterotrophic plate count under microbiological analysis, the water sample failed the DOH standards. It has a content of 2,000 heterotrophic bacteria which was more than the DOH standard of 500 only.

The water demand used on designing the WDN is the current demand in the population, since the design was focused on the current population. After collecting all the necessary data needed to be inputted in the EPANET, the design of the WDN consists of 25 mm and 50 mm diameter PVC pipes, six stations, one pump, and a main storage tank. The tank was placed near the node labeled as Int. 3 to minimize the head loss in the pipes 2, 3 and 4. The head loss within the whole water network ranges from 0.16 m/km to 4.71 m/km during peak hours. The pressure in each station was also acceptable and within the minimum and maximum limit of 7 psi to 60 psi. Lastly, the flow of water in the proposed WDN accurately accommodates the water demand in each station, having a value of 0.0613 LPS.

The bill of materials for the WDN design is P139,815. This is purely an estimated cost of the main materials for WDN, which does not include other fee like labor cost and professional fee.

4.2 Conclusions

The water sample failed the DOH standards for drinking water with respect to heterotrophic bacteria. Therefore, a water filter with granular activated carbon can be used to minimize the number of AOC, which consequently reduces the HPC. This granular activated carbon filter is mostly present in three-staged water filter commercially available today. However, three-staged water filter can only be utilized for small scale network like a residential house only. Also, when the design of WDN utilized this kind of filter, the flow rate and pressure are significantly reduced. Due to these, it cannot be utilized for the proposed design of WDN and instead, a water treatment facility is recommended.

After several adjustments regarding the diameter of the pipes, positioning of the tank, and the power generated by the pump, a successful designed of the WDN that can accommodate the current water demand in the barangay was produced. With the layout of the WDN, the maximum and minimum pressure attained throughout the six stations are 18.84m and 12.01m, which are in the range of 7 psi to 60 psi. It can be concluded that the pressure in each station, is proportional with its difference in elevation between water source. The greater the difference in elevation between the water source and the station, the higher the pressure in that station, and vice versa. Regarding the head loss, it can be assumed that it is inversely proportional to the pipe diameter, while it is directly proportional to the length of the pipe. In terms of rate of flow, it can clearly supply the water demand for each stationduring peak hours and normal hours having a value of 0.0613 LPS. Overall, the EPANET software gave reasonable and feasible design of WDN for the Aeta community in Brgy. Diaz, Porac, Pampanga.

This study focused on improving the current water distribution network in the Brgy. Diaz. The design of the WDN created with the help of EPANET can contribute to the improvement of life of the residents. Time and energy used to fetch water in a manually operated poso can be used in other necessary activities. Also, this research highlights the importance of acknowledging and addressing the challenges faced by indigenous communities, specifically in water problems.

4.3 Recommendations

1. Regarding the water filtration system integrated in the proposed water distribution network, make further research to enhance, or possibly merge, more effective water treatment facility to manage the content of heterotrophic bacteria in the water.
2. Since the main source of water in the locale is groundwater, it is recommended to have knowledge regarding its groundwater volume. This will give the researchers the freedom to set the design limit according to their accurate calculations. Consequently, the design of water distribution network will be more realistic and economic since it is based on the precise design limit.
3. For future researchers, calculate and allocate the right water demand per station with regards to the orientation of houses due to urban development of the barangay after several years.
4. Look for other water resources within the area that could supply water for the community. Groundwater being the only source of water in the community would not last as population growth increases, the water demand also increases.
5. Water management in rural areas is crucial for ensuring access to clean water. Strategies such as implementing rainwater harvesting system, protecting watersheds and other water resources through reforestation and land-use planning to preserve the quality and quantity of water.
6. Engaging the community in preserving the water distribution network by raising awareness about water conservation through educational programs and outreach initiatives encourages individuals and communities to adopt water-saving behaviors.

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