

**Performance assessment of rural water supply system: A case study of Matatani
Village, Musina Local Municipality, South Africa**

By

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ABSTRACT

Assessment of the performance of a water supply system is essential to ensure its effectiveness in supplying water to households. The study assessed the performance of rural water supply system using Matatani Village as a case study. Field observations were conducted to identify existing water supply sources. These were mapped in Quantum Geographical Information Systems to determine the spatial distribution of the water sources and their proximity to households. A questionnaire survey was conducted to gather community perceptions of the water supply system. Statistical Package for Social Science (SPSS) version 25 was used to analyse questionnaire survey data. Water quality sampling was conducted from December 2023 to May 2024, covering both dry and wet seasons. Sampling locations included Borehole 1 (BH1), Borehole 2 (BH2), River Upstream (RU), River Downstream (RD), the Municipal Tap (MT), and Spring water. Water samples were analysed for physical, chemical, and microbiological parameters. Extech EC500 Pocket Meter and Extech TB400 Turbidity Meter were used to measure physical parameters. Inductively Coupled Plasma Atomic Emission Spectroscopy and DR3900 Spectrophotometer were used to analyse metals and non-metals ions, respectively. Metals and non-metals which were analysed include calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), manganese (Mn), zinc (Zn), cadmium (Cd), arsenic (As), iron (Fe), lead (Pb), sulphate (SO₄), chlorine (Cl), phosphate (PO₄) and fluoride (F). Microbiological parameters including *Escherichia coli* form (E. coli) and total coliform were analysed using membrane filtration method. Groundwater yield and water requirements were estimated for the months of December 2023 to May 2024. These were compared to the estimated water requirements at basic, intermediate and optimal service levels. Key performance indicators on reliability and accessibility were compared to benchmarks to assess the performance status of the water supply system. The socioeconomic profile of Matatani Village is dominated by young population, with 31.4% aged 18–29 years. The high proportion of youth suggests that water demand and usage patterns are influenced by an active population engaged in both domestic and economic activities. Matatani Village faces economic vulnerabilities, with 68.6% of the population relying on grants and a high unemployment rate, with 75.7% of the population unemployed. The high unemployment status indicates significant economic hardship, which can limit the community's ability to contribute financially to water system maintenance. The findings from field observations and a questionnaire survey indicated that the community relies on diverse sources, including rivers, springs, boreholes, communal taps, rainwater, and municipal water tankers. BH3 and BH4 are non-functional, while BH1 remains operational but is situated far from the households, making access challenging for residents. BH2 was initially designed to support both Mbodi and Matatani residents, but supplying water consistently to Matatani Village has proven challenging. The Mutale River and springs are vulnerable to contamination, while water from municipal taps is infrequently available. The results indicated that only 15.7% of households use 1400 liters per household per week. About 37.1% use between 350–700 liters, 24.3% access 175–350 liters, and 7.1% receive less than 175 liters per week, all of which were below the benchmark of 1500 liters per household per week. The residents of Matatani face challenges in accessing water from their preferred main source. The travelling distances to BH1 varied from 536 m to 1.73 km while the river varied from 3.80 km to 6.56 km to households and were above the benchmark of 100 m. Majority of the respondents (81.4%) experience frequent water supply disruptions indicating poor reliability of the water sources. Groundwater yields varied from 61714.29 to 77142.86 L/d and were adequate to meet the water requirements of 7000, 14000 and 28000 L/d for basic, intermediate and optimal access levels. While most physical water quality parameters complied with water quality guidelines, turbidity for groundwater from BH1 did not meet the compliance standard. Most of the microbial and chemical parameters did not meet the compliance standards for water quality guidelines. Some of the microbial and chemical water quality parameters that exceeded the guidelines include E. coli, total coliform, Al, Zn, Mn, Pb, Cd and Fe in all water sources. Failure to comply with water quality guidelines for chemical and microbial water quality parameters compromised the safety of the water for domestic use. Although half of the population perceive community engagement in water supply management as beneficial, only 1.4% actively participate in paying for these services, which may affect the sustainability of the water supply system. The performance assessment of the Matatani Village water supply system highlighted challenges related to accessibility and reliability, thereby limiting its effectiveness in meeting community needs resulting in poor performance. The study recommends implementation of improved water distribution systems and rehabilitation of BH3, which will increase the water supply and alleviate pressure on other sources. Strengthening community participation through new water management committees and training programs is also recommended for ensuring the long-term sustainability of the system.

Keywords: Water supply system, performance assessment, performance indicator, water source, source

DECLARATION

I, Tshivhase Elelwani, hereby declare that this research study titled *“Performance assessment of rural water supply system: A case study of Matatani Village, Musina Local Municipality, South Africa”* is my original work and has not been submitted for any degree or diploma at any other institution. I declare that all sources of information utilised in this study have been duly acknowledged.

Signature:

Tshivhase E.

Date: 20/02/2025

DEDICATION

This work is dedicated to Almighty God, the source of my wisdom, strength, and inspiration. I am deeply grateful for His grace, guidance, and countless blessings that have enabled me to undertake and complete this study.

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LIST OF ABBREVIATIONS

BH1	Borehole 1
BH2	Borehole 2
BH3	Borehole 3
BH4	Borehole 4
RU	River upstream
RD	River downstream
MT	Municipal tap
QGIS	Quantum Geographical Information Systems
SPSS	Statistical Package for the Social Sciences
ICP-OES	Inductively coupled plasma atomic emission spectroscopy
WHO	World Health Organisation
UNICEF	United Nations International Children's Emergency Fund
SANS	South African National Standards
DWS	Department of Water and Sanitation
VDM	Vhembe District Municipality
MCA	multi-criteria analysis
ANOVA	Analysis of variance
PPMC	Pearson Product Moment Coefficient
PMS	Performance measurement system
ASWSD	Accelerating Sustainable Water Services Delivery
WSA	Water Services Authority
WSP	Water Services Provider
TWR	Total water requirements
PCWU	Per capita water use
EC	Electric conductivity
TDS	Total dissolved solids
E. coli	Escherichia coliform
MPN	Most probable number
O & M	Operation and maintenance
DWAF	Department of Water Affairs and Forestry

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Access to clean and reliable water is a fundamental human need and a cornerstone of sustainable development. Mismanagement of water resources affects everyone in South Africa, with the poorest people suffering the most because they lack access to potable water and proper basic sanitation (Molobela and Sinha, 2011). The efficient use of the country's limited water resources is crucial for sustainable water service delivery, and effective water management provides significant benefits to the economy (Dikgang et al., 2020). The current reliable yield of surface water which is certain and acceptable for the supply is approximately 10 200 m³/a wherein 70% volume of the water is stored in 252 largest dams in South Africa (Viljoen and Van der Walt, 2018). As a result, most of the rural areas do not have access to water from large dams, hence, they do not benefit from this resource.

The availability of safe and clean water is crucial for human life (Dharminder et al., 2019). However, an increase in demand for water, reduction of water resources, and increase in pollution of water driven by population and economic growth, will result in clean water scarcity by 2050 (Boretti and Rosa, 2019). The aforementioned will affect the performance of the water supply systems if they are not addressed urgently. According to Boretti and Rosa (2019), the strain on water will increase due to an increase in population growth. This will further strain the existing water supply systems in South Africa where water demand is already exceeding water supply.

Considering the importance of water to human survival, over 2.1 billion people lack access to safe drinking water (WHO and UNICEF, 2017). Performance assessment plays a crucial role in improving water supply services in the world (Nyathikala and Kulshrestha, 2020). A consistent assessment of the performance of a water supply system is vital to ensure efficient water supply to households (Naamani and Sana, 2021). Challenges concerning potable water supply in Vhembe District threaten the health and welfare of local communities (Malima et al., 2022). Assessing performance helps to identify gaps or challenges, ensure equitable distribution, and guide improvements. To address these challenges, a multi-faceted approach involving community engagement, infrastructure development, and sustainable water management is essential for ensuring reliable and equitable access to water resources.

1.2. Statement of the problem

According to the constitution of South Africa, everyone has the right of access to sufficient water (Section 27(1)(b) (South Africa, 1996). The Water Services Act, the principal policy regulating water service provision in South Africa, legitimises the right to basic water and sanitation provision by municipalities by articulating this (Section 3) (South Africa, 1997a). A minimum volume of 6000 liters of potable water shall be made available to a household per month which comply with the South African National Standards (SANS) 241 quality standards. Water must be available for at least 350 days per year and not be interrupted for longer than 48 consecutive hours (DWS, 2017). Rural areas do not have access to water as per these regulations, implying that their right to access basic water and sanitation is not achieved.

Regardless of many years of research on rural drinking water services, sustaining a reliable water supply is still a challenge in rural, inaccessible, and disregarded communities in developing countries (Mvongo and Defo, 2021). In 2020, about 25% of the global population lacked access to safe drinking water, with 80% living in rural areas (WHO and UNICEF 2021). The supply and management of safe drinking water is a rising concern with regards to inequitable service provision, mainly in developing countries (Abdisa and Reddy, 2014). The availability of potable water in rural areas is crucial. Many rural residents struggle to get access to household water for personal and environmental hygiene (Bello et al., 2021). Most rural areas in South Africa are also experiencing challenges in accessing water services (Mothetha et al., 2013).

South Africa is facing a water crisis caused by insufficient water infrastructure maintenance and investment, recurrent droughts driven by climatic variation, inequities in access to water and sanitation, deteriorating water quality, and a lack of skilled water engineers (Viljoen and van der Walt, 2018). In rural areas, such as Matatani Village, water supply systems are often characterised by poor accessibility and inconsistent reliability. Many rural communities lack access to safe water and resort to untreated water from rivers, rainwater, and springs to meet their basic needs. Lack of adequate water supply also hinders activities that can improve their livelihoods and economic growth. Large portions of the rural population in South Africa lack access to basic hand-washing facilities in their homes or they experience partial access and regular shutdowns (Jovanović et al., 2023).

Limpopo Province is recognised as one of South Africa's water-stressed provinces, with the Vhembe district being strongly impacted by the water crisis (Murei et al., 2022). Access to clean and safe water is crucial for drinking, cooking, and sanitation, all of which are essential for preventing diseases and promoting public health. Furthermore, effective and reliable water supply systems contribute to economic stability and growth. Effective and reliable water supply support job creation enhances quality of life and attracts investments by providing a necessary infrastructure that businesses and industries depend on. The community of Matatani relies on a handpump borehole which is far away from the households. This makes the community vulnerable to water shortages. If the hand pump breaks down or requires repairs, the entire community's water supply is disrupted, exacerbating the challenges of water supply in the area. With only one hand pump, breakdowns may occur frequently due to overuse. The excessive and unregulated usage might also lead to the depletion of the groundwater, affecting the availability of water in the long run. Long distances might discourage people from collecting adequate water for personal hygiene, including other sanitation-related needs. Inadequate access to clean water and sanitation facilities can lead to increased risks of waterborne diseases and poor hygiene.

1.3. Motivation of the study

Water is vital across various sectors, such as agriculture, energy, industry, and tourism, as well as for urban and rural development. Proper allocation, management, and protection of this resource are crucial for promoting economic growth, reducing poverty, and addressing inequality in South Africa (DWS, 2022). Reliable and sustainable access to potable water, particularly in rural areas, is critical for meeting basic needs and supporting livelihoods through activities like small-scale gardening, livestock rearing, brickmaking, and beer brewing (Adank, 2006). These activities contribute to rural development by enhancing health in terms of water and hygiene-related disease, as well as economic advantages (generation of income) and increased nutrition and food security (Adank, 2006). The study therefore aligns with the United Nations Sustainable Development Goals (SDGs) 1 (no poverty), 2 (zero hunger), 3 (good health and well-being) and 6 (clean water and sanitation). At regional level, it supports the African Union's Agenda 2063 goals 1 and 3. Goal 1 covers a high standard of living, quality of life and well-being for all citizens while goal 3 covers a healthy and well-nourished citizen (African Union Commission, 2022). At national level, it complements the objective of the national development

plan which is to ensure that all people have access to clean, potable water and that there is enough water for agriculture. This study is therefore crucial as it aligns with these imperatives.

Most villages in rural areas lack running tap water or an appropriate infrastructure, which necessitates urgent water supply interventions (Jovanović et al., 2023). Performance assessments of water supply systems are critical to identifying challenges, suggesting solutions, and ensuring the long-term sustainability of water services (Naamani and Sana, 2021). While previous studies, such as those by Yadav et al. (2014), Zvobgo (2020), and Naamani and Sana (2021), have focused on urban areas, there is a gap in rural-specific assessment of the crucial factors like reliability and accessibility of water supply systems, especially in rural areas with underdeveloped infrastructure (Majuru et al., 2012). Moreover, there is limited research addressing the performance of water supply systems in the Vhembe District Municipality, where a study on assessment of water supply system done 16 years ago by Rietveld et al. (2009).

The lack of robust monitoring systems further exacerbates the challenges of maintaining and improving water supply systems. Still (2017) noted that insufficient oversight can render financial investments ineffective and hinder the ability to learn from previous implementation failures. This study addresses these gaps by focusing on reliability and accessibility indicators for rural water supply systems. Therefore, the study will also serve as a baseline for research to be conducted in remote rural areas and emphasises the importance of monitoring for sustainable management of water supply infrastructure. Effective monitoring is thus crucial not only for accountability and learning but also for the continuous and effective management of these vital services. The qualitative data obtained from this study will be used to develop new measurement instruments and theory that will be subsequently tested.

This will improve the provision of potable water in rural areas. The findings of this study may be used as a tool to inform policymakers and the government at large on possible areas of intervention in improving water supply in rural areas. It is against this background that assessment of performance of a water supply system will be carried out in Matatani Village, with an aim to address water supply challenges.

1.4. Objectives of the study

1.4.1. Main objective

- The main objective was to assess the performance of the water supply system in Matatani Village.

1.4.2. Specific objectives

- To identify the available water supply sources and their status in Matatani Village.
- To determine the reliability and accessibility of the water supply sources during different climatic seasons at Matatani Village.
- To explore community participation in water supply management at Matatani Village.
- To determine the status of the performance of Matatani water supply system.

1.5. Research questions

- What are the current water supply sources at Matatani Village?
- What is the impact of varying climatic seasons on the reliability and accessibility of water supply sources in Matatani Village?
- How is community participation affecting water supply system performance in Matatani Village?
- What is the current performance status of Matatani water supply system?

1.6. Characteristics of the study area

1.6.1. Location of the study area

Matatani Village is in Limpopo Province, Vhembe District Municipality (VDM) within Musina Local Municipality with latitudes 22°33'54.16"S and longitudes 30°45'39.16"E (Figure 1.1). It is located 143 km from Musina and 86km from Thohoyandou town.

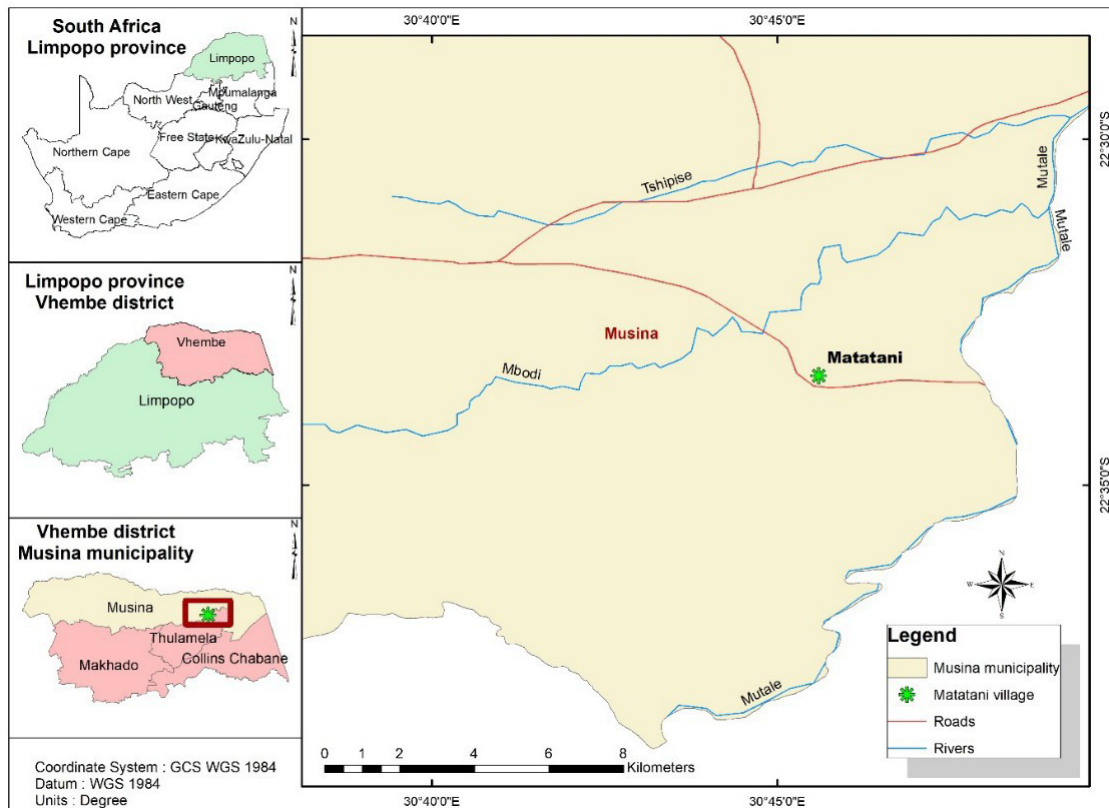


Figure 1.1: Map of the study area

1.6.2. Hydrology and hydrogeology of the study

The main river which passes through the area is Mutale River. Mean annual runoff of Mutale catchment is $156.5 \text{ Mm}^3/\text{a}$. Vhembe District is one of the drought-stricken municipalities in South Africa. However, borehole yields, and groundwater monitoring are major problems in the district (Statistics South Africa, 2018). Mutale catchment is underlain by hard rocks with aquifers developed in secondary features associated with weathering pockets and structures. Structural features are important and higher borehole yields are generally associated with these features. Localised occurrences of alluvial deposits occur along the Limpopo River, which are locally exploited for irrigation. The north-eastern part of the district has a dry climate and is predominantly semi-arid with frequent droughts (Mutale Local Municipality Integrated Development Plan, 2016/2017). The area experiences annual rainfall of approximately 500mm per annum out of which about 87.1% falls between October and March. The rainfall is erratic and is largely influenced by the orographic rain effect of the Drakensberg Mountains joining the Soutpansberg perpendicularly hence decreases from east to the west of the district. The mean annual temperature ranges from about 18°C in the mountainous areas to more than 28°C in the

northeast. Maximum temperatures are experienced in January and the least occur on average in July (Mutale Local Municipality Integrated Development Plan, 2016/2017).

1.6.3. Land use/land cover

The land use activities are irrigation (small holder irrigation schemes) and forestry. Much of the land is farmed, with concomitant low levels of productivity and has a scattered communal land settlement.

1.6.4. Water supply and water uses

The northern area in Mutale catchment is agricultural with few scattered settlements dependent upon groundwater for domestic supply and cattle watering. Matatani Village relies on one drilled borehole with hand-pump. The community also uses river water and rainwater and occasionally receive water from Nwanedi Water supply.

CHAPTER 2: LITERATURE REVIEW

2.1. Preamble

In this chapter, literature has been reviewed on commonly available water supply sources in rural areas, performance assessment of water supply system, community participation in water supply and performance management.

2.2. Commonly available water supply sources in rural areas and their quality status

Water plays a fundamental role in agriculture, energy, industrial development, tourism, rural development, and urban growth. It is therefore essential to ensure adequate access to water for all as this can reduce poverty and inequality and improve economic growth in South Africa (DWS, 2022). Humans need a substantial amount of clean and healthy water; yet just 3% of the world's water is fresh, and only 0.3% of this fresh water is available as flowing surface waters (Forare, 2009). Due to seasonal variations in rainfall and water availability, maintenance issues, and governance challenges, access to water can vary throughout the year and the seasons, causing people to change their water supply (Apraku et al., 2023). Most people in developing countries of the world still depend on untreated surface water as their primary source of household water supply (Fayiga et al., 2018), due to an insufficient supply of clean water. Other commonly used sources of water in rural areas include boreholes, rivers, springs and harvesting rainfall (Fayiga et al., 2018).

In rural areas, traditional water sources such as unprotected ponds, tanks, wells, cisterns, streams, and rivers are commonly used. However, these sources are often unsafe for consumption due to contamination by fecal matter and overuse, posing significant health risks to the community (Sundaravadivel and Vigneswaran, 2009). In Colombia, groundwater is used as drinking water without treatment, but analysis revealed contamination with total coliforms in 89% of samples and fecal coliforms in 58%, making these the primary pollutants and raising concerns about its safety for human consumption (Lora-Ariza et al., 2024). Similarly in South Africa, a considerable number of rural areas lack access to formal water services, with approximately 80% of rural villages depending solely on groundwater for their domestic water needs (Nkuna et al., 2014). The presence of pit latrines, pollution sources such as household waste dumping sites, poultry, and dairy farms, combined with the lack of properly constructed concrete platforms, facilitates the contamination of shallow aquifers. This contamination affects

the quality of groundwater extracted through tubewells (Dey et al., 2017).

Over 1.8 billion people worldwide are believed to acquire their drinking water from contaminated water sources (Pal et al., 2018). Kalt et al. (2014) concurred that rural communities continued to depend on unimproved water sources such as streams, fountains, rivers, and springs for their potable water survival. Rainwater was identified as an alternate source of water in South African rural communities by Kahinda et al. (2007). Furthermore, Van Koppen et al. (2020) noted that most households have two or more water sources to their homes as a necessary buffer against unpredictable supplies and droughts. These sources include boreholes, hand dug wells, rivers and rainfall harvesting. Assessing the status of drinking water quality and potential health hazards is essential for making informed decisions on drinking water quality protection and management (Li and Wu, 2019). Water quality is a key factor influencing the status of health and well-being of living organisms, including humans (Ganaie et al., 2023). Ezekiel and Dominic (2015) revealed that the primary water sources in Nassarawa Eggon town, Nasarawa State, Nigeria are hand-dug wells and streams, as there is no pipe-borne water available. Without access to pipe-borne water, the quality of available water becomes even more critical to the health and well-being of living organisms, particularly in communities that depend on these sources. In many developing countries, available surface waters are polluted, and municipal water services are unreliable (Forare, 2009). Pollution of surface water and poor municipal water supplies lead many individuals to rely on alternative sources. Surface water quality deteriorates rapidly with population development, and global reliance on groundwater sources has increased and this has become true in rural areas and the rapidly growing urban settlements (Forare, 2009).

Groundwater quality for human consumption varies depending on its source and frequently necessitates thorough monitoring (Forare, 2009). It was reported that 2.2 billion people still lack safely managed drinking water sources (UNICEF and WHO, 2024). Contaminants present in water disrupt the natural mechanisms of the human body, resulting in both short-term and long-term health issues. Poor drinking water quality is significantly affecting the health of consumers. Akib Jabed et al. (2020) reported the people's perception of poor-quality water impacts on their health in coastal areas of Bangladesh. Groundwater irrigation plays a crucial role in boosting agricultural production and the livelihoods in many parts of the world in rural communities (Qureshi, 2020). Groundwater has emerged as the world's most important source of drinking

water supply, both in industrialized and developing countries (Forare, 2009). Groundwater is widely recognised as an essential source of drinking water in low-income areas, and it therefore serves as an important role in the fulfilment of the human right to water (Carrard et al., 2019). Groundwater has emerged as the most important source of drinking water supply in the world. In both the developed and developing world, there has been a manifold increase in the use of groundwater among the populations in rural areas, as well as in the rapidly expanding urban areas (Forare, 2009). According to Auwal et al. (2021) boreholes are the primary source of water in Kano Metropolis North-Western, Nigeria. Ayiwulu and Edache (2015) revealed that hand- dug wells, boreholes and streams are the major sources of domestic water in Nassarawa Eggon Local Government Area of Nasarawa State, Nigeria. Rainwater provides a relatively reliable source of potable water supply to communities in rural areas, but its use in Uganda is still limited (Nayebare et al., 2014). According to Carrard et al. (2019), groundwater is already the preferred source of drinking water worldwide and is frequently considered to be more reliable and accessible than surface water since it can be utilised directly by consumers. One of the most important aspects impacting human health is the quality of drinking water. However, the quality of drinking water in many countries, particularly in developing countries, is not ideal, and several waterborne illnesses have been linked to poor drinking water quality (Li and Wu, 2019). Understanding the status of drinking water quality and associated health risks is the basis for making wise decisions on drinking water quality protection and management (Li and Wu, 2019). Drinking water quality is affected by multiple factors, among which the quality of source water is the most significant one, especially in rural areas where water treatment is usually inadequate (Scheili et al., 2016).

Mpenyana-Monyatsi et al. (2012) found that groundwater serves as the primary water source in Mpumalanga province, but in some areas, the water is unsuitable for human consumption. Lephalale Municipality in Limpopo Province faces water scarcity due to its arid conditions, relying on groundwater from approximately 138 municipal boreholes to supply all 38 villages with household water (Mulaudzi et.al., 2024). Hoffman and Nkadimeng (2016) investigated the water supply challenges faced by the Motetema Settlement in the Elias Motsoaledi Municipality. Due to the inadequacies of the municipal water system, communities often resort to alternative sources such as purchasing water or collecting it from natural sources like rivers and streams. These challenges include poor water quality, which poses significant health risks, and delays in resolving infrastructure breakdowns, resulting in unreliable access and exacerbating water provision issues in the area (Hoffman and Nkadimeng, 2016). Belle et al. (2021) highlighted the

poor quality of groundwater in the Welkom and Virginia areas of Free State Province, posing a significant health risk to local residents who rely on it as their main source of drinking water. The Limpopo Province is one of South Africa's most water-stressed provinces, with the VDM being strongly affected by water crisis (Njoku et al., 2022). The VDM is one of the most affected by drought in South Africa (Makungo et al., 2019). Since South Africa has been identified as a water-scarce country, immediate action is required to safeguard its water sources. To mitigate the implications of water scarcity, current water sources must be handled in a more sustainable and effective manner in the future.

2.3. Performance assessment of a water supply system

A water supply system is a crucial infrastructure designed to provide safe and reliable access to water for households and communities. It consists of several components that work together to ensure the consistent delivery of water, including water sources, treatment plants, distribution networks, and storage facilities. Water sources can include groundwater (For example., boreholes), and surface water (For example., rivers and lakes), or municipal sources. Water treatment plants are responsible for purifying water to meet safety standards, ensuring it is free from harmful contaminants. The distribution network, which includes pipes, pumps, and valves, delivers water to individual households, while storage facilities (e.g., reservoirs or tanks) hold water to ensure continuous supply, even during peak demand periods or seasonal fluctuations. The assessment of the performance of a water supply system involves assessing several critical aspects to ensure it meets the needs of the community effectively. Key considerations include the quantity of water supplied, ensuring it is sufficient to meet the population's demand, and the quality of the water. The quality of water must comply with physical, chemical, and microbiological safety standards. Reliability is also crucial, as the system should provide a consistent supply even during peak demand periods or seasonal fluctuations. Accessibility is assessed by examining how easily households can obtain water, factoring in proximity and infrastructure availability. Assessing the condition and performance of water supply infrastructure is crucial and can be achieved through routine physical inspections or modeling approaches (Boulenouar and Schweitzer, 2015). A well-functioning water supply system not only enhances the quality of life for residents but also supports essential activities such as agriculture, education, and overall public health (Abanyie et al., 2023).

According to Boulenouar and Schweitzer (2015), tracking infrastructure conditions over time enables effective planning for necessary routine maintenance. Several studies such as those by Yadav et al. (2014), Zvobgo (2020) and Naamani and Sana (2022) have identified and employed a variety of performance indicators for water supply systems, often tailored to urban context, while neglecting the rural areas. The absence of robust data collection and reporting mechanisms in rural areas makes regular assessment and evaluation challenging. The neglect of rural areas in water supply system assessments stems from a combination of practical, financial, institutional, and sociopolitical factors. Still (2017) assessed the key performance indicators in rural areas of South Africa. The key performance indicators that were used involved evaluating three main indicators which are water quality, reliability, and source sustainability. The study revealed that the lack of assessment and monitoring of water supply systems significantly hampers the ability to maintain and improve infrastructure. This deficiency undermines the sustainability and reliability of the water supply systems, highlighting the critical need for effective monitoring to ensure long-term service quality and infrastructure performance.

Zerihun and Mashigo (2022) assessed the service delivery in a case study of rural district municipality in Mpumalanga Province of South Africa. The study used primary data collected from 120 respondents. A descriptive quantitative method was used using questionnaire and content analysis of official documentation. The study revealed that residents in the study area are not satisfied with the level of current municipal services provided. In addition, the study discovered that municipality does not generate enough funds because of non-payment for the service rendered that will substantially reduce basic municipal services provision. Furthermore, contrary to the common belief that rural municipal residents demand free services, the study revealed that residents are willing to pay modest fees for the quality services rendered. Zvobgo (2020) evaluated the performance of water supply services in urban areas of Chitungwiza. The indicators considered in the study were coverage of water supply connection, the extent of metering of water connections, presence of water leakages, the extent of non-revenue water, continuity of water supply, quality of water supplied and efficiency in redressal of customer complaints. The findings show a high percentage of non-revenue water, inadequate maintenance of water infrastructure, a lack of investment in water that results in extensive distribution system leaks, poor water quality supply, and inconsistent service delivery. The majority (80%) of respondents said the municipal water supply services were inadequate which makes the households in Chitungwiza rely on alternative sources. Yadav et al. (2014) conducted

a performance evaluation of water supply services in Ahmedabad city in a developing country. The study utilised nine performance indicators including coverage of water supply connections, per capita water supply, metering of connections, non-revenue water, continuity of supply, water quality, customer complaint redressal efficiency, cost recovery, and collection efficiency. The findings revealed impressive performance in cost recovery, water quality, customer complaint redressal, and charge collection efficiency. However, challenges were identified in metering, continuity of supply, and reduction of non-revenue water, necessitating targeted interventions to improve service delivery.

Mvongo and Defo (2021) assessed rural water service performance in Sub-Saharan Africa specifically within the southern and eastern regions of the Republic of Cameroon. The study employed a multi-criteria analysis (MCA), to assess water services provided to rural communities in two councils (Mvangan and Mandjou). The analysis was structured around five key indicators including water availability, water quality, accessibility, affordability, and reliability. The study also used semi-structured interviews with the technical services of these councils and surveys with water point committees, including 25 in Mandjou Council and 52 in Mvangan Council. The findings revealed significant disparities between the two councils. In Mvangan Council, 43.40% of the villages experienced enhanced water services, whereas in Mandjou Council, only 4.76% of the villages reported such improvements. This stark contrast highlights the varying effectiveness of water service performance across different regions. The study suggested that consistent monitoring and evaluation of rural water services are crucial for enhancing the quality and reliability of water supply. Such measures are essential to advancing universal access to water, demonstrating that targeted interventions can significantly improve service levels in rural communities.

Adetunji and Oyenje (2022) evaluated the household accessibility to domestic water supply in Lokoja, Nigeria. Data was analysed using various methods, including the Likert scale to evaluate satisfaction levels, Analysis of variance (ANOVA) to compare satisfaction across residential areas, and Pearson Product Moment Coefficient (PPMC) to assess the relationship between water supply and household characteristics such as income, education, and residence. Findings indicated significant reliance on boreholes in areas like Zango Daji and Army Barracks, while well water and water vendors dominated in Felele. Public tap water provided by the Kogi State Water Management Board was deemed irregular and unreliable by residents of areas like Old Poly

Quarters and Lokongoma. Most urban households rated the availability and quality of domestic water supply as unsatisfactory. The study recommended improvements in potable water supply to reduce urban residents' vulnerability to water-borne diseases in Lokoja. Rietveld (2009) conducted a study reviewing a technical assessment tool for rural water supply systems in South Africa. The assessment criteria tool was used to assess the performance based on four criteria, namely availability, capacity, continuity, and condition. The findings revealed that despite the water supply systems being relatively new, many systems performed poorly. Quantitative availability of drinking water posed a significant challenge, often due to inadequately constructed boreholes that failed to yield sufficient water. The situation revealed that initial investments in these systems did not yield anticipated benefits and might never become operational. However, in most villages, the installed infrastructure showed sufficient to good capacity, although storage volumes were sometimes limited. These insights underline the critical need for rigorous technical assessments and effective maintenance strategies to ensure reliable and sustainable rural water supply systems in South Africa.

2.4. Factors affecting the performance of water supply systems

The performance of water supply systems is influenced by a variety of factors that can either enhance or hinder the effectiveness and sustainability of these systems. The study by Hofstetter et al. (2021) identified several factors affecting the performance of community-owned water supply systems using a case study of Tshakhuma, Limpopo Province. Key challenges included unreliable municipal services prompting self-supply initiatives, limited technical expertise for proper system maintenance, uneven financial contributions from community members, and difficulties in managing infrastructure sustainably. These factors collectively impacted on the reliability and long-term performance of the water supply systems, highlighting the need for external support, technical guidance, and equitable financial participation to improve system efficiency and sustainability.

Majuru et al. (2012) identified several factors affecting the performance of rural water supply systems in Limpopo, South Africa. A key issue was the reliability of services, as system downtimes led to reduced water availability and increased distances to water sources. While upgrades to basic services improved access, availability, and potability at the source, stored water in households remained of poor quality. Furthermore, only 8% of households met enhanced service benchmarks, highlighting gaps in performance even after upgrades. These

findings emphasize that reliability, consistent water quality, and effective system maintenance are critical factors influencing the overall performance of water supply systems. Vilanova et al. (2015) identified several factors affecting the performance of water supply systems, emphasising the importance of performance measurement systems (PMSs) and indicators aligning with the specific characteristics and goals of the water supply systems and involve collaboration among stakeholders and technical experts. Key factors include the availability of reliable data, the resources required for implementing PMSs, and the need to integrate sustainability and environmental performance metrics alongside traditional measures. The study further highlights that effective performance assessment depends on tailored methodologies and a holistic approach that balances efficiency, service effectiveness, and environmental considerations.

Mothetha et al. (2013) addressed the persistent challenges in providing sustainable water services to rural areas in South Africa, where many communities struggle to access water due to financial constraints. Using the framework of the Accelerating Sustainable Water Services Delivery (ASWSD) project, the study identified key challenges faced by Water Services Authorities (WSAs) and Water Services Providers (WSPs) in selected rural villages. These included the availability and maintenance of water sources and infrastructure, administrative inefficiencies, policy-related issues, and political interference. Although water sources and infrastructure exist in many areas, they are often poorly maintained, rendering them non-functional. Additionally, a lack of capacity within municipalities significantly impacts operations, maintenance, and overall service provision. The study concluded that rural municipalities are struggling to fulfill their mandate to provide basic water services, primarily due to systemic issues and capacity constraints. It recommended increased investment in infrastructure maintenance, enhanced administrative capacity, and greater efforts to support municipalities in fulfilling their constitutional obligations. Addressing these challenges is essential to ensure equitable and sustainable access to water services for rural communities.

Malima et.al. (2022) assessed the challenges and coping strategies related to potable water supply systems in rural areas of VDM, where inadequate water supply threatens community health and welfare. A mixed-methods approach was employed, combining qualitative and quantitative methods, with thematic content analysis and descriptive statistics used for data analysis. Key challenges identified include aged infrastructure, system breakdowns, lack of

funding, vandalism, poor maintenance, unskilled technicians, theft, and non-payment for services. The study recommended active community involvement in water projects, including contributing to the cost of services to ensure sustainability. Communities should also participate in water committees responsible for managing, operating, and maintaining the water supply, with support from VDM officials and cooperation among communities, government, and stakeholders to improve rural water supply systems and ensure sustainability. Aikowe and Mazancová (2021) investigated the determinants of water source choice and access challenges in rural communities in Kogi State, Nigeria. The study examined factors such as distance to water sources, time spent collecting water, water availability, and quality as critical determinants of water access using survey and interviews with 12 key participants. The results revealed that age, education level, ethnic group, and occupation significantly influenced water source choice. The study recommended prioritizing adequate water sources and addressing socio-demographic factors to ensure equitable access to clean and safe water in developing countries.

Poor sustainability of rural water schemes is a major problem in service delivery in sub-Saharan Africa. About half of the schemes fail one year after commissioning, mostly due to poor operation and maintenance (Komakech et al., 2020). Governance policies are very important to ensure the safety of drinking water supply and establishing sound and effective water governance policies which involve participation of governmental officials, professionals, and general publics (Li and Wu, 2019). However, the implementation of water governance policies often lacks sufficient community participation, which can result in ineffective policies that fail to address the specific needs and challenges of local communities. This can result in failure of water supply schemes thereby affecting performance assessment. Salom and Khumalo (2022) examined the key success factors for effective community management of rural water supplies in Namibia (Ohangwena Region as a case study). A mixed-methods approach was employed in the study. The findings highlighted several critical success factors, including good governance, strong leadership attributes of committee members, training and capacity building, active community involvement, effective coordination, and ongoing support. The study recommended enhancing governance structures, investing in training and capacity development for water committee members, fostering greater community participation, and improving coordination mechanisms to ensure the sustainable management of rural water supply systems in Namibia.

2.5. Community participation in water supply and performance management

Community participation in water supply and management plays a crucial role in ensuring that drinking water services are both sustainable and effective. This approach shifts the responsibility for water management from just the government or external entities to the community, empowering local communities to take an active role in the operation, maintenance, and development of their water systems. The involvement of the community is an important aspect in the management of a sustainable drinking water supply. Involvement of the communities in water governance, especially in developing countries, is considered an important aspect for improving sustainable access to drinking water and promoting broader local governance (Jones, 2011). Another approach to rural water supply is for communities, the private sector, and the government to develop a public-private partnership to address water sources and related issues in rural areas (Effah and Chan, 2013).

Active community involvement is dependent on communities wanting to participate and contribute to the management and governance of services, as well as governing institutions that seek such participation. According to Hope and Ballon (2019), the slow and lack of progress in rural Africa for drinking water service delivery necessitates innovative thinking to create alternative institutional models that will enable payment behaviors for faster repairs in days rather than weeks and months. One of the factors preventing residents from reporting water supply problems is a lack of knowledge regarding the roles and responsibilities of local and district municipalities (Rivett et al., 2014).

According to Dey et al. (2019), the majority of households in Bangladesh's coastal areas were willing to pay to improve the access to safe drinking water. Community participation is required to determine the sharing of costs and benefits, manage conflicting demands, avoid overuse of water supplies, and achieve necessary institutional reforms in the inception, design, and planning stages. Rural community management emerged as a solution to the centralized water domain. However, uncoordinated policies, lack of technical assistance, and post-construction support negatively hindered access to safe water and the system's sustainability (Machado et al., 2023). Bakari and Mbunda (2022) investigated community participation in rural water supply projects in Nyasa district where several community water supply projects have been initiated by the government. Non-experimental design particularly cross-sectional research design to collect both qualitative and quantitative data where primary data were collected from household heads

in the field using questionnaires structured with couple of questions. The key informant interviews were also done using checklists containing relevant questions. The projects have always collapsed once the country government pulls out, due to low community participation. The study concluded that most of the community members participated in water supply projects during the implementation phase due to material incentives. Community awareness was a significant factor that influenced people's participation negatively, and financial resources are a significant barrier for the community to participate in water development projects.

Korir et al. (2020) established the extent to which community participation in project closure principles influences the performance of community water supply projects in Kericho county Kenya. The study adopted descriptive survey design and correlation research design. The descriptive survey design was used to describe characteristics of the population being studied whilst correlational research was used to describe the degree to which variables under the study were related. The sample comprised of households and management committee members. The research instruments included questionnaires, focus group discussion and interview schedules. Stratified proportional sampling and random sampling were used to collect primary qualitative and quantitative data. The data was analysed using IBM SPSS version program for statistical analysis and presentation. The study concluded that the community should be encouraged to actively participate more during the project closure process to enhance the performance of their community water supply projects.

Bazaanah and Litabe (2023) examined the impact of community participation on water and sanitation services in the Mantsopa Municipality in South Africa. Qualitative methods, including interviews with community representatives and municipal officials, were used to gather and analyze data thematically. The results indicated that community involvement can enhance service delivery and improve resident satisfaction. Jones (2011) explores community participation in water governance in the rural municipality of Yélékébougou, Mali, and how it is influenced by 'capacity-development' initiatives of the international NGO WaterAid. The research methods used were semi-structured, narrative interviews and focus groups. The findings of the study revealed that 'participation as payment' as a way of seeking cost recovery from communities is ineffective, and it also undermines the prospect of fostering 'participation as citizenship' and the related potential long-term advantages to water access and democratic transformation.

Boakye and Akpor (2012) conducted research in Msunduzi Municipality, KwaZulu-Natal Province, South Africa, to investigate the level of engagement of historically disadvantaged communities in water management. A qualitative approach that involved the use of primary and secondary data sources was used. A semi-structured interview was used to obtain information from participants. The interviews were tape-recorded and transcribed verbatim with permission from the participants. The sampling method for the study was purposive. The results revealed that there was a lack of meaningful participation by disadvantaged communities in water management decisions. This was because most individuals that have interest in water resource management were excluded in such decisions at the community level. It was also observed that the organizations that attended the forum do not interact with their community, hence did not serve as intermediaries between the South African Department of Water Affairs and their communities.

Shields et al. (2021) analysed how an international nongovernmental organization engages rural communities in their rural water projects, and the ways in which community members can participate in the management and governance of their water supplies. Qualitative data were collected in 18 study communities in Ghana, Kenya, and Zambia through interviews, focus group discussions, and participatory mapping with community and water committee members. According to the study, community management does not naturally lead to broader community engagement but rather needs effort to enhance community participation. The study recommended that implementers adopt collaborative planning methods and actively deal with intra-community diversity and inequities to enable all community members to participate meaningfully in decision-making. Maritim and Boit (2019) investigated the effect of community involvement in monitoring and evaluation on the success of county water projects in Uasin Gishu County (Kenya). This study adopted a descriptive research design survey which was considered suitable for this work given that it involves gathering data to answer questions based on the status of the subjects of study. The study recommended that the project managers should involve as many community members as possible in monitoring and evaluation, employ their workforce from the community, and involve community members in planning and budgeting to ensure the success of the projects.

CHAPTER 3: METHODOLOGY

3.1. Preamble

This chapter outlined the procedures followed in this study which covered the data collection and sampling methods, selection of performance indicators and benchmarks, data analysis techniques and ethical considerations.

3.2. Data collection and sampling

3.2.1. Questionnaire survey and field observations

A questionnaire survey was conducted to collect data from the household heads. This ensured that acquisition of comprehensive information and generation of well-validated conclusions for assessing the performance of the water supply system in Matatani Village. Field observations were also conducted at Matatani Village to gather information on water supply sources and their status. The data collected assisted in gathering adequate information to assess the performance of the water supply system. This increased the credibility of research findings.

Census sampling was employed to gather data from the entire household heads, providing comprehensive insights. The questionnaire survey targeted community members of Matatani Village, particularly household heads, as the inclusion criterion. Due to the small population size of 70 households, the entire household heads were included in the sample. The questionnaire (Appendix 1) was structured into 3 sections focusing on interview details, the reliability and accessibility of water supply sources, and community participation in water supply and management.

3.2.2. Collection of water samples

Water quality samples were collected from the existing water supply sources at Matatani Village. The sampling locations included Borehole 1 (BH1), Borehole 2 (BH2), River Upstream (RU), River Downstream (RD), the Municipal Tap (MT), and Spring (Table 3.3). The water samples were collected once per month for a period of 6 months (December 2023 to May 2024) to cover dry and wet seasons. This included 3 months of the wet season (December 2023 to February 2024) and 3 months of the dry season (March 2024 to May 2024) to assess seasonal variations in water quality. Three samples were collected in each sampling point, two for chemical analysis and one for microbiological analysis. Samples were collected using 500 ml sterilised bottles and

stored in a cooler bag which were kept at 4-10°C during transportation. The samples were analysed within 6 hours of collection. The spring water was sampled only once in April 2024, as it was identified after conducting the questionnaire survey and was inaccessible in May 2024. BH2 was not sampled in March 2024 because it was out of service, undergoing maintenance due to a mechanical failure. The MT water was sampled only in February 2024 and March 2024, as municipal water was unavailable in Matatani Village during the other months of sampling.

Table 3.3: Description of the sampling points

Water sources	Description	Coordinates	Sampling period
BH1	Matatani borehole	22°33'51"S; 30°46'5"E	6 months
BH2	Mbodi borehole	22°32'46"S; 30°44'36"E	5 months
Spring	Natural spring	22°34'14"S; 30°45'49"E	April 2024
MT	Municipal tap	22°34'51"S; 30°48'27"E	2 months
RU	River upstream	22°34'42"S; 30°48'27"E	6 months
RD	River downstream	22°34'28"S; 30°48'27"E	6 months

3.2.3. Estimations for borehole yield

The groundwater yield was estimated through field experiments (Figure 3.1). The experiments involved recording the time taken to fill a 25L bucket. The experiment was repeated 3 times to improve the accuracy of the results. Three observers recorded the time taken to fill the bucket, to reduce bias. The field experiments were conducted from December 2023 to May 2024 to include both the wet and dry seasons. This was the only possible method for groundwater yield estimation as the study area is remote and lacks detailed quantitative data such as pumping tests that can be used for groundwater yield analysis. The selection of BH1 as the site for the experiments was based on its critical role in meeting the community's water needs.



Figure 3.1: Conducting yield estimation experiment

3.2.4. Selection of performance indicators and benchmarks

Still (2017) indicated that the most important indicators used for water supply performance are water quality, reliability, and source sustainability. The key performance indicators that were used to assess the performance of the water supply system in this study are reliability and accessibility. This is because reliability and accessibility are the indicators that cover the factors affecting water supply system in the rural area. In this study, accessibility and reliability have 2 sub-indicators, respectively. The sub-indicators for accessibility include access to basic water requirement and reasonable distance from the households to the water sources. The sub-indicators for reliability include sustainability of the water source (consistency of water availability from the sources over time, including during different climatic seasons) and the quality of the water from the sources). The benchmarks used in the study are in Table 3.1.

Table 3.1: Criteria for assessing performance indicators

Indicators	Sub-indicators	Benchmarks	Source (s)
Accessibility	Access to basic water requirement	A minimum of 1500 liters of potable water should be made available to each household per week	DWS (2017)
	The reasonable distance (m) from the households to the water Sources	Within a reasonable walking distance of not more than 100 m from the farthest household	DWS (2017) Howard et al. (2020)
Reliability	Sustainability of the water source	350 days per year and not interrupted for longer than 48 consecutive hours	DWS (2017)
	The quality of the water from the source	Water quality guidelines for domestic water use	DWAF (1996) SANS 241 (2015)

3.3. Data analysis

3.3.1. Analysis of questionnaire data, field observations and performance assessments

Statistical Package for Social Science (SPSS) version 25 was used to analyse questionnaire data. Data from the questionnaire survey was analysed to gain insights into the social, cultural, and economic factors influencing water access and reliability. The responses from the respondents were used to determine the extent to which the community participates in the water supply management and provided guidelines on improvement strategies for effective water supply at Matatani Village. The existing water supply sources were mapped in Quantum Geographical Information Systems (QGIS) to determine their spatial distribution and to estimate the distance between households and the sources, providing a comprehensive overview of the village's current water supply situation. The performance assessment of the water supply system was assessed by comparing the sub-indicators for the study with the benchmarks in Table 3.1.

3.3.2. Analysis of borehole yield and comparison with the water requirements

The average yield was calculated using the following equation:

$$Q_{borehole} = \frac{V_c}{T_{av}} \quad (3.1)$$

Where: $Q_{borehole}$ = borehole yield,
 V_c = volume of the container and
 T_{av} = average time.

The selected method for calculating the borehole yield was chosen for its simplicity, reliability, and practicality in field conditions. This method requires minimal resources, making it suitable for rural and resource-limited settings. It is particularly advantageous for assessing water supply performance where more sophisticated tools or methods may not be feasible. Additionally, the method allows for quick calculations and easy replication to ensure consistent and reliable results across multiple testing scenarios.

The total water requirements (TWR) were calculated by multiplying the per capita water use ($PCWU$) with the population of Matatani Village (Equation 3.2).

The population (P) was calculated using the total number of households (HH_{tot}) and the average number of members in a household (HH_{av}) (Equation 3.3). An average number of 4 people obtained from Ranwashe (2024) was used in the study.

$$TWR = PCWU \times P \quad (3.2)$$

$$P = HH_{av} \times HH_{tot} \quad (3.3)$$

The TWR was calculated for 3 levels of services (basic, intermediate, and optimal) described in Howard et al. (2020) (Table 3.2). This was done to enable the assessment of whether the main water source can meet the water requirements at these levels of service.

Table 3.2: Level of water service (LOS) water access, adequacy, and level of health concern

LOS and water quantity	Accessibility of water supply	Adequacy for health needs	Level of health concern
Basic (25 l/c/d) *	>100 m; 5-30 minutes collection time	Drinking, cooking, hygiene, hygiene, handwashing, and face washing, are assured; hygiene (food hygiene, handwashing, and face washing) may be assured; bathing and laundry cannot be assured at home but may be carried out at water source	High
Intermediate (50 l/c/d)	Water delivered through one tap on-plot, or within 100 m or 5 minutes total collection time	Drinking, cooking, hygiene, hygiene, handwashing, and face washing are assured; hygiene (all food hygiene, handwashing, and face washing assured under non-outbreak conditions; enhanced hygiene during infectious disease outbreaks not assured; bathing and laundry at the home should also be assured	Medium
Optimal access (100 l/c/d)	Water supplied through multiple taps and continuously available	All drinking needs are met; all cooking needs should be met; hygiene (all food hygiene, handwashing and face washing needs should be met, including for bathing and laundry at the home, and household cleaning)	Low

* Value of 25 l/c/d adopted in line with South African standard described in DWS (2017)

The limitations of the levels of services as stated by Howard et al. (2020) include:

- People tend to use less water if their main source is unreliable, inconsistent, or too expensive.
- Water safety is a separate health issue not included in this definition.
- Alcohol-based gels can help with hand hygiene.
- Basic drinking water service is referred to as using an improved source with a round-trip collection time of 30 minutes or less, and safely managed water as an improved source on-premises, available

when needed, and uncontaminated. This differs slightly from how “basic” and “intermediate” access are defined in this document.

3.3.3. Analysis of water quality parameters

Physical water quality parameters that were measured include turbidity, electric conductivity (EC), total dissolved solids (TDS) and pH. Physical parameters, except for turbidity, were measured in the field using the Extech EC500 Pocket Meter, which was self-calibrated to ensure accuracy. Turbidity was measured in the field using the Extech TB400 Turbidity Meter, which was calibrated prior to use to guarantee precise results. Metals ions analysed included calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), manganese (Mn), zinc (Zn), cadmium (Cd), arsenic (As), iron (Fe), and lead (Pb). Non-metal samples include sulphate (SO_4), chlorine (Cl), phosphate (PO_4) and fluoride (F). Metals ions were analysed using PerkinElmer Optima 8000 ICP-OES double-monochromator system and non-metals ions were analysed using DR3900 Laboratory Spectrophotometer. To prepare both metals and non-metals ions, samples were digested using the microwave digestion system, MARS ONE, 240/50 to ensure the complete release of metal ions for subsequent analysis. All the apparatus were sterilised using deionised water, and 45 mL water sample was measured and transferred into a centrifuge tube under the fume hood. Subsequently, 5 mL of concentrated nitric acid was added to water samples in a digestion vessel, which was then placed in the MARS ONE microwave digestion system. The microwave digestion process was activated and continued until the system reached its idle state.

After digestion, the sample was transferred from the centrifuge tube to a smaller vessel for subsequent analysis using ICP-OES. The instrument was standardised with eight working standards from the Multi-Element Calibration Standard IV for ICP, targeting elements such as manganese (Mn), iron (Fe), cadmium (Cd), arsenic (As), zinc (Zn), and lead (Pb). Analytical precision was maintained by regularly analysing standards and blanks. Additionally, ICP multi-standard solutions (1000 ppm) for potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) were prepared using ammonium acetate to verify the accuracy of instrument calibration and quantification. Metals/analytes were determined with a detection limit of 0.0001 ppm. For non-metals analysis, the spectrophotometer was calibrated using standard solutions to verify instrument accuracy. The prepared samples were then placed into pre-cleaned cuvettes and inserted into the spectrophotometer. To maintain quality control, blank samples were analysed

to correct any background interference. Triplicate measurements for quality assurance were done to verify data accuracy. The final concentrations of non-metals were recorded, interpreted and then compared to water quality standards.

Microbiological parameters analysed were *Escherichia coli* form (*E. coli*) and total coliform. Microbiological parameters were analysed using membrane filtration method. Distilled water was filtered for both growth media and incubated to serve as a control for quality assurance. The water sample of 10 ml was diluted with 90 ml of distilled water. The diluted samples were filtered through a membrane filter of pore size 0.45µm that retains the filtered material. The filter was placed on a petri dish that contains a nutritional Agar (M-Endo Les for total coliform and M-Fc for *E. coli*). These two Agars support the growth of the specified organisms. *E. coli* is considered as all the faecal coliforms, which test, indole-positive at 44.5°C. The petri dishes containing the samples was incubated for 20 hours at 35°C. After incubation, the colonies that have grown were identified and counted using the most probable number (MPN) method to generate results. To ensure quality control, all the samples were conducted in triplicate. Measuring samples more than once helped in determining sample variability and ensured accuracy by comparing the results.

3.4. Ethical considerations

The ethical clearance was requested from the Faculty Research Ethics Committee at the University of Venda before the study commenced. Permission to conduct research was obtained from the community leaders at Matatani Village. Consent forms were distributed and the rights to participants were thoroughly discussed. A letter of introduction was included which described the objective of the study, the fact that participation was voluntary, anonymous, and that participants were free to withdraw at any time without penalty. Prior to collecting data, approval from respondents was obtained through an informed consent form.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1. Preamble

This chapter covered the results on the socio-economic profile of respondents in Matatani Village, providing insights into their interaction with water supply systems. It examines the existing water supply sources, infrastructure, and their current condition, identifying the main water source relied upon by the community. Key findings on water accessibility, reliability across seasons, and community participation in management were discussed. The chapter incorporates a comprehensive analysis of water quality assessment, performance assessment along with questionnaire responses. Additionally, estimation of borehole yield was discussed to assess the performance and sustainability of water resources in the village.

4.2. The socio-economic profile of the respondents in Matatani Village

Table 4.1 presents the gender and age distribution among the household heads in Matatani Village. The gender category shows that 48.6% were male, 50% were female and 1.4% preferred not to say. The age distribution showed that most of the residents (31.4%) are between 18-29 years, 24.3% are between 30-39 years, 20% are between 40-49 years, and 24.3% are 50 years and above. The age category revealed a predominantly high youth population, with 31.4% of residents aged 18-29 years. This suggests that water demand and water use activities in the community may be influenced by a predominantly active population, with younger individuals driving domestic and economic water use. The predominance of youth in the study area indicates the presence of a population with the potential to contribute to water supply and management actively and positively if provided with proper guidance and training. This will be beneficial to the current and future sustainability of water supply in Matatani Village. The smallest group, representing 20% of the population, is 40-49 years, which may impact on the types of water needs and management strategies.

Table 4.1: Gender and age distribution of the respondents

Variable	Description	Percentage (%)	Frequency
<i>Gender</i>	Male	48.6	34
	Female	50	35
	Prefer not to say	1.4	1
Total			70
<i>Age category</i>	18-29 years	31.4	22
	30-39 years	24.3	17
	40-49 years	20	14
	50 years and above	24.3	17
Total			70

Table 4.2 shows the distribution of respondents' marital status and household sizes. Most of the residents (57.1%) are single, while 32.9% are married. A smaller percentage are widowed (5.7%), and 4.3% chose not to disclose their marital status. In terms of household size, most households (65.7%) consist of more than four people, indicating relatively large family sizes, followed by 14.3% of the households with three members, while those with two or four members each account for 8.6%. Single-member households are the least common, representing only 2.9% of the population. Large household sizes and young to middle-aged populations drive water demand.

Table 4.2: Distribution of marital status and household size

Variables	Description	Percentage (%)	Frequency
<i>Marital status</i>	Single/Never married	57.1	40
	Married	32.9	23
	Widow/Widower	5.7	4
	Prefer not to say	4.3	3
Total			70
<i>Household size</i>	Household with one people	2.9	2
	Household with two people	8.6	6
	Household with three people	14.3	10
	Household with four people	8.6	6
	Household with more than four people	65.7	46
Total			70

Table 4.3 indicates that 68.6% of the population relies on grants, while 11.4% rely on salaries and wages, and 4.3% each rely on pensions and other sources. A striking 75.7% are unemployed, with only 14.3% employed and 10% self-employed. Half of the population (50%) have secondary education, and 20% have completed matric (high school), while 8.6% have vocational or college education. Only 18.6% completed primary education, and 2.9% have no education. The socio-economic profile of Matatani Village indicates a community with economic vulnerabilities, high unemployment, and a significant dependence on grants. The high unemployment status indicates significant economic hardship, which can limit the community's ability to contribute financially to water system maintenance. Research shows that people with higher education levels tend to have higher water consumption rates (Makki et al., 2015). Limited income sources, coupled with education levels centered at the secondary level, may influence both willingness and ability to engage in community-driven water management (Biswas, 2004).

Table 4.3: Income sources, employment status, and educational level of respondents

Variables	Description	Percentage (%)	Frequency
Source of income	Grant	68.6	48
	Salary	11.4	8
	Pension	4.3	3
	Wages	11.4	8
	Others	4.3	3
Total			70
Employment Status	Employed	14.3	10
	Unemployed	75.7	53
	Self-employed	10	7
Highest educational Level	Primary education	18.6	13
	Secondary education	50	35
	Matric	20	14
	TVET/College education	8.6	6
	None	2.9	2
Total			70

4.3. Water supply sources, infrastructure, and their status in Matatani Village

Identifying and understanding the various sources of water, particularly the main source, plays a crucial role in assessing the performance of a water supply system. This assessment involves

analysing reliability and accessibility to determine its ability to meet the community's needs. By exploring these sources, challenges such as seasonal variations, capacity, distance, quality from the main source and infrastructure limitations can be identified, enabling more effective planning and management strategies to ensure a sustainable and adequate water supply. The respondents of the questionnaire survey indicated that the available water sources in Matatani Village include river water (85.7%), communal boreholes (64.3%), springs (58.6%), communal municipal taps (37.1%), rainwater (37.1%), municipal water tankers (21.4%), household boreholes (18.6%), water vendors (5.7%), and a small proportion (2.9%) of households with access to municipal tap water within their homes (Figure 4.1). The various water sources used in Matatani Village reflect varying levels of accessibility and reliability. These results revealed that residents rely on multiple water sources based on availability and accessibility, reflecting an adaptive strategy to cope with water access challenges. However, the high dependence on natural sources, such as rivers and springs, highlights potential risks associated with seasonal variability and environmental contamination.

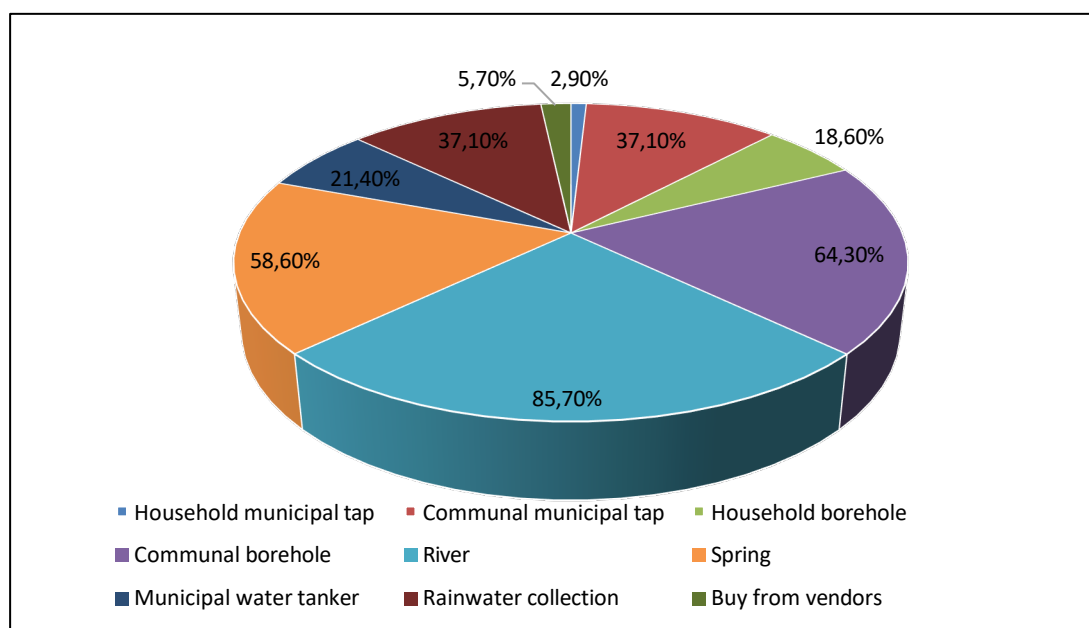


Figure 4.1: Available water sources in Matatani Village

Figure 4.2. shows the location of the identified water supply sources and infrastructure in Matatani Village which include 4 boreholes, 1 river, and 2 springs. The infrastructure comprises of 9 communal taps and one steel tank. BH1 was drilled in the 1960s and supplies water that residents collect directly from the source, located far from their homes. BH2 is situated in Mbodi Village and was drilled to serve the 2 communities (Mbodi and Matatani). BH3 which used to

supply water through a steel tank reservoir was operational from 2014 until 2018 when the pump ceased functioning. BH4 was drilled in the 1980s and remains non-functional. A pipeline which is connected to the 9 communal standpipes, occasionally supplies water from the Nwanedzi water supply scheme to Matatani Village. During field visits, residents reported receiving water from this scheme approximately once every six months.

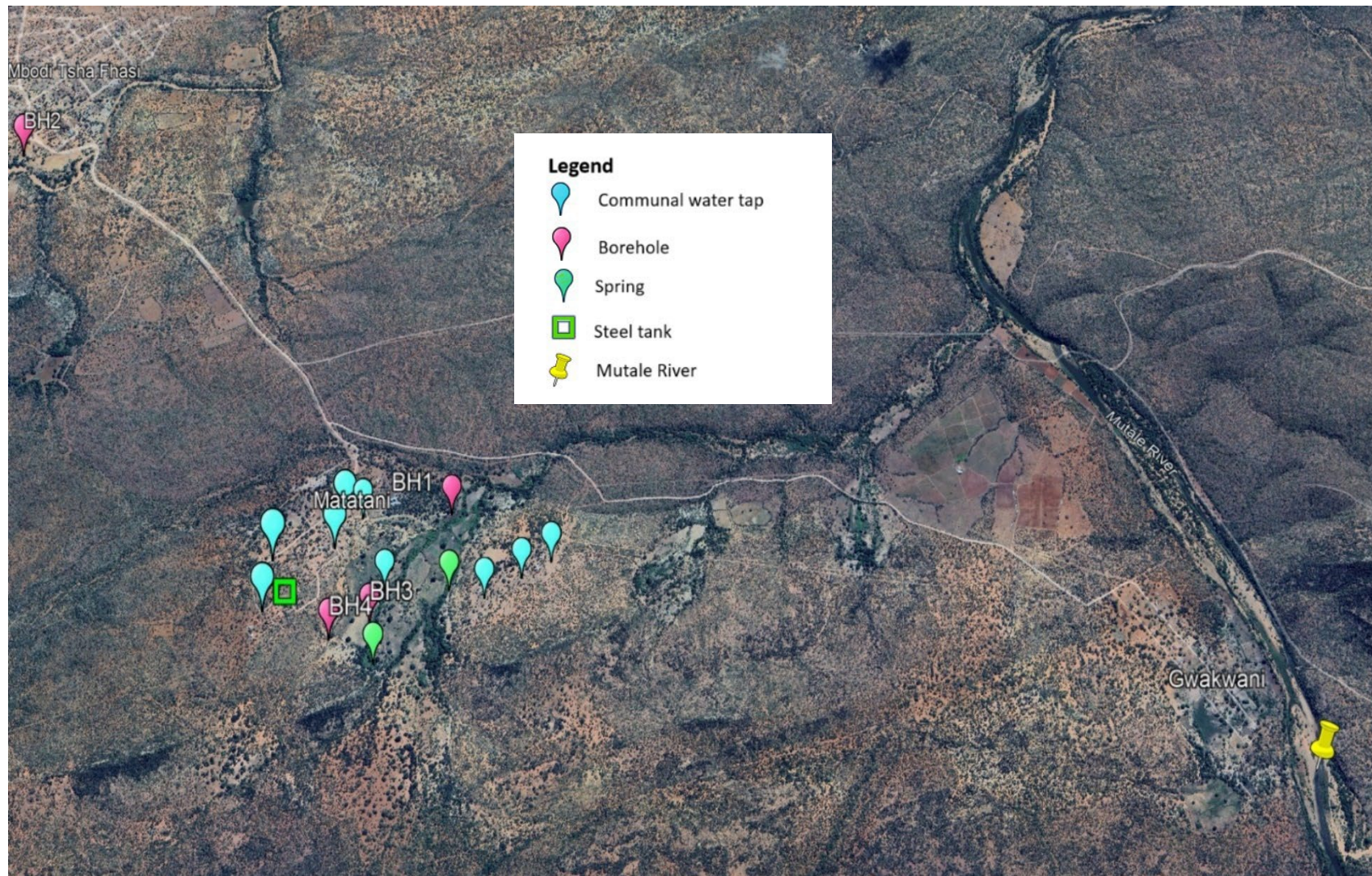


Figure 4.2: The identified existing water supply sources and infrastructure in Matatani Village

One of the springs in (Figure 4.3a) Matatani Village serves as one of the key water sources for the community. However, it lacks formal infrastructure to protect or enhance its utility, leaving it in a vulnerable state. It is exposed to direct contamination from birds and other animals, which compromises the quality of the water and poses health risks to users. Without protective measures such as proper drainage, or treatment facilities, the spring remains susceptible to pollution, making it an unreliable and unsafe source of water for the community. The municipal tap water (Figure 4.3b) could serve as one of the water sources, however, its reliability is significantly limited. According to the questionnaire survey, the tap only supplies water once a month, highlighting critical issues with its reliability and effectiveness as a consistent water source. A handpump borehole (BH1) shown in (Figure 4.3c) is operational, although it is situated far away from the households. Mutale River (Figure 4.3d) serves as a crucial water source for the community, especially during dry seasons when alternative supplies may be limited. However, the lack of adequate infrastructure to protect, treat and supply water from this resource has led to significant challenges. The river is often polluted by cattle and other animals, which access it for drinking and grazing along its banks. This unrestricted interaction compromises the water quality, posing health risks to the community members who rely on it for domestic purposes.

The BH3 (Figure 4.4a) was once an essential source of water for the community, is currently non-operational due to a pump malfunction. This borehole played a crucial role in the local water supply system, extracting groundwater and channeling it into a steel storage tank (Figure 4.4b) before distribution through a network of pipes to households. The pump failure has rendered the entire system inoperative, leaving the infrastructure underused and the community without a reliable water source. The BH4 (Figure 4.4c) equipped with a hand pump is no longer functional due that it has dried up, further exacerbating the village's water challenges. These issues emphasise significant concerns regarding the sustainability and maintenance of groundwater resources. The situation highlights the vulnerability of depending on groundwater in areas prone to limited recharge or inadequate resource management, emphasising the urgent need for repairs, alternative water sources, or improved water management strategies.



a



b



c



d

Figure 4.3: Water sources in Matatani Village - a) Spring water, b) MT, c) BH1 and d) river

The BH2 in Mbodi Village (Figure 4.4d) is connected to a water supply line that serves Matatani Village. This borehole was initially designed to support both Mbodi and Matatani residents, but supplying water consistently to Matatani Village has proven challenging. The shared resources add complexity to its management, as they require careful coordination to ensure an adequate and reliable water supply. The gravity-fed supply to Matatani occurs only after the Mbodi pipeline is fully supplied, a process that can take over five hours to fill the tank and distribute water. Consequently, residents of Matatani Village often face inconsistent access to this source.



a



b



c



d

Figure 4.4: a) BH3, b) steel tank, c) BH4 and d) BH2 in the study area

The results indicate that the communal borehole is the main source of water in Matatani Village, as indicated by 44.3% of respondents (Figure 4.5). This is followed by river water (21.4%), which represents the second most used source, highlighting that Matatani residents rely on natural water bodies, due to insufficient infrastructure. Springs contribute to 17.1%, indicating a moderate level of reliance among households situated in closer proximity to this water source. Household boreholes and communal municipal taps each serve 8.6% of the population, highlighting limited access to municipal water infrastructure, emphasising the need for improved water supply systems to ensure reliable and equitable access.

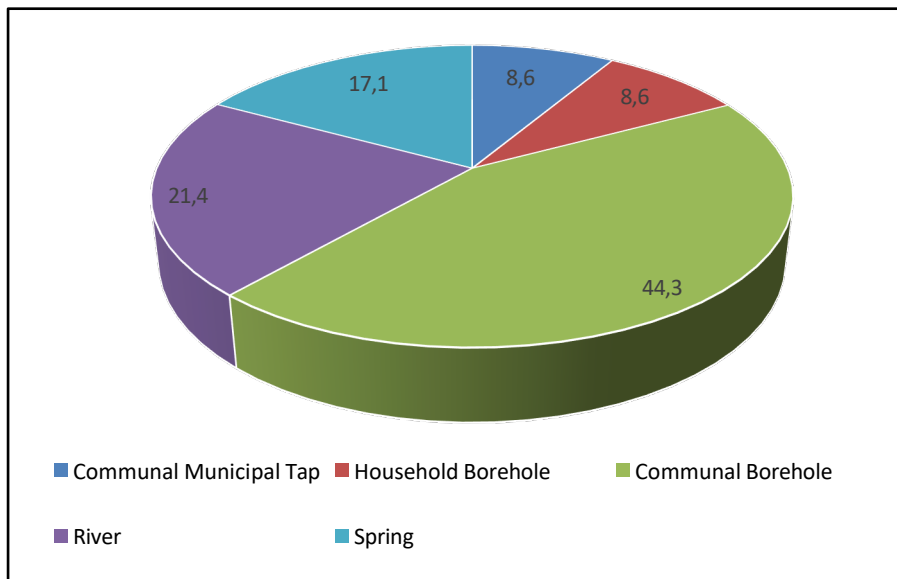


Figure 4.5: The main source of water supply in Matatani Village

High reliance on communal borehole (44.3%) (Figure 4.5) revealed absence of sufficient household-level infrastructure and limitations in municipal service coverage. This led to challenges such as long queues and inadequate supply during peak times or seasons. Figure 4.6 indicates the borehole that Matatani community relies on for water supply. The high reliance on the communal borehole also raises concerns about the potential overextraction and depletion of groundwater. The extraction of groundwater poses various environmental risks, including the potential for landslides (Musa and Fumen, 2013). Overuse may also result in decreased water quality and a higher vulnerability to water shortages during dry seasons. The results from this study are similar to the study conducted by Malima (2020), where boreholes were identified as the main sources of water in Vhembe District Municipality. Additionally, 70% of respondents accessed water from open water bodies, while 30% depended on a single community borehole in Madida Village (Mbana and Sinthumule, 2024). Musa and Fumen (2013) found that most residential areas in Ilorin, Nigeria, rely on dug wells and boreholes rather than water as their primary source. This shift is often due to challenges with the reliability and quality of tap water, leading communities to seek alternative sources.



Figure 4.6: BH1 in Matatani Village

While rivers provide a natural and often continuous water source, this reliance (21.4%) may expose the community to risks of contamination, especially during the rainy season when run-off carry pollutants (Figure 4.5). Tasi'u et al. (2016) found that rivers are the primary source of water supply for rural communities in Kano State, Northern Nigeria. Mbana and Sinthumule (2024) also reported that all respondents (100%; $n = 205$) in Enqabeni Village, South Africa indicated they relied on open water bodies, such as rivers, wetlands, streams, springs, and ponds, as their primary water sources. The low percentage (8.6%) of households with access to a municipal tap also indicates limited infrastructure for direct household water supply, potentially affecting convenience and water access.

4.4. Accessibility and reliability of water supply sources across seasons

According to the Department of Water and Sanitation (DWS, 2017) guidelines, a minimum of 1500 liters of potable water should be made available to each household per week. Figure 4.7 showed that most households (37.1%) use between 350-700 liters per week, which is lower than the recommended 1500 liters. A smaller proportion (24.3%) uses 175-350 liters weekly, which also falls short of the guideline. Only 15.7% of households consume over 1400 liters per week. The other 15.7% of households use 700-1400 liters per week and 7.1% of households use less than 175 liters per week. The residents are facing severe water scarcity, as all of them use less than 1500 liters per week indicating a need for improved water access and supply. Majuru et al.

(2016) indicated that households may adopt coping strategies to manage limited water availability, such as adjusting their daily routines to times when water is accessible and reducing the amount of water used for various tasks.

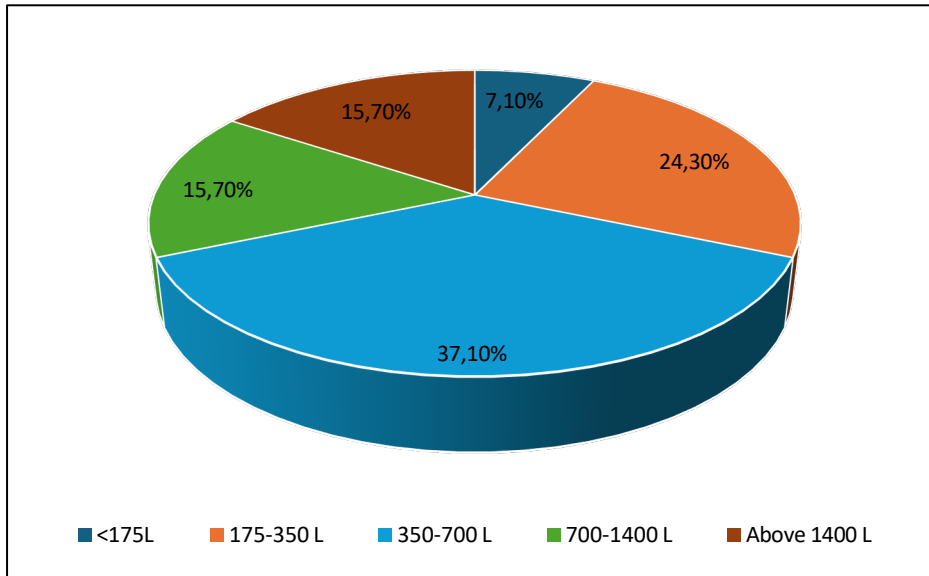


Figure 4.7: Household weekly water usage

Figure 4.8 illustrates the distribution of responses regarding the adequacy of water supply for household use. Most households (60%) indicated that their water supply is not sufficient, highlighting a significant challenge as they face difficulties in accessing an adequate water supply. With 60% of households lacking sufficient water, there is a considerable shortfall in meeting basic water requirements and vulnerability within the water distribution system. According to Tasi'u et al. (2016), 62.9% of respondents in rural villages in Kano State, Northern Nigeria reported that the water supply was insufficient. This finding highlights a common issue in many rural areas, where access to sufficient and reliable water is often limited. A smaller group of households (14.3%) reported that they receive more than enough water for their needs (Figure 4.8). This suggests that only a few households receive an optimal or even surplus water supply. About a quarter of the households (25.7%) reported that their water supply is sufficient for their needs.

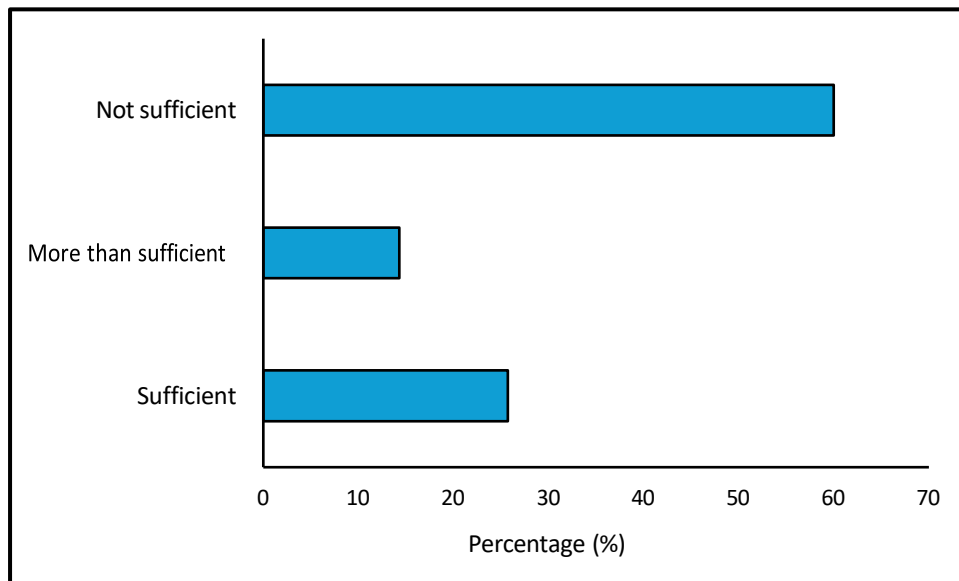


Figure 4.8: Adequacy of water supply to meet the demand of household

Figure 4.9 shows residents' perceptions regarding the quantity of water available from their main source throughout the year. Only 15.7% of respondents felt that their main water source provides a sufficient supply all year, followed by 35.7% of respondents who mentioned that their water supply is seasonal and nearly half of respondents (48.6%) consider their water supply insufficient year-round. The results showed that the majority face challenges with water quantity throughout the year, suggesting a need for improved infrastructure, additional water sources, and better management strategies to ensure reliable year-round access. These findings highlighted a widespread issue of chronic water shortage affecting almost half of the community. This also reflects a significant concern about water security where most residents do not have reliable access to adequate water supplies.

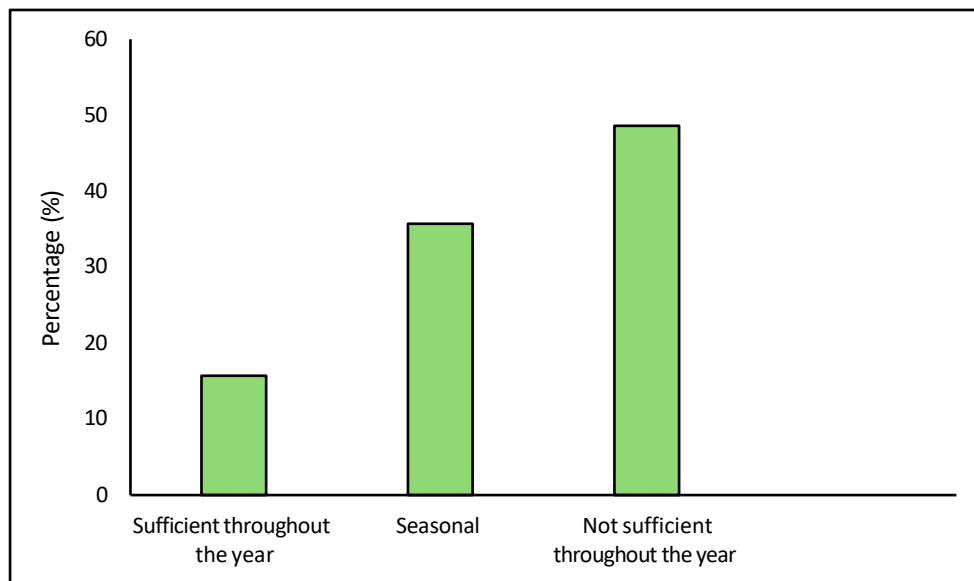


Figure 4.9: Perception of quantity of water from the main source

The residents of Matatani Village face challenges in accessing water from their preferred main water sources (borehole and river water). The approximate direct distance from the farthest household (which is at an altitude of 490 m) to BH1 as measured from Google Earth is 1.73 km (Figure 4.10). The closest household (which is at an altitude of 451 m) is located at 536 m from BH1 (Figure 4.11). The elevation profile indicates a topography that slopes towards the borehole location. This indicates that residents face the challenge of transporting water to their households as they have to travel towards an uphill direction. The river is at approximate distances of 6.56 km and 3.80 km to the farthest and closest households, respectively (Figures 4.12 and 3.13). As shown in Figures 4.12 and 4.13, the pathway usually used by the residents to access the river has an undulating landscape (average slope of approximately 4%) which also limits access to the river. Due to this, residents usually use this water source for washing clothes, bathing and other activities such as swimming and fishing. The use of carts and containers for water collection from BH1 is a common practice in Matatani Village due to the distances households must travel to access water. The residents rely on wheelbarrows and carts driven by donkeys for water collected mostly in 25 liters containers, which poses another challenge for individuals who cannot afford these transportation methods (Figure 4.14).



Figure 4.10: Pathway from farthest household to BH1



Figure 4.11: Pathway from closest household to BH1

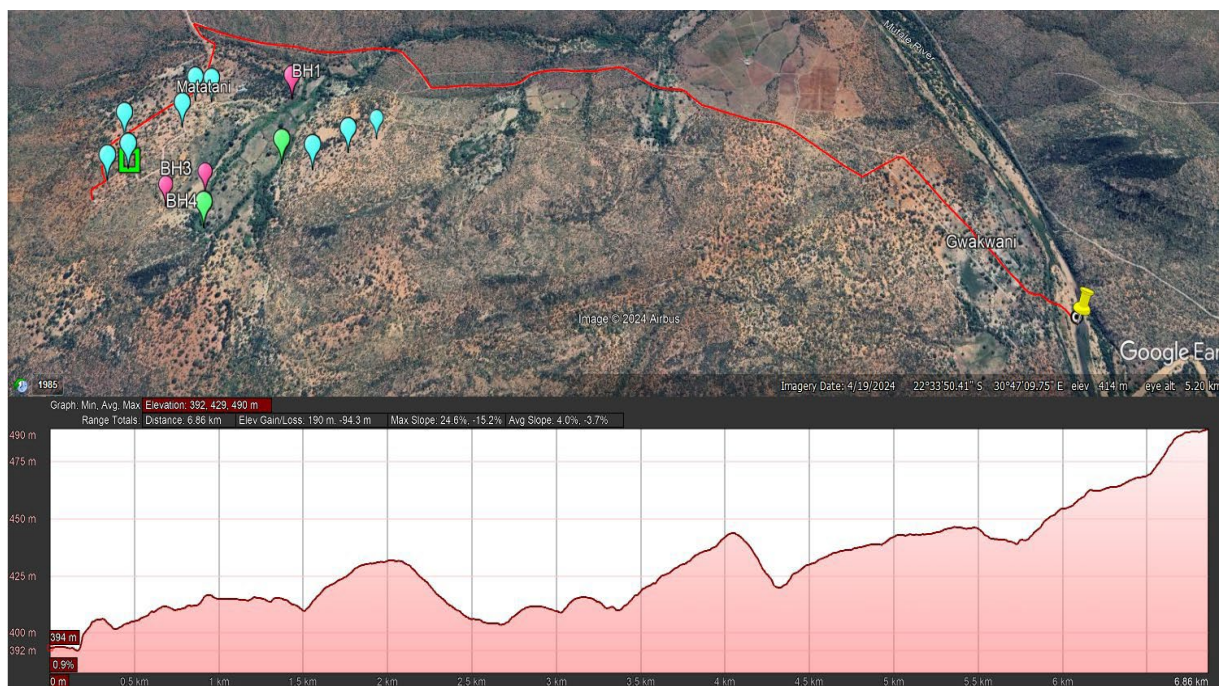


Figure 4.12: Pathway from farthest household to the river

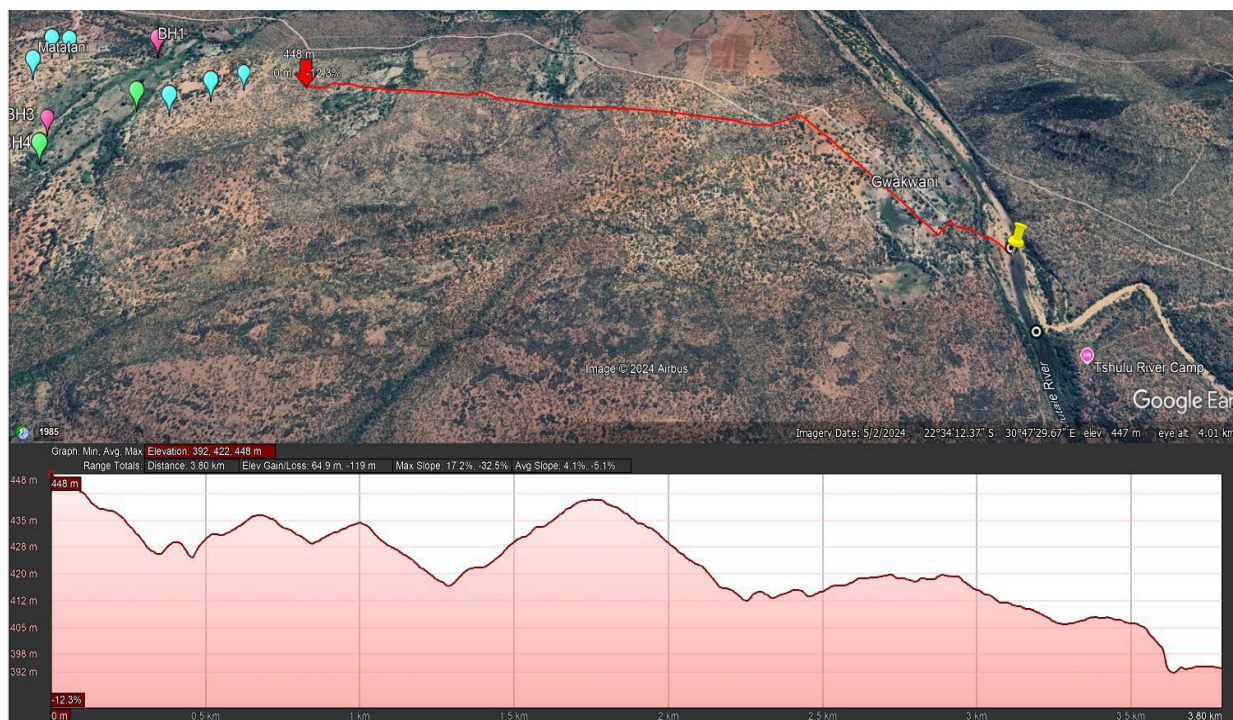


Figure 4.13: Pathway from closest household to the river



Figure 4.14: Carts and containers for collection of water from BH1

Long distances may also limit the frequency of water collection, potentially forcing residents to restrict their water use or rely on alternative sources. Additionally, the physical burden of carrying water over such distances could disproportionately affect vulnerable groups, such as the elderly or children. It therefore becomes a challenging task for them to transport water to their households. DWS (2017) stipulated a reasonable walking distance of no more than 100 m from the farthest household from a communal standpipe. The residents travelled distances exceeding the standard guideline which recommends a maximum walking distance of 100 m from the farthest household. This indicates that it is impossible to achieve the minimum level of water supply services in Matatani Village. Bazaanah and Mothapo (2024) found that the majority (85%) of respondents in rural communities in Lepelle Nkumpi Local Municipality traveled over 4 km to fetch water. A key informant emphasised the burdens of water collection, particularly for women, who often endure long and dangerous walks home, sometimes at night, exposing themselves to risks such as snake bites, attacks, violence, and even sexual assault (Bazaanah and Mothapo, 2024).

Research reveals that minimising the distance between households and water sources significantly decreases the incidence and spread of water-washed diseases, such as diarrhea and trachoma (Evans et.al., 2013). Improved access reduces the likelihood of contamination during transportation and enhances water availability for hygiene practices. Howard and Bartram (2003) mentioned that when households travel over one kilometer or spend more than 30 minutes collecting water, the amount of water fetched declines to a point where only the bare minimum

quantity for drinking and cooking needs is collected. Such limitations compromise hygiene and overall health, highlighting the importance of closer water access to ensure adequate usage for all household needs.

Figure 4.15 shows the frequency of water supply disruptions within a year from the main source of water. The result revealed that disruptions are common, with a significant portion of the population experiencing them regularly. The disruptions in water services affect the performance of the water supply system negatively. More than half of the respondents (60.0%) reported that they "sometimes" face water disruptions, while 21.4% indicated that they "always" experience disruptions. Together, these groups constitute 81.4% of the respondents, highlighting a recurring issue with water reliability. In contrast, only 8.6% reported that disruptions "seldom" occur, and a minimal 10.0% reported that they "never" experience any disruptions maybe because they rely on natural sources such as rivers and springs. The results showed a persistent issue in water supply consistency, affecting the majority of the village's population. The DWS (2017) guidelines recommend no more than 350 days of water supply disruptions per year to ensure a reliable water supply. However, the results highlight significant deviations from this standard. A substantial 81.4% of respondents reported frequent disruptions, with 60.0% stating they "sometimes" face interruptions and 21.4% indicating they "always" experience them. These frequent disruptions suggest that water supply reliability is far below the recommended standard.

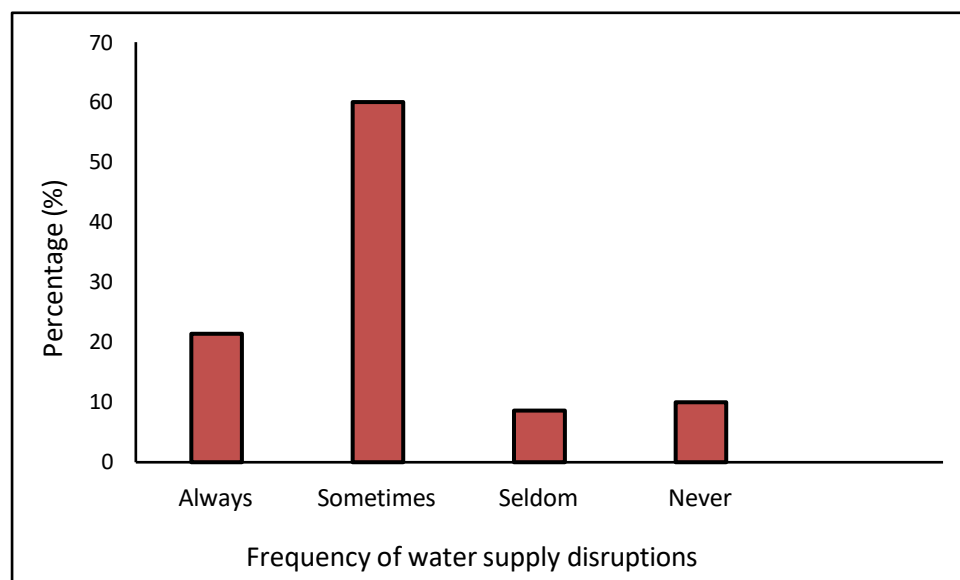


Figure 4.15: Frequency of water supply disruptions from the main source of water

Among the households surveyed, 67.1% reported that disruptions last a month or more, indicating a major reliability issue (Figure 4.16). Additionally, 22.9% experienced disruptions lasting three weeks, while only 10% had interruptions lasting as short as two weeks. These results show that most residents endure extended periods without water, significantly affecting daily activities and overall quality of life. Selelo et al. (2017) revealed that 37.5% of respondents in Maun, Botswana encountered disruptions lasting 5 to 10 days per month, and 35% faced interruptions exceeding 16 days within the same period. Matatani Village is experiencing significantly more severe and prolonged water supply disruptions as compared to the ones identified by Selelo et al. (2017).

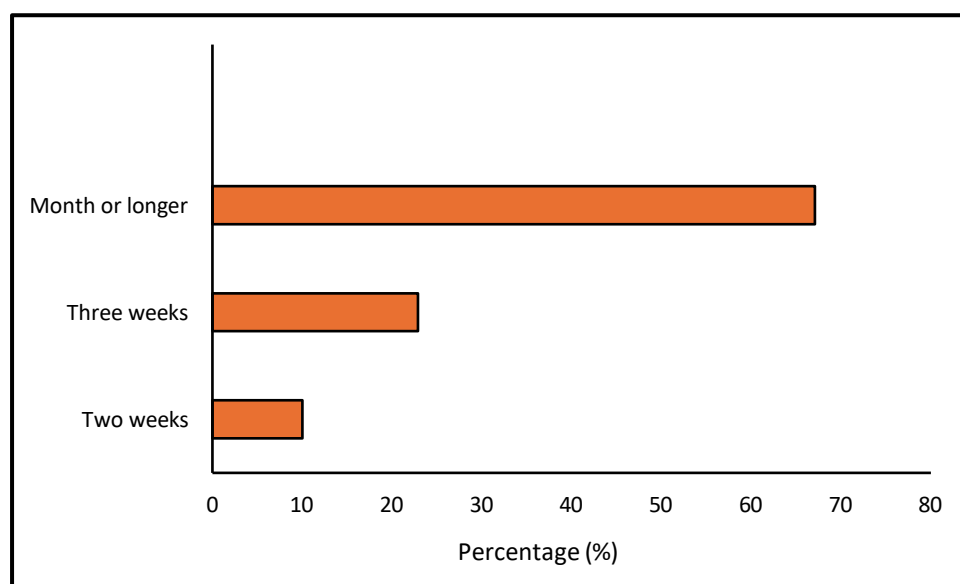


Figure 4.16: Period for water supply disruption to be fixed

The estimated groundwater yields for the months of December 2023 to May 2024 ranged from 61714.29 to 77142.86 L/d (Figure 4.18). The estimated groundwater yields are within the range of values of fractured aquifer of 0.5 to 2.0 L/s (Figure 4.17). The highest yield was observed in February and March 2024 and the trend indicates seasonal variability in groundwater availability, which is likely influenced by changes in recharge rates and water demand. Nemaxwi et al. (2019) estimated the response of groundwater recharge to rainfall events within a semi-arid fractured aquifer in Mhinga area, in Limpopo Province, South Africa. The study also noted rapid rise in groundwater levels after extreme single rainfall in quaternary catchment A91H of the Luvuvhu River Catchment. The lowest yield of approximately 61714.29 was recorded in January 2024, possibly due to limited rainfall during that period. The borehole demonstrated adequate quantity in both seasons, despite the slight decline in groundwater yield in January

2024. This highlighted the need for sustainable management of water to ensure consistent supply. Figure 4.19 illustrates the comparison between groundwater yield and water requirements (basic, intermediate, and optimal levels of access) over six months, from December 2023 to May 2024. The estimated water requirements for a population of 280 people were 7000, 14000 and 28000 L/d for basic, intermediate, and optimal access levels respectively. The results indicate that groundwater yields from December 2023 to May 2024 were adequate to meet the water requirement at basic, intermediate and optimal access levels. This indicates the potential of the main water source to meet the water requirements for the study area. The reliability of groundwater as a main water source in the study area is therefore not limited by the quantity of available water for supply, but it is mainly due to water supply disruptions. Makungo (2019) established that boreholes with yields ranging 0.5–2.0 L/s had the potential to supply the Siloam rural community. However, under development of water supply infrastructure limits access to groundwater. In Matatani Village, water supply disruptions may mainly be attributed to frequent breakdown of the borehole as well as the associated delays in repairs.

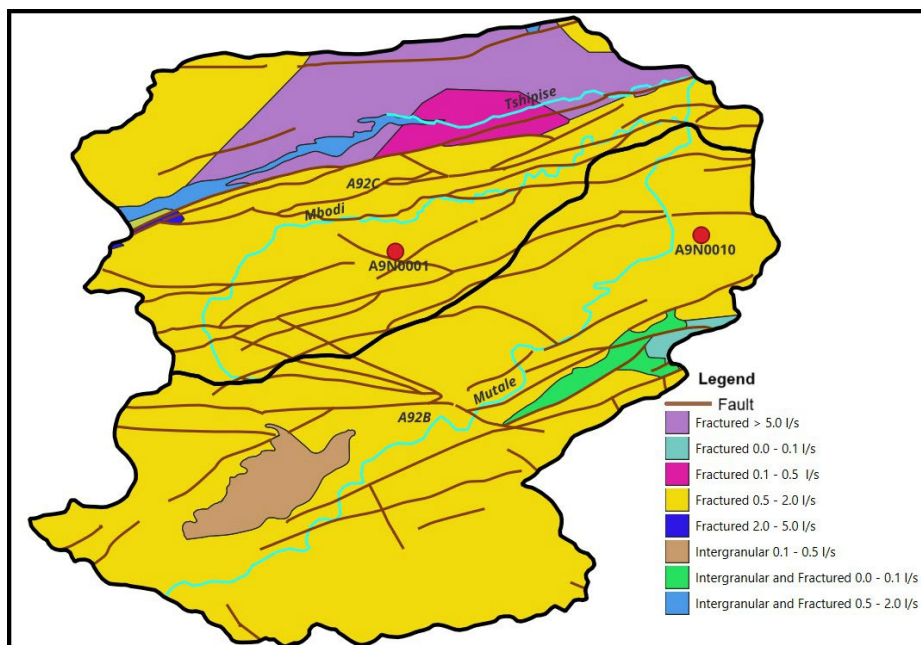


Figure 4.17: Aquifer type and groundwater yield ranges

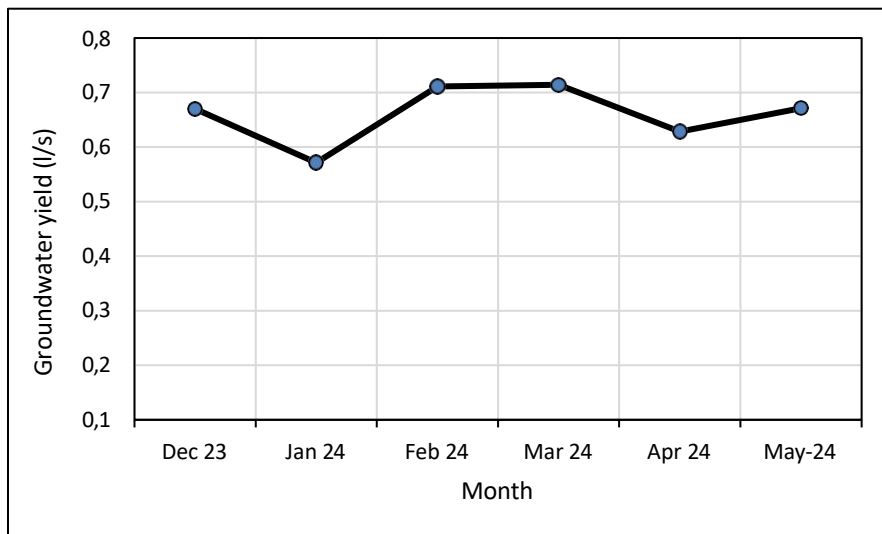


Figure 4.18: Estimated groundwater yield for BH1

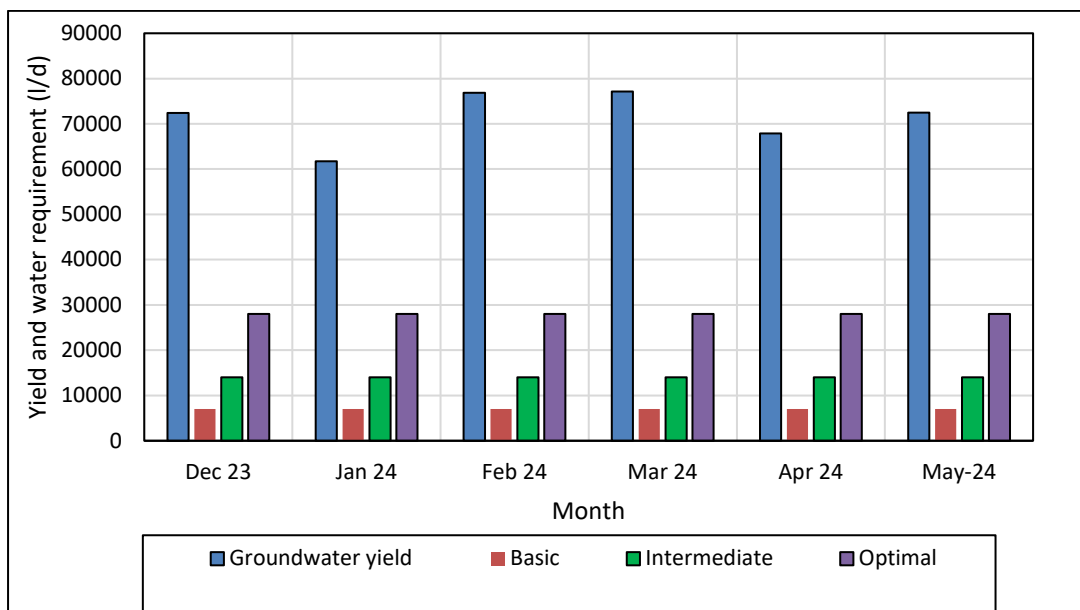


Figure 4.19: Groundwater yield and water requirements

Figure 4.20 illustrates the perception of water quality provided by the main source in Matatani Village. The results revealed dissatisfaction among residents, with the majority rating the water quality as "Very Poor" (38.6%) and "Poor" (30.0%), leading to a total of 68.6% expressing dissatisfaction. These findings raise concern about the water's suitability for drinking and other purposes. Only a small proportion of respondents rated the water quality as "Fair" (21.4%), "Good" (4.3%), or "Excellent" (5.7%), highlighting the limited availability of acceptable water quality. The majority (74.3%) of respondents consider their main water source non-potable, and unsuitable for drinking or other domestic uses without treatment. Only 25.7% of respondents reported that their main water source is potable. The majority (74.3%) of respondents mentioned a serious water

quality issue. Non-potable water can increase the risk of waterborne diseases and may necessitate additional treatment or filtering methods that can be costly or inaccessible. The minority have access to a water supply that they consider safe for drinking. However, this low percentage indicates that safe water is not widely accessible.

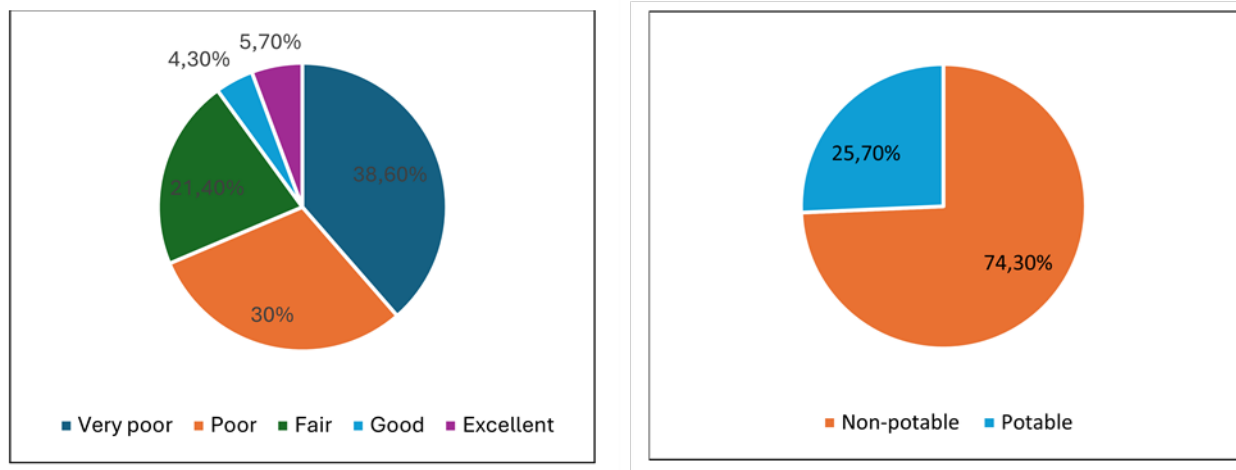


Figure 4.20: The perception on quality of water from the main source

Figure 4.21 showed the perceptions on seasonal changes in water availability in Matatani Village. The results revealed that water availability is perceived to change most significantly during the dry season, as reported by 42.9% of respondents. Meanwhile, 38.6% observed changes during the wet season, which might reflect issues such as flooding or inconsistent water supply management during periods of higher rainfall. Only 18.6% did not specify any seasonal changes, which could suggest limited awareness or stable access regardless of the season. These findings highlighted the challenges posed by seasonal variations, particularly in the dry season, emphasising the need for targeted interventions to enhance water reliability and mitigate seasonal shortages. Vyas and Sawant (2008) investigated seasonal variations in the drinking water quality of selected borewells in urban Kolhapur City. The results showed that the physico-chemical characteristics of the water samples were influenced by seasonal changes, with higher values observed during the summer season.

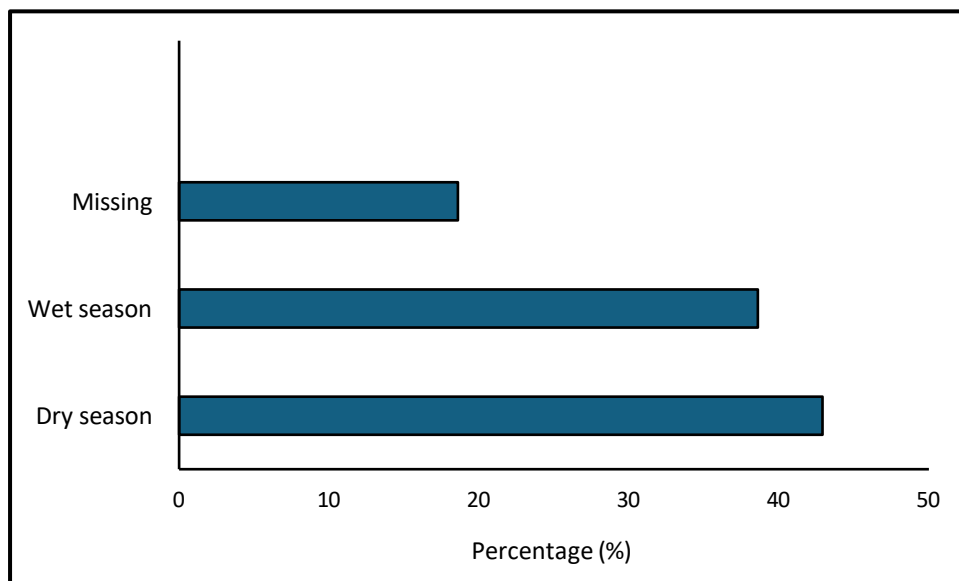


Figure 4.21: Seasons with changes in water availability

4.5. Results on community participation in water supply management

The results showed varying levels of community participation in water supply and management in Matatani Village. Nearly half of the respondents (48.6%) reported active involvement in community water projects, reflecting a level of engagement in water management initiatives. However, 44.3% stated they do not participate, reflecting a portion of the community not involved in these efforts. Additionally, 7.1% of respondents were unaware of any such initiatives, highlighting potential gaps in communication or outreach about water management programs (Figure 4.22). These findings suggest a need for increased community mobilisation and awareness campaigns to encourage broader participation. Enhancing engagement is critical for improving water supply management, as active community involvement is often linked to more sustainable and effective water systems. Collaboration between local committees, authorities, and residents is essential to bridge participation gaps and ensure the success of water supply projects.

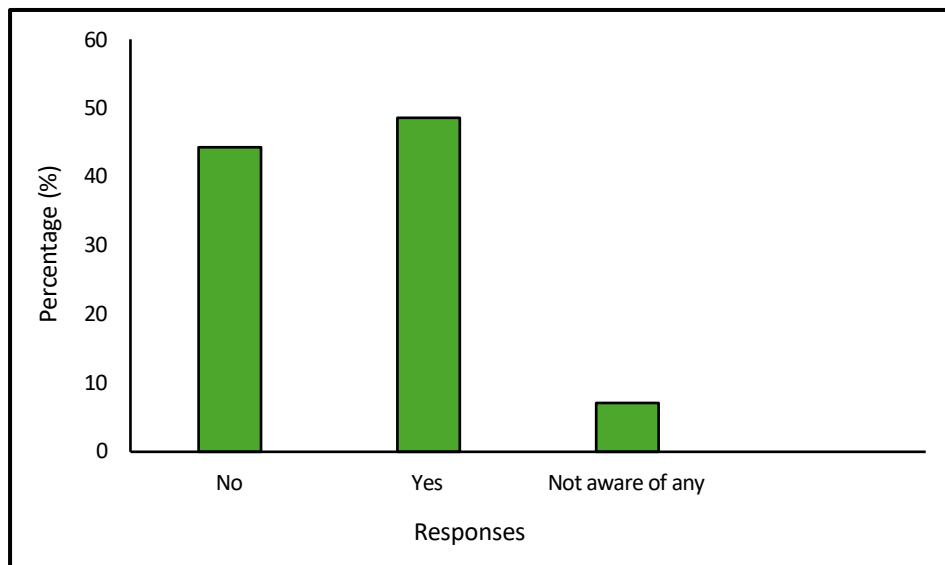


Figure 4.22: Participation in community water supply and management

The results indicated that the majority of respondents (52.9%) perceive community engagement in water supply management as "very effective," suggesting that most people believe the involvement of local communities will play a significant role in improving water systems (Figure 4.23). Additionally, 18.6% found the engagement "effective," further supporting the positive perception of community participation. However, a smaller portion (15.7%) was neutral, and 12.9% viewed the engagement as ineffective or very ineffective. These mixed responses indicate that while many recognise the value of community engagement, there are concerns about its full impact, possibly due to gaps in participation, resources, or communication. Such mixed perceptions highlight the need for targeted improvements in community involvement to enhance its effectiveness in water supply management. Waithaka et al. (2016) also revealed that 56.5% of respondents believed that community participation in rural water management had significantly enhanced their livelihoods in Kenya.

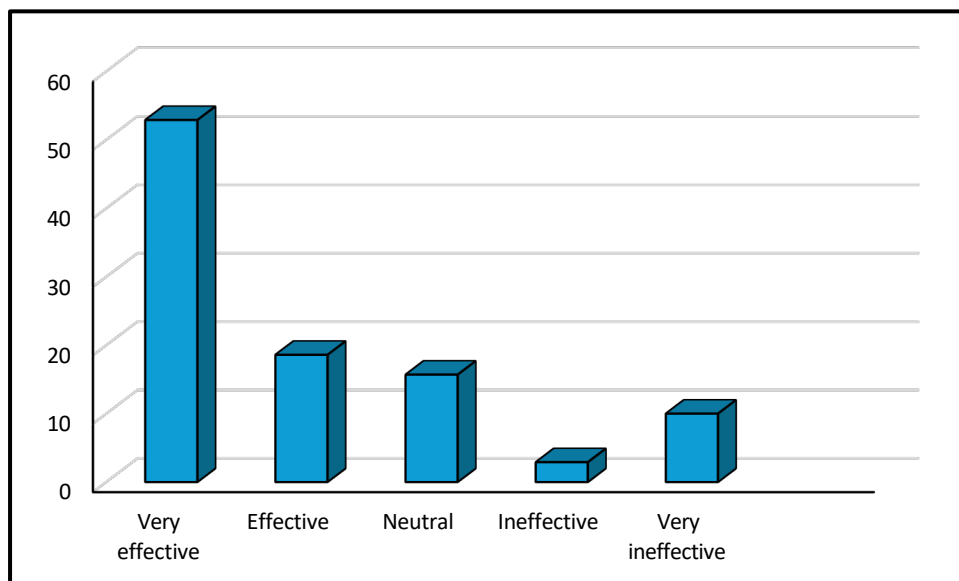


Figure 4.23: Perception on effectiveness of community engagement in water supply

The results showed a low level of community participation (Figure 4.24) in paying for water supply and services in Matatani Village. Only 27.1% of respondents mentioned that they were "highly involved" in payments, while 8.6% were moderately involved. A portion (47.1%) were not involved in any payment for water services, and 17.1% were unsure of their participation. While most residents of Matatani Village perceive community engagement in water services as beneficial, many do not participate in paying for these services. This indicates that community members may either not prioritise payment for water services or face financial constraints that hinder their ability to contribute. These findings align with challenges reported in other studies such as those by (Mothetha et al., 2013; Akinyemi et al., 2018; Coetzee et al., 2016 and Nti et al., 2020), which highlighted that, communities were reluctant to contribute financially to water supply systems due to affordability issues or the perception of water as a basic right. The findings of the study by Kahimba et al. (2020) revealed widespread dissatisfaction among smallholder farmers in the Ruaha Sub-basin, Tanzania, regarding water-user fees. Paying for piped or drinking water has a significant impact on a water utility's viability and financial self-sufficiency, as well as the long-term sustainability of the services offered (Adeoti and Fati, 2022). Addressing payment issues may require improved communication about the importance of payments for sustaining water services, as well as exploring alternative financing mechanisms such as government subsidies or community-based funding models

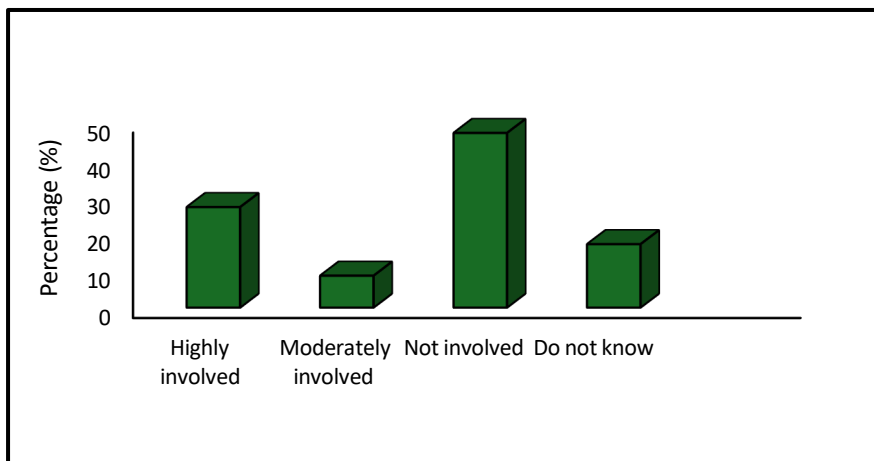


Figure 4.24: Level of community participation in payment for water supply and services

The results showed that a very small proportion of respondents (1.4%) believe that paying for water services should be justified by the “maintenance and operational costs and the reliability of the water supply” (Figure 4.25). This suggests that a minimal number of community members recognise the need for financial contributions to ensure sustainable water service delivery. However, 95.7% of responses were missing, which indicates that many participants do not believe that they should contribute to the payment of water services. This strong resistance suggests a significant reluctance to financially support water infrastructure, possibly due to economic challenges, perceptions of water as a basic human right, or a lack of understanding about the costs involved in maintaining the system. The lack of response further emphasises the challenges in fostering a culture of payment for water services, as community members may not fully understand the operational and maintenance costs involved or may not perceive them as directly linked to their water supply reliability.

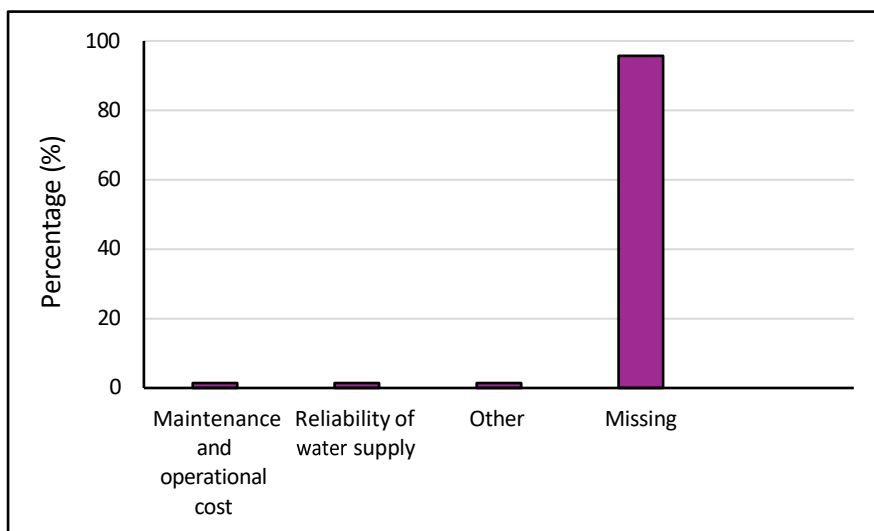


Figure 4.25: Reasons community members pay for water services

The results indicated that payments for water supply maintenance are irregular and infrequent in Matatani Village. Only 2.9% of respondents make payments when there is no diesel, suggesting that payment is tied to specific operational issues rather than a regular schedule (Figure 4.26). A larger portion (15.7%) contributes when the machine or pump is broken, highlighting a reactive rather than proactive approach to maintenance. Some respondents (4.3%) make monthly payments, but this is not the norm. A significant number (75.7%) did not respond, which indicates the absence of involvement in the payment process. Such resistance to payment may limit the community's ability to fund essential repairs, upgrades, and consistent operation of the water system. This irregularity in payment frequency suggests that there may be challenges in creating a sustainable financial model for water supply maintenance, and the community may need more consistent engagement and communication about the importance of regular contributions for the upkeep of water systems.

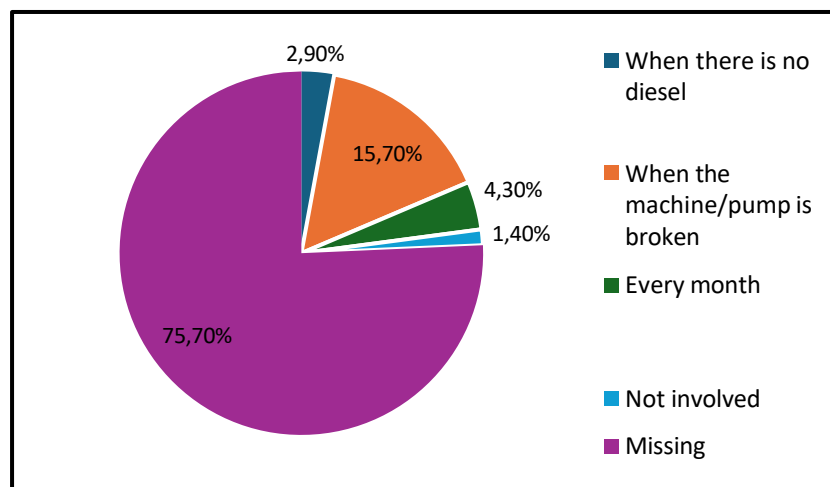


Figure 4.26: Frequency of payment and maintenance

Community members in Matatani Village were opposed to paying for water services, with 98.6% of respondents expressing their disapproval (Figure 4.27). Only 1.4% agreed that members should pay. This reflects a strong preference for water services to be provided free of charge, which may be rooted in perceptions of water as a basic right or due to economic constraints within the community. Similar trends have been observed in other communities, where residents expect external entities, like the government, to bear the costs of water infrastructure (Wang et al., 2017). Resistance to paying for water could hinder the establishment of a maintenance fund, potentially affecting the reliability and long-term functionality of water systems. There is a need for educational campaigns to emphasise the benefits of sustainable water management practices to ensure the long-term viability of water systems.

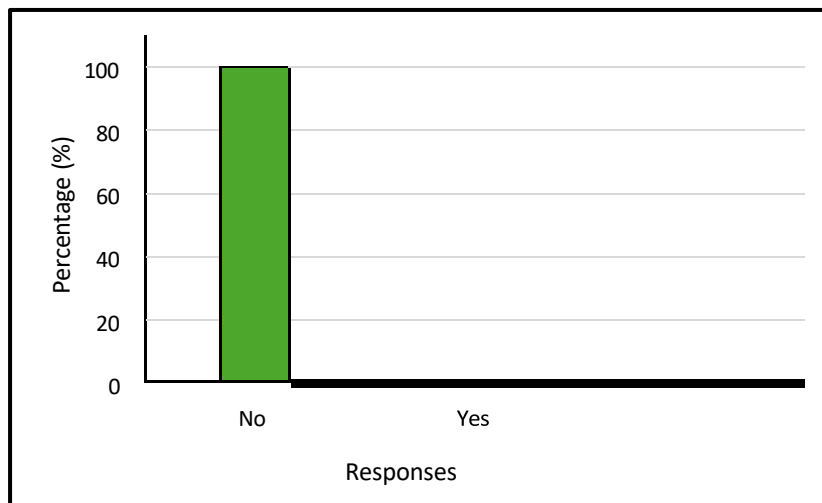


Figure 4.27: Responses to whether community members should pay for water services

The results indicated a clear preference for the government or municipality to cover the costs of operation and maintenance (O&M) of the water supply system, with 62.9% of respondents supporting this view (Figure 4.28). This revealed that the majority expect that public utilities, such as water supply, should be financed by government bodies rather than relying on households or local entities. A smaller proportion of respondents believed that households (12.9%) or communities' contributions (21.4%) should cover these costs, while only 2.9% supported water committees taking on this responsibility. The findings suggested a reliance on external support, particularly from the government, to ensure water system sustainability. This preference may stem from a belief that the government can provide more reliable, equitable, and long-term solutions. There seems to be limited enthusiasm for shifting the financial burden of O&M to the community members themselves, highlighting a potential challenge for local authorities in securing long-term financial sustainability for water systems.

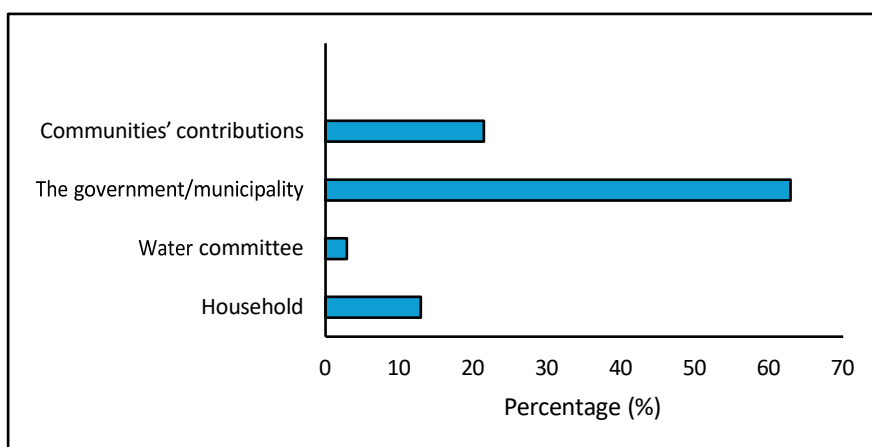


Figure 4.28: Respondents' opinion on who should cover operation and maintenance cost

4.6. Quality of water sources in Matatani Village

The pH values of all water sources, as shown in Figure 4.29, ranged from 6.32 to 8.13 during both wet and dry seasons. All the pH values for the water sources fell within the SANS 241 (2015) guideline, which recommend a pH range of 5 to 9.7 for domestic water use (Figure 4.29). The pH of the water is suitable for consumption and other domestic uses without immediate risk of corrosiveness or alkalinity issues. All the EC values for the water sources were within the acceptable limit of 1700 $\mu\text{S}/\text{cm}$ set by SANS 241 (2015). However, the groundwater from BH1, despite meeting the acceptable standard, had the highest EC values during the wet season exceeding 900 $\mu\text{S}/\text{cm}$ (Figure 4.29). The high concentration of dissolved salts or minerals associated with EC could pose potential concerns for its suitability, particularly for drinking and irrigation purposes.

The TDS revealed significant variations between the wet and dry seasons and among various sources (Figure 4.29). Groundwater for BH1 had TDS values of 703 mg/L in the wet season and 579.33 mg/L in the dry season, exceeding the guideline of 450 mg/L in both seasons. This indicates potential risks to water usability and health. Higher TDS values in water negatively affect both health and the environment, causing various human health issues such as gastrointestinal, cardiovascular, and skin problems (Pushpalatha et.al. 2022). Additionally, higher values of TDS lead to scaling in household appliances, reducing their efficiency (Pushpalatha et.al. 2022). High TDS levels in water have been found to harm animal health by impairing feed consumption, nutrient absorption, and utilization (Meyer and Casey, 2012). Groundwater for BH2 had lower TDS value of 2.69 mg/L in wet season and 1.72 mg/L in dry season, far below the guideline. The water from the RU, RD, and MT displayed seasonal variations, with wet season TDS levels (167.56, 211.22, and 186.67 mg/L, respectively) which were higher than dry season levels (90.52, 79.79, and 98.9 mg/L, respectively). Spring had a TDS level of 191.67 mg/L, measured in the dry season, which also complies with the guidelines. These values remained within the DWAF (1996) guidelines, suggesting good water quality for these sources.

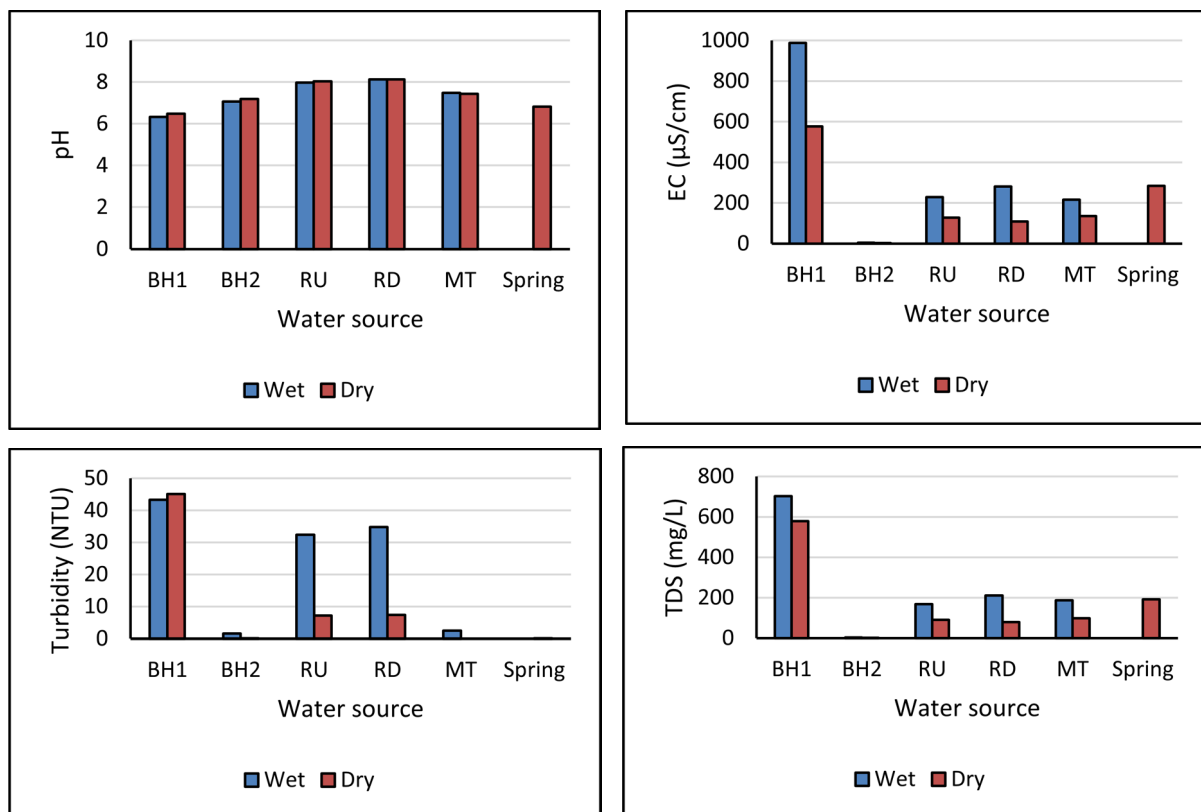


Figure 4.29: Physical water quality parameters of the water sources

Turbidity values ranged from 0.03 to 45.12 NTU for all water sources in both seasons (Figure 4.29). Groundwater from BH1 showed consistently high turbidity values in both seasons, indicating potential contamination. Groundwater from BH2 had a turbidity value below 1.59 NTU wet season and 0.07 in the dry season. The water from the RU and RD had high turbidity during the wet season (up to 33.36 and 34.78 NTU respectively). However, the turbidity values decreased to 7.15 and 7.40 NTU, respectively, during the dry season. The water from the spring had turbidity level of 0.03 NTU. The water from the groundwater BH1 and water from the river sources exceeded the recommended guideline of 1 NTU set by DWAF (1996) and SANS 241 (2015). This highlights the need for improved treatment or alternative sources to ensure water safety and usability for households relying on untreated sources. The survey responses regarding water quality aligned closely with the laboratory results, especially BH1 and river sources, reinforcing concerns about the quality of water in Matatani Village.

The E. coli counts (Figure 4.30) in all the water sources showed varying degrees of contamination. Groundwater from BH1 showed E. coli counts of 35 cfu/100 mL in the wet season and 25 cfu/100

mL in the dry season, highlighting faecal pollution. These values exceeded the recommended guidelines for drinking water by SANS 241 (2015) and WHO (2011), which set the acceptable limit for *E. coli* at 0 cfu/100 mL. The presence of *E. coli* indicates microbial contamination and poses significant health risks, such as waterborne diseases like diarrhea and cholera. It has been proven that high counts of faecal coliforms cause cases of acute diarrhea in rural areas (Odiyo and Makungo, 2012). Groundwater from BH1 had health risks if the water is consumed untreated, potentially leading to waterborne diseases. Water from both RU and RD sources showed increased *E. coli* contamination during the wet season, likely due to surface runoff. This pattern makes them unreliable and unsafe, especially during rainy periods. The results aligned with the findings of the study by Kostyla et al. (2015), which noted increased faecal contamination in water sources during rainy seasons, largely due to runoff in developing countries. The water from MT had exceptionally low *E. coli* counts in wet season and not detected in dry season, indicating that the water is well-treated and meets safe drinking water standards. This source appears to be the safest for consumption.

The total coliform counts (Figure 4.30) in all the water sources demonstrated seasonal variations, with most counts exceeding the acceptable limit of 10 cfu/100 mL as per the drinking water quality guidelines by SANS 241 (2015). In the wet season, water from the RU and RD samples had the highest counts of 127.33 and 91.67 cfu/100 mL, respectively. Groundwater from BH1 and water from MT had 38.83 and 30.5 cfu/100 mL, respectively. Groundwater from BH2 had the lowest counts in the wet season of 14.25 cfu/100 mL which increased to 61.5 cfu/100 mL in dry season. The water from the spring and RD had the highest counts of 127 cfu/100 mL and 126 cfu/100 mL, respectively in dry season. Groundwater from BH1, BH2, and RD had high total coliform counts of 96.33, 61.5, and 126 cfu/100 mL respectively, in dry season as compared to wet season. Water from the MT had total coliform counts of 30.5 cfu/100 mL in wet season and 33.5 cfu/100 mL during dry season. All sources exceeded the recommended guidelines of 10 cfu/100 mL set by SANS 241 (2015), indicating significant microbial contamination that poses a risk to public health.

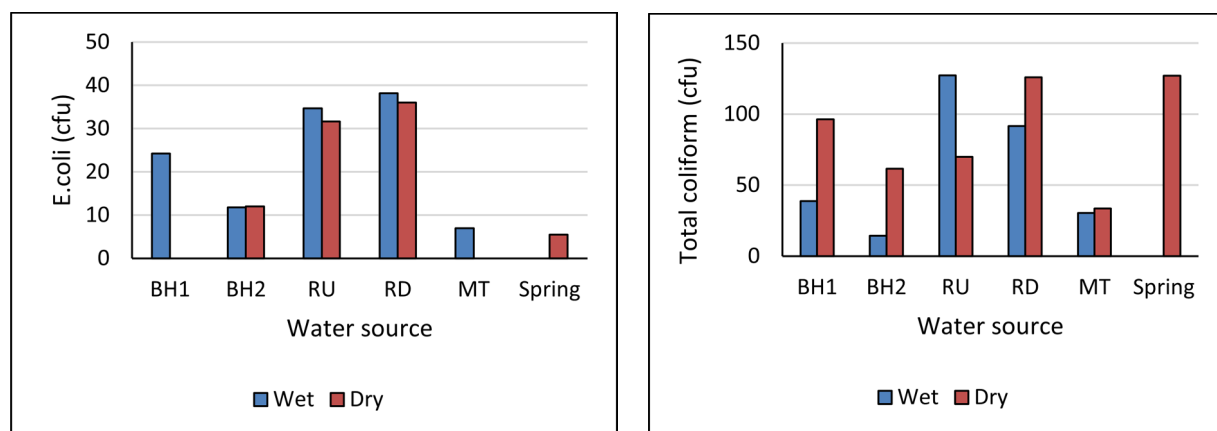


Figure 4.30: Microbial water quality parameters of the water sources

The Ca concentrations showed variations during wet and dry seasons. The Ca concentration for groundwater from BH1, water from RU, and RD decreased from 40.37 to 34.89 mg/L, 15.92 to 13.86 mg/L, and 25.60 to 13.74 respectively (Figure 4.31). The water from MT increased from 16.59 to 18.16 mg/L. The water from the spring had a concentration of 18.36 mg/L during dry season, and groundwater from BH2 had a concentration below detectable limit. Compared to DWAF (1996) target guideline of 32 mg/L, most sources fell below this value, except groundwater from BH1, which had increased Ca concentrations that contribute to water hardness and scaling. This highlights the need for monitoring and potential treatment to manage Ca concentrations and ensure water quality compliance. The K concentrations (Figure 4.31) across the water sources showed significant seasonal variations. Groundwater from BH1, BH2, and the spring exceeded the DWAF (1996) and SANS 241 (2015) guideline limit of 50 mg/L in both seasons. Concentration of Ca in groundwater from BH1 decreased from 57.75 mg/L (wet) to 42.47 mg/L (dry), while that of BH2 increased from 60.32 to 65.06 mg/L (Figure 4.31). Water from the spring had K concentration of 57.80 mg/L in dry season. The K concentrations for water from RU, RD, and MT remained below the limit and ranged from 8.87 to 4.96, 7.57 to 6.07, and 12.56 to 13.76 mg/L respectively. High concentrations of K in groundwater from BH1, BH2, and the spring may cause a salty taste and potential health risks for sensitive individuals, requiring targeted interventions.

DWAF (1996) guidelines for drinking water, set the acceptable Mg concentration to 30 mg/L. However, groundwater from BH1 exceeded the limit with concentrations of 83.67 mg/L in the wet season and 65.70 mg/L in the dry season (Figure 4.31). Water from RU, RD, MT and spring had Mg concentrations below the acceptable limit, ranging from 10.17 to 29.03 mg/L. The Na

concentrations showed variations during wet and dry seasons. The concentration water from RU and RD concentrations decreased from 87.48 to 82.75 and 100.64 to 80.97 mg/L, respectively (Figure 4.31). All the water from the sources were below the acceptable limit of 100 mg/L set by DWAF (1996) guidelines. However, the spring source had a significantly high Na concentrations of 274.98 mg/L during the dry season, exceeding the standard and posing potential health risks. These results suggest target interventions are needed for the spring source to ensure compliance with water quality standards.

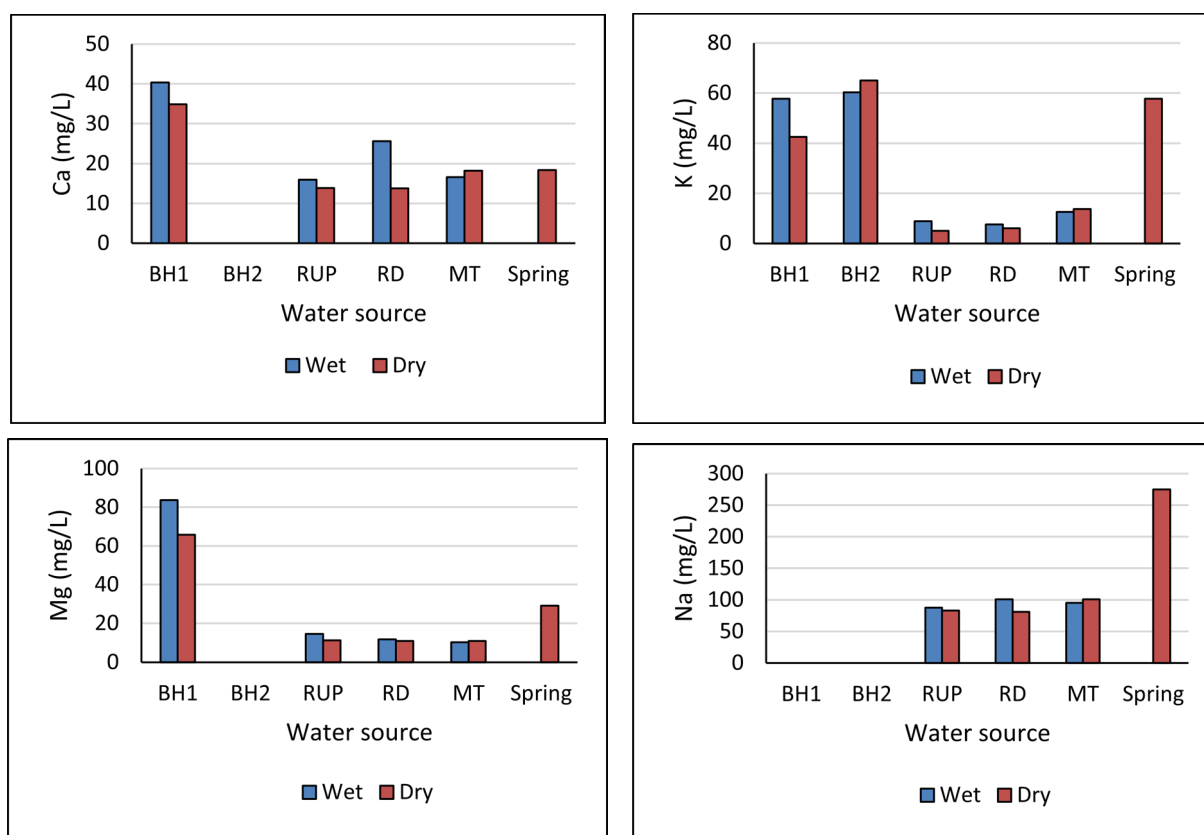


Figure 4.31: The Ca, K, Mg and Na concentrations in water sources

The Al concentrations in all water sources remained consistent between wet and dry seasons, ranging from approximately 4.75 to 5.36 mg/L, which exceeded the SANS 241 (2015) recommended limit of 0.3 mg/L for drinking water (Figure 4.32). This indicates potential health risks and the need for treatment to reduce aluminum concentrations. High Al concentrations (3.6 to 6 mg/L) can form aluminum hydroxide precipitates, causing consumer dissatisfaction, and are potentially linked to neurological conditions such as Alzheimer's disease and presenile dementia (Srinivasan et.al, 1999). Rondeau et al (2000) also supported the hypothesis that a high

concentration of Al in drinking water may be a risk factor for Alzheimer's disease. The Zn concentrations in all water sources showed variations between wet and dry seasons. All water sources exceeded the 3 mg/L limit set by DWAF (1996), with concentrations ranging from 3.31 to 7.64 mg/L (Figure 4.32). The water from the spring had the highest concentration of 7.64 mg/L. These high concentrations may pose health risks especially the water from the spring which is considered the second most utilised source in Matatani Village. The Mn concentrations (Figure 4.32) varied across water sources. Water from the RD showed the highest concentration during the wet season (5.08 mg/L). The water from spring had the lowest (2.10 mg/L) in the dry season. Groundwater from BH1, and BH2 had concentrations ranging from 3.61 to 5.45 mg/L and 4.42 to 4.63 mg/L, respectively. The Mn concentrations for the water from RU and MT ranged from 2.98 to 5.00 mg/L and 2.29 to 4.54 mg/L respectively. All values exceeded the SANS 241 (2015) guideline of 0.1 mg/L. Groundwater from BH1 and BH2 showed slight increase in Pb concentrations during the dry season, while water from RU and RD showed seasonal variations (Figure 4.32). The water from the RD had the highest concentration of Pb in the wet season (5.08 mg/L). Spring had the lowest Pb concentration (2.10 mg/L) in the dry season. The Pb concentrations in all water sources exceeded the acceptable limit of 0.01 mg/L set by SANS 241 (2015), indicating contamination and potential health risks. High concentrations of As, Cd, Cr, Mn, and Pb can result in serious health problems, including cancer, hypertension, anemia, and Alzheimer's disease (Mandindi et al., 2022).

The Cd concentrations in all the water sources showed seasonal variations. The water from MT and RD had the highest concentrations in the wet season at 12.41 and 12.28 mg/L, respectively (Figure 4.33). In the dry season, the water from MT remained high at 10.41 mg/L, while the water from RD dropped significantly to 4.10 mg/L. The water from RU showed consistently high concentrations of Cd which increased from 8.23 mg/L in the wet season to 9.51 mg/L in the dry season. Groundwater from BH1 had an increase from 4.90 to 7.52 mg/L, while groundwater from BH2 demonstrated a sharp decline from 7.29 to 1.36 mg/L. The water from the spring had a concentration of 7.99 mg/L in the dry season. All the sources exceeded the acceptable limit of 0.03 mg/L for drinking water set by WHO (2011) guidelines which poses threat to human health. Cd primarily targets the kidneys, causing proximal tubular cell toxicity, and can lead to bone demineralization and lung damage, including an increased risk of lung cancer, due to excessive industrial exposure (Bernald, 2008).

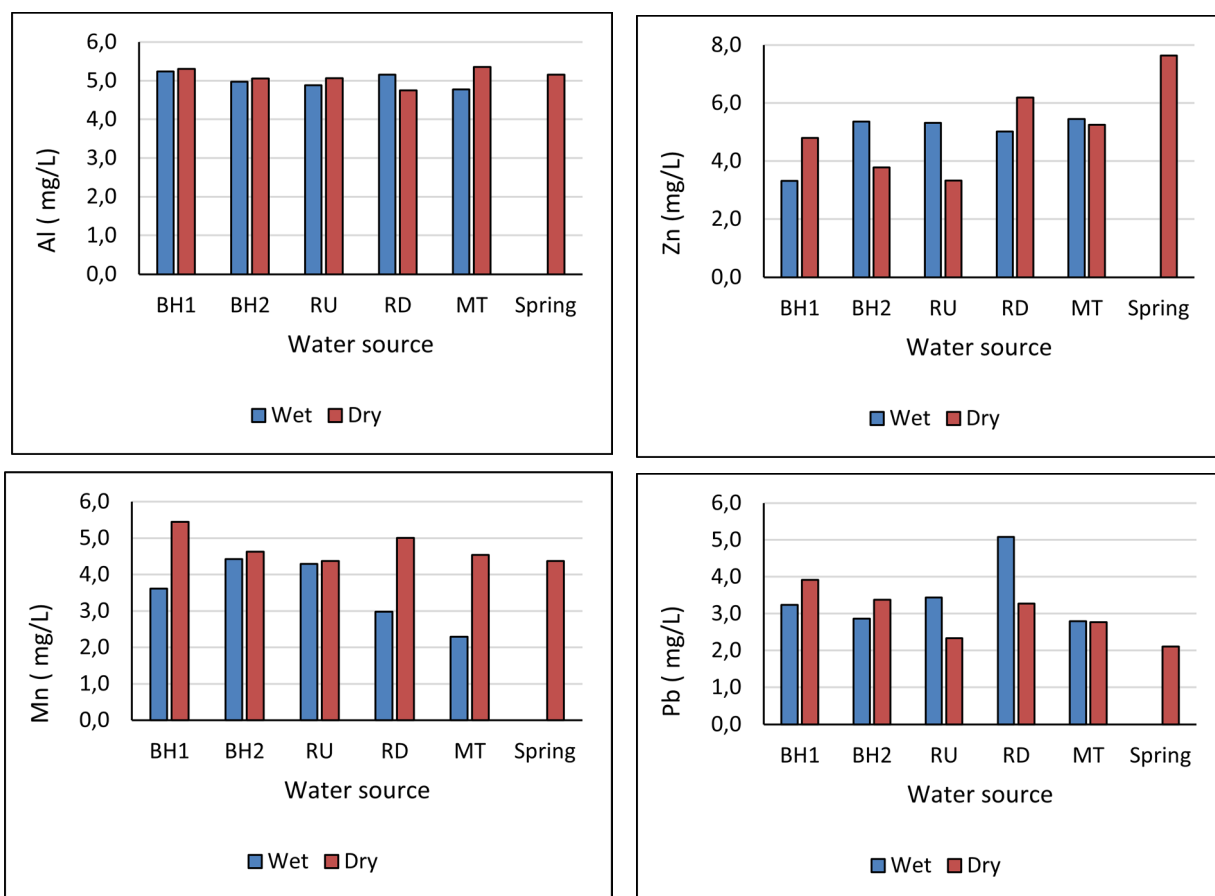


Figure 4.32: The Al, Zn, Mn and Pb concentrations in water sources

The As concentrations in all the water sources revealed noticeable seasonal variations. The As concentrations in groundwater from BH1 decreased from 4.67 mg/L during wet season to 3.80 mg/L in the dry season (Figure 4.33). Groundwater from BH2 showed a similar trend, declining from 4.97 to 2.70 mg/L. The water from RU, RD and MT also decreased from 3.65 to 2.15 mg/L, 3.78 to 2.94 mg/L and 4.70 to 2.92 mg/L respectively. The water from the spring had 0 mg/L in the dry season. All sources except the water from the spring, exceeded the acceptable limit of 0.01 mg/L set by SANS 241 (2015) guidelines. The recorded concentrations far exceeded this limit, highlighting severe contamination. The As exposure has been associated with an increased risk of developing several types of cancer, including those affecting the skin, kidneys, liver, bladder, and lungs (Bhat et.al, 2024). A health risk assessment conducted by Mandindi et al. (2022) in Eastern Cape (South Africa) revealed the potential of As to cause non-carcinogenic health effects in community members. Furthermore, the incremental lifetime cancer risk (ILCR) values for As, Cd, and Pb were above acceptable limits, indicating a significant risk of cancer due to their

accumulation over time.

The Fe concentrations in all water sources exceeded the DWAF (1996) limit of 0.1 mg/L. Groundwater from BH1, BH2 and water from RU showed increases in Fe concentration in dry season, with concentrations up to 5.22, 5.68 and 6.44 mg/L, respectively (Figure 4.33). The water from RD and MT decreased to 5.09 and 4.63 mg/L in the dry season, respectively. The water from the spring had a concentration of 3.92 mg/L in the dry season. All the sources exceeded the limit set by DWAF (1996) guideline. According to Rahman et al (2023), if iron concentrations exceed normal ranges, serious health effects can develop, including hemochromatosis, which can cause damage to the liver, heart, and pancreas, and may also contribute to the development of diabetes.

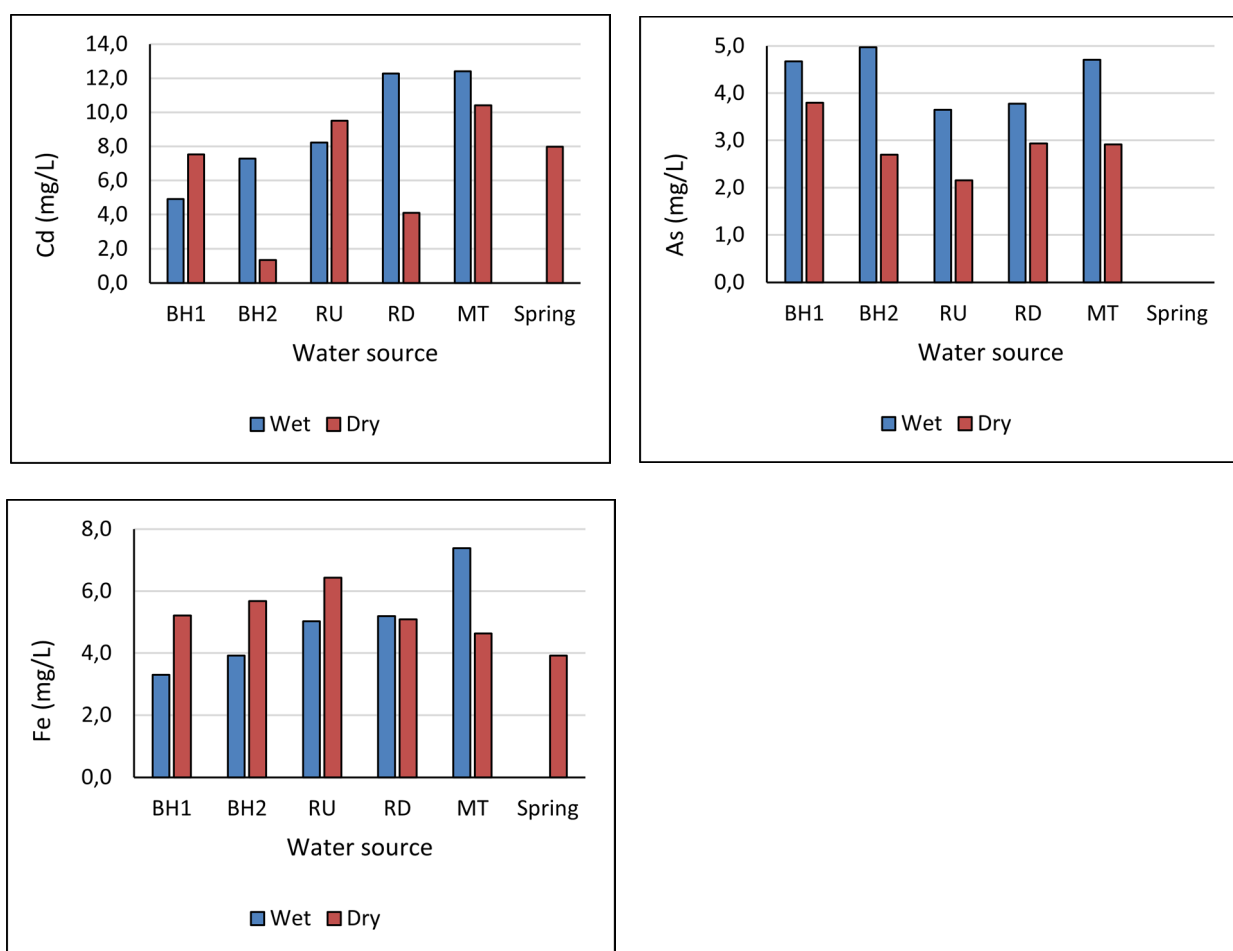


Figure 4.33: The Cd, As, and Fe concentrations in water sources

The F concentrations (Figure 4.34) in all water sources ranged from 0.05 to 0.39 mg/L during wet season and 0.22 to 0.49 mg/L in dry season. All these concentrations were below the SANS 241 (2015) guideline of 1.5 mg/L, posing no health risks. The Cl concentrations (Figure 4.34) in most water sources complied with the DWAF (1996) guideline of 200 mg/L, except the groundwater

for BH2, which exceeded the limit in both season (243,65 mg/L in dry season and 372,80 in wet season). A high concentration of Cl can give water a salty taste and increase the corrosion rate of metals (DWAF, 1996). However, when chloride concentrations range from 200 to 600 mg/L, water may have a noticeably salty taste without posing significant health risks. The SO_4 concentrations (Figure 4.34) ranged from 0 to 82 mg/L in wet season and 0 to 29.33 mg/L during dry season with all the values within the SANS 241 (2015) guideline of 250 mg/L. The PO_4 concentrations (Figure 4.34) in water sources showed seasonal variation. The concentration levels varied from 0.00 to 0.35 mg/L in both seasons. The ground water from BH1 and BH2 values were 0.35 and 0.24 mg/L which exceeded the recommended guideline of 0.005 mg/L set by WHO (2011) during wet season. The water from MT and spring had Cl concentrations of 0.06 and 0.09 mg/L, respectively in dry season which also exceeded the recommended guideline set by WHO (2011).

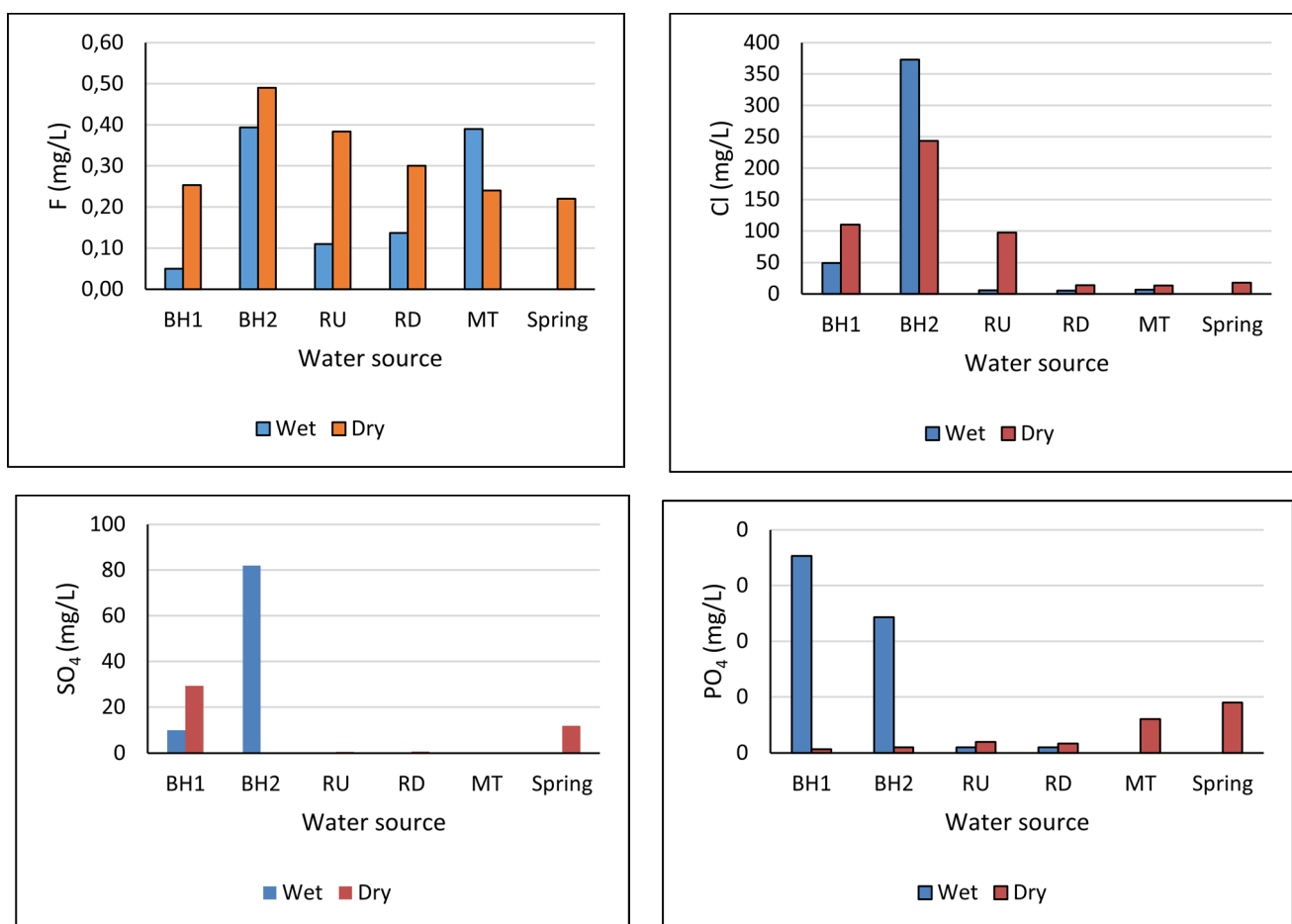


Figure 4.34: The F, Cl, SO_4 and PO_4 concentrations in water sources

4.7. Results on performance assessment of Matatani water supply system

The results on performance assessment are in Table 4.4. The quantity of water accessed by households in Matatani Village is lower than the benchmark of 1500 liters per household per week, which indicates insufficient access of water for basic needs. Only 15.7% of households use above 1400 liters weekly. Additionally, the distance travelled to water source which varied from 536 m to 6.56 km exceeded the benchmark of 100 m, which creates accessibility challenges. These results therefore indicate inadequate access to basic water requirement in Matatani Village, and hence poor accessibility.

Results from the questionnaire survey indicated that 81.4% of households experienced frequent or occasional disruptions. This makes the system unreliable as the benchmark requires no interruptions of no longer than 48 consecutive hours. Despite adequate groundwater yield with potential to meet estimated daily water demands across all access levels (Table 4.4.), frequent disruptions and the long distance to BH1 place an additional burden on households and limit the amount of water they can collect. Furthermore, while most physical water quality parameters complied with the water quality guidelines (see section 4.6), high turbidity levels further diminish the microbial quality of water. The failure to comply with water quality guidelines for chemical and microbial water quality parameters compromised the safety of the water for domestic use. Some of the microbial and chemical water quality parameters that exceeded the guidelines include *E. coli*, total coliform, Al, Zn, Mn, Pb, Cd and Fe in all the water sources. These are associated with potential health effect such as an increased risk of waterborne diseases, gastrointestinal infections, cancer, and kidney problems. The results of this study therefore indicate that the Matatani Village water supply system performed poorly in based on accessibility and reliability indicators.

Table 4.4: Performance assessment of Matatani water supply system

Indicators	Sub-indicators	Matatani water supply	Benchmark	Remarks
Accessibility	Access to basic water requirement	37.1% access between 350-700 liters per week, 24.3% access 175-350 liters weekly, 15.7% access 700-1400 liters weekly, 15.7% access over 1400 liters weekly, 7.1% access less than 175 liters per week.	1500 liters per household per week	Poor
	The reasonable distance (m) from the households to the water sources	The closest household is located 536 m and the farthest household is located 1.73 km from BH1. The distance from the river to the closest households is 3.80 km and the farthest household is located at 6.56 km from the river.	100 m from the farthest household	Unreasonable
Reliability	Sustainability of the water source	81.4% reported frequent water disruptions, 8.6% reported disruption as often, 10.0% reported no disruptions. Estimated groundwater yields ranged from 61714-77143 L/d. The estimated water demands were 7000, 14000, and 28000 L/d for basic, intermediate, and optimal access levels, respectively.	350 days per year and not interrupted for longer than 48 consecutive hours	Poor
	The quality of the water from the source	Most of the chemical and microbial parameters did not meet compliance standards. Most physical parameters complied, except the turbidity.	Water quality guidelines	Mostly poor

Rietveld et al. (2009) concluded that despite the water supply systems (which consist of piped distribution systems with public standpipes, mostly fed by groundwater) in Vhembe District Municipality being relatively new, their performance was poor due to poorly constructed boreholes, insufficient storage capacity, damaged standpipe taps, and disputes over diesel payments for pumping, as well as maintenance and repair challenges. Zvobgo (2020) also found that Chitungwiza Municipality's urban water supply services failed to meet the benchmark for all key performance indicators due to major issues in the current water system, including an unreliable municipal water supply that eroded residents' trust, poor water quality, inadequate maintenance, slow response to leakages, and a lack of transparency and accountability by the municipality. This indicates that the poor performance of water supply systems is an issue affecting both rural and urban areas.

Poor performance of water supply systems forces communities to rely on unprotected water sources, increasing the risk of waterborne diseases and exposure to contaminants (Adetunji and Oyenje, 2022). The poor performance of the water supply system also negatively affects the socioeconomic status of an area by limiting economic opportunities, increasing financial burdens, and reducing overall quality of life. Inadequate water supply disrupts agriculture, industries, and businesses that depend on water for production, leading to reduced food security and income (Israilova et al, 2023). The poor performance of the system exposes inhabitants to serious health risks, particularly immuno-compromised individuals, while also negatively impacting social well-being and economic progress (Rietveld et al, 2009). This emphasises the need to improve the water supply system for Matatani Village as their livelihoods are also affected by these challenges.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This study assessed the performance of the water supply system in Matatani Village, focusing on reliability and accessibility indicators. A questionnaire survey was conducted to gather information on socio-economic status, information on reliability and accessibility indicators and community perceptions on the water supply system. The existing water supply sources were identified through field observations while QGIS was used to map out their locations and estimate distances travelled to fetch water. This shows that the first specific objective, on identification of the available water supply sources and their status in Matatani Village was met. Estimated groundwater yields and water requirements were compared to determine the potential of the main source to supply water to the community. Water quality analysis was done to assess the suitability of water for consumption. Matatani Village has a predominantly young population, with 31.4% aged 18–29 years, 24.3% between 30–39 years, 20% between 40–49 years, and 24.3% aged 50 and above. The presence of youth suggested that water demand and usage patterns are driven by an active population engaged in both domestic and economic activities. Economically, the village faces challenges, with 68.6% of residents relying on social grants and an unemployment rate of 75.7%. This high level of unemployment indicates financial hardship. This may hinder the community's ability to contribute to the maintenance of the water supply system. The identified primary water supply sources for the village include rivers, springs, boreholes, communal taps, rainwater, and municipal water tankers. However, these sources differ in their ability to meet the water requirements with some proving inadequate due to limited supply, distance challenges, and concerns over water quality. The majority of residents (44.3%) rely on groundwater from BH1 as their main source of water for supply. The low percentage (8.6%) of households with access to a municipal tap also indicates limited infrastructure for direct household water supply, potentially affecting convenience and water access.

The results indicated that only 15.7% of households use 1400 liters per household per week. About 37.1% use between 350–700 liters, 24.3% access 175–350 liters, and 7.1% receive less than 175 liters per week, all of which were below the benchmark of 1500 liters

per household per week. Matatani residents faces difficulties in accessing water from their preferred main source. The distance to BH1 ranges from 536 m to 1.73 km, while the river is located between 3.80 km and 6.56 km from the closest and farthest households. These distances exceeded the 100 m benchmark recommended by (DWS, 2017). Uneven terrain, with an average slope of 4%, makes access to the river more difficult, especially for those without transportation or who carry water manually. Distance impacts daily routines, and residents may fetch limited quantities of water for cooking, cleaning, and other needs.

Groundwater yields for BH1 varied from 61714.29 to 77142.86 L/d and were adequate to meet the water requirements of 7000, 14000, and 28000 L/d for basic, intermediate, and optimal access levels. Despite the availability of a water supply, residents face challenges with accessibility, as long travel distances create burdens and limit the amount of water collected, leading to inadequate supply for household needs. All assessed physical water quality parameters complied with the water quality guidelines. However, turbidity in BH1 exceeded acceptable levels in both seasons, which compromised its safety for consumption and reduces its reliability as a drinking water source. The microbial and chemical water quality parameters that did not meet the water quality guidelines include *E. coli*, total coliform, Al, Zn, Mn, Pb, Cd, and Fe in all water sources. Contaminated water poses significant health risks to the community, potentially leading to waterborne diseases and also compromises the reliability of the water supply system as a safe source for daily use. The water from MT has relatively better water quality. However, the water supply is irregular, limiting its reliability as a dependable source for the community. This shows that the specific objective of determining the reliability and accessibility of the water supply sources during different climatic seasons at Matatani Village was met.

Results from the questionnaire also showed that limited community involvement in water supply and management was identified as a challenge to sustainability. Although half of the population perceive community engagement in water supply management as beneficial, only 1.4% actively participate in paying for these services, which may affect the sustainability of the water supply system. This shows that the specific objective on exploring the community participation in water supply management at Matatani Village was also met. The reliability and accessibility of the water supply system is therefore

influenced by multiple interrelated factors. The Matatani Village water supply system faces challenges with accessibility and reliability, which limits its effectiveness in meeting community needs. Therefore, the Matatani water. This shows that the objective, which was to determine the status of the performance of the Matatani water supply system, was also met.

5.2. Recommendations

The study recommends the rehabilitation of the BH3 borehole, which ceased functioning due to a pump malfunction. Restoring this critical infrastructure will not only add a vital water source to the community but also help alleviate the pressure on other existing water points. An upgraded and fully operational BH3 borehole will improve water availability, reduce waiting times, and ensure a more equitable distribution of resources. Additionally, modernising the system with durable materials and incorporating low-maintenance technologies, such as solar-powered pumps, can enhance its reliability and sustainability over time.

Matatani residents face the challenge of traveling long distances to access water, implementing improved water distribution systems is crucial. Improving infrastructure, such as bringing water closer to households through boreholes or piped connections, could alleviate the burden on those living farther away. This could also help reduce the time and energy spent on water collection, ultimately improving the overall well-being of Matatani Village. Establishing a centralised water storage and distribution facility, such as elevated water tanks, could effectively reduce the burden of fetching water from distant sources. These tanks could be strategically placed closer to the households and connected to the borehole or spring via a pipeline system. An existing pipeline system could be used to connect water sources to these storage facilities, minimising the distance residents must travel to fetch water.

The study recommends the development of additional water sources, such as new boreholes, to enhance availability and meet the growing demands of the population. Implementation of solar-powered pumps to minimise operational costs and ensure a sustainable water supply for the community. This solution would reduce travel distances and save time and energy, particularly for women and children, who are often tasked with

fetching water. Given the community's limited willingness to pay for water services, solar-powered pumps offer an efficient, cost-effective alternative that can alleviate financial pressures while improving access to water. Addressing potability is crucial for ensuring safe and sustainable water access, reducing health risks, and improving overall quality of life in the community. Introducing basic water treatment systems, such as chlorination for borehole water and filtration units for spring water and educating the community of the water treatment methods can significantly reduce contaminants. Community trainings on safe water storage and handling practices can help minimize contamination risks at the household level. Additionally, it is recommended that the relevant authorities be notified of the water quality concerns to ensure timely intervention and support.

It is also recommended that there should be collaboration between communities, government, and other key stakeholders, with a focus on collective efforts to allocate resources and implement effective, practical solutions. This is crucial in the improvement of rural water supply. Strengthening community participation and capacity-building is required to ensure long term sustainability of the water supply system. There should also be establishment of new water management committees and training programs to empower the community to take ownership of the system's operations and maintenance. Financial contributions or in-kind support from community members can further enhance the sustainability of these efforts. Integrating water supply improvements into broader village development plans and conducting regular monitoring and evaluation is recommended to ensure that the system remains responsive to the needs of the community. These recommendations aim to provide a community-based management plan that promotes, sustainable, reliable, and accessible water supply system and supports the health and well-being of Matatani Village residents. Future researchers should explore the feasibility of rainwater harvesting as a sustainable solution to supplement the existing water supply in Matatani Village. It is also recommended that more detailed analysis of borehole yield and gathering additional data to support the application of a more robust analytical framework be conducted in future studies.

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LIST OF APPENDICES

Appendix 1: Questionnaire

Date of interview:

Name of interviewer:

Name of village:

Municipality ward No:

Section A: Demographic details of the respondent

Name of Respondent	
Household head status	Choose from: Traditional Leader Member of civic organisation Ward councilor Vhembe District Officer Water operator Community member
Years of residency in Matatani Village	Choose from: 0 – 5 years 6 – 10 years 11 – 20 years 21 – 30 years 31 years and above
Gender	Choose from: Male Female Prefer not to say
Age category of the respondent	Choose from: 18-29 years
	30-39 years 40-49 years 50 years and above

Marital status	Choose from: Single/Never married Married Divorced Widow/Widower Prefer not to say
Household size	Choose from: Household with one person Household with two people Household with three people Household with four people Household with more than four people
Employment status of the respondent	Choose from: Employed Unemployed Self employed Piece job
Source of income	Choose from: Grant Salary Pension Wages Others, ...
Monthly household income	Choose from: R0 - R1 000 R1 000 - R5 000 R5 000 - R10 000 R10 000 -R15 000
	Above R15 000

Highest educational level	Choose from: Primary education Secondary education TVET/College education University education None
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Section 2: Reliability and accessibility of water supply sources

What are the sources of water available in Matatani Village?	Choose from: (multiple selection allowed) Household Municipal Tap Communal Municipal Tap Household Borehole Communal Borehole River Spring Municipal water tanker Rainwater Buy from vendors Others, ...
What is the main source of water in your household?	Choose from: Household Municipal Tap Communal Municipal Tap Household Borehole Communal Borehole River Spring Municipal water tanker Rainwater collection Buy from vendors

	Others, ...
How frequently do you access the aforementioned water source?	Choose from: Daily Weekly Monthly Rarely Once in 6 months Once in a year
Why do you prefer this water source?	Choose from: It is reliable Distance Time Water quality There are no better alternatives Other, ...
Distance from the household to the main water source selected?	Choose from: Less than 100 meters 100-200 meters 200-500 meters More than 500 meters
How reliable is your main water source throughout the year?	Choose from: Very reliable Reliable Unreliable Don't know
Is the main water source potable for domestic uses?	Choose from: Portable Not portable
Rate the quality of water from the main source?	Choose from: Excellent Good

	Fair Poor
If the answer from above is poor, what could be the reason?	Choose from: Water is salty Water is muddy Water is rusty Others, ...
How concerned are you about the quality of drinking water in your area	Choose from: Not concerned at all Slightly concerned Moderately concerned Very concerned Extremely concerned
How do you cope with poor water quality?	Choose from: Drink as it is Boil Others, ...
Are you familiar with the different methods used for water treatment?	Choose from: Yes, very familiar Somewhat familiar No, not familiar
Which water treatment methods do you use?	Choose from: Chlorination Filtration Boiling UV treatment Reverse osmosis Ozonation None Other,

	
Which factor (s) influence the choose of water treatment method you use	Choose from: Cost-effectiveness Effectiveness in removing contaminants Ease of use Environmental impact Health safety Other, ...
What is the alternative source you use when water is not available from the main sources?	Choose from: Buy from vendors Collect from water tanker Collect from spring /fountain Collect from the River Travel distances to search for water Others, ...
Do you buy from alternative sources?	Choose from: Yes No
If you buy from alternative sources, how much do you pay?	Choose from: Free < R10.00 R10.00 – R35.00 >R35.00
Have you noticed any changes in water availability during different seasons?	Choose from: Yes No
If the answer is yes, which season do you notice changes in water availability?	Choose from: Dry season Wet season
How often do you face difficulties in accessing water during wet (summer)	Choose from: Always

seasons?	Sometimes Seldom Never		
How often do you face difficulties in accessing water during wet (winter) seasons?	Choose from: Always Sometimes Seldom Never		
Indicate consistency of water supply sources	Frequency	Wet (summer)	Dry (winter)
	Daily		
	Once a week		
	Once a month		
	Never		
How frequently do you experience water supply disruptions within a year?	Choose from: Always Sometimes Seldom Never		
How long does it take for disruptions to be fixed?	Choose from: Within three days Up to one week Two weeks Three weeks Month or longer		
What is your perception of the quantity of water from the source?	Choose from: Sufficient throughout the year Seasonal Not sufficient throughout the year		
If your answer is seasonal, which month (s) is the water available?			

How satisfied are you with the reliability of the current water supply?	Very dissatisfied Dissatisfied Neutral Satisfied Very satisfied
Indicate the water supply challenges you face with respect to source (s) of water supply	Choose from: Poor water quality Inadequate quantity of water Irregular supply or water shortages Lack of access to clean water sources Frequent water cuts Infrastructure issues (broken pipes, outdated system) Financial constraints Other, ...
How do these challenges impact your daily lives or activities?	Choose from: (Multiple selection allowed) Difficulty in meeting basic water needs Compromised hygiene and sanitation practices Health concerns due to poor water quality Agricultural or livelihood disruptions Other, ...
How long do you queue to get the water from the source?	Choose from: Less than 15 minutes Less than 30 minutes Less than 60 minutes More than 1 hour Not applicable
How long does it take to fill one bucket (25L) from a selected source?	Choose from: Less than a minute Less than 5 minutes

	Less than 10 minutes More than 20 minutes Do not know
How much water does your household use in a day?	Choose from: <25L 25-50(L) 50-100(L) 100-200(L) Above 200(L)
What are the primary uses of water within the household?	Choose from: HH consumption and use Vegetable husbandry Livestock husbandry Other uses, ...
Is the current supply of water sufficient to meet the needs of your household?	Choose from: Sufficient More than sufficient Not sufficient
If the water is not sufficient, what could be the reason(s) for water supply not meeting the demand	Choose from: Inadequate water sources Poor infrastructure Poor management and distribution Bad water quality/pollution of water Distance to the water source is far Others, ...
Which improvements do you think are necessary to enhance the reliability of the water supply in the village?	Choose from: Upgrading aging infrastructure Implementing better monitoring systems Increasing water awareness on water conservation Strengthening security measures to prevent

	vandalism Exploring alternative water sources Other.....
How important do you think these improvements should be addressed rapidly?	Choose from: Extremely important Very important Important Not important
How would you rate the current state or condition of the water supply sources in your village?	Choose from: Excellent Good Fair Poor Very poor

Section 3: community participation in water supply and management

Which institutions are there to influence water supply, water use and management of water?	Choose from: Municipality Water Service Authority Municipal water service workers Community based water service workers Traditional authorities Water committee Civic organisation Other.....
Are you a member of any of the institutions mentioned above?	Choose from: Yes No
If yes, which ones?	
How effective do you think community engagement is in addressing water supply	Choose from: Very effective

issues?	Effective Neutral Ineffective Very ineffective
Do you participate in community water supply and management activities?	Choose from: Yes No Not aware of any
How would you describe the level of community participation in maintaining the water supply infrastructure?	Choose from: Highly involved Moderately involved Not involved Do not know
How would you describe the level of community participation in payment of the water supply service?	Choose from: Highly involved Moderately involved Not involved Do not know
What do you believe are the primary responsibilities of community members regarding water supply system maintenance?	Choose from: (multiple selection allowed) Reporting leaks or damages Participating in repair or maintenance activities Contributing financially for system repairs Promoting water conservation practices Protecting water sources from vandalism Protecting and safeguarding water infrastructure Payment for water supply service Others, ...
Do you pay for water services?	Choose from: Yes No
If "Yes", how much do you pay?	Choose from:

	R0-R50 R50-R100 R100-R200 More than R200
How often do you pay?	Choose from: When there is no diesel When the machine is broken Every month Other, ...
Do you think community members should pay for water services?	Choose from: Yes No
If "Yes", why do you think community members should pay for water services?	Choose from: Maintenance and operational cost Reliability of water supply Other.....
What are the reasons for not participating in paying for water services?	Choose from: Affordability issues Lack of transparency in billing Irregular water supply Inadequate infrastructure Poor service delivery Other
Do you pay for operation and maintenance of the water supply system?	Choose from: Yes No
If yes, how often do you pay for operation and maintenance of water supply infrastructure?	Choose from: When there is no diesel When the machine/pump is broken Every month Other

What challenges do you face when participating in water supply system maintenance?	Choose from: Lack of awareness/information Limited resources or funds Insufficient community engagement Infrastructure accessibility issues Other, ...
Do you think people should pay for water services?	Choose from: Yes No
What do you think people who can't afford to pay, should contribute to water supply services?	Choose from: Contribute labour to the system Provide security services to infrastructure Do monitoring and support to the system Other (please specify)
In your opinion who should cover the operation and maintenance costs?	Choose from: Household Water committee The government/municipality The chief Communities' contributions Other, ...
Do you believe the community is actively involved in maintaining water sources?	Choose from: Strongly agree Agree Neutral Disagree Strongly disagree
How important do you think it is for the community to be actively involved in maintaining the water supply infrastructure?	Choose from: Extremely important Very important Important

	Not important
Rate the level of community cooperation in resolving water supply issues.	Choose from: Very high High, Moderate Low Very low
Do you think the local government should allocate more resources for improving water supply?	Choose from: Yes No Not sure
What kind of support or resources do you think would enhance more community participation in water supply system maintenance?	Choose from: Training workshops on maintenance techniques Access to maintenance tools and equipment Financial incentives/rewards for active participation Regular communication and updates about the water supply system Collaborative decision-making processes Others, ...
How effective do you think community engagement is in addressing water supply issues?	Choose from: Very effective Effective Neutral Ineffective Very ineffective