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ACADEMIC YEAR 2023/2024
DEPARTMENT OF CIVIL ENGINEERING
OPTION OF CONSTRUCTION TECHNOLOGY

UPGRADING WATER SUPPLY SYSTEM

Case Study: Kicukiro District, Gahanga Sector

Submitted in partial fulfilment of the requirements for the award of
ADVANCED DIPLOMA
IN CONSTRUCTION TECHNOLOGY

Presented by

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Under the guidance of

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Kigali, October 2024

DECLARATION

I declare that this work titled **UPGRADING WATER SUPPLY SYSTEM** is my own work, that it has not been submitted for any degree or examination in any other higher learning institution, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

AKIMANA Doris Rahmat

Sign: ___________________________

Date: _________________

CERTIFICATION

This is to certify that this work titled UPGRADING WATER SUPPLY SYSTEM is a study carried out by AKIMANA Doris Rahmat under my guidance and supervision.

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Signature …………………………..

DEDICATION

It is dedicated to all the people who have been part of my journey and imparted valuable contributions to making this work possible.

I especially thank my loving family, whose endless encouragement and love, patience have kept me going through this process. Your belief in me has been the bedrock upon which my achievements have been built.

To my friends, who always provide motivation, laughter, and strength. Thanks for standing through it all, both when we felt on top and when the challenges showed us their faces. Thanks for making me remember to take breaks when most needed, too. Your support meant so much to me.

To my mentors and professors: for the guidance and valuable wisdom that has sculpted not only this project but my view of the world. Your encouragement toward critical thought, insightful feedback regarding the work at hand, and commitment to my learning have been paramount in my growth. I am very grateful for your mentorship.

Last but not least, I dedicate this effort to all the future students and dreamers who, just like me, had and will have in them the drive to bring change with the help of knowledge and determination. Let this work be a small contribution toward inspiration in the pursuit of innovation and excellence.

ACKNOWLEDGEMENT

First and foremost, I am grateful to Almighty God for the abundant grace, guidance, and strength in this journey. Without His blessings and continuous presence, I would not have possessed the wisdom, courage, or perseverance to complete this project. Glory to Him alone for making this accomplishment possible.

I am indeed grateful to my supervisor, RUKUNDO Emmanuel, for the insight so invaluable and for standing by me throughout this journey. Your guidance has been instrumental in shaping this work.

The knowledge imparted, and facilities provided by my professors and the faculty of the Department of Civil Engineering, are all gratefully acknowledged here. Their drive for teaching and their readiness to assist proved fundamental in my academic stay.

To my family, words cannot express my gratitude for your unwavering love, patience, and belief in me. Your emotional support and sacrifices have been my greatest source of strength, and I am eternally thankful for everything you have done.

I would not forget to express a special word of thanks to my friends and colleagues, who by way of encouragement, thought-provoking discussions, and constant motivation, helped me hugely. Your support made this journey much more agreeable and pleasant.

Finally, I would like to acknowledge everyone who contributed in any way to the completion of this project. Whether through advice, feedback, or moral support, your efforts have had a meaningful impact on this work, and I am sincerely grateful for each one of you.

ABSTRACT

This project explores the UPGRADING WATER SUPPLY SYSTEM, focusing on the need for upgrading the existing water supply system in kicukiro district, kabidandi village. The aim of this study is to assess the current challenges, identify critical areas requiring improvement, and propose feasible solutions for enhancing the efficiency, reliability, and sustainability of the water distribution network.

The research incorporates both qualitative and quantitative methods, including field assessments, data collection, and analysis of the water supply infrastructure. The study evaluates key factors such as population growth, water demand, and resources to be used while taking into consideration the environmental, economic, and social impacts of the proposed upgrades.

Results from the study indicate that by increasing and enlarging the resources the population in the village will be acquired enough amount of water. The analysis suggests that implementing the project by using the underground water that is available in the village would lead to significant improvements in water accessibility and management, addressing both short-term and long-term needs.

The conclusions drawn from this project provide a roadmap for decision-makers and stakeholders involved in water management, offering practical recommendations for the optimization of the water supply system. The proposed solutions are expected to enhance service delivery, reduce water losses, and ensure a sustainable supply of clean water to meet the growing demands of the community.

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CHAPTER 1. GENERAL INTRODUCTION

1.0. Introduction on water

Around the world, it’s known that” without water, life is impossible”, this is because all living organisms survive in the presence of water, plants, and animals depend on water availability, not only water also helps in economic activities that help in the development of Nations. Water is indispensable to life and a fundamental human right.

Water is a big part of my Environment. The standard of living around the whole globe is more dependent on access to clean water. The level of access to water differs according to region or country. In Rwanda, ensuring universal access to safe and reliable water has been both a challenge and a triumph. Governmental and non-governmental institutions have set different policies to achieve a hundred percent access to clean water for the population.

Situated in the heart of Rwanda, kicukiro district has witnessed transformative changes in its water infrastructure, particularly in kabidandi village, located in the gahanga sector, kagasa cell. Some people suffer due to shortage of water, Water supplied in kabidandi village is succeeded compared to the available population which results into a shortage of water in some parts, That affects people in different ways like affected water-related diseases and it may also lower the development of that area and even for country generally because most infrastructures depend on water availability.

A comprehensive approach is taken to enhance water access in kabidandi village. It examines the planning processes, the features of infrastructure development, and the profound impact on community well-being and environmental management. Through detailed case studies, it captures the individuals whose lives have been transformed by reliable access to clean water. Moreover, the reflects on the broader implications of Rwanda's water supply upgrading efforts. It underscores the importance of policy frameworks, governance structures, and community engagement in achieving sustainable development goals.

1.1. Background of the study

Access to clean and reliable water is essential for human health, economic development, and environmental sustainability. In Rwanda, a country known for its commitment to sustainable development goals and recovery from historical challenges, ensuring universal access to safe water has been a critical priority. The government of Rwanda has recognized that access to clean water is a fundamental human right and is essential for achieving socio-economic development and poverty reduction. (United Nations Development Program and World Banks reports)

Rwanda's water sector has undergone significant transformations over the past decades, with the government implementing various initiatives to improve water supply and sanitation services across the country. Despite these efforts, challenges persist, particularly in rural areas such as the Gahanga sector of kicukiro district.

In Gahanga sector, located in the southern part of kicukiro district, faces specific challenges related to water availability, distribution, and quality. The topography of the area, characterized by hills and valleys, presents logistical challenges in delivering reliable water services to its dispersed population. Historically, communities in the gahanga sector have relied on unprotected water sources, leading to high incidences of waterborne diseases and sanitation-related issues. Moreover, rapid population growth and urbanization have strained existing water infrastructure, highlighting the need for sustainable solutions to meet growing demand. (Rwanda water and sanitation corporation; annual report 2019)

Recognizing these challenges, the Rwandan government, in collaboration with local authorities, non-governmental organizations (NGOs), and international partners, has embarked on ambitious initiatives to upgrade the water supply system in the gahanga sector. These initiatives aim to enhance infrastructure resilience, improve water quality, promote efficient water management practices, and ensure equitable access to safe water for all residents. (Government of Rwanda Publications and Policy Documents and non-governmental organisation, 2016)

The upgrading of the water supply system in gahanga is not only a response to immediate water supply challenges but also a strategic investment in the long-term socio-economic development of the region. By addressing these challenges comprehensively, Rwanda aims to achieve its national targets of universal access to clean water and sanitation, contributing to the broader global agenda of sustainable development goals (SDGs). **(**United Nations Development Programme (UNDP) ("Rwanda SDG Country Report" (2020))**)**

1.2. Statement of the problem

Clean water is very essential in day-to-day human life where it is used for different purposes (Reid, 2018). According to different government policies, All Rwandans are supposed to have 100% water access by 2024 for better living standards. By considering the report of NISR in 2021 the growth rate will be 2.5% (NISR, 2021). I have found that today kabidandi village is populated with 980 people among those people, the access to clean water is around 74.07% of all population, it’s about 724 people which access to clean water and the remaining 25.93% people can hardly get access to clean water for their activities. This shortage of water leads to low levels of living standards for the people living in kabidandi village. They also travel long distances away from their homes searching for water fetching points. ("Rwanda Population Growth Report" (2021))

1.3. Research objectives

General objectives

The main objective of the study will be to increase access to clean water to reach 100% from 74.07% of the people of kabidandi village by designing a supply system from the nyagafunzo area (gasamagi spring) to kabidandi village.

Specific objectives

The specific objectives of the study Will be:

- To evaluate the population and the water demand.
- To identify water consumption per capita/day.
- To identify the losses in the water system.
- To know the pipe size can be used in water supply.
- To know how the water will be storage of water.

Research question

- What will be the discharge of water demand in kabidandi village in a minimum of 3 decade?
- What will be the losses during the water supply system?
- What will be the incremental increase in the future decade and the best water storage in kabidandi village?
- Which size of pipes will be used during water supply systems?
- What will be water consumption per capita/day

1.4. Scope and limitations

This project will focus on the design of a water supply system for a design period of 30 years. This study will be limited to kicukiro district for the population of kabidandi village. The study focuses on assessing water demand, selection of water sources, and design of storage tanks and pipes.

As my project will be aimed at raising water accessibility in kabidandi village, I will have plenty of information that will be helpful in my study. Due to different limitations like time, I will not have access to some data and this guided as into making possible assumptions for the purpose of having an effective design.

1.5. Significance of the study

Upgrading water supply systems in the kabidandi village of kicukiro district holds profound significance for the community. The probable beneficiaries of the study findings encompass residents, local authorities, and development organizations. Residents will benefit directly from improved access to clean and reliable water. This upgrade reduces the burden of water to access to potable water, particularly for women and children, allowing them more time for education and income-generating activities. Access to safe water also improves health outcomes by reducing waterborne diseases, thereby enhancing overall well-being and quality of life within the community.

Firstly, they will contribute to the advancement of technological knowledge in water treatment, distribution, and management. Insights gained from studying different water supply systems can inform best practices and innovations that can be applied not only in Kicukiro District but also in similar rural communities globally facing water supply challenges. Secondly, the research will contribute to socio-economic development by demonstrating the link between improved water access and enhanced livelihoods. Sustainable access to clean water supports agricultural productivity, small business growth, and local economic resilience, thereby lifting communities out of poverty and contributing to overall development goals.

This research will increase my knowledge about water supply systems and distribution networks by pumping and gravity systems, and the different knowledge and skills that I will be gaining within this scientific research period.

1.6. Organization of the study

This research project will be organized into five chapters:

Chapter 1 which is the introduction includes the background of the study, statement of the problem, research objectives, research questions, scope and limitations, significance of the study, and organization of the study.

Chapter 2 will contain with literature review and other theories related to the research purpose.

Chapter 3 will focus on the research methodology, and methodology used within the research to collect and analyse information and data.

Chapter 4 will be focused on system design analysis and implementation of the results and discussion about the major and minor findings collected data from the study.

Chapter 5 will be concerned with the conclusion and recommendation

CHAPTER TWO: LITERATURE REVIEW

2.0. Introduction

Water is the most abundant molecule on Earth's surface. It can also be the most abundant natural resource on earth. It consists of about 75% of the Earth's surface (N.G.W.A, 2018). Water is a vital component of life for both plants and animals. It is available in the forms of rain and snow thereby making rivers, oceans, streams, lakes, springs, etc.

A spring can be described as any natural occurrence where water flows onto the surface of the earth from below the surface. Some springs discharge where the water table intersects the land surface, but also, occur where water flows out from caverns or along fractures, faults, or rock contacts that come to the surface. Spring may result from karst topography where surface water has infiltrated the earth's surface (recharge area), becoming part of the area's groundwater that travels through a network of cracks and openings ranging from intergranular spaces to large caves. The water eventually emerges from below the surface, in the form of spring (Water Science School, 2019).

The forcing of the spring to the surface will be the result of a confined aquifer in which the recharge area of the spring water table rests at a higher elevation than that of the outlet. This spring serves as a water source for the inhabitants of the area who utilize the water for their daily activities. Hence there arose the need to assess the quality of this spring to make recommendations where necessary. Mineral springs are natural springs that produce water containing minerals or other dissolved substances that alter its taste or give it a purported therapeutic value, salts sulfuric compounds, and gases are among the substances that can be dissolved in spring water during its passage underground. It will also note that water from certain springs appeared to have medicinal qualities. It will involve the logic to assume that these medicinal effects reflected the different composition of spring waters. Spring water is a major resource of water for drinking, agricultural, and industrial use. (Todd, D. K., & Mays, L. W. (2005))

The availability of water determines the location and activities of humans in an area and the increase of population places great demands upon natural fresh water resources. However, they are sometimes exposed to various forms of pollution such as industrial, agricultural, and residential.

In the present study, spring water samples were collected from the spring and were analyzed for physio-chemical parameters., electrical conductivity, total suspended solids (TSS), total alkalinity, and total hardness. **(**"Water Quality and Pollution Control" (2009)**)**

2.1. Concepts, opinion, ideas from authers/experts

Water springs have been of interest to different fields of experts; each criterion has lured it into questioning its importance and character. Hydrogeologists emphasize, first of all, that spring is a critical point at which groundwater is enriched further by geological processes and discharges to the Earth's surface. According to David W. Hyndman, understanding the hydrogeological framework from which springs obtain their water is based on aquifer properties, subsurface flow dynamics, and the geologic structures that enable the water to move. Hence, springs are the physical manifestations of the health of the groundwater and geological conditions, playing critical roles in sustaining ecosystems and human communities.

In addition, the environmental significance of springs has been well-recorded by scholars such as Luna B. Leopold. These natural water bodies provide support for a broad range of flora and fauna, many times constituting unique ecosystems that may have an impact on the respective local biodiversity. Furthermore, they might assist in developing major sources of water during periods of drought, hence affecting the resiliency of the surrounding ecosystems. Here, its environmental importance is not only in terms of immediate biological impacts but also in respect to its effect on hydrological cycles.

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Spring development should be thoroughly planned and managed through engineering. Arthur Maas and other water resource engineers discuss the protection of spring catchments against contamination and overexploitation. Healthy aquifer conditions are what guarantee in additionally to the mentioned protection of contaminants the reliability and the resilience of the water supplies in the communities and autonomous regions of that country. Mean engineers even take into consideration the variability of spring flows and the seasonality of the same. They build infrastructure prepared for variations in water levels and to develop to meet different patterns in water demand.

Springs are often valued as natural filtration systems for water. Mary Douglas, among other anthropologists, reports on the historic signs of the cultic spring advertisements for Purity and Medicine. Relations to modern-day water supply intakes decrease treatment, which can become costly and could consume energy during treatment. However, maintaining water quality standards requires continuous monitoring and adherence to environmental regulations. springs have profound symbolic and practical significance. Brian Fagan and Hermann Hesse have explored the spiritual and cultural connections that societies have with springs, viewing them as sources of life, renewal, and communal gathering. Incorporating these cultural perspectives into water management practices can foster local stewardship and community engagement, enhancing conservation efforts and promoting sustainable water use practices.

2.2. Definitions

I. Water tanks

A water tank is a container for storing water. Water tanks are used to provide storage of water for use in many applications; drinking, irrigation, agriculture, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses. Water storage serves two general purposes, meeting variation in water demand and providing a reserve supply in emergency situations. Selection of the optimal location for reservoirs depends upon the topography, pressure situation in the system, economic aspects, climatic conditions, and security (Azgar, Mohammed, and N. Ramya Smruth, 2017).

There are three types of water tanks:

- **Underground water tank**

An underground storage tank is a reservoir that has at least 10 percent of its volume underground, these types are subjected to an internal force resulting from water pressure and outside pressure due to earth. The quantity of liquid inside the reservoir, the earth pressure along the reservoir, the soil pressure under and above the reservoir as well as the location of the water table must be considered while reservoirs are being designed (Somerton, Wilbur H, 1992).

- **Surface tanks**

These are the types of reservoirs that are placed at the top of the soil for storing water. These tanks are generally made of steel, plastic, or reinforced concrete. The side wall of reinforced concrete reservoirs has to be designed so that they will resist both water and earth pressure (Worm, Janette, 2006).

- **Elevated tanks**

When water is to be distributed at a very high pressure, an elevated tank must be constructed with steel, plastic or reinforced concrete cement, these tanks are known as elevated tanks. Elevated water tanks with steel or plastic are preferable because the self light is less than tanks with an

R.C.C water tank. Ventilation pipes, drain pipe, and stairs are provided for aeration, evacuation and inspection of the reservoir (Abdulla, Fayez A., & Al-Shareef, (2009).

II. Groundwater

Groundwater is water located beneath the Earth's surface in soil and rock layers. It fills porous spaces in aquifers, which can be unconfined (close to the surface) or confined (trapped between impermeable layers). The level of groundwater is marked by the water table. Groundwater is recharged by rainfall and other precipitation that infiltrates the ground and is discharged through springs, wells, or into surface water bodies. It is a key resource for drinking water, agriculture, and industry. However, groundwater can be vulnerable to contamination from pollutants, making its protection and sustainable management vital for health and environmental stability.

2.3. Origin and formation of springs

A spring is a natural point of discharge where groundwater flows out onto the Earth's pedosphere, its top. Groundwater is a part of the hydrosphere and a component of the water cycle. Springs may be classified by their rate of flow: The groundwater for a spring may be provided by seepage from an aquifer, a spring can be a component of the local water table, or through the resurfacing of some of the water stored in a glacial reservoir.

It is also possible to obtain springs from groundwater. The most common way this happens is when water gets to the surface when the ground level becomes higher than the table or when the terrain depresses sharply. Springs can also occur due to karst topography, aquifers, or volcanic activity. The floor of the ocean has also been realized to have springs, which spout warmer, low-salinity water directly into the ocean.

Spring water emanates naturally from the partial rain, which infiltrates the soil and consequently filtrates through a porous medium. The water keeps filtrating until it reaches a layer of impervious material, such as clay or rock, which restrains any downward flow out of the ground. In a few locations, the impervious layer reaches the surface; this phenomenon forces the flow of groundwater toward the surface and causes a spring. (Todd, D. K., & Mays, L. W. (2005)

2.3.1. Purpose of spring analysis

Spring analysis assures that springs are able to work nicely and effectively in different applications. It involves assurance that they can support the applied forces without failure, that their designs are optimized in turn, in cost and material usage, and meet safety and regulatory requirements. Analysis of springs enhances the performance of the system by controlling unwanted vibrations and increasing the life of springs. All in all, it assists engineers in designing reliable and effective products.

2.3.2. Classifications of spring

- Gravity Springs

Gravity springs form when groundwater naturally flows to the surface due to gravity. This happens when the water table intersects the ground surface, typically on sloping terrain. Often found on hillsides or in valleys. The flow is usually steady and can vary with changes in groundwater levels.

- Artesian Springs

Artesian springs occur in confined aquifers where water is trapped between impermeable rock layers. The pressure from the water in the aquifer forces it to the surface through natural openings or wells it can appear in flat terrains, as pressure alone drives the water up. Water may flow freely to the surface without mechanical pumping.

- Fault Springs

fault springs form along geological faults, where fractures or breaks in the Earth's crust create pathways for groundwater to rise to the surface it is common in tectonically active areas or regions with significant geological faulting. Water flows through fault lines, often resulting in noticeable springs along fault zones.

- Fracture Springs

Fracture springs occur when groundwater flows through natural fractures or joints in bedrock. These fractures provide channels for water to move from underground sources to the surface it is typically found in areas with complex rock formations, where fractures are common. The flow can be influenced by the extent and connectivity of the fractures.

- Karst Springs

Karst springs form in regions with soluble rocks like limestone. Over time, the dissolution of these rocks creates extensive underground channels and caves. Water flowing through these channels emerges as a spring it is common in karst landscapes, where limestone or similar rocks are present. Often high flow rates due to extensive underground drainage networks.

- Seep Springs

Seep springs form when water slowly seeps out from saturated soil or rock layers. This type of spring results from groundwater gently emerging from porous materials it is frequently found in wetlands, marshes, or areas with loose, moist soil. The flow is usually gentle and steady, providing a consistent source of water.

2.4. Quality of water

The quality of water is a crucial factor for human health, environmental sustainability, and various industrial processes. It is determined by its physical, chemical, and biological characteristics. Here's an overview of key aspects that define water quality:

- Physical Characteristics: Includes clarity, colour, odor, and taste. Clean water should be clear, colorless, odorless, and tasteless
- Chemical Characteristics: Measures pH level, dissolved oxygen, total dissolved solids (TDS), hardness, and contaminants. Safe water should have a balanced pH, adequate oxygen, low TDS, appropriate hardness, and minimal harmful chemicals.
- Biological Characteristics: Concerns about the presence of microorganisms like bacteria and algae. Water should be free from harmful pathogens and excessive algal growth.

Regular monitoring for contaminants and physical properties to ensure water meets quality standards, specific tests for pollutants, toxins, and trace elements that may not be detected in routine checks. Regular monitoring and treatment are key to ensuring that water remains safe and clean for all uses.

Drinking Water Standards Set by organizations such as the Environmental Protection Agency (EPA) or the World Health Organization (WHO). These standards define acceptable levels for various contaminants to ensure safety for human consumption.

Table 2.1: Drinking water quality

PARAMETER	UNIT	STANDARD VALUE
PH	-	6.5-8.5
Total dissolved solids(TDS)	Mg/l	500
Total suspended solids(TSS)	Mg/l	250
Alkalinity	Mg/l	100
Turbidity	Ntu	5.00

Magnesium	Mg/l	30
Fluoride(F^-)	Mg/l	1.0
Iron	Mg/l	0.3
Calcium	Mg/l	100
Chloride	Mg/l	250

2.5. Water distribution system

A water distribution system is a network of pipes, pumps, and storage facilities that deliver treated water from sources to consumers, ensuring it is safe, reliable, and available for various uses. It involves collecting water, treating it to remove contaminants, storing it in reservoirs or tanks, and distributing it through a network of pipes to homes and businesses while maintaining quality and pressure throughout the system.

2.5.1. Types of water distribution system

- ✓ Gravity system

A gravity water distribution system uses natural elevation differences to move water from a high source to lower areas without mechanical pumps. It relies on gravity to drive the flow, making it energy-efficient and low-maintenance. Elevated tanks or reservoirs store water and maintain pressure. This system is ideal for hilly terrains but has limited flexibility and is less effective in flat areas.

- ✓ Pumping System

A pumping water distribution system uses mechanical pumps to move water through pipes and maintain pressure. It is suitable for flat terrains or where precise control is needed. Pumps lift water from sources or boost pressure within the network, allowing for flexible and reliable delivery. However, it requires energy and regular maintenance.

- ✓ Combined System

A combined water distribution system integrates both pumping and gravity. It uses pumps to elevate water to storage tanks, which then distribute the water using gravity. This approach optimizes energy use, ensures consistent pressure, and provides flexibility in both flat and varied terrains, but involves more complex infrastructure and higher initial costs.

- ✓ Grid System

A grid water distribution system features interconnected pipes forming a network of loops, allowing water to flow from multiple directions. This design enhances reliability, ensures consistent pressure, and facilitates easy maintenance without widespread service interruptions. It's commonly used in urban areas but involves higher construction complexity and cost.

- ✓ Dual System

A dual water distribution system separates potable (drinking) water from non-potable water, using distinct networks for each. This approach conserves treated water by using non-potable sources for irrigation or industrial processes, reduces treatment costs, and improves resource management. It requires additional infrastructure and management but promotes efficiency and sustainability.

- ✓ Radial System

A radial water distribution system distributes water from a central point outward, like the spokes on a wheel. This design simplifies management and is efficient for zoned areas. However, if the central point fails, it can affect multiple zones, making it less reliable compared to systems with multiple supply paths.

2.5.2. Characteristics considered for choosing water distribution system

When choosing a water distribution system, the key characteristics to consider include:

- ❖ **Topography**: Elevation and terrain shape system design and determine the need for gravity or pumping.
- ❖ **Water Demand**: Influences system size and complexity based on population and usage patterns.
- ❖ **Infrastructure**: Compatibility with existing facilities and future expansion plans.
- ❖ **Cost**: Includes initial construction, operational expenses, and maintenance.
- ❖ **Reliability**: System redundancy, ease of maintenance, and failure risks.
- ❖ **Pressure Management**: Ensures adequate and controllable water pressure throughout the system.
- ❖ **Water Quality**: Ability to maintain and manage water quality and treatment needs.
- ❖ **Flexibility**: Adaptability to changes in demand and emergency response capabilities.
- ❖ **Community Needs**: Aligns with consumer preferences and preparedness for emergencies.

2.6. Water demand

It is the total amount of water required by various sectors, including domestic, industrial, agricultural, and commercial, within a specific area and time. It reflects the needs of the population and activities in that area, influenced by factors like population size, economic activity, climate and weather conditions, the living standard of people, industrial and commercial activities, the pressure in the distribution system, and the cost of water. Managing water demand involves forecasting, conservation, and ensuring adequate supply to meet current and future needs.

2.6.1. Types of water demand

Water demand can be categorized into several types based on the sector or purpose for which the water is used. Understanding these types helps in planning and managing water resources effectively. Here are the main types of water demand:

- ✓ **Domestic water demand**

It refers to the water used for household activities such as drinking, cooking, bathing, cleaning, and sanitation. It is influenced by factors like population size, lifestyle, and climate. Managing this demand involves using water-efficient appliances and promoting conservation practices to ensure sustainable usage.

- ✓ **Industrial water demand**

It refers to the water required for manufacturing processes, cooling, and cleaning in industrial operations. It is influenced by the type of industry, production scale, and technology used. Efficient management includes optimizing water use and recycling within industrial processes.

- ✓ **Agricultural water demand**

It is the water needed for irrigating crops and watering livestock. It depends on crop type, climate, soil conditions, and irrigation methods. Efficient use involves optimizing irrigation techniques and managing water resources to support crop growth sustainably.

- ✓ **Commercial water demand**

It refers to the water used by businesses and service establishments, such as offices, restaurants, and hotels. It varies based on business type, size, and customer volume, with efficient management focusing on conservation and minimizing waste.

2.6.2. Factors affecting water demand

- Increases in population lead to higher domestic and municipal water use.
- Industrial and commercial growth raises water consumption.
- Hot and dry climates increase irrigation and cooling needs.
- Efficient distribution systems reduce water losses and demand.
- Education on conservation encourages responsible water use.
- Regulations and pricing influence water conservation and demand.

2.7. Materials and equipment used in water distribution

The materials used in water distribution systems are selected based on factors like durability, corrosion resistance, and application, while the equipment ensures the system operates efficiently and safely. These components work together to maintain the reliability and quality of the water supply. Water distribution systems rely on a combination of materials and equipment to effectively transport and manage water.

2.7.1. Materials used in water distribution

I. Pipes

Pipes are long, cylindrical objects designed to transport liquids, gases, or granular materials. They are characterized by their consistent cross-sectional shape, which is typically round, although other shapes can be used depending on the application. Pipes can be made from various materials, each chosen based on the specific requirements of the system they are part of. Pipes come in several types and sizes.

Pipes can be divided into three main categories based on their material composition and intended use. These categories help classify the wide range of pipes available for various applications, from residential plumbing to large-scale industrial systems. The three main categories are:

1. Metallic Pipes

metallic pipes are cylindrical conduits made from metals like steel, copper, ductile iron, and cast iron. They are known for their high strength, durability, and ability to withstand extreme pressures and temperatures, making them ideal for applications such as water distribution, gas pipelines, industrial processes, and residential plumbing.

2. Non-Metallic Pipes

Non-metallic pipes are pipes made from materials other than metals, such as plastics (PVC, HDPE, PEX), concrete, and ceramics. These pipes are lightweight, corrosion-resistant, and easy to install, making them ideal for applications like residential plumbing, irrigation, sewage systems, and low-pressure industrial processes. They are often chosen for their flexibility, chemical resistance, and cost-effectiveness.

3. Composite Pipe

These pipes are designed to draw the best properties from various materials. They are constructed by layering different materials for special characteristics, such as strength, flexibility, and corrosion resistance. Examples include fiberglass-reinforced plastic (FRP) pipes and multi-layer composite pipes. These pipes apply in areas like specialized chemical processing, oil and gas pipelines, and HVAC systems that require enhanced performance characteristics.

Types of pipes used in water distribution

In water distribution systems, different types of pipes are selected based on factors like durability, pressure ratings, and cost. Here are the types of pipes most commonly used in water distribution:

Ductile Iron Pipes

Ductile iron pipes are metallic pipes highly regarded for their strength, flexibility, and durability, making them very appropriate for the distribution of water and high-pressure applications. Having the capacity to withstand high pressures, opposing loads due to external shocks, and resisting corrosion provided with proper coatings, they are much accustomed to municipal and industrial

Figure 2.1: Ductile iron pipes

piping systems.

Characteristics of Ductile Iron Pipes

- ✓ Strength: High tensile strength, capable of handling high pressure and external stresses.
- ✓ Flexibility: More flexible than traditional cast iron, allowing for better resistance to impacts and ground movements.
- ✓ Corrosion Resistance: Typically coated or lined to protect against corrosion and extend the pipe's lifespan.

Advantages of Ductile Iron Pipes

- ✓ Durability: Long service life due to its strength and resistance to impact.
- ✓ Flexibility: Better performance in seismic areas and areas with shifting soils compared to traditional cast iron.
- ✓ Repair and Maintenance: Easier to repair and maintain compared to older cast iron pipes.
- ✓ Cost-Effectiveness: Generally, more cost-effective over the long term due to durability and reduced need for frequent replacements.

Limitations of Ductile Iron Pipes

- ✓ Weight: Heavier than plastic pipes, which can make transportation and installation more challenging.
- ✓ Cost: Initial cost can be higher than some non-metallic pipes, although this is often offset by their longevity and durability.

Applications of Ductile Iron Pipes

- ✓ Water Distribution: Widely used in municipal water supply systems, including mains and service lines, due to their ability to handle high pressures and resist damage from external forces.
- ✓ Sewage and Wastewater: Used in sewage and wastewater systems where strength and durability are required.
- ✓ Fire Protection: Often used in fire hydrant systems and fire sprinkler systems because of their strength and ability to withstand high pressure.

PVC (Polyvinyl Chloride) Pipes

PVC (Polyvinyl Chloride) pipes, under the category of plastic pipes, are considered cost-effective, easily installable, and corrosion-resistant within many plumbing installations: water supply, drain, and irrigation systems. In short, they provide a smooth and long-lasting solution to most plumbing needs, though they are best for use on cold water systems and may not prove good in aggressive

Figure 2.2: PVC pipes

chemical environments or where very high temperatures occur.

Types of PVC Pipes

- ✓ Rigid PVC Pipes: The most common type, used for a variety of plumbing and drainage applications. They have a rigid structure and are often used in both residential and industrial settings.
- ✓ Flexible PVC Pipes: Used in situations where flexibility is required, such as in irrigation systems and some industrial applications.

Characteristics of PVC Pipes

- ✓ Lightweight: Easier to handle and install compared to metallic pipes.
- ✓ Corrosion Resistance: Resistant to rust, corrosion, and scale build-up, making it suitable for many water-related applications.
- ✓ Smooth Interior: Provides a smooth surface that reduces friction and minimizes the risk of clogs.

Advantages of PVC Pipes

- ✓ Cost-Effective: Generally, less expensive than metallic pipes, both in terms of material cost and installation.

- ✓ Easy to Install: Lightweight and easy to cut and join, which simplifies the installation process.
- ✓ Durability: Long-lasting and resistant to corrosion, chemicals, and UV radiation (when properly coated or treated).
- ✓ Low Maintenance: Requires minimal maintenance compared to metal pipes, which can rust or corrode over time.

Limitations of PVC Pipes

- ✓ Temperature Sensitivity: Not suitable for high-temperature applications as it can deform under excessive heat.
- ✓ Brittleness: Can become brittle and prone to cracking in extremely cold temperatures.

Applications of PVC Pipes

- ✓ Water Supply: Commonly used for cold water distribution in residential, commercial, and municipal systems.
- ✓ Drainage and Waste: Frequently used for drain, waste, and vent (DWV) systems due to its resistance to chemical and organic materials.
- ✓ Irrigation: Utilized in irrigation systems for its durability and resistance to environmental factors.

HDPE (High-Density Polyethylene) Pipes

HDPE (High-Density Polyethylene) pipes are flexible plastic pipes with high strength and durability. They are one of the most preferred choices in the water, gas, and sewage distribution system because of their flexibility, durability, and resistance to corrosion. Considering the pressure handling, environmental resistance, and leak-free joints through heat fusion, these pipes become an excellent option for municipal and industrial applications. However, these materials can only apply in environments that are not very hot or cold and requires protection from long-term UV exposure.

Figure 2.3: HDPE pipes

Characteristics of HDPE pipes

- ✓ Flexibility: Highly flexible, which allows for bending and reduces the need for fittings, especially in curved installations.
- ✓ Corrosion Resistance: Impervious to corrosion, rust, and chemical reactions, making them ideal for water and gas distribution.
- ✓ Lightweight: Easier to handle and install compared to many other types of pipes, such as metal or concrete.
- ✓ Smooth Interior: Low friction surface that minimizes pressure loss and allows for efficient flow.

Advantages of HDPE pipes

- ✓ Durability: HDPE pipes have a long service life, often exceeding 50 years, due to their resistance to environmental stress and corrosion.
- ✓ Leak-Free Joints: Can be joined using heat fusion, creating a seamless and leak-free system.
- ✓ Impact Resistance: Resistant to impact and pressure, even in cold temperatures, reducing the likelihood of pipe bursts.
- ✓ Cost-Effective: Lower installation costs due to fewer fittings and reduced labour for joining and laying pipes.
- ✓ Environmentally Friendly: HDPE is recyclable, and the pipes have a lower environmental impact during production and use compared to some other materials.

Limitations of HDPE pipes

- ✓ UV Sensitivity: Prolonged exposure to sunlight can degrade HDPE pipes, although UV-resistant coatings or burying them underground mitigates this issue.
- ✓ Temperature Limits: HDPE pipes are suitable for temperatures up to around 120°F (49°C) but are not ideal for high-temperature applications.

Applications of HDPE pipes

- ✓ Water Distribution: Commonly used in municipal water systems, including mains and service lines, due to their durability and resistance to environmental factors.
- ✓ Gas Distribution: Widely used in natural gas and propane systems due to their resistance to corrosion and leaks.

- ✓ Irrigation Systems: Used in agricultural and landscaping irrigation for delivering water over long distances.
- ✓ Sewage and Drainage: Employed in sewage and stormwater management systems due to their strength and ability to handle large volumes.
- ✓ Industrial Applications: Used in transporting chemicals, slurries, and other industrial fluids where corrosion resistance is critical.

Steel Pipes

Steel pipes are widely used in various applications due to their strength, durability, and ability to withstand high pressures and temperature. Despite their higher cost and weight, steel pipes are essential in many critical infrastructure and industrial applications.

Figure 2.4: Steel pipes

Types of Steel Pipes

- ✓ Carbon Steel Pipes:

Are pipes made from steel with a higher carbon content, which enhances their strength and hardness. They are widely used in high-pressure and high-temperature applications due to their durability. These pipes come in various grades, (e.g., ASTM A106, ASTM A53) based on their composition and intended use. each suited for specific uses, and are often used in oil and gas pipelines, water distribution, and structural applications. However, they are prone to corrosion and may require additional coatings.

- ✓ Stainless steel pipes

Are pipes made from stainless steel, an alloy that includes chromium and often nickel? This composition provides excellent resistance to corrosion, rust, and staining. They are used in applications where durability, cleanliness, and resistance to environmental factors are crucial, such as in chemical processing, food and beverage industries, and medical applications. Stainless steel pipes are known for their strength, longevity, and ability to maintain structural integrity in harsh conditions

- ✓ Galvanized steel pipes

Are steel pipes coated with a layer of zinc to protect against corrosion and rust. This zinc coating enhances the pipe's durability and extends its lifespan, making it suitable for outdoor and moisture-exposed applications. Galvanized steel pipes are commonly used in water supply systems and construction. However, over time, the zinc coating can wear off, potentially leading to corrosion and reduced performance.

- ✓ Black steel pipes

Are uncoated steel pipes that have a dark, oxidized finish. They are used for transporting fluids, such as water and gas, as well as in construction and fire protection systems. Black steel pipes are known for their strength and durability but are prone to rust and corrosion without additional protection or coating. They are typically used in applications where aesthetic appearance is less critical and strength is a primary concern.

Characteristics of Steel Pipes

- ✓ Material: Made from steel, which is an alloy of iron and carbon, and can also include other elements to enhance properties.
- ✓ Strength: High tensile strength and ability to handle high pressures, making them suitable for demanding applications.
- ✓ Durability: Resistant to mechanical damage and capable of withstanding harsh environmental conditions.
- ✓ Corrosion Resistance: Steel pipes are prone to corrosion unless treated or coated, but they can be enhanced with protective coatings.

Advantages of Steel Pipes

- ✓ Strength: High strength and load-bearing capacity, making them suitable for high-pressure and heavy-duty applications.
- ✓ Durability: Long-lasting and capable of withstanding harsh conditions and mechanical stress.

- ✓ Versatility: Can be used in a wide range of applications, from industrial to residential.

Limitations of Steel Pipes

- ✓ Corrosion: Steel pipes can rust and corrode, especially if not properly coated or maintained.
- ✓ Cost: Generally, more expensive than plastic pipes, both in terms of material cost and installation.
- ✓ Weight: Heavier than plastic pipes, which can make handling and installation more challenging.

Applications of Steel Pipes

- ✓ Oil and Gas Pipelines: High-strength carbon steel pipes are used for transporting oil and gas over long distances.
- ✓ Water Distribution: Steel pipes are used in municipal water systems, especially for large-diameter and high-pressure applications.
- ✓ Industrial Processes: Stainless steel pipes are used in industries where hygiene and corrosion resistance are essential.

II. Fittings and valves

fittings and valves are other main components of a water distribution system. They provide appropriate functions in connecting pipes, controlling the flow of water, and ensuring the whole system runs effectively and safely.

Fittings

Fittings are used to connect, redirect, or terminate pipe sections in a water distribution system. They are available in various materials to match the pipes they connect.

Types of Fittings:

- Elbows: Change the direction of the flow (usually 90° or 45° angles). It is used in corners or

Figure 2.5: Elbows

when pipes need to navigate around obstacles.

- Tees: Allow a single pipe to branch into two, creating a "T" shape. It is used to split or combine water flows in distribution lines.

Figure 2.7: Couplings

Figure 2.6: Tees

- Couplings: Connect two straight sections of pipe. It is often used to extend the length of a pipe run or repair a damaged section.

- Reducers: Connect pipes of different diameters. It is used to transition from a larger pipe to a smaller one or vice versa.

Figure 2.8: Reducers

Unions: Allow easy disconnection and reconnection of pipes. It is used in areas where maintenance

Figure 2.9: Union

or pipe replacement is frequent.

- Caps and Plugs: Close off the ends of pipes. It is used to terminate a pipe run or temporarily seal a section.

Figure 2.9: Caps and plugs

VALVES

Valves control the flow of water through the distribution system. They can stop, start, regulate, or divert the flow, making them critical for system operation and maintenance.

Types of Valves:

Gate Valves: Control the flow by raising or lowering a gate inside the valve. It is used in systems where a straight-line flow and minimal flow restriction are needed. Ideal for on/off control, not for throttling.

Ball Valves: Use a spherical disc (ball) to control the flow, with a quarter-turn operation. It is common in residential and industrial systems for shutoff and control. They provide reliable sealing and easy operation.

Butterfly Valves: Use a rotating disc to control flow, with a quarter-turn operation. It is suitable for large

Figure 2.11: Ball valve

Figure 2.12: Butterfly valve

diameter pipes and where space is limited. Used for flow regulation as well as isolation.

Figure 2.10: Gate valve

Check Valves: Allow flow in one direction and prevent backflow. It is used in water pumps and distribution systems to maintain directional flow and prevent contamination.

Globe Valves: Use a movable disk and stationary ring seat to regulate flow. it is ideal for throttling flow, commonly used in systems requiring precise flow control.

Figure 2.13: Globe valve

Pressure Reducing Valves: Reduce and regulate the pressure of water as it flows through the system. it is used in municipal water systems and buildings to maintain consistent water pressure.

Figure 2.14: Pressure reducing valve

III. Meters

Basically, it measures the quantity of water that passes through a meter. A water meter is mainly used to monitor and measure both residential, commercial, and industrial water usages.

How water meters work

Water meters are devices that measure the volume flows into a building or property. Most of the devices are normally installed at the supply point of water entrance. It makes this possible with the observation of the movement of water and thus translates it into readable measurements.

- **Water flow detection**: As water flows through the meter, it interacts with components designed to measure this flow.
- **Measurement mechanism**: Different types of meters use various mechanisms to measure the

flow rate and total volume. For example, mechanical meters use moving parts that turn or move in response to the flow of water.

Data recording: The measurement is then recorded, typically on a dial or digital display. In the case of smart meters, the data can be transmitted wirelessly to a central system for monitoring and billing purposes.

Types of water meters

Mechanical Meters

- Positive Displacement Meters: These meters measure water volume by capturing fixed amounts of water in chambers. Each chamber's displacement corresponds to a specific volume, and the total volume is calculated based on the number of displacements.
- Turbine Meters: These use a turbine that spins as water flows through it. The rate at which the turbine spins correlates to the flow rate, which is then used to determine the volume of water.

Electromagnetic meters

These meters use Faraday’s Law of Electromagnetic Induction to measure water flow. An electromagnetic field is applied to the flowing water, and the voltage generated by the movement of the water through the field is used to calculate the flow rate. They are highly accurate and can handle a wide range of flow rates.

Ultrasonic meters

These meters measure the velocity of water flow using ultrasonic waves. They emit sound waves that travel through the water. By measuring the time it takes for the waves to travel, the meter calculates the flow rate and volume of water. Ultrasonic meters are known for their accuracy and minimal maintenance requirements.

Smart meters

Equipped with advanced technology, smart meters collect and transmit data on water usage in real-time. They often include features like remote reading, leak detection, and detailed usage analytics. Data is sent wirelessly to utility companies, which can improve billing accuracy and customer service.

Applications and Benefits

Residential use: In homes, water meters help measure the amount of water used for billing purposes, promote water conservation, and detect leaks early.

Commercial and industrial use: Businesses and industries use water meters to monitor usage, manage costs, and ensure efficient water use.

Municipal use: Utilities use water meters to track overall water consumption, manage water distribution, and maintain infrastructure.

Environmental benefits: By providing accurate measurements, water meters support conservation efforts and help manage water resources sustainably.

2.7.2. Equipment used in water distribution

I. Tanks and reservoirs

Tanks and reservoirs are critical components in water distribution and management systems. They help ensure a steady, reliable water supply, manage fluctuations in demand, and support various functions in both urban and rural settings.

Tanks

Tanks are containers used to store liquids, gases, or even granular materials. They can be found in various industries, including agriculture, manufacturing, and fire protection.

Types of Tanks:

- **Storage Tanks**: To store water for various uses, helping to smooth out supply and demand variations

  Types of storage tanks

  - Above-Ground Tanks: Positioned above the ground, these tanks can be made from materials such as steel, concrete, or plastic. They are often used for residential, commercial, and industrial applications.
  - Underground Tanks: Installed below the ground to conserve space and protect water from environmental factors. Made from materials like concrete, fiberglass, or plastic.
- **Pressure Tanks**: Designed To maintain consistent water pressure in a distribution system, especially in systems where water is pumped from wells or other sources. These tanks include a flexible bladder or diaphragm that separates water from air pressure, allowing the system to maintain steady pressure.

- **Elevated Tanks**: To provide gravity-fed water pressure to a distribution system. Elevated on a stand or tower to use gravity for pressure. Generally large to supply a significant area.

Tanks can be made from various materials depending on their use:

Metal Tanks: Often made from steel or aluminium, used for durability and strength.

Plastic Tanks: Made from materials like polyethylene, these are resistant to corrosion and are often used for water and chemical storage.

Fiberglass Tanks: Used for their resistance to chemicals and corrosion.

Reservoirs

Reservoirs are large-scale storage systems designed to accumulate and manage significant quantities of water or other fluids. They are often natural or artificially created and can vary widely in size.

Types of Reservoirs:

- **Natural Reservoirs:** Lakes, ponds, or other natural bodies of water that collect and store water.
- **Artificial Reservoirs:** Man-made lakes or ponds created by constructing dams or barriers. These are often used for water supply, hydroelectric power generation, or flood control.
- **Service Reservoirs:** Part of municipal water supply systems that hold treated water before it is distributed to consumers.

Applications:

- Large reservoirs provide water to cities and towns.
- Reservoirs are crucial for irrigation in farming regions.
- Used in hydroelectric power generation to produce electricity.

Functions and benefits of tanks and reservoirs

Supply and Demand Management

- **Tanks**: Store water during low-demand periods to be used during peak times or emergencies.

- **Reservoirs**: Store large volumes of water to manage seasonal variations and droughts.

Pressure Regulation

- **Pressure Tanks**: Help maintain consistent pressure in systems where pumps are used.
- **Elevated Tanks**: Use gravity to ensure stable water pressure throughout the distribution network.

Emergency Supply

- **Tanks**: Provide immediate access to water in case of system failures or emergencies.
- **Reservoirs**: Serve as a large buffer to ensure water availability during unexpected shortages or natural disasters.

2.8. Water pressure

Water pressure is the force exerted by water per unit area within a system, determining how strongly water flows through pipes or fixtures. It is measured in units like pounds per square inch (psi), bars, or kilopascals (kPa). Water pressure is essential for ensuring effective water delivery and system performance, influencing both flow rate and system efficiency.

Types of water pressure

Static Pressure is the force exerted by a fluid at rest on the walls of its container or surrounding surfaces. It is calculated using the formula; $P=\rho gh$, where **ρ** is the fluid density, **g** is gravity, and **h** is the fluid height. Static pressure increases with depth due to the weight of the fluid above. It is crucial for designing tanks, reservoirs, and plumbing systems, influencing safety and efficiency.

Measured with gauges or manometers, static pressure impacts various applications, from household plumbing to industrial processes, and varies with fluid density and external factors like temperature.

Dynamic Pressure is the pressure exerted by a fluid in motion, related to its velocity. It is calculated using the formula $P_d=1/2\ \rho v^2$ where ρ is the fluid density and **v** is the flow velocity.

Dynamic pressure represents the kinetic energy per unit volume of the moving fluid and is crucial for understanding fluid flow behavior in systems like pipelines, air ducts, and aerodynamic surfaces. It affects the performance of pumps, fans, and other machinery. Unlike static pressure, which deals with fluid at rest, dynamic pressure focuses on the energy and force resulting from fluid movement.

Factors affecting water pressure:

- Height of Water Column: In a static system, water pressure increases with the height of the water column. This is described by the hydrostatic pressure formula: $P = \rho g h$ where P is the pressure, ρ is the density of the water, g is the acceleration due to gravity, and h is the height of the water column.
- Gravity: Water pressure is directly influenced by gravity. The greater the depth of water, the higher the pressure.
- Flow Rate: In dynamic systems, the rate of water flow can affect pressure. Higher flow rates can cause pressure drops due to friction in pipes.
- Pipe Diameter and Roughness: The size and condition of pipes affect water pressure. Smaller or rougher pipes create more resistance, which can reduce pressure.
- Pumps and Valves: Pumps can increase water pressure, while valves and other controls can regulate or reduce it.

Applications:

Residential: Managed by municipal supply, wells with pressure tanks, and pressure regulators.

Commercial/Industrial: Requires booster pumps and pressure tanks for consistent pressure.

Municipal Systems: Managed through reservoirs, tanks, and booster stations to ensure consistent delivery.

CHAPTER THREE: MATERIALS AND METHODS

3.0. Introduction

In this chapter, the research methodology used in this study is described. The research design, the population of the study , sample size and sampling techniques are described. The instrument used to collect he data, including method of data collection; method of data analysis and method of data presentation are described.

3.1. Research design

As data is most important in the research, there are two approaches of collecting and analyzing data: qualitative and quantitative research. Quantitative deals with numbers and statistics while qualitative research deals with words and meanings

In this study, the researcher used the two research methods. Quantitative research is referred to as the process of collecting as well as analyzing numerical data. It is generally used to find patterns, averages, predictions, as well as cause-effect relationships between the variables being studied.

A qualitative research method focuses on exploring ideas and formulating a theory or hypothesis and is analyzed by summarizing, categorizing, and interpreting ideas (Streefkerk,2019:3).

Therefore, through semi-structured interviews and non-participant observation, the methods and techniques that will be employed in the project are those that will be found to be appropriate in relation to the data that will be needed in the project.

Using interviews with people is a good way of getting information during the primary stages of any project. During the initial stages of the project local community was approached for reliable information on the water situation in the area. Therefore was no existing water committee to talk to, so we found out that the communities had no installed water system and that the existing sources of water were distantly located. Interviewing people in data collection shows that the problem of people in kabidandi village is based on the distance traveled by people to the source.

On the other hand, the people show that there is no negative effect on the people who use and consume water from the source and no changes even when the climate changes, in both watercolor or its quantity.

After analyzing the above information, the decision takes was to continue the research and work on the project of collecting and supplying gasamagi spring in kabidandi village.

3.2. Research population

As population is a large collection of individuals that are the main focus of social scientific research (Kenneth E N,2015:28).

Our research population is the population of kabidandi village, which is located in Kigali city, kicukiro district, gahanga sector, kagasa cell. kabidandi is one of the 333 administrative villages in Kicukiro. It is habited with about 978 people who have different living standards.

Kicukiro District has Approximately 166.7 kilometers square, as of the 2022 census, Kicukiro has a population of approximately 500,000 people, with a population density of 2994 people per square kilometer.

The population of kicukiro district has water source from the nyabarongo River, the water is treated at nzove and kimisagara water treatment which supply much of Kigali water including kicukiro district. In areas that are not fully a centralized water system, they rely on underground water sources such as; boreholes, wells, and springs, particularly in sectors like gahanga.

3.2.1. Population growth

Population growth is defined as a change in the number of people within a particular population during a specific period usually expressed as a percentage or rate and can be judged through births, deaths, or migration.

The population growth of kabidani village, which is currently populated with 980 people, is projected for 30 years.

To project the population of 980 people after 30 years with the annual growth rate of 3.25% you can use the formula of geometric growth rate to calculate the growth rate.

Using the following formula:

$P_t = P_0 (1+r)^t$

Where:

P_t is the future population,

P_0 is the current population (980),

r is the annual growth rate (3.25% or 0.0325 as a decimal),

t is the number of years (30).

Solution

$P_t = 980\ (1+0.0325)^{30}$

$P_t = 980\ (1.0325)^{30}$

P_t = 2558 people

3.2.2. Factors affecting population growth

- The fertility rate is the basis for the population growth. High fertility rates are the surety for higher population growth.
- Mortality Rate: Lower death rates translate to a high population increase.
- Economic and Social Conditions: Economic opportunities, access to health care, and
- social policies can majorly cause population increase or decline.
- Migration Trends: Immigration inflates the population size while emigration depletes it.

3.3. Sample size

Sampling is a process of choosing a smaller and more manageable number of people to take part in the research process and generalize the results to the whole of the research population (Catherine, 2002). Then simple random sampling method was employed to ensure that all populations stand an equal chance of being selected to avoid sample bias and ensure that the results were reliable enough to be generalized.

Given that the population size of kabidandi village is 980 people, the required sample size using the finite population correction formula. With a 95% confidence level and a 5% margin of error, the adjusted sample size is approximately 276 people.

Data Gathering Procedures

The data collection procedure is a systematic approach to gathering and measuring information from a variety of sources to obtain a complete and accurate database.

The objective

As the topic states, the study is to upgrade the water supply system and the objective is that all the people in kabidandi village get access to water in their homes, that is clean and the best quality. The study will be designed for 30 years.

The data source

The researcher used both primary and secondary data for the study

The primary data was obtained by means of the survey method. These were done by asking of questions and collecting data from respondents from the villagers'. For the purpose of achieving the aim and objective of this study, well-formulated questions were rates such as strongly disagree to strongly agree were formulated to gather information from appropriate respondents. The wordings were written without bias and the questions provided multiple-choice options, which were given to the respondents who were given the opportunity to showcase their ideas by way of selecting from the options that were provided.

Secondary data is data collected by someone other than the user. A clear importance of using secondary data is that much of the background work needed has already been carried out or analyzed (Wikipedia). Because the data already exist, you can evaluate them prior to using it. These include desk review of both published and unpublished material including policy documents, newspapers, internet, journals, articles, reports, bulletins, newsletters. The secondary source was to get a deeper understanding of published information on the compliance of the population. The information gathered from these sources helped guide the second phase.

I. Data collection method

In collecting the data the following methods were used:

Interview: An interview is a formal discussion focusing on a specific topic where one party poses questions and the other provides answers. The major objectives here are information collection, qualification assessment, or thematic understanding.

The following are the asked questions:

- what are the primary issues or difficulties you face with the current water supply system?
- Does demand on water use increase greatly at certain times of the year?
- They just pump water between the Nawabganj Barrage and Indian Border, How good do you think the quality is?
- Water safety—is there anything we should be worried about?
- The condition & maintenance of existing water infrastructure?
- Which features do you think the new water supply system ought to have and which services should be provided?
- Are there any future new developments in the neighbourhood or changes, which may impact water demand and usage?

Observation: Observation is the systematic process of recording and analyzing behaviours, events or conditions to gather data on information more effectively. It involves:

- Systematic Monitoring: The careful and methodical observation of the focus group.Now the collecting of data becomes just documenting what is witnessed in field notes, photographs and the not so fun upkeep on these sites.
- Processing: interpreting read data to unlock patterns, trends or problems.

Observation, in research and practical applications, helps to understand real-world scenarios, validate hypotheses or arrive at data-driven decisions.

Existing records: Records that are available to review and analyze refer to the data or information previously collected & documented. This can include:

- Numeric: Historical Data [Quantitative]; e.g. Numeric Values around past activities, events or transactions
- Primary Documents: Records held in an organization or institution, including reports, statistics, and legal documents.
- Archived Materials: Data collected before and stored in some form, such as a database or physical archives.

It is used for context, further research, proofing information, and guiding decisions based on existing records.

Survey: A survey is an efficient research tool, it involves evaluation for the collection of information from individuals or groups by using questions. It is used to measure certain topics, opinions, behaviors, or characteristics. They come in the form of questionnaires, interviews or even online forms and are widely utilized across a variety of fields to determine trends, measure attitudes and guide decision-making.

II. Documentation

Document the entire data collection process, including methodologies, challenges, and decisions made along the way. This ensures transparency and reproducibility.

3.4. Limitation of the study

Upgrading a water system can be a complex and multifaceted process, and several limitations or challenges might arise especially for a student who is not that experienced;

- Infrastructures currently in place may not support new technology or system

- Collaborate with technical experts or institutions oriented in rural water systems to provide the necessary guidance and support.
- Look at all sources of funding, be it a grant from the government, NGOs, or a community-based fundraising platform.
- The environmental impact assessment and mitigation will be conducted in order to assuage the negative impacts

By recognizing these limitations and addressing them proactively, an undergraduate study can provide a realistic and practical approach to upgrading water systems in a village, demonstrating both awareness and problem-solving skills.

CHAPTER FOUR: SYSTEM ANALYSIS AND IMPLEMENTATION

4.0. Introduction

This chapter will contain the calculation, specification, analysis, and implementation of the study.

Major calculations in the design of the water supply system must meet the level of dependability and efficiency that shall be satisfactory for the supply of water to the consumer. The major issues to be covered by these calculations include demand estimation, pipe sizing, pump selection, reservoir sizing, and network analysis.

4.1. Water demand calculation

Water demand refers to the quantity of water a town or area requires for all purposes, including domestic, commercial, industrial, and public. Water demand per head refers to the amount of water that is taken in by a single person in a given area in a day. This is usually in the form of liters per capita per day (Lpc/d).

1. **Population and growth projection**

The first step is to determine the current population and forecast the future population growth over a certain design period (in our case 3 decades or 30 years).

We divide the village into two parts (part A and part B)

Actual total number of population =part A + part B = 500+480 = 980capital

Future total number of population in 30 years = 2558 people

Actual domestic water demand is noted as quantity of actual domestic water demand ($Q_{act,dom}$)

2. **Per capita water demand**

Water demand per head refers to the amount of water that is taken in by a single person in a given area in a day. This is usually in the form of liters per capita per day (Lpc/d). This figure is very important to be calculated for the design and planning of the water supply systems as it helps to estimate the total water demand for the community.

Rwanda's Per Capita Water Demand

The average consumption demand per capita is evaluated as follows (Source: water and sanitation corporation):

1. Drinking 5L
2. Cooking 5L
3. Bathing 50L
4. Clothes washing 20L
5. Utensils washing 10L
6. House washing 10L

Total = 100L/c/d

Rwanda's urban areas will probably have increased per capita water demand due to the improved living standards and the water infrastructures if the country continues to develop. These figures are of course the results of factors like access to clean water, population density, and economic activities.

3. **Calculation of water domestic demand**

Domestic water demand is defined as water demand needed by households to meet daily needs, including drinking, cooking, bathing, hygiene, washing clothes and dishes, toilet flushing, and general cleaning of floors, yards, and gardening.

Formula:

($Q_{act,dom}$) = P x Per capita demand(LPCD)

Where:	data:
P: Population	P=2558 People
LPCD: Liter per capita demand	per capita demand:100L/cap/day

The projected domestic demand in 30 years is given by

Calulation:

$(Q_{act,dom})$ = 2558 X 100L/day

$(Q_{act,dom})$ = 255800L/day

$(Q_{act,dom})$ = 255.8 m^3 /day

4. **Industrial and commercial demand**

Industrial and commercial demand for water refers to the usage of water by businesses, factories, and various industries for production processes, operational needs, and service delivery.

This demand is driven by the needs of both industrial sectors (such as manufacturing) and commercial sectors (such as offices, hotels, and restaurants).

In the country which is developing in industrial and commercial demand it is estimated at 200L/c/day,

Quantity of water in industrial and commercial sector = 200L/C/day*2558P =511,600 L/day

5. **Public and fire demand**

Public and fire water demand refers to the water requirements for everyday public use and for firefighting purposes within a community.

For public and fire demand, the average consumption demand for public and fire and is estimated at 90L/c/day,

Quantity of water in public and fire sector = 90L/c/day * 2558P = 230,220L/day

6. **Losses and wastewater demand**

Losses and waste refers to the water supplied but not effectively used. The quantity of losses and wastewater demand is estimated at 60L/c/day.

In a flow of fluid via pipes, the losses are major and minor. The major and minor losses are some forms of energy loss because of friction and due to several fittings, bends, valves, or other forms of obstructions.

Major losses(hf) + minor losses(hm) = h_{total}

Quantity of water in losses and waste = 60L/c/day * 2558P = 153,480L/day

Hf = htotal /2 =153480L/2 = 76,740L/day

Hm = htotal – hf = 153480 + 76740 = 76,740L/day

7. **Projected water demand**

Total water demand after 30 years

Total Quantity of water (Qtot) =255800L/day + 511600L/day + 230220L/day + 153480L/day

Qtot = 1,151,100L/day = 1,151.1 m^3/day = 0.013m^3/sec

To determine the thickness of the pipe we take the nominal diameter minus the internal diameter and divide by two the result obtained

Nominal pressure application

The pipes of PN6 are used unless 60m water head

The pipes of PN10 are used unless 100m water head

The pipes of PN16 are used unless 160m water head

The pipes of PN 25 are used unless 250m water head

In over, it is recommended to use pipes made of galvanized steel or ductile melting. For the considered section one will choose class hoses of PN6, PN10, PN16and PN25 pressure, according to the static pressures. The diameters and class of pressure produced in Rwanda are indicated in the counts below.

4.2. Design of each section

4.2.1. Design of section C-B to the water tank with pumping system

L= length of pipe

S= slope

Length of pipe of section C-B=713.46m

Elevation of points C= 1650m;

Elevation of point B= 1665m

$S = \frac{\Delta H}{L}$

Slope = (1665-1650)/713.46 = 0.021 say 2.1%

Required discharge at section A =0.013*480/980=0.006m^3/s

Required discharge at section B =0.013*500/980=0.007m^3/s

For this section Q required at B is 0.007m^3/sec ,

Using Hazen William's formula we determine diameter laying in the section:

Q = A*V

Q = Flow rate (m^3/s)

A = Cross-sectional area of the pipe (m^2), which is related to the diameter by $A=\frac{\pi D^2}{4}$

V = Flow velocity (m/s)

Now, substitute the Hazen-Williams velocity formula into the flow rate equation:

$Q = (\frac{\pi D^2}{4}) * (0.849 * C * D^{0.63} * S^{0.54})$

$Q = 0.849 * C * S^{0.54} * \frac{\pi D^{2.63}}{4}$

$D = (\frac{4*Q}{0.849*C*S^{0.54}*\pi})$

$D = (\frac{4*0.007}{0.849*150*0.021^{0.54}*3.14})^{1/2.63}$

$D = (\frac{0.028}{127.35*0.389})^{1/2.63}$

D = 0.04569m = 45.69mm

Provide **D = 48.3mm/PN10 which is available**

As, Q=V*A then V= Q/A

And, Q= 0.007m^3/s

$A = \frac{\pi D^2}{4} = \frac{3.14*0.04569^2}{4}$

A=0.0016m^2

V=0.007/0.0016 = 4.375m/s

Head loss is based on the **Hazen-Williams formula**, commonly used for calculating head loss due to friction in water pipes.

Head loss= 10.675 * L* $(Q/C)^{1.852}$ * $(1/D^{4.87})$

Head loss = 10.675 * 713.46 * $(0.007/150)^{1.852}$ * $(1/0.04569^{4.87})$

Head loss = 0.0952m

Total head represents the total energy per unit weight of fluid in a hydraulic system. It is the sum of several types of energy that a fluid possesses, expressed in terms of height.

Equation: Total head(hp) = ΔH + Head loss + $\frac{V^2}{2g}$

- hp = Total pressure head (measured in meters, m)
- ΔH = Elevation difference (meters), which accounts for the change in height
- Head loss = Loss due to friction
- $\frac{V^2}{2g}$ = Velocity head, representing the kinetic energy of the fluid
- v = Fluid velocity (m/s).
- g = Gravitational acceleration (9.81m/s^2)

Total head(hp) = 15 + 0.0952 + 1.951 = 17.046m

4.2.2. Design of section B-A :

L=length of pipe

S=slope

Length of pipe of section C-B = 834.461m

Elevation of points A=1575m;

Elevation of point B=1665m

S= $\frac{\Delta H}{L}$

Slope = (1665-1575)/834.461=0.108 or 10.8%

For this section, with a head (h) of 90m the local topography will met the head losses. The velocity in gravitational flow ranges from 0.5 to 1.5m/second.

For this section Q is $0.007 m^3/sec$

For this section Q is $0.007 m^3/sec$

Using Hazen William's formula we determine diameter lying in the section:

Q = A*V

Q = Flow rate (m^3/s)

A = Cross-sectional area of the pipe (m^2), which is related to the diameter by $A = \frac{\pi D^2}{4}$

V = Flow velocity (m/s)

Now, substitute the Hazen-Williams velocity formula into the flow rate equation:

$$Q = \left(\frac{\pi D^2}{4}\right) * (0.849 * C * D^{0.63} * S^{0.54})$$

$$Q = 0.849 * C * S^{0.54} * \frac{\pi D^{2.63}}{4}$$

$$D = \left(\frac{4*0.007}{0.849*150*0.108^{0.54}*3.14}\right)$$

D = 0.002m = 2mm

As, Q=V*A then

V= Q/A

As, Q= $0.007 m^3/s$

$$A = \frac{\pi D^2}{4} = \frac{3.14*0.002^2}{4}$$

A = $0.00314 m^2$

V = 0.007/0.00314

V = 2.229m/s

H**ead loss** is based on the **Hazen-Williams formula**, commonly used for calculating head loss due to friction in water pipes.

Head loss= $10.675 * L * (Q/C)^{1.852} * (1/D^{4.87})$

Head loss = $10.675 * 834.461 * (0.007/150)^{1.852} * (1/0.002^{4.87})$

Head loss = 33.41m

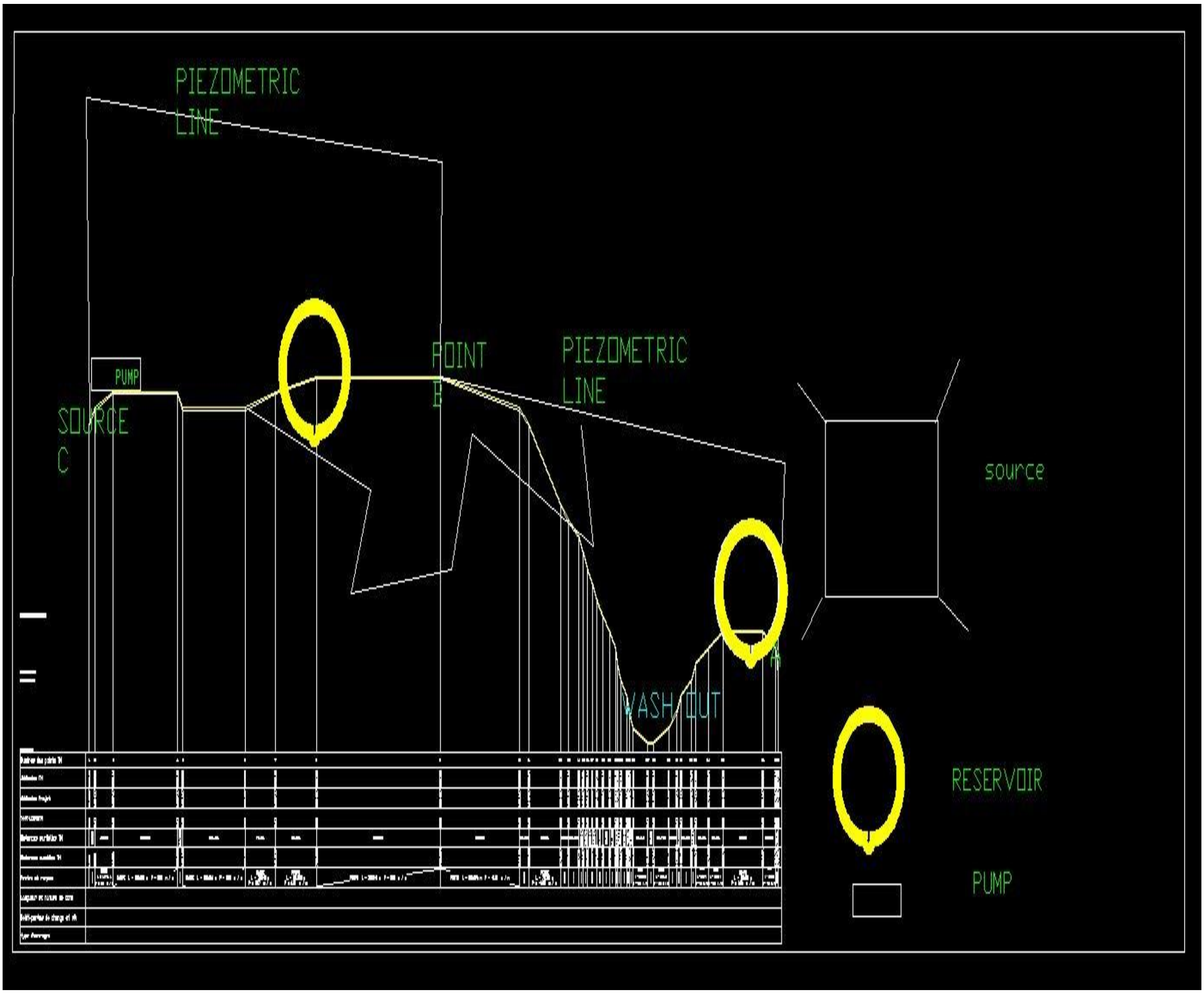

Figure 4.1: longitudinal profile of the main supply

4.3. Design and layout of the storage reservoir

4.3.1. Sizing of the water storage reservoir

To size a storage reservoir, several factors need to be considered, depending on its purpose (e.g., daily supply, emergency storage, firefighting, etc.). we are going to design the emergency storage.

Daily water demand (Qd): The daily demand that the reservoir needs to supply. For example, in our case, this is 575,550 L/day.

Formula for reservoir volume:

The basic formula to calculate the reservoir volume is:

Vres = [Qreq - Qpump] * T

V_{res} = [Qreq - Q_{req}/2] * T

Vres = $\frac{Qreq*T}{2}$

Where:

Qreq: water required: 575,550 L/day = 575.55 m^3/day

T: time : 7days

Qpump: $\frac{Qreq}{2}$

Vres =(575.55 * 3)/2

Vres = 863.325m^3

4.3.2. Dimensions calculation

For a cylindrical reservoir, the volume V can be calculated using the formula:

V = л r^2 h

Where:

V = Volume(in m^3)

r = radius of the base

h = Height (in meters)

r= $\sqrt{\frac{V}{л\, h}}$

r= $\sqrt{\frac{863.325}{3.14*2}}$

r= 11.72m

Diameter D = r * 2 = 11.72 * 2 = 23.44m

To calculate the surface area of a cylindrical reservoir, you can use the formula:

Surface Area = 2 π r(h + r)

Insert the values into the surface area formula:

Surface Area = 2π (11.72) (2+11.72)

A = 2 * 3.14 * 11.72 (2+11.72)

A= 1009.81m^2

To calculate the allowable bearing capacity of the foundation for the cylindrical reservoir, we need to use the total load that the reservoir exerts on the ground and the area over which that load is distributed.

Given data

Total Load (Weight of the Reservoir):

- Weight of water: Weight = V × Density = 863.325 m^3 × 1000 kg/m^3 = 863325 kg

Area of the Base:

- The area A of the base of the cylindrical reservoir can be calculated using the formula for the area of a circle:

  A = π r^2

  Radius r = 11.72 m

  Area: A = 3.14 (11.72) ^{2} = 431.3 m^2

Total Load in Newtons:

- Convert the weight of water to Newtons:

  Total Load = 863325 kg × 9.81 m/s^2 = 8469218.25 N

4.3.3. Allowable bearing capacity calculation

The allowable bearing capacity qa can be calculated using the formula:

Qa = Total Load/Area = 8469218.25 N/431.3 m^2 = 19636.49 Pa

Qa = 19.63kpa

Design for tensile forces

To design for tensile forces in the reservoir structure, particularly for the walls and base, we need to consider the effects of the loads acting on the reservoir and the resulting stresses.

Calculate the weight of the water

The weight of the water is:

W water = Vres × Density of water × gravity

Where the density of water is 1000 kg/m^3 and g = 9.81 m/s^2

W water = $863.325m^3 \times 1000kg/m^3 \times 9.81m/s^2$

W water = 8,469,218.25N

The weight of the reservoir structure using concrete with a density of 2300 kg/m^3 is:

W structure = V structure × Density × g

W structure = $448.07m^3 \times 2300kg/m^3 \times 9.81m/s^2$

W structure = 10,109,803.4N

Total Load

The total load on the foundation is the sum of the weight of the water and the weight of the reservoir structure:

P total = W water + W structure

P total = 10,109,803.4N + 8,469,218.25N

P total = 18,579,021.65N

4.3.4. Design for tensile forces

To design for tensile forces in the reservoir structure, particularly for the walls and base, we need to consider the effects of the loads acting on the reservoir and the resulting stresses.

Determine the Relevant Loads

Using the above data :

- Weight of Water (W water) = 8,469.2KN
- Weight of Reservoir Structure (W structure) = 10,109.8KN
- Total Load (W total) = 18,579KN

Calculate stress in the walls

To assess tensile forces, we need to consider the stress in the walls due to hydrostatic pressure and any additional loads.

Hydrostatic Pressure (P):

The hydrostatic pressure at a depth h in the reservoir can be calculated as:

$P(h) = \gamma \text{ water} * h$

Where γ water is the unit weight of water. At the bottom of the reservoir (height H=2m)

$P(2) = 9.81 kN/m^3 * 2m = 19.62 kN/m^2$

Resulting forces on the wall:

The total force acting on the wall can be calculated by integrating the pressure over the wall area.

For a circular wall:

$F \text{ wall} = \int_0^H P(h) * A(h) * \, dh$

Where $A(h) = 2 * \pi * r * h$ (circumference times height).

The total force on the wall at depth H is given by:

$F \text{ wall} = \frac{1}{2} * P(H) * A_{wall}$

F wall = $\frac{1}{2}$ * 19.62 * (2πr H)

Using r = 11.72m

F wall = $\frac{1}{2}$ * 19.62 * (2π * 11.72 * 2)

F wall = 244.3K

Design for tensile reinforcement

The maximum bending moment (M) in the wall due to hydrostatic pressure can be calculated using:

M = $\frac{F\ wall*H}{3}$

Where H=2m:

M = $\frac{244.3*2}{3}$ = 162.87 kNm

Calculate required reinforcement:

Using the bending moment, the required area of steel reinforcement (As) can be determined using the following formula from design codes (e.g., ACI 318):

Mu = As * fy * d * $\frac{1}{1000}$

Where:

fy = yield strength of steel (410 MPa)

d = effective depth of the section (d = 0.20m)

As = $\frac{Mu}{fy*d} * 1000$

As = $\frac{162.87}{410*0.20}$ * 1000

As = 1986.21mm^2

Select Rebar Size

$A16 = \frac{\pi}{4} \times (16mm)^2 = 201\ mm^2$

Number of bars required:

$n = \frac{As}{A16} = 1986.21/201 = 10$ bars

So you would typically use **10 bars** of 16 mm diameter.

4.4. Foundation design

To calculate the foundation for the reservoir, we need to ensure that the foundation can safely bear the loads from the reservoir, including the weight of the water, the reservoir structure itself, and any additional live or dead loads.

Calculate the required foundation area

The foundation area should be large enough to spread the load evenly, ensuring that the bearing pressure on the soil does not exceed the allowable bearing capacity.

Using the total load:

$A_{base} = W\ total/\ q_{allow}$

Where:

- $Wtotal = 18,579$ KN
- $q_{allow} = 19.63\ KN/m^2$

$A_{base} = 18579\ /\ 19.63$

$A_{base} = 946m^2$

Foundation dimensions

Since the reservoir is circular, the foundation will also be circular to ensure an even load distribution. The area of a circular foundation is:

$A_{base} = л\ r^2_{base}$

Solve for r_{base}

$R_{base} = \sqrt{\frac{Abase}{л}} = \sqrt{\frac{946}{3.14}} = 17.35m$

4.5. Reinforcement design for foundation

Bending moment calculation:

The total load is spread uniformly, so the foundation experiences bending moments due to the applied loads. The bending moment at the centre of the foundation can be calculated using:

$M = (q_{allow} * r^2_{base})/8$

Where: $q_{allow} = 19.63 KN/m^2$

$R_{base} = 17.35m$

$M = (19.63 * 17.35^2)/8$

M = 738.7 KNm

Reinforcement Area (As):

Using the bending moment, the required area of steel reinforcement can be determined. For a reinforced concrete slab, the reinforcement is typically designed based on:

Where : M = 738.7

fy = yield strength of stell is 410Mpa

d = effective depth of the slab, **0.35 m** (slab thickness of 0.4 m minus cover)

$As = \frac{M*10^6}{fy*d}$

$As = \frac{738.7 * 10^6}{410 * 0.35} = 5147.7 mm^2$

The above is the total area of steel required for the foundation

Select Rebar Size:

$A = (л / 4) * 16^2$

$A = (3.14/4) * 16^2$

$A = 201mm^2$

The number of 16mm bars required is:

N = As/A = 5147.7 / 201 = 26bars

4.6. RESERVOIR DESIGN DATA SUMMARY

Table 4.1: Reservoir data

PARAMETER	VALUE	UNIT
Reservoir dimension		
Radius of reservoir	11.72	m
Height of reservoir	2	m
Volume of water	863.325	m^3
Loads and weights		
Weight of water	8469.2	KN
Weight of reservoir structure	10109.8	KN
Total weight	18579	KN
Allowable bearing capacity	19.63	KN/m^2
Foundation design		
Required foundation area	946	m^2
Radius of foundation	17.35	m
Foundation thickness	0.4	m
Bending moment	738.7	KNm
Reinforcement details		
Required reinforcement area	5147.7	mm^2
Number of 16mm rebars	26	
Spacing of vertical rebars	20 -40	Cm
Spacing of horizontal rebars	20 – 40	cm
Strength of steel	410	Mpa

4.7. PIPE SIZING CALCULATION

Sizing pipe for underground water supply would help them in choosing the proper flow with fewer pressure losses in the water supply. The size of the pipe will surely have an effect on the velocity of the flow.

Formula:

$$Q = A * v = \frac{\pi D^2}{4} * V$$

Where:

Q = Flow rate (volume per second)

A = Cross-sectional area of the pipe (square meters)

v = Flow velocity (meters per second)

D= pipe diameter

Data for section B-A

Q= 0.007m^3/s

V= 2.229m/s

Solution:

$$D = \sqrt{\frac{4Q}{\pi V}}$$

$$D = \sqrt{\frac{4 \ X \ 0.007}{3.14 \ X \ 2.229}} = 0.063\text{m} = 63 \text{ mm}$$

The diameter of the pipes in section of B-A is 63mm

Data for section C-B

Q = 0.007m3/s

V = 4.375m/s

Solution :

$$D = \sqrt{\frac{4Q}{\pi V}}$$

$$D = \sqrt{\frac{4*0.007}{3.14*4.375}} = 0.045\text{m} = 45\text{mm}$$

The diameter of the pipes in section C-B is 45mm

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

One of the main tasks of the present project was to investigate in what manner and at what level the potable water would be supplied to the population, and therefore to design a system for its efficient water supply by properly developing one selected source of water to enhance the life of the people in the village. Reports on the current project concern how water would be supplied to the house population located in KABIDANDI village from the water source system designed towards the location of the population. To achieve such a task, it is a combined system of pumping and gravity system that will simply make it possible to design a water supply and distribution system for householders so as to enhance their day-to-day life.

Provisions of water to the people in Rwanda are among the most important areas of focus for enhancing the 3 quality of life of the population, as articulated in 2050. Paradoxically, this is still inadequate because one out of every two people in Rwanda does not have access to safe water. That is the reason why we need to find out how all the people would be helped with the water by clearly outlining a practical structure for how the water should be distributed.

5.2. Recommendations

The health and safety regulations across the different levels of water supply upgrade projects should be the focus of the engineers to ensure that workers and people in the community are free from harm. The population should keep in touch with the WASAC to inform them if there are any changes or damages.

As the project is designed for 3 decades I recommend the engineers work with the city and MINIFRA to ensure that the infrastructures to be constructed or the zone plan and make sure that the constructed waterline will not affect the construction of the future development.

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