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Tebogo Vivian Siphambe

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Designing of a rainwater harvesting system to foster the utilization of rainwater as an alternative water source and address the obstacles preventing its adoption: A case study of Westwood International School, Gaborone, Botswana.

Defended on 22/04/2024 Before the Following Committee:

Chair	Dr. Boumediene Maamar	University of Tlemcen, Algeria
Supervisor	Prof. Piet Kebuang Kenabatho	University of Botswana
Co-Supervisor	Prof. Chicgoua Noubactep	University of Göttingen, Germany
External Examiner	Prof. Dr-Ing-Benedict M. Mutua	The Technical University of Kenya, Kenya
Internal Examiner	Prof. Bessedik Madani	University of Tlemcen, Algeria

**PAN AFRICAN UNIVERSITY FOR WATER AND ENERGY SCIENCES
(INCLUDING CLIMATE CHANGE)**

The potential of rainwater harvesting for improved water security and sustainable management in semi-arid regions: Case study of Westwood International School Gaborone, Botswana

A master's thesis submitted to the Pan African University Institute for Water and Energy Sciences (Including Climate Change) in partial fulfilment of the requirements for the award of Masters of Science degree in water sciences (Engineering Track).

Presented By

Tebogo Vivian Siphambe

(B.Eng Soil and Water Conservation Engineering)

Supervisor: Prof. Piet Kebuang Kenabatho

April, 2024

Tlemcen, Algeria

APPROVAL PAGE

This supervised research project has been examined and approved as meeting the required standards of scholarship for the partial fulfillment of the requirements for the Master degree in Water Engineering.

Tebogo Vivian Siphambe  22/03/2024

Submitted by

Signature

Date

Professor Piet Kebuang Kenabatho  22/03/2024

Supervisor

Signature

Date

Professor Chicgoua Noubactep  22/03/2024

Co-Supervisor Signature

Date

Internal Examiner

Date

External Examiner Date

DEDICATION

This thesis is dedicated to my husband and children. We've made it!

STATEMENT OF THE AUTHOR

By signing below, I attest that this thesis/dissertation is solely my creation. Throughout its development, data collection, analysis, and finalization, I have adhered to ethical standards of academic integrity. All scholarly content has been duly acknowledged with precise citations and references. I confirm the proper citation and referencing of all sources utilized in this work, has taken utmost care to prevent plagiarism.

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Name: Tebogo Vivian Siphambe Signature:

A handwritten signature in blue ink that reads "T. Siphambe". The signature is written in a cursive style with a large initial "T" and a stylized "S" for "Siphambe".

Date: 22 March 2024

Track: Water Engineering

PAU Institute: PAUWES

BIOGRAPHIC SKETCH

Tebogo Vivian Siphambe completed her Bachelor's degree BSc Soil and Water Conservation Engineering from Botswana College of Agriculture now Botswana University of Agriculture and Natural Resources in 2013. She previously worked as a teacher, a data collector at Mahalapye Water Affairs Botswana and at Water Utilities Corporation Botswana as a Wastewater Treatment Plant Operator before joining PAUWES for Master's Degree. In her study at PAUWES she was elected class representative, where she was responsible for leading and representing students at various platforms like administration.

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ACRONYMS

DPSIR- Driving Forces- Pressures- State- Impacts- Responses

DWS-Department of Water and Sanitation

FEE- Foundation for Environmental Education

IB- International Baccalaureate

ICT- Information and Communication Technology

IWRM- Integrated Water Resources Management

NGO-Non-Governmental Organization

NYC- New York City

PRA- Participatory Rural Appraisal

RHS- Rainwater Harvesting Systems

RWH- Rainwater Harvesting

RRWH-Roof Rainwater Harvesting

SMT- Senior Management Team

WIS- Westwood International School

WUC- Water Utilities Corporation

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ABSTRACT

Rainwater harvesting (RWH) stands as a versatile solution in regions with water scarcity, offering an additional and self-sufficient water source while safeguarding existing resources. The need for sustainable water management in Botswana is critical due to limited water resources and reoccurring drought in the country. To address the issue of water scarcity and improve utilisation of water resources, this study explored the potential of RWH for improved water security and sustainable management in semi-arid regions, using Botswana as a case study. This was done by assessing the current state of RWH awareness, designing an optimizing RWH system, and proposing strategies for RWH implementation in Botswana. Adopting a qualitative case study research design, data was obtained using interviews conducted with 14 purposively selected staff personnel from different departments in Westwood International School (WIS) in Gaborone, Botswana. Findings from collected data which was analyzed thematically gave varying insights on the potentials of RWH in Botswana. Generally, there is awareness about RWH in WIS but when it comes to adoption, cost, limited space for storage tanks, and Botswana's low rainfall patterns were major challenges. These challenges can be overcome by exploring alternative storage solutions, enhancing public awareness campaigns, and advocating for policy support to incentivize RWH implementation. In addition to including RWH system in school curriculum to raise awareness, this study proposed a suitable design for WIS needs that can ensure full utilisation of RWH in the school, taking into consideration their intention and concerns. The proposed design is a dual system; it features both underground storage and surface storage. The surface storage is used for awareness raising where key messages about RWH will be illustrated for educational purposes. The underground storage will store excess rainwater that surface storage could not cater for. Findings underpinned the need for collaboration, continuous monitoring and evaluation of RWH initiatives to impact water availability, quality, and sustainability. Additional research is needed to broaden the examination of RWH awareness among a larger and more diverse participant pool. This will provide deeper insights into RWH practices and water usage dynamics, facilitating more informed decision-making and effective resource management strategies at WIS.

Keywords: Botswana, rainwater harvesting, decentralised water management, resource management, sustainability.

CHAPTER I: INTRODUCTION

1.1 Background to the study

Rainwater harvesting (RWH) is a low-impact, decentralized technique for capturing, storing, and delivering rainwater for potable or non-potable purposes Wang & Zimmerman(2015). According to Hari(2019), rainwater harvesting proves vital, particularly in arid urban zones and areas with limited water availability.

Rainwater collection for urban drinking water has a rich history, particularly in semi-arid regions. It dates back to the establishment of permanent settlements during the late Neolithic and early Bronze Age periods. In areas like Mesopotamia (now Iraq and Jordan), inhabitants recognized the vital importance of water for survival, leading them to adopt rainwater harvesting as one of the earliest methods for water supply. In Jordan, this tradition of RWH systems is deeply intertwined with specific cultural values that have been acquired and passed down through successive generations Abdulla(2019). Similar systems were identified in Minoan Crete and the Indus Valley around the 3rd millennium BC, showcasing deliberate construction and utilization of water supply networks and bathrooms Angelakis(2016). Throughout the driest and most rainfall-abundant regions globally, rainwater harvesting has found extensive use.

While RWH dates back to ancient Roman times, its prevalence diminished with the advent of centralized treatment facilities providing treated drinking water. Presently, rainwater harvesting is experiencing resurgence due to diverse environmental and economic factors. Undoubtedly, technological advancements and methods have significantly evolved since the days of ancient Rome, but the fundamental theory remains unchanged, Abdulla(2019). Techniques like safe RWH can be promoted and practiced as an effort to promote water conservation and sustainable water management Gomes *et al.*,(2012)

In Africa and Asia, this practice has been entrenched for millennia, employing traditional earthen containers, basic water channels, or by channelling water from roof edges Ertop, *et al.*,(2023). In China, Gansu and nearby provinces, a regional government initiative, initially launched as the 1-2-1 program in 1995, effectively addressed drinking water challenges,

significantly improving the quality of life for over a million rural residents by installing water tanks in home courtyards and eliminating the need for water transportation Cook(2004).

A national program for large-scale rainwater harvesting, called "One Million Rural Cisterns (P1MC)", has been implemented in rural areas across the state of Minas Gerais (Brazil). It involves the construction of 372,000 cisterns with a storage capacity of 16 m² of water. The program has successfully provided water supply to rural populations in that semi-arid region Gomes *et al.*,(2012).

Rainwater harvesting stands as a versatile solution in regions with water scarcity, offering an additional and self-sufficient water source while safeguarding existing resources. The selection of a suitable system is based on the specific water needs of the area and its prevailing climatic conditions Semaan *et al.*,(2020). Its straightforward technology ensures easy maintenance at a low cost, curbing the demand on both surface and groundwater Hasse(1989). With its flexibility, the public can easily grasp its operation and maintenance, while also aiding flood control during heavy rainfall, making it an invaluable asset in sustainable water management strategies Ertop *et al.*,(2023). RWHs have the potential to alleviate pressure on the centralised water system/ decentralised infrastructures Semaan *et al.*,(2020).

In Southern Sudan, cost-effective methods for harvesting rainwater were developed. These included using simple materials like corrugated iron rooftops, gutters, diverters and plastic or ferrocement tanks to collect and store rainwater. Plastic sheeting, alongside locally available items, were utilized to collect rainwater and direct it into suitable containers like jerry cans and drums. Locally sourced materials, including clay pots for storage, were commonly employed Burt & Keiru(2009). One particularly successful design involved securing a plastic sheet to four poles in the ground, enabling water to be channelled into containers placed along the sheet's edge or through a central hole. With a 6 m² plastic sheet, around 100 litres of water could be collected in approximately 30 minutes of rainfall. Additionally, traditional rainwater harvesting methods in Uganda and Sri Lanka involved utilizing natural items like banana leaves or stems as temporary gutters on trees, gathering up to 200 litres of water during a single storm Burt & Keiru(2009).

Given the rising water scarcity and growing need for water, RWH emerges as a highly promising solution for freshwater supply. Challenges such as strain on rural water sources, heightened environmental impacts from new initiatives, and declining water quality restrict the

government's capacity to fulfil the demand for freshwater. However, these challenges also create an opening for enhancing water supplies through the adoption of rainwater harvesting technology Kamutati(2006).

Botswana, a dry, landlocked country with around 2 million people, with an area of around 580,000 square kilometres, experiences an annual population growth of 2.4%. In the north-west of Botswana lies Okavango River. This is the only permanent water source in Botswana that holds significant amount of water. There are no permanent rivers elsewhere within Botswana besides trans-boundary waters. Drought is a reoccurring circumstance; most rivers are seasonal therefore water is a scarce resource Jefferis & Kenewendo(2012). According to Hasse(1989) and Setlhogile & Harvey(2015) the need for sustainable water management is critical due to limited water resources. Roughly 10% of the population resides in Gaborone, in the south-east of Botswana. They continued to state that rainfall averages at 416 mm per year, varying from 650 mm in the north to 250 mm in the south-west. Inefficient storage, transportation, and usage of water could hinder Botswana's future economic growth as resources are constrained. Projections indicate that water demand might reach 285.8 cubic megametres (Mm³) annually by 2030, a significant increase from 193.4 Mm³ in 2000.

The historical documentation of rainwater harvesting in Botswana is limited, but it is believed that for centuries, Batswana collected rainwater from their thatched roofs into containers and pits Hasse(1989). The love for the taste of rainwater is a common response among Batswana Habangana & Aliwa(2006). The research further elaborated that the first significant study on rainwater RWH took place around 1969, involving ground catchment tanks at 12 Primary Schools in the Eastern Region of Botswana to store water for irrigating school gardens. Unfortunately, the project failed due to its labor-intensive nature. Botswana has a good history of RWH where it's seen in majority of primary schools, clinics and other government buildings Hasse(1989).

There is limited studies on institutional rainwater harvesting in Botswana and there is high dependence on centralised water system. Baumann and Boland, 1998, cited on Toteng(2008) alluded that Botswana is a water scarce country. Gaborone, being one of the fastest growing cities in Africa Mosha(1996), this rapid urbanisation put strains on the available water resources due to increased water demand. Generally, water use efficiency in Gaborone is negative. There is a lack of widespread adoption of effective household water conservation products which highlights the potential for implementing water-saving initiatives and alleviates

current limitations. Decentralised systems like RWH would improve water security and sustainability at a household level in Gaborone.

In Ngamiland, Botswana Kujinga *et al.*,(2014) studied how households cope with short-term water insecurity and adapt to long-term challenges. As part of their adaptation strategy, a small percentage (5%) of households in different areas (3.4% in Maun, 1.2% in Matlapana, and 0.4% in Somelo) practice RWH using rooftop gutters that lead to storage tanks ranging from 2.5 m³ to 10 m³. This harvested water lasts until the following rainy season, usually from around March, and is used only when there is no water from the main sources. About 63% of households rely on RWH as a short-term coping mechanism to combat water shortages. However, despite facing water scarcity issues, the community also resorts to other measures like fetching untreated water from perennial rivers and using neighbours' taps or bulk water hauling. RWH is not widely adopted as a long-term solution to this ongoing problem.

Geospatial tools such as Google Earth Pro, Bing Maps, and software such as ArcGIS are incredibly useful for determining rainwater harvesting areas and identifying potential sites, particularly in situations where extensive on-site surveys are necessary Hari(2019). Geospatial technologies are tools used to map and analyse Earth's surface and patterns in human societies Center for Environmental Policy(2021).

To address the issue of water scarcity and improve utilisation of water resources, it's crucial to create new methods and reassess the ones we currently use. Over time, numerous methods for harvesting water have been created. Consequently, their existence diverse explanations and classifications for these techniques, lacking a clear, standardized name for practices, used both locally and globally. Two prevailing criteria are frequently employed to classify water harvesting systems: the method of water storage utilized and the size and type of the catchment area Studer & Liniger(2013). The authors further outline the examples of water harvesting techniques based on catchment type are as follows; floodwater harvesting, macro-catchment water harvesting, micro-catchment water harvesting, courtyard and rooftop water harvesting. Elements comprising roof rainwater harvesting (RWH) systems typically include a collection surface (such as a roof), a system for conveying water, a cistern or storage tank, filtration mechanisms, a delivery system, and treatment processes Abdulla(2019).

In water management there is a clear need for change as an adaptability for integrated water management. *“Sustainable management of water resources and the implementation of*

Integrated Water Resources Management (IWRM) cannot be realized unless current water management regimes undergo a transition towards more adaptive water management” is one of the logic discourses towards water management as highlighted by Pahl-Wostl *et al.*,(2008). It is therefore necessary to establish the correlation between implementing rooftop rainwater harvesting systems within institutions and addressing issues related to water scarcity and the management of water resources in Gaborone, Botswana.

This study was motivated by poor rate of sustainable water management practices like RWH in Botswana, even though Botswana is known for its water scarcity and its aridity. Therefore, the researcher aimed to determine the potentiality of institutional rainwater harvesting in Gaborone, Botswana. The study has therefore determined the potential of institutional RWH at Westwood International School, Gaborone, Botswana focusing on a specific technique that ensures optimum sustainable water management practice as a measure to manage water scarcity using geospatial tools.

1.2 Statement of the problem

The water scarcity and aridity of Botswana present a pressing challenge, threatening the availability of vital water resources for ecosystems, agriculture, and human consumption, thereby impacting livelihoods and sustainable development within the region. Currently, Botswana heavily relies on underground water resources to meet its water demands. However, the hydrologic cycle reveals that the groundwater is just a small fraction of infiltrated rainfall, and experience teaches that rainwater harvesting (RWH) enhances groundwater recharge Brands *et al.*,(2016). Therefore, RWH should be regarded as one of the options for sustainable water management in regions already facing a growing challenge of water scarcity Siphambe *et al.*,(2024). It is rather counterintuitive that RWH has not been universally adopted in Botswana. More so, RWH is often perceived as occasional coping solution to increase water conservation. This study addressed the issue of underutilisation rainwater harvesting in Botswana, with a specific and deliberate focus on the urban context at institutional level and additionally investigated the factors influencing its adoption, as well as its potential implications for sustainable water resource management.

1.3 Research objective of the study

To comprehensively examine the awareness, adoption levels of rooftop rainwater harvesting (RWH) practices and design a system suitable for Westwood International School, Gaborone, and analyse the factors influencing its current state.

1.3.1 Main Objective

To evaluate the feasibility and efficacy of implementing an optimized rooftop rainwater harvesting (RWH) system at Westwood International School in Gaborone, while considering local conditions and constraints, with the aim of maximizing water harvesting efficiency.

1.3.2 Specific objectives

The specific objectives of the study were to:

- i. To investigate the current state of RWH awareness and adoption in Westwood International School, Gaborone.
- ii. To develop or adopt an optimized rooftop rainwater harvesting (RWH) system at Westwood International School in Gaborone by evaluating its feasibility and ensure maximum efficiency in water harvesting.
- iii. To propose strategies for implementation of roof rainwater harvesting in Botswana

1.4 Research questions

- i. What is the state of RWH awareness and adoption in Westwood International School?
- ii. What RWH optimized rooftop system is at Westwood international School?
- iii. Which strategies could be relevant for the implementation of RWH in WIS?

1.5 Scope of the study

This research sought to identify the factors contributing to the limited adoption of rainwater harvesting in Gaborone, Botswana, with a specific focus on Westwood International School. Additionally, it aimed to develop a tailored, effective system to address these barriers and promote more efficient utilization of rainwater.

1.6 Significance of the study

This study helps to highlight the importance of RWH in Botswana, identify some key barriers to RWH and their possible solutions. It gives relevant technical information to policy makers, and raise awareness about rainwater harvesting for educational purposes. It paves the way for the widespread adoption of sustainable rainwater harvesting practices in Gaborone, contributing to water conservation, resilience against water scarcity, and sustainable urban development in Botswana. This study plays a role in the realisation of Botswana's vision 2036, Pillar 3 "By 2036 sustainable and optimal use of natural resources will have transformed our economy and uplifted our people's livelihoods. This pillar includes the ecosystem functions and services, sustainable utilization of natural resources, water security, energy security, sustainable land use and management, sustainable human settlements, climate resilience and disaster risk reduction and pollution and waste" (Vision 2036 Presidential Task Team , 2016). It is also aligned with SDG 6, Target 6.4 "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity" (United Nations, 2023).

1.7 Outline of the Thesis

The thesis is structured such that Chapter 1 introduces the topic, while Chapter 2 delves into water demand and availability, awareness and adoption of rainwater harvesting, and the challenges associated with rooftop rainwater harvesting including considerations of affordability, efficiency, and sustainability. This chapter also outlines strategies for implementing RWH, concluding with the DPSIR framework, which analyses the intricate interactions between human activities and the environment.

Chapter 3 provides an overview of the steps taken to collect, organize, and analyse relevant data to address the research questions. In Chapter 4, the results and discussions are presented in two parts: the first part covers the findings and discussions from interviews, while the second part proposes designs that WIS can adopt for installing RWH systems.

Chapter 5 presents the Conclusion and Recommendations derived from the study, followed by References and Appendices.

CHAPTER II: LITERATURE REVIEW

2.1 Introduction

Rainwater harvesting (RWH) has emerged as a critical strategy for mitigating water scarcity and promoting sustainable water management practices worldwide. Within this context, awareness and adoption of RWH have garnered increasing attention as essential components for its successful implementation. Understanding the factors influencing awareness levels and adoption rates of RWH systems is paramount for fostering widespread acceptance and utilization of this water conservation technique. Moreover, the affordability, efficiency, and sustainability of rooftop rainwater harvesting (RRWH) systems have become focal points in discussions surrounding urban water management Dijk *et al.*,(2020). Assessing the economic viability, effectiveness, and environmental impact of RRWH systems is crucial for informing decision-making processes and encouraging their widespread adoption in urban settings. Furthermore, exploring various strategies for implementing RWH initiatives is essential for overcoming barriers and maximizing the effectiveness of RWH programs. By examining the challenges and opportunities associated with RWH implementation strategies, stakeholders can develop tailored approaches to promote the integration of RWH into water management practices at local, national, and regional levels. This section delves into the key themes of awareness and adoption of RWH, the affordability, efficiency, and sustainability of RRWH systems, and strategies for implementing RWH initiatives, aiming to provide insights into the current state of knowledge and identify areas for future research and intervention.

2.2 Water demand and availability

The worldwide demand for water has been steadily rising at approximately 1% annually, influenced by factors such as population growth, economic advancement, and shifting consumption habits. This trend is expected to persist and experience significant growth in the next two decades. While agricultural demand will continue to be the largest overall user, industrial and domestic water needs are projected to escalate at a faster pace. Notably, the bulk of this heightened demand will emerge from nations with developing or emerging economies. Concurrently, climate change is exacerbating the global water cycle, resulting in wetter regions experiencing increased precipitation and drier regions facing exacerbated aridity Siphambe *et al.*,(2024). Presently, around 3.6 billion people, nearly half of the global population, reside in areas susceptible to water scarcity for at least one month annually, a figure projected to rise to

approximately 4.8–5.7 billion by 2050 (UN-Water, 2018). According to UNICEF(2021), presently, 1.42 billion individuals, encompassing 450 million children, reside in regions characterized by high or exceedingly high-water vulnerability.

For instance, figure 2.1 displays water demand projections represented by the orange line (high water use), the yellow line (medium water use), and the green dashed line (low water use). These projections encompass Botswana's entirety and incorporate analyses on factors such as population growth forecasts, per capita water consumption, and water usage across various sectors including: industrial, mining, and agricultural activities (both crops and livestock). The estimated water demand for 2021 is approximately 278 million cubic meters per year (Mm^3/year) (Department of Water and Sanitation-Ministry of Land Management, Water and Sanitation Services,2021). Additionally, the current average water availability across Botswana is illustrated by the blue vertical bar below, indicating an average annual water supply of around 225 million cubic meters (Mm^3/year). This total water availability encompasses existing river flows, reservoirs, and groundwater resources (Department of Water and Sanitation-Ministry of Land Management, Water and Sanitation Services,2021).

It is expected that upcoming infrastructure projects in Botswana will incorporate wastewater reuse as an alternative water source, alongside sustainable groundwater development efforts. This combined approach is projected to augment the total available water supply to approximately 265 Mm^3/year by 2025, as indicated by the coloured vertical bars in Figure 2.1.

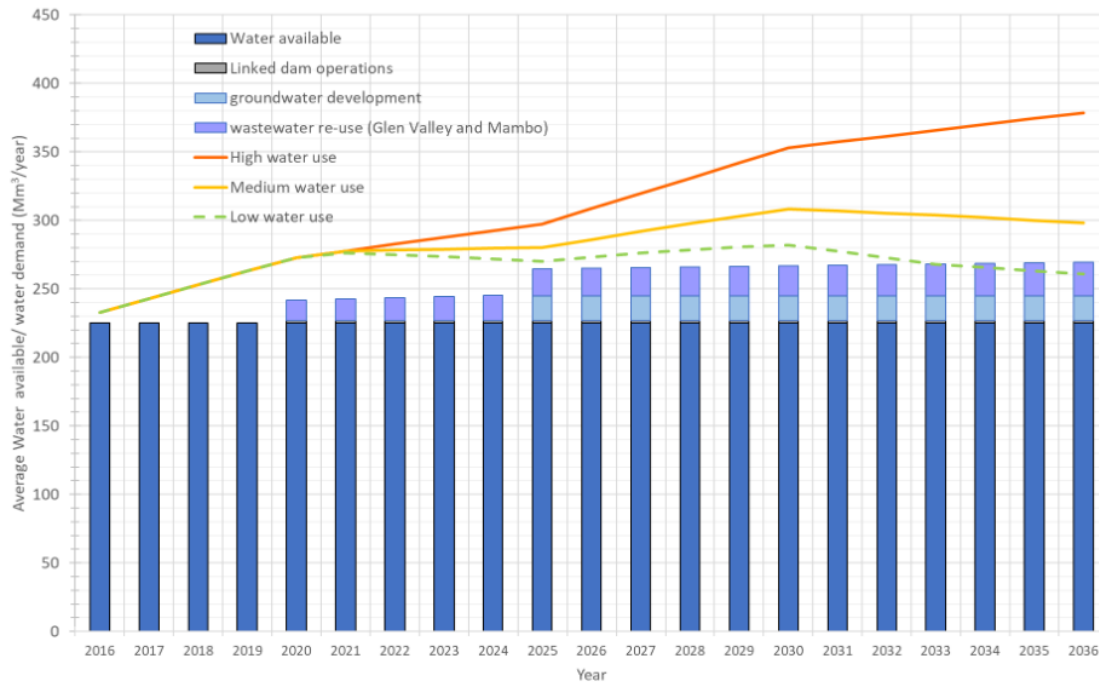


Figure 2. 1 Chart depicting water conservation and demand management

Source: (Department of Water and Sanitation-Ministry of Land Management, Water and Sanitation Services, 2021)

2.3 Awareness and adoption of rainwater harvesting

The assessment conducted by Klein *et al.*,(2023) on the financial feasibility of rainwater harvesting (RWH) implementation on permeable pavements in Florianópolis, Brazil, underscores the importance of community involvement in project planning. By incorporating the community's perspective through surveys, the project ensured the adoption of user-friendly solutions, aligning pedestrian behaviours with eco-friendly practices. This approach highlights the crucial role of raising awareness to enhance the adoptability and effectiveness of RWH systems.

Similarly, Ghosh & Ahmed(2023) emphasize the significance of understanding the design, operation, and maintenance aspects of RWH systems for effective household management. Public awareness about the positive impacts of proper operation and maintenance practices is essential and can be achieved through capacity-building programs facilitated by government institutions, NGOs, and donor agencies. Establishing institutional operation and maintenance

strategies, along with dedicated resources, is key to the successful operation of RWH systems, especially at the household level.

However, despite strategic initiatives and policies promoting RWH systems, (Mutschinski & Coles, 2023) highlight a gap between national recognition and local implementation efforts in Kenyan counties. Challenges include limited access to knowledge, high investment requirements for large-scale systems, inadequate technical understanding, and the absence of standardized regulatory frameworks. Similarly, in Botswana, rainwater harvesting is identified as a gap in the implementation of Integrated Water Resources Management (IWRM) strategies, despite its potential as a water source for the country (Department of Water and Sanitation-Ministry of Land Management, Water and Sanitation Services, 2021).

Overall, there is a noticeable disconnect between institutional-level preparations and practical implementation of RWH techniques across Africa (Staddon *et al.*, 2018; Hoffman *et al.*, 2021; Nya *et al.*, 2023). This disparity underscores the need to bridge the gap between awareness and adoption of RWH technology, particularly in countries like Botswana, where understanding and addressing this divide are paramount for effective water resource management.

2.4 Challenges of rooftop rainwater harvesting

2.4.1 Affordability

A study by Khan (2023) in Islamabad, Pakistan, delved into the challenges and cost efficiency associated with current water sources for both drinking and non-drinking purposes, comparing them with the implementation of Rainwater Harvesting (RWH) systems. Through the evaluation of four models, the study revealed that while some existing supply sources are cost-effective, they fall short in meeting demand, whereas others are more expensive but adequate. The integration of RWH systems with the government supply line emerged as a cost-effective solution for meeting potable water demand, while also addressing non-potable water needs. The study concluded that RWH systems, particularly when combined with government infrastructure, offer a more economically viable solution for both potable and non-potable water usage.

According to Guizani (2016), the importance of accurately calculating the expenses associated with RWH units, which encompass material costs, transportation, labour, and maintenance. Key components of planned RWH systems include; collection pipes, gutters, down pipes, filter

chambers, storage tanks, distribution pipes with taps, and overflow pipes, with storage tanks constituting a significant portion of the system's cost.

Rainwater harvesting systems, as highlighted by Yawalkar *et al.*,(2021), employ simple and easily maintainable technologies, resulting in minimal operational expenses. These systems not only promote self-sufficiency but also contribute to the conservation of water resources (Nya *et al.*, 2023; Siphambe *et al.*, 2024). Burt & Keiru (2009), further underscore the simplicity and effectiveness of RWH technologies, particularly in emergency situations, through their pilot initiative 'RWH in emergencies.' This initiative focuses on 'ultra-low-cost' rainwater harvesting innovations at the household level, employing readily available materials like plastic sheeting to capture rainwater efficiently (as illustrated in Photograph 1 given as figure 2.2). Such initiatives demonstrate the versatility and adaptability of RWH systems in providing sustainable water solutions, even in challenging circumstances.



(Burt & Keiru, 2009)

Figure 2. 2 Rainwater harvesting system using plastic sheet

According to Pembe-Ali, *et al.*,(2021), the innovative Kilimanjaro Concept (KC), which relies on rainwater harvesting (RWH), has the potential to address seawater intrusion in Unguja (Zanzibar, Tanzania) while ensuring a universally accessible safe drinking water supply on the island. The rationale behind this lies in analysing the water balance of the entire Island. The study demonstrates that by systematically harvesting rainwater, storing it in sufficient quantities, and allowing for partial infiltration, it is possible to reverse seawater intrusion and

ensure a consistent safe drinking water supply. Additionally, the study proposes water treatment using cost-effective technologies such as filtration and adsorption. The applicability of the KC approach to small islands is also highlighted. Further research is recommended to pilot test this concept on Unguja Island and other island nations. The KC was introduced six years ago as a pragmatic solution for safe drinking water supply in fluoride polluted areas Marwa *et al.*,(2018). This has however rapidly evolved to the driving concept for a universal RWH-based integrated water resources management (IWRM) (Nde-Tchoupe *et al.*,2019; Qi *et al.*,2019; Nya *et al.*,2021; Siphambe *et al.*,2024). In retrospect, the KC is an independent of the century-old vision of King Parakkramabahu (1153-1186 A.D.) of Sri Lanka who once stated: "Not let a single drop of rainwater flow to the sea without first being used for the welfare of mankind" Van Meter *et al.*, (2014). According to Siphambe *et al.*,(2024), there are many similar slogans across the modern society, including: "all water, for all and by all", "catch it when you can", "catch it where it falls", "catch it while you can", "from drain city to rain city" or "never let rainwater flows to the sea".

2.4.2 Efficiency

The efficiency and reliability of Rainwater Harvesting Systems (RWHs) have been extensively studied across various climatic regions, shedding light on factors influencing their performance and effectiveness (Hasse,1989; Khan, 2023).

Xueer *et al.*,(2017) conducted an assessment of RWH efficiency and economic viability in different climatic zones in China, revealing that RWH systems with larger storage capacities exhibit increased water conservation efficiency and supply reliability, especially in regions with lower water demand and higher humidity. Conversely, higher water demand scenarios, lower rainfall, and larger storage capacities are associated with higher storm water capture efficiency.

Similarly, Molaei *et al.*,(2019) investigated RWH performance in two cities with contrasting climatic conditions, demonstrating that increasing tank size led to noticeable rainwater savings in both cold climate and semi-arid climate. This underscores the importance of storage capacity in maximizing RWH efficiency across diverse environmental contexts.

A study by Ghosh & Ahmed (2023) contributed to the discourse by establishing a theoretical framework to assess the efficiency of RWH systems post-installation in the south western

coastal region of Bangladesh. Their analysis highlighted several influential factors, including family size, income level, maintenance regularity, and organizational support, in determining RWH effectiveness.

However, Taffere *et al.*,(2016) identified shortcomings in conventional RWH systems in Mekelle city, Ethiopia, attributing their unreliability to suboptimal design and inadequate consideration of factors such as rainfall variability, family size, water demand, rooftop area, and storage tank size.

Despite these insights, there remains a notable research gap concerning the effectiveness of Roof Rainwater Harvesting (RRWH) in Botswana. The government through the Department of Water Affairs-Ministry of Minerals, Energy & Water Resources(2013) noted underutilization of rainwater tanks in government institutional houses due to inadequate maintenance, indicating a lack of understanding or appreciation for RRWH, even in water-scarce regions.

Addressing this gap, the present study evaluated the viability of RRWH in Botswana and explored strategies for optimizing design to ensure optimal efficiency and utilization of rainwater resources. By filling this research void, the study sought to contribute valuable insights to the field of sustainable water management and inform policy and practice in water-scarce regions.

2.4.3 Sustainability

The study conducted by Yawalkar, *et al.*,(2021) highlights the suitability of rooftop rainwater harvesting for meeting water needs in the Bhandara district of Maharashtra, India, particularly within College Campuses. This method is anticipated to contribute significantly to water fulfilment up to a specific level, showcasing its economic efficiency and its potential as a viable solution to address global water scarcity issues. A study by Huang *et al.*,(2021) argues that viewing Rainwater Harvesting (RWH) solely as an effective alternative water supply solution for addressing water scarcity is misguided. Their study emphasized the importance of implementing a systematic approach to RWH and partial infiltration wherever rain occurs. This approach not only mitigates the adverse effects of flooding but also replenishes groundwater, stores water for agricultural and livestock use, and conserves conventional water sources. In essence, RWH should form the cornerstone of water management practices globally Siphambe

et al.,(2024). Achieving this objective is feasible even in resource-constrained settings, as infiltration pits and small dams can be constructed using local expertise and materials.

Across Sub-Saharan Africa, where enhancing water productivity is paramount for substantial livelihood improvements, the viability of rainwater harvesting assumes critical importance. A study by Pachpute *et al.*,(2009) conducted a study in the Makanya catchment of rural Tanzania to assess the sustainability of various storage-based rainwater harvesting systems. Their findings underscored the influence of factors such as rainfall variability, runoff quality and quantity, local skills and investment capacity, labour availability, and institutional support on the sustainability of these systems.

In Botswana, traditional rainwater harvesting methods involve collecting rainwater from ground surfaces or thatched and corrugated iron roofs using various containers Gould(1997). The study Mpatane *et al.*,(2016) evaluated the socio-economic viability of Rainwater Harvesting (RWH) methods for crop cultivation in the semi-arid region of Bobirwa Sub-district, Botswana. Inadequate and unpredictable rainfall emerged as a primary limitation to the effectiveness of RWH. Data collection primarily relied on Participatory Rural Appraisal (PRA) techniques and field experiments managed collaboratively by researchers and farmers. However, there is limited literature available on the potential of collecting rainwater from institutional rooftops in the country. Therefore, the second research question aimed at exploring the optimization of rooftop rainwater harvesting systems at Westwood International School. This investigation sought to evaluate the sustainability and effectiveness of rooftop rainwater harvesting in Botswana, particularly within institutional settings, offering valuable insights into sustainable water management practices in the region.

2.5 Strategies for implementation of RWH

In India at Mangalore University, Mangalagangothri, several water conservation strategies have been implemented on Campus. Among the most significant is the implementation of rainwater harvesting using rooftop catchments and check-dams. Together, these measures account for approximately 50% of water conservation on Campus. In this case, two dams and a reservoir with a capacity of 2,000 litres were constructed to store rainwater Yadapadithaya *et al.*,(2022). Two more additional RWH systems based on rooftop were constructed on two different campus blocks; the lecture hall complex and humanities block, with storage capacities of 100 m³ and 200 m³, respectively. The addition of these two constructed rainwater-harvesting systems,

combined with existing ones, has enabled the Campus to achieve self-sufficiency in sustaining the natural vegetation (463,192 m²), planted vegetation (439,670 m²), and gardening areas on the premises Yadapadithaya *et al.*,(2023).

Most research indicates that Rainwater Harvesting (RWH) systems are limited in their infrastructure capacity and often come with high costs El Bouzidi, Anouar *et al.*,(2024). However, previous evaluations overlook two crucial advantages: multi-functionality and high adaptability. By enhancing the integration of these benefits in their analysis of 1.06 million buildings with diverse design and water demand characteristics, along with 20-year hourly precipitation records in New York City (NYC), Dijk *et al.*,(2020) demonstrated a different perspective. Contrary to existing findings, they showed that strategically designed, financed, and implemented rooftop RWH systems in all or a subset of the buildings can address significant infrastructure development needs for water supply and stormwater management. RWH implementation, particularly through public-private partnerships (PPP) in 43–96% of the buildings, has the potential to fulfil 17–29% of the city’s non-drinking water demands while simultaneously reducing public expenditure per unit of water supply by 13–85%. Moreover, citywide distributed RWH implementations prevent 35–56% of rooftop runoff from entering the sewage system, rivers, and/or waterways per month, with observed reductions in rooftop runoff reaching as high as 90% for a single

According to a study by Thuy *et al.*,(2019) for numerous years, rainwater harvesting has been extensively employed as a natural solution in rural regions of Vietnam, aiming to provide affordable, energy-efficient, and high-quality drinking water. Recently, there has been heightened interest from the Vietnamese government in utilizing rainwater for drinking purposes. However, despite governmental efforts, the outcomes have fallen short of expectations due to local barriers. Their study examined demonstration projects involving rainwater for drinking in specific areas of Vietnam, identifying technical, economic, and social obstacles while proposing potential strategies for overcoming them. A key take away from that study was the importance of promoting rainwater for drinking initiatives in developing nations, with a focus on achieving sustainability.

A study by Selabe & Minyoi (2018) suggests that despite the growing recognition of rainwater harvesting as a viable long-term solution to urban water scarcity, urban areas in Botswana have yet to fully embrace it as a sustainable development strategy. Despite the escalating water demand, there remains a notable lack of efforts to harness and utilize rainwater, a decentralized

and locally available resource. The findings reveal that rainwater harvesting adoption at the household level in Gaborone is still in its infancy, with many households primarily utilizing rainwater for storm water management rather than augmenting their water supply.

Nonetheless, the government through (Department of Water and Sanitation-Ministry of Land Management, Water and Sanitation Services, 2021) Promoted and implemented water conservation practices effectively hinged on two fundamental pillars: public awareness and education. These aspects play a crucial role in fostering water conservation practices among various stakeholders, including the general public, planners, and a diverse range of institutions, such as the education system. Public awareness and education efforts serve to sensitize individuals about water conservation issues, encourage public involvement and participation, and facilitate the exchange of knowledge and technology transfer regarding water conservation measures and techniques. Such activities can also inspire water planners, designers, developers, and end-users to explore and adopt suitable practical methods for conserving water resources.

Despite the existence of policies and plans aimed at promoting rainwater harvesting strategies in Botswana, there remains a disparity in their implementation and utilization specifically in Gaborone.

2.7 DPSIR Framework

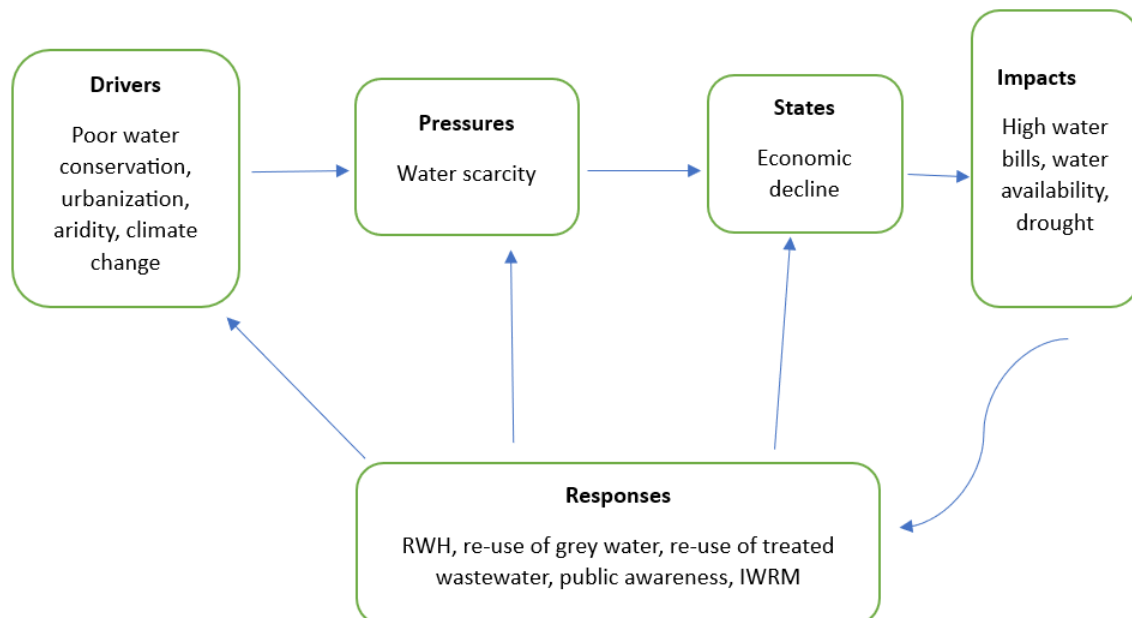


Figure 2. 3 DPSIR Framework

In the context of water resource management, the Drivers-Pressures-States-Impacts-Responses (DPSIR) framework provides a comprehensive lens through which to analyze the complex interactions between human activities and the environment. In this framework, drivers such as poor water conservation practices, rapid urbanization, increasing aridity due to climate change, and economic decline contribute to mounting pressures on water resources, resulting in water scarcity. This scarcity manifests in various states, including diminished water availability and heightened economic strain. Consequently, the impacts are felt across multiple sectors, characterized by soaring water bills, heightened vulnerability to drought, and compromised water quality. In response to these challenges, a range of strategies and interventions have been proposed, including the implementation of rainwater harvesting (RWH), the re-use of greywater and treated wastewater, heightened public awareness campaigns, and the adoption of Integrated Water Resources Management (IWRM) approaches. Through these responses, efforts are made to address the root causes of water scarcity, mitigate its adverse effects, and foster sustainable water management practices for the benefit of both present and future generations.

CHAPTER III: METHODOLOGY

3.1 Introduction

This chapter introduces and justifies the methodology employed to design a rainwater harvesting system to encourage its utilisation and address barriers inhibiting its adaptation in semi-arid regions, focusing on Westwood International School in Gaborone, Botswana. It includes descriptions of the study area, approach, and design, as well as details on population, sample size, sampling technique, and tools for data collection and analysis. It shows how the design of the rainwater harvesting system at WIS was carried out, quantifying cost and quantity savings, explaining software used for measuring catchment areas.

3.2 Study area description

The study area for this study was Westwood International School, located in the South East of Botswana in Gaborone City, Phase 4 at Latitude: 24° 40.653' S, Longitude: 25° 53.195' E at an elevation of about 1017 meters above mean sea level. Average temperature in summer is 32.7 °C and in winter is 23 °C. The average amount of annual rainfall is 485 mm. It covers an area of 4.6 hectares, having a population of 693. After carefully selecting Westwood International School as the case study because of ease of access, and its position as the first in the country to be recognised in the ECO Schools Organisation which recognized and awarded it for its initiatives in environmental sustainability efforts. Westwood International School utilises two water resources, a borehole and the centralised city supply, which makes it peculiar as other schools of its kind do not have it. The school's curriculum is different from other schools, both government and English medium, it uses international Baccalaureate (IB). It provides students with the abilities and attitudes necessary to take accountable action for the future. A time frame allowable for this research also influenced the choice to select Westwood as a case study.

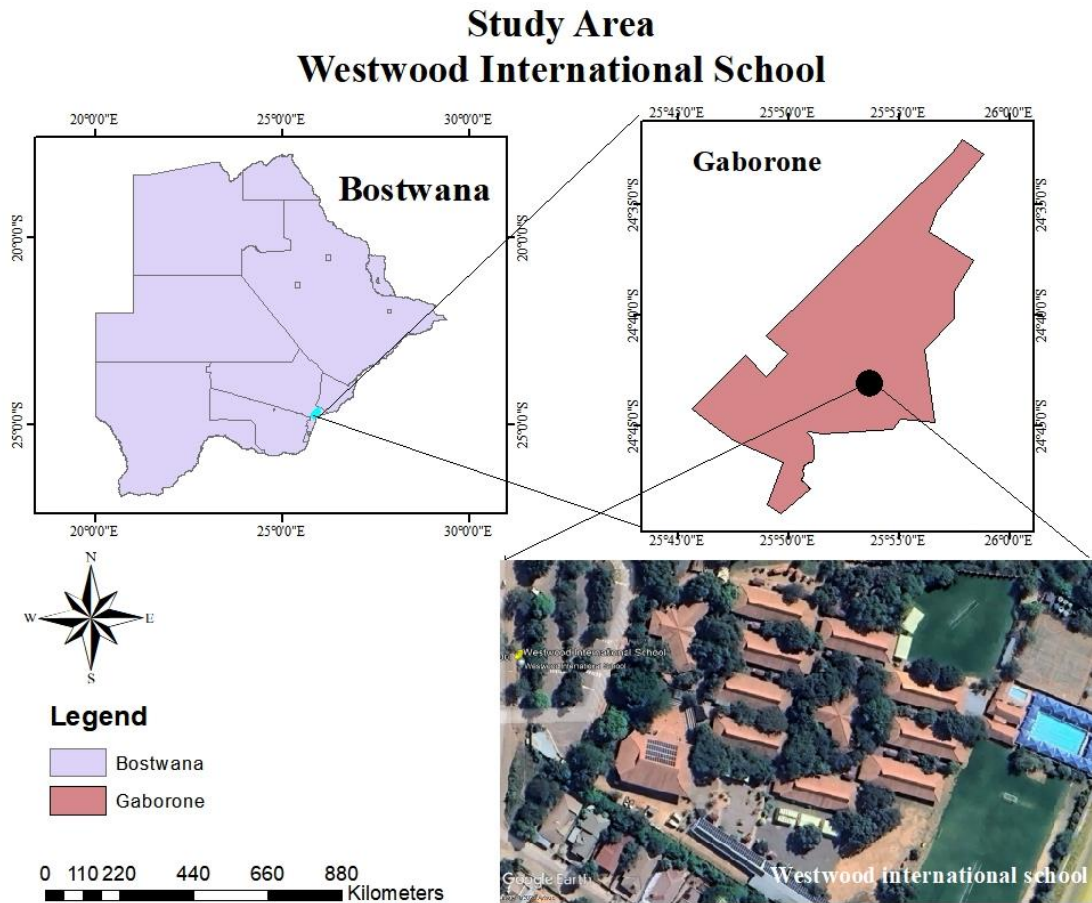


Figure 3. 1 Map of study area

3.3 Research approach

The research approach involved obtaining permission to conduct interviews with staff personnel at Westwood International School. These interviews were structured around the research questions of the study. Following the face-to-face interviews, the collected responses informed the course of the study. A rainwater harvesting (RWH) system design was conceptualized as a proposal tailored for Westwood International School, aimed at harnessing rainwater and overcoming initial barriers to its utilization. Rainfall data from 1985 to 2022, sourced from the Sir Seretse Khama International Airport, was utilized to estimate the potential volume of rainfall that could be harvested from the roofs of Westwood International School buildings. The area of these roofs was determined using Google Earth Pro. Additionally, water utility bills were examined to estimate both the quantity of water consumed and the associated costs at Westwood International School.

This research utilized qualitative methodology to extensively investigate the viability of rainwater harvesting for enhancing water security and promoting sustainable management in semi-arid areas. By employing this approach, the researcher gathered data that offered a detailed understanding of participants' perspectives on rainwater harvesting as an alternative water source.

Despite the historical evidence supporting rainwater harvesting as an ancient practice with evident advantages over alternative sources, its decline in recent years necessitated a qualitative inquiry into participants' perspectives on this traditional method. Understanding the reasons behind this decline and exploring strategies for revitalization, particularly in arid regions like Botswana, was imperative for sustainable water management. Adopting a qualitative approach facilitated a thorough investigation into the impact of rainwater harvesting on citizens, as highlighted by Luciani & Budimansyah(2022). This approach was well-suited for the study, conducted within the natural settings of the respondents, enabling the researcher to engage directly with their real-life experiences, as noted by Mohagan (2018). Qualitative methods offer a deeper comprehension of the researched issue, valuing the voices of participants and yielding richer data compared to the more rigid structure of quantitative research, where responses are typically confined to predetermined options, as emphasized by (Family Health International, 2012). Given constraints in resources and time, a mixed methods approach was not feasible for this study. The subsequent section outlines the research design that guided this investigation.

3.4 Research design

This research embraced the case study research design to delve into the capacity of rainwater harvesting to tackle water security and promote sustainable water management in semi-arid areas such as Botswana.

Rainwater harvesting system was designed using the parameters of roofs (area, coefficient of gradient, annual rainfall) Gould and Nissen Formula (1999) on (Hari, 2019) to explore the amount that can be harvested. Designing the Rainwater Harvesting (RWH) system allowed the researcher to precisely measure the volume of water that could be collected and conserved. This information was subsequently utilized to ascertain the financial savings achieved, particularly in terms of reduced water expenses.

The data in this study was therefore gathered through interviews which were rich, profound and detailed, and a rainwater harvesting system design was made so as to contribute to the understanding of the phenomenon under investigation.

3.5 Population, sample and sampling techniques

3.5.1 Population

The population of this study was staff personnel at Westwood International School. Staff personnel were chosen because they have direct involvement and influence in the implementation and maintenance of rainwater harvesting systems.

3.5.2 Sample size

The sample size for this study was 14 staff personnel from different departments to ensure representation across the entire staff population (Administration, senior management team, environmental club (ECO-schools club), maintenance department and teachers). The Senior Management Team are in charge of enforcing any policies in the school, they also make executive decisions for instance, resource allocation, therefore, their input on how they view RWH and its implementation at WIS was critical. The maintenance team deal with the school infrastructure on a daily basis, so they are well knowledgeable with regards to technicalities. The ECO- schools club formulate and engage the school with environmental sustainability affairs. The teachers deal with matters of disseminating information therefore their participation was important when it came to raising awareness issues. The administration contained of different occupations like human resources and financial manager, of which their presence was critical in sharing whether the school will benefit if they were to harvest and if the school will invest even. The reason for this sample size was because this study was aimed at exploring perception of about RWH in Westwood international school only.

3.5.3 Sampling techniques

In this research, purposive sampling was employed to select Westwood International School and two staff members from each of its eight departments. This sampling method involves selecting respondents based on their expertise relevant to the research questions of the study, as discussed by Gentles *et al.*,(2015).

3.6 Data collection procedure

3.6.1 Gaining entry

In order to gain entry into the research site, the researcher obtained permission and approval from the School Head. The researcher's supervisor wrote a support letter to the School Head asking for permission to collect data. The letter stated the type of data required. The letter was preceded by researchers visit to the school head to ask permission to carry research in their school and permission was granted. Selected respondents for both the pilot and main study were required to sign a consent form before participating in the study.

3.6.2 Conducting interviews

Prior to commencing interviews, participants were required to sign a consent form (Appendix 2). This step occurred subsequent to the researcher holding private meetings with the participants to establish trust and clarity regarding the research objectives. Additionally, participants were asked for permission to record the interview using a tape recorder. As indicated in the consent form, participants were assured of confidentiality regarding their responses and were informed of their right to abstain from answering any questions or withdrawing from the study entirely. Participants were also given the choice of conducting their interviews either in person or over the phone. All fourteen participants opted for face-to-face interviews, conducted in English. Adhering to interview protocol Creswell (2009), the researcher delved into specific lines of inquiry to gather comprehensive information. Adequate pauses were provided between questions for accurate recording, and participants were thanked for their time at the conclusion of each interview Creswell (2009). Subsequently, the researcher securely stored the notes and audio recordings before proceeding with data analysis.

3.7 Data collection instrument

3.7.1 Document analysis

A review of existing literature was employed to ascertain the extent of rainwater awareness within Westwood International School through review of curriculum, school policies, posters around the school etc WIS environmental audit tool(2022). In this study, the researcher examined documents including curriculum, the school's policy related to environmental sustainability and annual water bills were sourced directly from the school office, ensuring accuracy and reliability. Subsequently, Google Earth Pro, renowned for its accessibility and premium high-resolution imagery, served as primary tool for digitizing various roof catchments

within the study area. It was used to evaluate the overall catchment area suitable for rooftop rainwater harvesting and to calculate rainfall quantities based on a runoff coefficient.

Secondary rainfall data was obtained from Sir Seretse Khama International Airport rain gauge station, longitude -24.7 and latitude 25.92, elevation 975, precipitation from 1985 to 2022.

Additionally, the software played a pivotal role in conceptualizing the study area, allowing for comprehensive spatial analysis and visualization. Through its robust features, we were able to delineate and analyse geographic boundaries, facilitating a nuanced understanding of the area under investigation.

3.7.2 Interviews

Interviews, as outlined by Wiersma (2000), entail in-person exchanges between respondents and the researcher, facilitating the direct verbal gathering of data. For this study, a semi-structured interview approach was considered suitable, enabling the collection of qualitative data offering insights into rainwater harvesting (RWH) at Westwood International School. This method involved utilizing a predetermined list of questions while allowing flexibility for respondents to freely discuss any related topics during the interview, as suggested by Wahyuni (2012).

According to Hall & Hall (2004), interviews offer a significant advantage in providing detailed and highly valid information, particularly in scenarios where the researcher has no predetermined outcome. However, interviews also possess notable drawbacks, including being time-consuming and costly. Additionally, respondents may feel uneasy discussing their perspectives on the subject matter, as noted by Yin (2009), and there is complexity involved in coding and transcribing the obtained data. To address these limitations, a small number of respondents (specifically 14) were selected for the interviews. Furthermore, efforts were made to minimize interviewer bias, which tends to be high in face-to-face interviews, by adhering strictly to research ethics and utilizing the data collected directly from the respondents. The interview questions were meticulously designed by the researcher to align with the research inquiries posed.

Following the recommendation by David & Sutton (2004), the researcher ensured the selection of a secure location and suitable timing for conducting the interviews, minimizing interruptions and ensuring the comfort of the respondents. Moreover, in accordance with the guidance by Trochim (2006), the researcher had the capability to rephrase and clarify any questions that

respondents appeared to have difficulty understanding. Additionally, respondents were given the autonomy to select the interview method that best suited their preferences: either face-to-face interviews or telephone interviews.

Upon obtaining consent, a voice recorder was employed to record the verbal expressions of the respondents during the interviews, while written notes were concurrently taken for verification and subsequent data analysis, as recommended by Nieuwenhuis (2007). Subsequent to the interviews, the tape recordings were reviewed and the notes were compiled during the sessions. Raw data were transcribed verbatim by the researcher, and emerging themes were systematically coded.

3.7.3 Water utility bills

Water utility bills were used to estimate the total consumed water at WIS, also to estimate the costs spent on water. This is just an estimation as WIS has a borehole as another water source, of which the consumable quantity is not quantified and recorded.

3.7.4 Rain Water Harvesting System design

Google Earth was used for the measurement of roof areas that were used to calculate the potential of rooftop rainwater harvesting. It offers functionality for generating placemarks, tagging photos with geo-location data, sketching lines, outlining polygons, and calculating the dimensions of terrain elements and buildings, such as length, height and area. These data can be exported in the KML format for sharing purposes. With the above being said, Google Earth Pro was chosen to measure the catchment areas (roof areas) to calculate the potential of harvest.

The steps involved in designing the RWH system were as follows:

Step 1

Digitization of rooftops using Google Earth Pro

Various rooftops within the study area were digitally mapped using the polygon tool provided by Google Earth Pro. This procedure yielded digitized representations of buildings, identifying 12 tiled roofs. These digital representations were saved in KMZ format and are depicted in the figure 4 above.

Step 2

Calculation of the area of roofs using Google Earth Pro

The software was employed to determine the rooftop area of buildings. This software is an open-source desktop geographic information system (GIS) application that is compatible across different platforms and facilitates tasks such as viewing, editing, and analysing geospatial data.

Step 3

Estimation of Rainwater Collection Capacity

Estimation of Rooftop rainwater harvesting Potential in the study area using (Equation1: Estimation of rooftop rainwater harvesting potential)

Gould and Nissen Formula (1999) on (Hari, 2019):

$$S = P \times A \times Cr \quad (1)$$

Where, S stands for potential of roof rainwater harvesting (In cu. m.), P average annual rainfall in m. A for roof area in (m²) and Cr for coefficient of runoff.

3.8 Data analysis

Qualitative data underwent thematic analysis following Creswell's guidelines Creswell (2009). The qualitative data analysis comprised several steps:

- i. Organizing and transcribing collected data using verbatim responses from participants, arranging them by similarity according to Creswell (2009). This process, also known as memoing, involved jotting down reflections, thoughts, and future questions by Melanie *et al.*,(2018).
- ii. Coding, where data segments were organized into meaningful units before extracting their significance according to Creswell (2009). Coding facilitated the identification of themes emerging from the study's findings, which were then used to structure the findings. These themes were interpreted concerning the research questions posed in the study, and findings were presented using verbal expressions that best represented the majority of respondents' views according to Demir & Pismek (2018).

3.9 Data, trustworthiness, validity and reliability

This section outlines the methods used to address issues of data credibility and trustworthiness in this study. Trustworthiness in qualitative research refers to the extent of accuracy and thoroughness in coverage Cohen *et al.*,(2011). To ensure trustworthiness, the researcher committed to impartially observing, describing, and explaining the phenomenon under investigation, devoid of personal biases, interests, or emotional inclinations Cohen *et al.*,(2011). Research achieves trustworthiness when it faithfully represents the experiences of the study participants.

In qualitative research, a member check or informant feedback is utilized to validate the accuracy of data transcription outcomes. In this study, member checking was conducted following the transcription of interview data. This process involved presenting transcripts to participants to verify their authenticity and provided an opportunity to address any perceived errors or misinterpretations. Consistent with the principles outlined by Guba & Lincoln (1981), the researcher adhered to various aspects of trustworthiness, including credibility, transferability, dependability, and confirmability.

Codes were cross-checked to ensure that another coder would code particular information with the same or similar codes. To ensure validity the transcribed interviews were taken back to the respondents (member checking) to determine whether they were accurate according to Creswell (2009) before proceeding with the analysis. Peer debriefing was also used to ensure content validity by involving the course mates of the researcher to review the study so that the findings did not only resonate from the researcher and his supervisors, but also from other researchers in the field of education.

3.10 Ethical considerations

It is considered unethical to utilize data obtained from respondents for purposes other than research (Kumar, 2005). Therefore, this research prioritized the confidentiality of the collected data. To maintain confidentiality and anonymity, participants were identified using codes. Respondents were assigned letters abbreviating their occupational positions; Senior Management Team (SMT), Maintenance (M), Teacher (T), ECO Schools Club (ECO) and Administration (A). Additionally, numbers 1, 2, 3 and 4 were assigned to identify two respondents from each same group. The actual names of individuals involved in the study were

not disclosed. Furthermore, measures were taken to protect respondents from harm, ensuring they did not endure physical or psychological injury. Questions that might cause a loss of self-esteem, embarrassment, or jeopardize employment were carefully omitted. The next section presents the findings of the study.

Table 3. 1 Methodological framework for data collection and analysis

<u>Methodological framework for data collection and analysis</u>					
OBJECTIVE	RESEARCH QUESTIONS	VARIABLES	INDICATORS	DATA SOURCE/TOOLS	EXPECTED OUTCOME
1.To investigate the current state of RWH awareness and adoption in Westwood International School Gaborone.	What is the state of RWH awareness and adoption in Westwood International School?	Awareness Adoption Existing infrastructure Policy support (Government and institutional)	Presence, condition and functionality of RWH system in the school. Sources of RWH information around the school Policies and regulations promoting RWH	Available literature (School policies, curriculum) Observati on	Insights into current RWH practices, challenges and opportunities for improvement

<p>2. To design an optimized rooftop rainwater harvesting (RWH) system at Westwood International School in Gaborone to evaluate its feasibility and ensure maximum efficiency in water harvesting.</p>	<p>What strategies can be employed to develop an efficient rooftop rainwater harvesting (RWH) system tailored to the specific needs and conditions of Westwood International School in Gaborone, and how feasible is its implementation in terms of maximizing water harvesting efficiency?</p>	<p>Roof material and size Annual precipitation Temperature System components and storage Cost effectiveness Water capture efficiency</p>	<p>Optimised and efficient RWH system design Cost effectiveness Reduction in freshwater demand Minimal contaminants and pathogens</p>	<p>Google Earth Pro ArcGIS Microsoft Excel Roof area Rainfall data Annual water bills</p>	<p>Volume of rainwater to be harvested Size and location of storage tank RWH design illustration Cost analysis Volume of water to be saved Money saved on water bills</p>
<p>3. To propose strategies for implementation of roof rainwater harvesting in Botswana</p>	<p>What are the most effective strategies for implementing roof rainwater harvesting systems in Botswana?</p>	<p>Cost of RWH system Awareness and knowledge Financial incentives Socio</p>	<p>Awareness level Adoption rate Policies Cost effectiveness Community</p>	<p>Existing literature and research studies within Botswana and in other</p>	<p>Proposed strategies considering factors such as local environmental conditions,</p>

		economic status	y engageme nt	regions with similar climatic conditions . Governme nt reports and policy documents	socio- economic factors and technologic al feasibility
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CHAPTER IV: RESULTS AND DISCUSSION

4.1 Introduction

This section presents and discusses the findings of this study. To evaluate the feasibility and efficacy of implementing an optimized rooftop rainwater harvesting (RWH) system at Westwood International School in Gaborone, while considering local conditions and constraints, with the aim of maximizing water harvesting efficiency. A case study of Westwood International School (WIS) Gaborone, Botswana. Part 1 of the presentation includes the findings and discussions from the interviews, followed by the design of the proposed RWH system at WIS. The design was influenced by the findings of the interview. As mentioned in the previous chapter, the available roof areas (catchment areas) which were calculated by Google earth pro were used to calculate the potential of rain water that can be harvested from WIS buildings. Using the findings from the water utility bills obtained from the financial officer, average costs spent on water and average volume of water used in a year were computed to compare the savings that can be made from RWH both monetary and quantity. This section is labelled Part 2. The findings are presented in line with the three research questions posed in this study:

- i. What is the state of RWH awareness and adoption in Westwood International School?
- ii. What RWH optimized rooftop system is at Westwood international School?
- iii. What strategies are proposed for the implementation of RWH in Westwood International School?

This section presents the occupational roles of the participants in order to show that they possessed the necessary characteristics needed to provide the requisite information for answering the research questions. This is followed by the presentation and discussion of the findings from the first, second and then the third research question. As described in the previous chapter, the findings were presented using direct quotes that are reflections of the views of the majority. The occupational positions of the participants purposefully selected are senior management team, administration, maintenance, teachers and the ECO schools club. The participants and their roles are represented using tags as shown in table 4.1 below. The senior management team is represented by the tag SMT, the administration is tagged by A, the ECO

schools club is tagged EC, the maintenance is tagged M and the teachers are tagged T and they are tagged 1 -4, respectively for anonymity. The data were collected from 14 participants in the school, to give a total of 14 participants. The next section presents the identifier of the participants.

Participants' identifier

Table 4. 1 Participants identifiers

Category	Participants	Number of participants
A. Senior Management	SMT 1 SMT 2 SMT 3	3
B. Administration	A1 A2 A3 A4	4
C. Maintenance	M1 M2	2
D. ECO Schools club	EC 1 EC2	2
E. Teachers	T1 T2 T3	3
TOTAL		14

4.2 The state of RWH awareness and adoption in Westwood International School

4.2.1 Familiarity and perception of rainwater harvesting among participants

A significant portion of the respondents observed rainwater harvesting being implemented in their households. When questioned about their knowledge or views on the system, the majority attributed their awareness to their upbringing, recalling instances where their parents engaged in various forms of rainwater harvesting, ranging from rudimentary methods to more sophisticated setups involving installations and storage facilities.

Participant A2 affirmed

Yes, am familiar because we've used it back at home many years ago even though we no longer use it, we used to use it at home but now we have taps at home. We used it because we use to fetch water from far

Participant A3 re-affirmed:

Yes am very familiar with RWH, traditionally its starts from when we grew up, our parents used to put these buckets and collect from roofs even though here in Botswana, we hardly receive rains especially in the rural area where I grew up. We did not have these modern houses. And I don't think it was about saving water at that time but it was saving us the journey of going to collecting water far at the river. For me that's the background of how I started to recognise and that has been instilled in me to at least appreciate the importance of rainwater so even in my house I have it, I have installed some gutters around my house and put a 5000L at the corner of my yard to try and collect rainwater for my plants

Participants T2 however posited thus, in affirmation:

Am familiar with it but not the technicalities of it, I won't be confident in explaining exactly what it is. Generally it dates back to when I was a kid, when it rained we would put buckets by the roof to collect that water, some to drink if the container is clean and some to water the plants. my parents used it as a water saving strategy,

Participant SMT 1 also said

Yes I am, so in other countries that I have worked in particularly in Europe its very common, even as a child I remember we had lots of water in the UK but my parents used to collect, normally they would use that for the garden and it was same when I used to live in France, my inlaws used to keep tanks on which they would collect rainwater. It's very common in European homes.

Participant EC 1 also seconded that:

I know it in principle from growing up

Some participants not only inherited their knowledge of rainwater harvesting from their parents but also consider it a tradition that they are actively maintaining in their own households, motivated by diverse reasons.

Participant SMT 3 said:

Yes, I am, my experience with it is at a personal level uuuh because uuum I love gardening and uuuh I got a huge pool at home and lot of trees as well. And with the water being so expensive, we decided 10 years back that we are going to harvest rainwater. So we've got uum 2 5000L jojo tanks in the house and we collect water from our roof and which you would be surprised, we have a big pool and it fills up and we water plants too

Participants T3 affirmed:

Am very familiar because all our houses at our place we make sure we have a gutter and we collect rainwater, that water we use it for various things, my parents have it so every time there is a building that we do the roofs are installed with gutters and these big tanks and water is pumped there, so its very important. When we are building its always factored in, it's a must

For some participants they were aware but not sure they are aware. But they had some idea

Participant A1 mentioned:

Uum I don't know if am thinking of the same thing which you are talking about, you mean when its raining and we put buckets to collect that water. Growing up that is something that has always been done at our homes for watering plants and all that.

Participant A4 affirmed:

I don't know anything about rainwater harvesting but am assuming its probably a system whereby we collect rainwater with a bucket and am thinking along those lines because that's what we used to do at home, when it rains we would but like a bath tub or something next to the roof where water would be dripping

Generally, the participants in the study have a general understanding of Rainwater Harvesting (RWH). They are either directly involved in practicing RWH themselves or are indirectly connected to it as secondary participants, which could mean they are aware of its

implementation within their communities or have some level of involvement or knowledge about it through other means. This indicates a level of familiarity and engagement with RWH among the participants, suggesting potential receptiveness to further exploration or promotion of RWH initiatives.

Regarding the awareness of rainwater harvesting systems in WIS, responses varied from affirmative to negative, with some participants completely unaware of their presence. Despite the primary lack of recognition of RWH systems, participants indicated that they collect water droplets from air conditioners. This demonstrates the WIS community's awareness and practical approach to water conservation. They are accustomed to the practice of harvesting water, suggesting that adopting RWH may not pose a significant challenge as they are already involved in similar practices. The issue of the school landscape also surfaced as the reason why RWH can't be there. These are seen in the reflections below;

Participant EC 1 affirmed

No, it's not, but many students have mentioned that it would be a good idea to have it. What we do is harvest water from the ACS. RWH not yet but it will happen

Participant EC2 re-affirmed

We have that as part of our initiative for our eco school programme, so what we do is we recycle water from the air con. We put plastic bottles to collect water that drips from air cons, we then grew to not only collecting with bottles but planting trees underneath the air con pipes. Rainwater specifically not yet but I usually see our auxiliary staff when it rains they put flower pots under the roofs to water the plants

Participant T2 mentioned

Oooh is it? I think so, I think at the gate we've got a big jojo tank they use to collect rainwater and I think at the gardens as well, I've seen the tanks around the school and yaa I think we have.

Participant T3

In Westwood, now that you are saying that, it gets me thinking, when its raining, I know that I don't see water pouring out on the ground a lot. So that means I think There must be underground tanks that collect the water because according to my experience there is always a lot of water when it rains but here it doesn't pour out as much, so think they must have done a gutter that collects water underground and direct it somewhere

Participant SMT 1 posited:

I've not seen it, am not aware of it, uuum I, since I've been here I don't think we've done any RWH and that's like 5 years

Participants SMT3 highlighted:

Unfortunately, no because you can see how the school is built,uum we've got blocks of classes and with us students being in primary, fitting a jojo tank right in the middle of the pathways is something that we can't do, for child safety reasons.

4.3 Benefits and challenges of installing RWH at WIS

Given that the majority of participants expressed some level of awareness regarding rainwater harvesting, the researcher proceeded to explore their perspectives on the advantages and obstacles associated primarily with its implementation at WIS. Predominantly, participants indicated that the benefits outweigh the challenges, citing Botswana's limited rainfall and space constraints within the school as significant hurdles. However, they emphasized numerous advantages, including the educational potential of RWH at WIS, cost savings on water utility bills, the suitability of rainwater for gardening, and its role as an additional water source. Notably, challenges most frequently mentioned in interviews centered on Botswana's scant rainfall and the logistical challenge of finding space for a storage tank within the school premises. This is seen in the following views:

I don't think we have many challenges, apart from that we have very little rain obviously, but I, you know, am always saying that people in this country needs to see that whatever falls from the sky is a precious resource um and currently we don't do that, I mean we waste whatever falls most of it gets wasted so I think it would be extremely important and useful for us as a community to start collecting rainwater. Here in Westwood like with the solar panels I think it

can be an educational tool for the vast majority of our students, I think it would be great for them to see it in action and that's how they will learn about it. Am sure a few of them have go RHW at home or on their farms again I think its important for us to be a model for them. (SMT 1)

The benefits and challenges uum am not sure but I think our trees would be happy because we water them with rainwater and the other thing would be the finance team would be happy because that means reduced costs on water bills and challenges I think, its not a change in terms of collecting it and storing but the main challenge is that our rain in Botswana is scarce we never know when to expect it and when not to expect it, in a year it doesn't rain that much in Botswana, so collecting rain in something big...its not going to work. (A1)

Here in this school the challenge would be the space and it would mean we have to dig an underground reservoir. But this being an educational institution for it to be underground would not serve its purpose of educating. The benefits would be when our borehole is damaged which can take 2-3 days without having water to irrigate our fields and flowers of which if you have a rainwater collection, we know we would always be having water. (M1)

Well, if say for example in a time like now where there is drought, I assume there is drought we can use that same water to feed the plants and facilitate other things. So, the challenge now because we don't have these things, our grass is looking dry. In implementing it I think the challenge would be where would we even put the tank, I mean really. (T1)

I mean uuuuum there are lots of benefits pertaining to that mostly because Botswana on its own its water scarce country. Especially right now we not having any rainfall so it's better to have stored water somewhere, in case of emergencies but also it promotes that practice of ensuring that everyone participates in water management. So, I think it would benefit us and increase our knowledge on water conservation as a concept (EC 2)

4.4 Optimized rooftop system at Westwood international School

In essence, the research question sought to identify and possibly analyse the specific type or design of the rainwater harvesting system implemented on the rooftop of Westwood International School. This could involve examining its components, efficiency, effectiveness, environmental impact, or other relevant factors. Majority of the participants revealed that there is an already existing component of RWH in WIS buildings which is gutters. The gutters play

a crucial role in a Rainwater Harvesting (RWH) system by collecting rainwater from the rooftops of buildings and conveying it towards storage tanks or other collection points. Gutters serve as channels that guide rainwater efficiently, preventing it from running off the roof and being wasted. Properly installed gutters ensure that rainwater is directed away from the building's foundation, minimizing erosion and water damage risks. Additionally, gutters help in filtering out debris such as leaves, twigs, and dirt, thus improving the quality of collected rainwater. Overall, gutters are essential components that facilitate the effective capture and utilization of rainwater in RWH systems, contributing to water conservation and sustainability efforts. Therefore, one can confidently say the only major component remaining in WIS buildings is storage, some part of the system is in place already, this is expressed through the following views:

Participant SMT 1 affirmed:

I don't think that rains that fall in our roofs are used in any way that I've seen, it just flows into various paths of the school and then most rainwater eventually channels into our field. So at least there is some kind of benefit but honestly there is no system and I don't think it would be difficult to do that because like I said our roofs are well pitched uuum each one has a gutter, we just renovated out of the 9 blocks that we have 5 have just been recently renovated with new gutters. So And I've tested, we've had one rainfall since we've done the renovation and all the guttering is working perfectly well, but the water just goes.... you.... know... randomly across the school, there's no system

Participant M2 re-affirmed:

Currently we have gutters that are installed for the sole purpose of directing water away so that it doesn't spill on people, they just direct the water to the outlets, we do not collect and store rainwater at all, we don't have the tanks to collect.

Participants SMT 2:

We have just recently renovated our roofs and getting the Jojos (storage tanks) to harvest is a future plan that's why we have the gutters. The gutters right now are taking water to our small little gardens around the school but we are not harvesting to keep

Participants A2:

I think we have an advantage since we already have gutters rather than having it go all to waste. We don't use them to harvest but to make sure water doesn't go to the ceiling and staff like that, it wasn't necessarily for water harvesting. RWH can be a good opportunity

Participants EC 2:

Of recent, we have just replaced our roofs and of course these gutters I think have been replaced as well to put them in a state where they could be functional, so I think its initial purpose its just to redirect rainwater to a place where ... you know... the corridors don't get flooded and staff like that, This is me just thinking, am not sure if that was the main concept but I haven't really seen that connectivity leading to perhaps plants or loko I said , I may not have observed it, It could be done that way, but I think our maintenance unit would know better.

4.5 Assessing water demand for sustainable school management

Understanding the anticipated water demands or usage requirements within a school premises is crucial for efficient resource management and sustainability. As educational institutions strive to uphold standards of hygiene, cleanliness, and functionality, delineating the expected water usage becomes paramount. This investigation aims to shed light on the diverse facets of water consumption within the school environment, encompassing activities ranging from sanitation to recreational pursuits. By comprehensively assessing these demands, stakeholders can devise informed strategies to optimize water usage, promote conservation practices, and ensure the long-term resilience of the school's water infrastructure. From the responses of the interview, the participants highlighted the water demands in the school besides the potable water demands for drinking, demand was seen in areas of swimming pools, toilets and bathrooms, plants, sports fields. In their conversations they showed more confidence in the availability of a borehole as an extra water source and this thinking derailed them from actually knowing and quantifying the water demand in school. So, in not knowing the exact amount of water they are using put them in a position of not fully being aware of how to manage this resource. They are applying water conservation initiatives blindly.

In this school we use a lot of water in the toilets and bathrooms, water plants, sports fields. We have divided our sources of water in 2. We have a borehole and we pump water out of those boreholes and we fill tanks with, this water is then used to water plants and the water from the

utility company we use it for drinking, that's how the uses are separated according to sources.
(M2)

We use water for watering plants, grass, trees, swimming pool, the toilets, drinking ya I think that's what we use the water for (T1)

We use water for watering plants, grass, trees, swimming pool, the toilets, drinking ya I think that's what we use the water for (SMT 2)

Well, we are very fortunate we have a borehole and umm, so you know... that puts us in a very privileged position. We have used the borehole for all of our swimming pool, for our fields, our irrigation, so, I think really RWH we just... if anything else it will serve as a Like an educational model or a too I think for our students more than being something that would be you know, essential or practical, I think it would more than anything else be educational. (SMT 1)

4.6 Design and functionality preferences in RWH Systems at Westwood Int'l School

In the quest for sustainable water management solutions, the design and functionality of rainwater harvesting (RWH) systems play a pivotal role, particularly in educational institutions like Westwood International School. Exploring specific preferences and priorities concerning these systems provides invaluable insights into the school's environmental ethos and resource management strategies. This inquiry seeks to uncover nuanced perspectives guiding the selection and implementation of RWH technologies, aiming to elucidate how these preferences align with broader sustainability goals while addressing the unique operational needs of the school. By delving into these considerations, this investigation endeavours to inform future decisions regarding RWH system design, fostering an environment conducive to water conservation and ecological stewardship within the school community. The findings reveal that appearance, site location of storage tanks with regards to space, being an educational tool, the student's safety, played a role in the participants views on design and functionality of RWH at WIS.

Mmmh.... sure... I just hope it won't something that's too ugly as I like so say we got lots and lots of ugly things, Jojos are ugly, really ugly uuum they just... nothing looks natural so you know when you look at our school we are very proud and very fortunate to have a very natural looking school, lots of beautiful trees, green spaces, lots of plants, so if we were to have a

system we would like it to be something that looks natural or as natural as possible, you know, I don't like ugly things, I go around the school and we try to remove a lot of ugly things, we still have a few ugly things but a lot of them have gone now. (SMT 1)

Uuuuummmm, I think just like we are doing with the borehole, even with rainwater we can do like that. Collect from roofs and store it in tanks, the tanks are separated and kept outside of the school so that they don't become hazardous to the students. So, I think we can apply the same strategy we are applying with borehole water. (M2)

Like I said earlier, with the school not having enough space but has too many water requirements, I think an underground water tank will be best. (T3)

If you look at how the school itself is, there is no space and whatever design would be made it would be a cost. (T1)

I am not too technical, am not a scientist but I think the issue will be finding a balance between them being visible but not too visible. The important thing is having the students see this being carried out. We had to train the students on a lot of environmentally sustainable things like turning organic matter in to compost and litter separation. Now they are used to it, that's why am convinced that if there is this system (rwh), the students will get used to it fast. (EC 1)

Our school is big on child safety, so I think the first thing we would need to keep in mind when we are designing this kind of a system is that it doesn't in any way uuuh you know, harm the students, we've these 4 year olds to 19 year olds so we got quite a range, so we don't want to sort of have that right in the middle where the children decides to climb up on it and it becomes hazardous and things like that so obviously when we and if we ever get in to rwh these are the things we would have to keep in mind, it definitely cannot be in our existing structure at the moment maybe the other side of the school. (SMT 3)

4.7 Strategic implementation of Rainwater Harvesting at Westwood International School

In line with the third research question, this section is aimed at presenting strategies that can be proposed for the implementation of RWH in WIS. Just like the two research questions, the findings from the third research question will be presented in line with the themes that emerged from the views and experiences of the majority of the participants. The views of the participants from both their awareness in relation to the system and their thoughts to the optimized system

in WIS in relation to its adoption. The most reoccurring views are used to present the findings of the third research question. The findings reveal that there are no strategies in place for RWH in WIS, that strategies that can be used to raise awareness is through education and even though RWH is not in the curriculum, it is something that can be considered. Majority also opined the need to prioritise it and direct resources towards its implementation.

4.7.1 Strategies in place for the implementation of RWH in Westwood International School

Exploring the implementation of rainwater harvesting (RWH) at Westwood International School involves an intricate understanding of the strategies employed to ensure its successful integration. With a focus on sustainability and environmental stewardship. The views of the majority are captured in the words of A2 who opined that while RWH has these benefits, there are no strategies in place for its implementation at WIS.

Not that I know of (A2)

Agreeing with A2, SMT 1 maintained:

Am not aware of any

Participant SMT 3 pointed out:

We don't have any strategies for that

Participants EC2 maintained:

We don't have a comprehensive strategy; we just have some sort of ideas... conservation plans but nothing specific to rwh

4.8 Proposed strategies for effective increase in awareness and fostering support for the implementation of RWH systems in WIS

The effective ways of raising awareness and fostering support about RWH in WIS as proposed by the majority of the participants are seen below. These strategies are in relation to the WIS as an institution, tailor made to suit its landscape and the vision of the institution. The most common proposed strategies were, through raising awareness, through education by including RWH in the curriculum. The views of the majority are captured below

Participant SMT 2 seconded:

Continue teaching people the importance of water and the importance of water harvesting and once we are all in agreement that it can save the pocket am sure we would all run for that

Participant T2 agreed:

Awareness is for everybody right, so everybody should participate, and it can start as a simple act of educating the kids and educating us as teachers as well, on what it's about and its benefits then we can come up with strategies on how we can harvest water and then working together with the kids, they are very smart they can help and be actively involved, that way they learn better.

Participants EC2 affirmed:

I think linking it to the curriculum especially subjects like integrated humanities which is geography I think and social studies combined, so uum..m if we could link that to the curriculum, make it easy to understand to our high school kids, because if they are getting it in the classroom and practical's here and there with case studies, I think that's when it sticks

Participant SMT 1 re-affirmed:

Ya..mmh.. sure, well because most of our important stakeholders are the children, the important part is getting it in to the curriculum, you know, so that when we are teaching the kids about stuff, it's the ...like you know the solar project, it's a good example, like you know we have a display right here outside and teachers are bringing the kids out to explain that we used to use to use coal to produce electricity, we still do, but explaining that solar is clean. Making these things part of our curriculum making it a part of what we teach it becomes something that is relevant for the kids, I think we can do the same with rwh and it's a cool project, there can be a lot of maths involved, you know, and environmental awareness so, for me that's kind of like... the key is making it a part of what we do. We teach environmental studies to our kids. I emphasize the fact that young Batswana need to realise that rain is a resource, water is very important resource in our country, every drop is precious. And I do not really think that is something that is taught enough

Even when the majority of the participants highlighted the importance of raising awareness about RWH. Some participants stood their ground that this is known, the students know or can be open the knowing more as they have embraced other environmentally sustainable practices like turning organic matter to compost and selling it to the community, harvesting drops of water from air conditioners and water the plants with it, installing solar system, separating their waste disposal and many others.

Participant SMT 3 affirmed:

Alright uh look, for our students, they are quite aware of these things because we are an eco-school and uh three themes which we have which are energy, water and biodiversity has been identified by the students, it's not coming from the teachers going down. A lot of projects we have around the school are student initiated and not something that the management decides so I do noit know what in future the students may come up with but they are well aware, we have units in the curriculum talking about rainwater

Participant T3 re-affirmed:

We have the students eco representatives and they represent their classes at the meetings and identify problems and come up with solutions and the school always backs them up. Even during assemblies, kids always share these issues and usually parents are there too and these ways are ways of raising awareness.

Participants M2 opined:

We are currently doing a lot of environmentally sustainable practices like turning our organic waste into compost, in doing this the students and community at large were taught and because of this education we are environmental cautious. So, in the way we taught everyone of environmental sustainability that's how they can be taught about RWH

4.9 Platforms available in preparing for the adoption of RWH in WIS

By fostering a culture of environmental awareness through tailored educational programs, Westwood International School can empower its community to embrace and effectively utilize RWH systems for a greener future. In terms of ways that can be used to raise awareness about RWH and its implementation at WIS. The participants mentioned a couple of ways but the

most dominant were the school environmental club and the presence of water in the curriculum where these topics are addressed there.

Eco club and class level we have units that are focusing on water (SMT 3)

We have an eco-club which fosters and promotes environmental sustainability therefore the community is already sensitized and have taken upon these programs very well. The kids will be very eager to learn (M1)

There are previous educational teachings on water conservation that can be adopted, like installing pressure regulators on bathroom tap nozzles. (SMT 2)

I do know however that there is an eco club, which is for certain individuals but if there was a programme that is actually a subject that is given here at school and not just for a select few (T1)

Like I said before, whats great about our curriculum is that is much more flexible, we go about it in this interdisciplinary themes and environmental awareness is part of what we teach today to the kids so anything that contributes to that, that helps with that, I think its making an impact into the lives of our young people. (SMT 1)

4.10 Resource Allocation for RWH Implementation at Westwood International School

The researcher sought to find out if the community of WIS would prioritize it and direct resources towards it. Majority of the participants indicated that they would prioritize it and direct funds to it, but key personnel who authorises the use of funds in the school mentioned that with all the benefits mentioned for now RWH installation can't be a priority because of its slow financial returns. This is seen in the following views:

I'll give it top priority because its something that can help us cut the water bills. (A2)

I think it's a good idea to invest in it because in any institution saving is a must, (SMT 2)

I'd say it can be prioritised. (M1)

So far I haven't seen the school decline any initiative like this. (M2)

Absolutely, I think Westwood would really jump in to it. (EC 2)

We are guided by the strategic plan. (SMT 3)

I can't say that I would, with the solar system it was easy to get the council and investors on board with it, because in 4 -5 years, we can start to benefit financially from it, but with rwh there is no financial benefit to it, you know if we had to, we could assist but I like to think that it wouldn't be too much of a cost to the school as well. (SMT 1)

PART 2

4.11 The design of the proposed RWH System at WIS

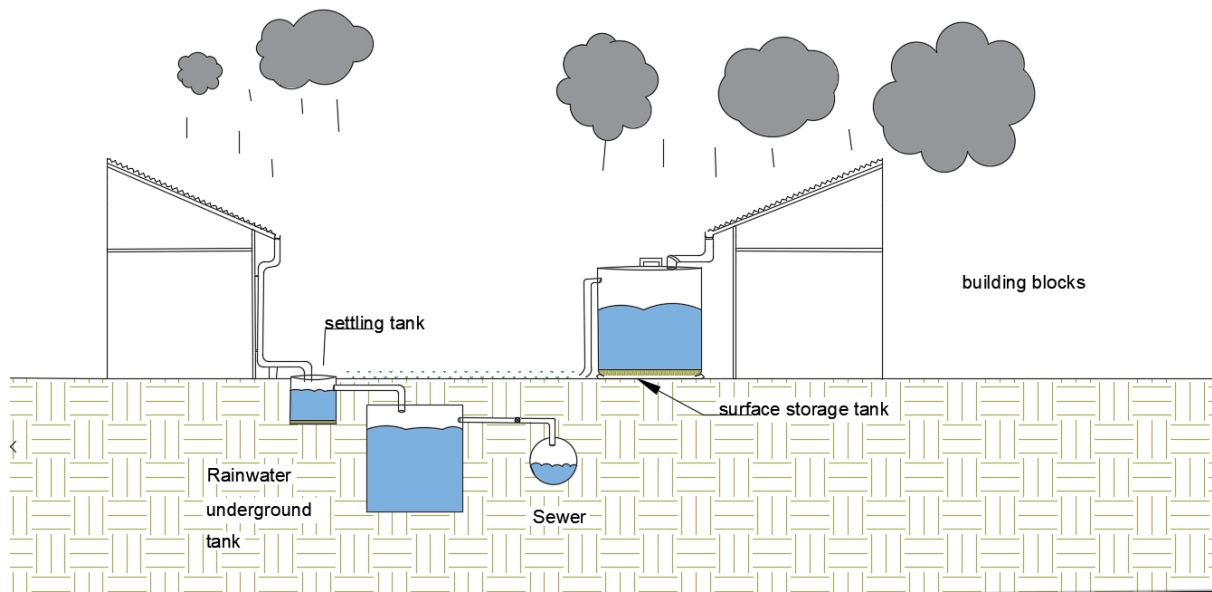


Figure 4. 1 Schematic representation of the proposed RWH system at WIS

The RWH system design above was influenced by observations and interview findings from the participants. In the effort to address the key issues that arose with respect to the implementation of the system at WIS. Key issues which were raised were taken into consideration, which are, availability of space for the storage tank, the aesthetics of the school and the system to be an educational model. Therefore, the above proposed system shows that the storage tanks can both be on the surface and underground. The surface storage tank can be used as a model to demonstrate RWH importance, paintings and key information about RWH will be painted on the walls of the storage tank by the students, this will be a capacity building initiative to empower students to be custodians. The underground tank will fulfill the purpose of capturing all the rainwater that could not have been stored on the surface tanks because of unavailability of space. The system was influenced by key areas of efficiency, sustainability and affordability. WIS being an environmentally sustainable school and driving the green initiative, the overflow from the surface storage is designed to flow to the plants grown around classes and the sports field to water them. This model/ design is the answer to the key issues that emerged as seen in the interview findings.

4.12 RAINFALL DATA ANALYSIS

Rainfall data analysis serves as a cornerstone in the comprehensive understanding and effective utilization of Rainwater Harvesting (RWH) systems (Hasse , 1989: Siphambe , et al., 2024). In this study rainfall data from 1985 to 2022 was used to compute average annual rainfall which was further used to estimate the volume of rainwater that can be potentially harvested from WIS roofs.

Table 4. 2 Rainfall data analysis from 1985-2022

Sum of Rainfall	Column Labels														
Row Labels	1	2	3	4	5	6	7	8	9	10	11	12	Annual Total		
1985	67.1	49.8	66.1	0	7.2	0	0	3	24.4	19.3	3.9	78.6	319.4		
1986	72.8	29.3	39.1	13.9	0	5.8	0	12.3	7.6	50.9	97.7	46.1	375.5		
1987	53.4	39	80.5	8.6	0	0	0	0	0	6.7	50.3	87.2	325.7		
1988	24.2	216.3	132.2	46.9	0	3.5	0	0	55	82.7	33.6	32.2	626.6		
1989	94.5	181.8	5.6	105.7	11.2	7.5	0	0	0	13.1	124.1	101.7	645.2		
1990	60.4	72.1	30.3	46.4	23.3	0	0	0	0.6	34.7	44.8	40.1	352.7		
1991	225.9	45.1	135.5	0	0	56.9	0	0	4.7	94.8	72.8	72.3	708		
1992	19.2	24.2	4.4	15.4	0	0	0	0	0	6	146	82.3	297.5		
1993	15.4	107.7	24.5	10.7	0	0	2	0	0.3	103.5	40.5	48.9	353.5		
1994	114.7	120.7	54.6	3.5	0	0	0	0	0	27.6	7.2	87.2	415.5		
1995	47.1	36.5	121.4	37.2	2.5	0	0	0	0.8	27.9	114.2	119.6	507.2		
1996	140.5	105	29.2	75.4	24.2	0	0	0	2.4	70.7	119.9	72.2	639.5		
1997	137.5	39.3	198.1	39.3	51.7	0	0	3.8	70.5	8	89.7	48.6	686.5		
1998	105.2	24	99.1	5.8	0	0	0	0	0	59.7	48.3	68.6	410.7		
1999	33.7	27.7	28.8	9.3	27.8	0	0	0	0	22.6	14.6	224.9	389.4		
2000	162.4	261.3	106.7	24.7	17.9	18	4.5	0	0	17.8	22.9	61.8	698		
2001	29.4	193.6	41.9	69.4	106.1	19.6	0	0	13	112.6	285.1	51.2	921.9		
2002	30.8	54.1	12	20.2	57.6	3	0	8.2	0.4	30.4	18	98.8	333.5		
2003	81.6	78.4	18	5.6	0	22	0	0	0	86.9	55.3	27.4	375.2		
2004	45.4	164	40.3	53.4	0	2.9	0	0	0	12.2	18.1	128.6	464.9		
2005	53.9	34.5	37.4	72.6	0	0	0	0	0	0	60.5	35.3	294.2		
2006	248.3	217.9	74.1	6.1	14.2	4	0	3.7	0	6.3	26.1	84.9	685.6		
2007	7.7	23.9	15.7	21.5	0	20	0	0	23	100.9	72.7	140	425.4		
2008	219.2	51.9	158.4	19.7	18.8	5.8	4	0	0	2.2	71.8	23.2	575		
2009	179.6	72.9	111.1	1.8	16.3	105	13	0	14	27.4	99.5	98.9	739.5		
2010	77.3	40.8	4.3	149.3	14.7	0	0	0	0	0	4.5	77.5	368.4		
2011	74.9	22.8	96.4	98.4	18	5.7	0.1	0	0	5.7	46.7	100.9	469.6		
2012	55.7	19.6	39.4	0	0	0	0	0	0.3	37.4	52.6	97.4	302.4		
2013	34.8	37.8	7.8	33.3	0	0	9.5	0	0.7	23.1	47	111.2	305.2		
2014	38.8	39.1	55	12	0	0	0	0	0	1.8	48.7	35	230.4		
2015	60.3	10.9	9.5	13.3	0	0.8	0	0	21.6	1.3	39.6	52.7	210		
2016	30.4	43.7	164.8	32.3	6.9	19.6	0	0	0	28.5	101.2	44.6	472		
2017	99.2	168	8.9	34.6	1.2	0	0	0	3.2	57.4	87.6	59.4	519.5		
2018	110.8	80.7	112.9	29.6	0	0	0	0	0	24	6.6	56.7	421.3		
2019	79.4	34.5	48.4	35.8	0	0	0	0	0	0	64.6	37.8	300.5		
2020	81.6	7.7	4.2	0	35.8	0	0	0	0.1	36	47	56.6	269		
2021	5.8	0	1.1	4.4	0	0	0	0	4	39.5	35.2	128.8	218.8		
2022	24.4	6.9	74.8	183.4	11.4	1	0	0	0	19.4	187.8	120.6	629.7		
										Average Annual	rainfall		454.813158		

Different Roof Catchment Area

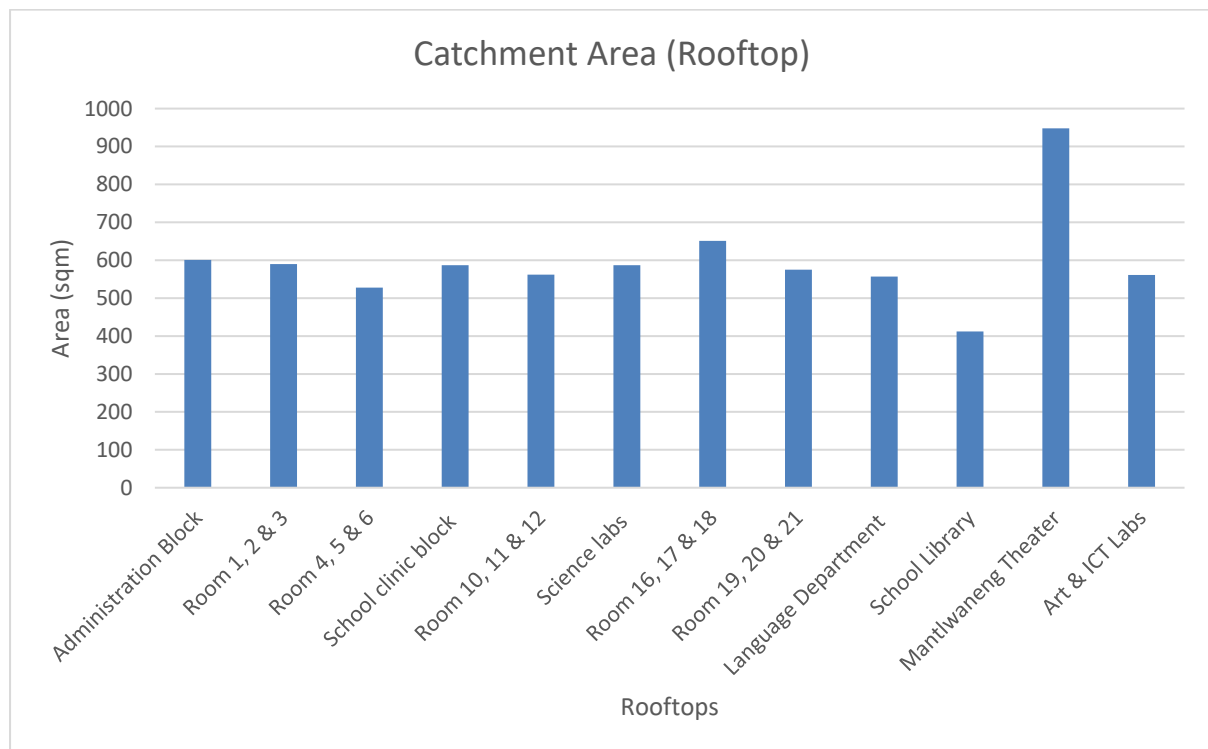


Figure 4. 2 Roof catchment areas

The presented bar chart illustrates the potential roof areas available for use as catchment areas. These measurements were conducted using Google Earth Pro, chosen for its cost-effectiveness, efficiency, and safety compared to manual methods involving climbing and direct measurement. The data reveals the following areas: the administration block with a roof area of 601m², Block with Room 1, 2, and 3 totalling 590m², Block with Room 4, 5, and 6 at 528m², the school clinic block covering 587m², Block with Room 10, 11, and 12 with 562m², Science laboratories spanning 587m², Block with room 16, 17, and 18 measuring 651m², Room 19, 20, and 21 block at 575m², the language department block covering 557m², the school library area 412m², Mantlwaneng theatre with a roof area of 948m², and the art and ICT laboratories measuring 561m². The total area therefore is 7159m².

4.13 Estimation of Rainwater Collection Capacity

Estimation of Rooftop rainwater harvesting Potential in the study area using

Gould and Nissen Formula (1999) on (Hari, 2019) (Equation 1)

$$S = P \times A \times Cr \quad (1)$$

Refer to equation 1 above.

Runoff coefficient may be as high as 0.9 or as low as 0.24, depending on the surface material and other factors which may reduce the efficiency like evaporation, clogging, leakage, infiltration, overspill, and retention (Gould & Nissen-Peterson , 1999). Taking runoff coefficient as 0.75 because it is the runoff coefficient of tiled roof material as mentioned on the Manual on Construction and Maintenance of Household Based Rooftop Water Harvesting Systems, Report prepared by AFPRO (Action for Food Production) on (Kumar, 2004). The estimation of rainwater collection capacity for $C_r = 0.75$ and $P = 0.454813158$ m/a is summarized as:

Table 4. 3 Potential of rainwater that can be harvested at WIS

Catchment area (Rooftop)	Area (m²)	S (m³/a)
Administration Block	601	205.007
Room 1, 2 & 3	590	201.2548
Room 4, 5 & 6	528	180.106
School clinic block	587	200.2315
Room 10, 11 & 12	562	191.7037
Science labs	587	200.2315
Room 16, 17 & 18	651	222.0625
Room 19, 20 & 21	575	196.1382
Language Department	557	189.9982
School Library	412	140.5373
Mantlwaneng Theater	948	323.3722
Art & ICT Labs	561	191.3626
TOTAL	7159	2442.006

Total potential of roof rainwater that can be harvested Westwood International School buildings is 2442.006 m³/a.

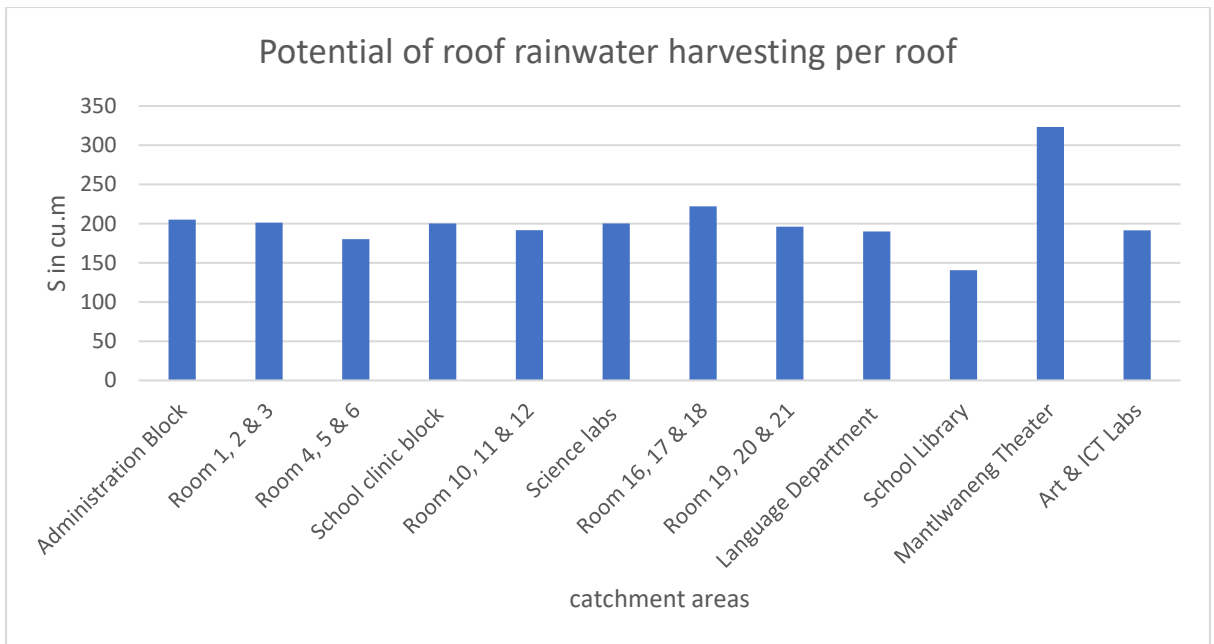


Figure 4. 3 Potential of RWH per roof

The bar chart above shows that the potential of rainwater harvesting is highest on the Mantlwaneng theater roof, followed by administration block and room 16, 17 and 18. The lowest potential of harvest is seen in the school library, room 4,5 and 6 and the art and ICT blocks.

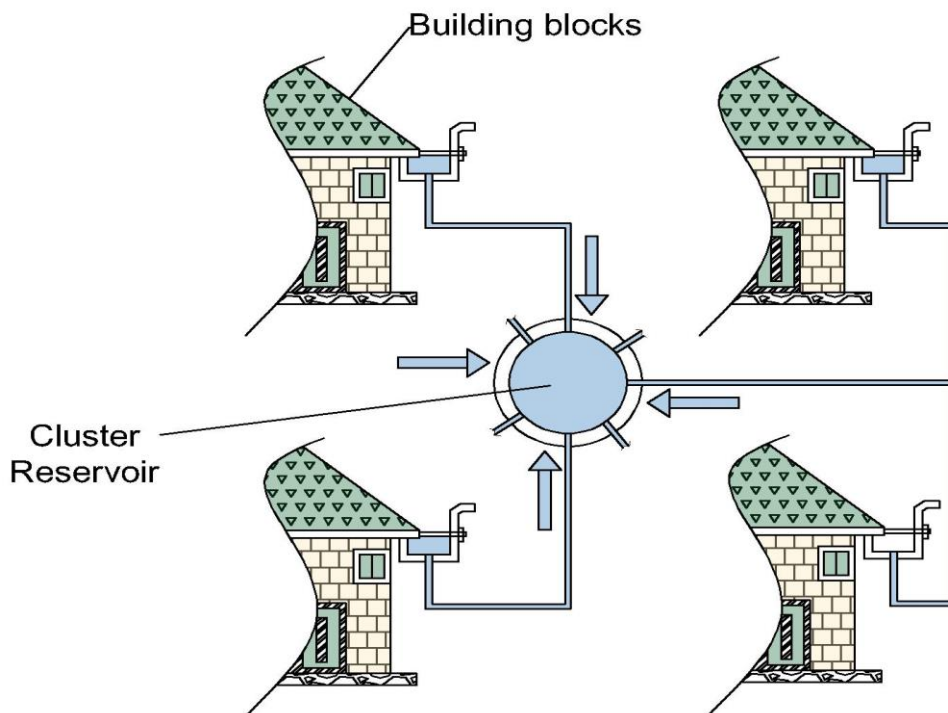


Figure 4. 4 Proposed decentralised rainwater harvesting per block, modified after (Siphambe et al., 2024)

Figure 4.4 shows a system of catchment areas collecting and storing harvest in one storage. The proposed design can for instance have the language department and the Art and ICT block collecting on one storage. The school library and the Block with room 19, 20 and 21 to share a storage tank. The Mantlwaneng theater to have its own storage and finally Block with room 16, 17, 18 and Block with room 10, 11,12 to share a storage tank positioned towards the school soccer field. The positioning and size of the storage tanks is primarily based on space available and not necessarily the amount of water that can be harvested. These matters are explained below. According to Siphambe *et al.*, (2024), it is advantageous to have a storage tank closed to each building and a cluster’s tank for overflows from individual tanks. A further advantage of smaller tanks is that in emergency situations, small amounts of water can be trucked to the school (e.g. 5000 L).

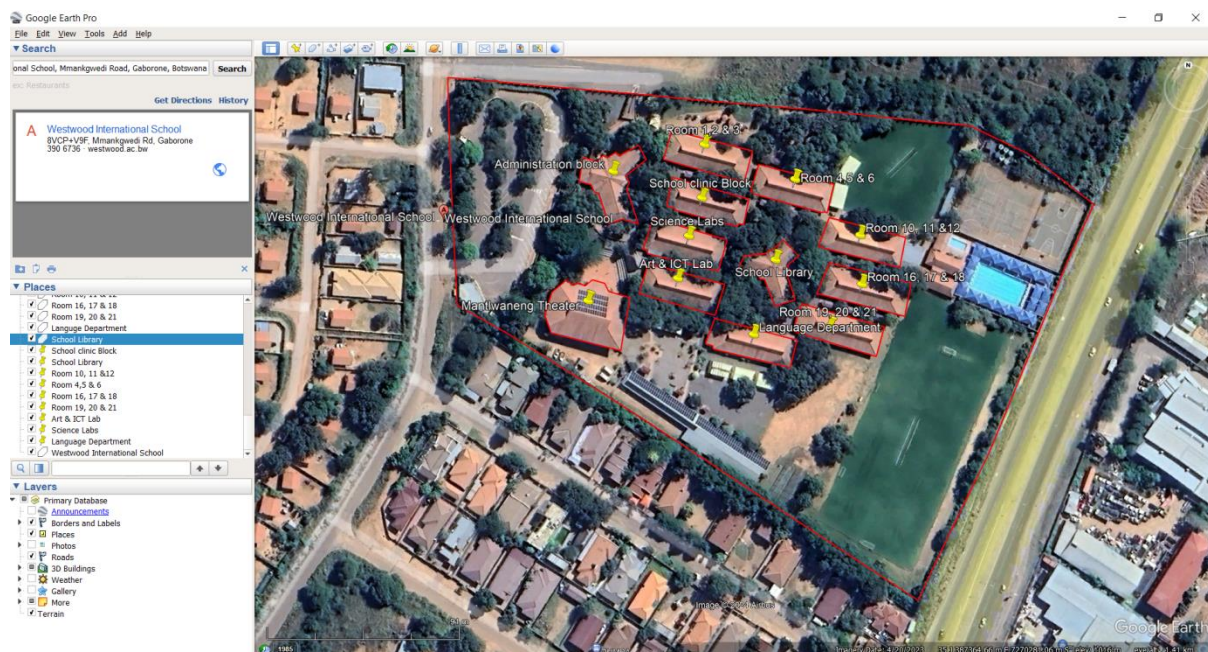


Figure 4. 5 Westwood International School

Source: Google Earth Pro

Through observation and consultations with the maintenance manager, the school head and the head of curriculum development and other interviewees, only four 5000L storage tanks can be constructed and installed on the surface while other storage tanks can be constructed underground. This is mainly because of space availability, as given in figure 4.5. They highlighted that this being a school environment, there is need for enough space to allow the children to play around and move around, without the tanks being hazardous as they do so. The overall school aesthetics also was one of the reasons given by some of the interviewees. They

highlighted that the storage tanks should be able to blend in with the school appearance also emphasizing that with that said, the tanks cannot be installed underground only as they would be invisible therefore not serving their purpose as educational tools to water conservation and sustainability. According to the perspective of most interviewees, this exercise will mostly be for educational purposes and not necessarily driven by the need to harvest and use that water for significant purposes. Majority of the leadership and key personnel making the decisions around the school mentioned the variability in Botswana's rainfalls and the school having their own borehole, they did not see the need to harvest rainfall other than for educational purposes.

The presence of a borehole at WIS offers the community a fallback option, potentially reducing their inclination to prioritize and invest in rainwater harvesting (RWH). They perceive the borehole as a sufficient solution to potential water challenges, thus diminishing the perceived urgency for RWH investment. However, this perception may be short-sighted, as they may overlook the future implications of relying solely on a borehole, particularly considering potential changes in water regulations. The uncertainties surrounding future water laws and developments underscore the importance of considering the long-term sustainability and financial implications of relying on a borehole versus investing in RWH systems.

Siphambe et al. (2024) recently recalled/revealed that rooting RWH on Equation 1 alone is not giving the whole picture. This is because harvested rainwater as given in Equation 1 is just the minimization of surface runoff (R) as rightly revealed by several interviewees. However, as it rains, a fraction of water is evaporated (E) and another fraction is infiltrated (I). These three components make the hydrologic cycle and are interconnected (Equation 2).

$$P = E + I + R \quad (2)$$

Groundwater is accumulated infiltration (I) of rainfall (P), meaning that the school should actively infiltrates rainwater to secure the long-term productivity of the school borehole. Another aspect is that if the number of boreholes within the neighbourhood drastically increases, it can happen that the bore dries up. This aspect was not considered in the interview.

The ferrocement as suggested by the maintenance manager to build the storage tank as they can be constructed by the school artisans. It can be constructed in the school. Cement is readily available, it is a good material to store water and its repairable and more resistant than plastic which are mostly common, commonly known as JoJo tank. The material also allows for the message of sustainable use of water to be written on the tank and its visible to all those seeing

the tanks as other environmentally sustainable messages are displayed in the school e.g separation of waste, see figure below. This will be promoting sustainable use of water as well.



Figure 4. 6 Waste separation bins

4.14 Storage material

The cisterns are built at low cost, approximately €240 in 2019, and are made with locally available tools and materials. The idea is to collect rainwater and store it close to the point of need. It has taken nine years to develop the design of the Calabash Cistern therefore it has been experientially tested and tried. The material used for construction of the water cistern is ferrocement it is chosen because cement is a very good material to store water. It is cheaper than stainless steel and more resistant than plastic. It can be constructed on the spot using hand tools. Cement is an available substance to find. They are durable and leaking wall is repairable. The life span can be 50 years, depending on maintenance. According to Akkerman (2020) this type cistern has not been used in Botswana (figure 4.6), common water tanks are polyethylene, concrete and metal of which have a lower life span than the ferrocement cistern.

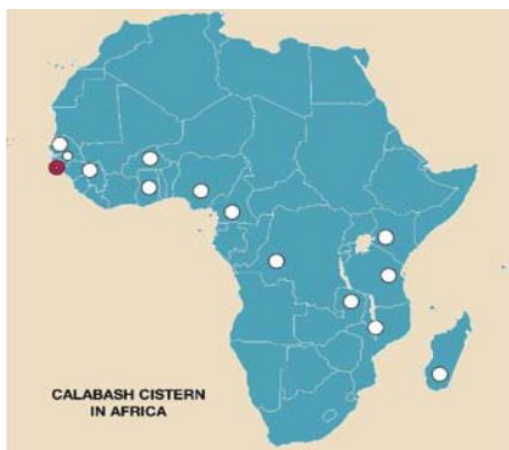


Figure 4. 7 Calabash cistern in Africa Figure 4. 8 Calabash cistern 5000L

WATER UTILITY BILLS FOR DECEMBER 2022-JANUARY 2023

Table 4. 4 Water utility bills from Dec 2022 to Jan 2024

MONTHS	AMOUNT BWP	IN	QUANTITY KLS
Dec-22	5855.4		155
Jan-23			
Feb-23	6416.48		168
Mar-23	14962.16		366
Apr-23	16127.48		393
May-23	13667.36		336
Jun-23	12502.04		309
Jul-23	10603		265
Aug-23	7322.84		189
Sep-23	9567.16		241
Oct-23	6459.64		169
Nov-23	7322.84		189
Dec-23	7495.48		193
Jan-23	10344.04		259
AVERAGE	9895.84		248.6153846
TOTAL	138541.76		3232

Table 4.4 shows the monthly water bills of Westwood International School from December 2022 to January 2024. In these bills the quantity/ volume of water used per month is also stated and their averages are computed respectively. The purpose of using bills was to compare the volume of water normally used by the institution and compare it to how it will be affected if the institution were to harvest rainwater according to the optimised system proposed. The average monthly volume used in the school is 248.6 Kl/month (248.6m³), the total volume of water used in the school from December 2022 and January 2024 is 3232 Kl and the potential that can be harvested from the school as a whole is 2442.006 m³/a. Therefore, WIS can harvest an estimated 75% of their yearly water consumption and save an estimated P100 000.00. These estimations did not factor in initial investment costs.

4.15 DISCUSSIONS

4.15.1 Introduction

Through a synthesis of the results obtained and a comprehensive review of relevant literature, the discussion aims to provide insights into the feasibility, limitations, and potential for adopting and implementing rainwater harvesting initiatives as a sustainable water management strategy in semi-arid regions like Botswana, using Westwood International School in Gaborone, as a case study. This chapter critically analyses the findings from the research conducted, exploring the efficacy of rainwater harvesting systems in addressing water scarcity challenges in the semi-arid context of Botswana. Furthermore, it highlights key recommendations for policymakers, stakeholders, and practitioners to optimize the benefits of rainwater harvesting systems while addressing existing water security concerns and promoting long-term sustainability. Additionally, it considers the socio-economic and environmental implications of implementing rainwater harvesting techniques within the school premises.

The results chapter is divided into part 1 and part 2. Part 1 shows the results emerged from the interview process which resulted from the research questions seeking to find out the state of awareness and adoption of RWH at WIS. This part is also influenced by the need to seek strategies that can be used for the promotion of the system at the school. Part 2 of the results, was influenced by the answers obtained from the interview. This part attempts to bring solutions to proposed hindrances of the installation at WIS.

4.16 Botswana’s surface waters

The perception of the users was the crucial piece of information needed to answer the question of “Why”, Botswana being a water scarce country, Botswana’s rivers being seasonal, relying on transboundary waters, Jefferis & Kenewendo (2012), Botswana’s dams declining in quantity, as summarised in Figure 4.9. Why is RWH practiced at this low level, not well documented as it would be perceived to be, looking at the above-mentioned facts.



Figure 4. 9 Botswana's Dam levels

Source: (Water Utilities Corporation, 2024)

The above dam levels as presented by the Botswana Water Utilities Corporation, which is the primary provider of water around the country,; shows the capacity of Botswana’s dams and their levels for the year 2024 compared to last year’s 2023. Figure 4.9 shows decline in percentage dam levels on all the dams, indicating the severity of the water scarcity challenge.

Botswana has 9 official dams providing the country with water and 1 dam (Molatedi dam) which is a South African dam providing the Botswana Water Utilities Corporation with additional water to meet the Botswana's demand (Statistics Botswana, 2016). The dams which are providing case study area with water and their decline percentage levels compared to last years as shown in the table above are as follows; Dikgatlong Dam has declined by 16.7%, Letsibogo Dam has declined by 44.9%, Molatedi Dam from South Africa supplying Botswana has declined by 36%, Gaborone Dam has declined by 33% and lastly Bokaa Dam has declined by 42.3%. The reported decline in dam levels across key dams in Botswana signifies a significant strain on the country's water resources. This decline underscores the vulnerability of Botswana's reliance on dam reservoirs as the primary source of water supply and underscore the urgent need for proactive measures to address it. It indicates heightened pressure on existing water resources, potentially leading to shortages in the near future. This could have far-reaching consequences for agriculture, industry, and domestic consumption, impacting livelihoods and economic development. Measures like RWH can be used to mitigate against circumstances like these

4.17 Rainwater harvesting awareness at WIS

The major finding from the first research question is that there is awareness about RWH in WIS but when it comes to adoption, factors of costs do play a major role. Furthermore, costs involved in implementing it are compared to financial benefit coming out of it. The results in cost savings using water bills did show major savings with regards to monthly payable bills. Key personnel did highlight in the interviews that prioritising RWH system installation is unlikely, due to its inability to promise returns in a short space of time but rather would need high investment costs. The availability of more than water source (borehole), did also put RWH at the last spot, when possible, water sources are considered. Majority of the participants showed confidence in the presence of a borehole. Challenges stemming from expenses are significant hurdles. The high cost associated with implementing Rainwater Harvesting Systems (RHS) presents a major obstacle, surpassing that of other water supply options Lani *et al.*, (2018).

In response to the question about the benefits of RWH in WIS, majority of the participants suggested that it would be beneficial especially for plants and sports fields, which do not necessarily need potable water to flourish. Some even believed rainwater is the best for

gardening. They did highlight that it would be a prospective water alternative rather than letting the water flow away. In the context of environmental considerations, rainwater harvesting systems serve as prospective alternatives for future water supply. They have the capacity to supplement current water sources for both potable and non-potable purposes Jamalluddin & Feng (2007).

4.18 Feasibility of RWH at WIS

According to the research question looking in to the feasibility of RWH in WIS, the results above show that the system will be feasible in WIS in terms of costs, among other reasons, saved in water bills. This result focused only on cost savings made with respect to the utility bills paid. Even though WIS proud itself with ownership of a high yielding borehole, the savings made from implementing RWH systems appears to be significant. By integrating Rainwater Harvesting (RWH) systems, there's potential for enhancing water supply alternatives and enabling sustainable reuse. Additionally, RWH has the added benefit of reducing water bills, making it a cost-effective solution Fakhira & Nazri (2022)

Addressing the feasibility of RWH in WIS, most scholars suggest that mainly annual rainfall, storage tank capacity, and catchment area are the major parameters affecting RWH installations Juliana *et al.*,(2017). During the researcher's investigation, significant concerns arose regarding the visual aspect of storage tanks during interviews. Questions emerged about how the school's aesthetics would be affected, pondering whether the tank would be conspicuous or seamlessly integrated into its surroundings. This was particularly relevant in scenarios where alternative water sources existed like in a case of WIS, suggesting that users not only consider the functionality of rainwater harvesting system but also its appearance. Location of the storage tank seemed to be the most influential parameter in RWH system installation at WIS. The visual presentation of a product plays a significant role in shaping consumer preferences in various ways. It can hold aesthetic appeal for consumers, convey functional attributes, and create an impression of quality (functional value). Additionally, it can signify ease of use (ergonomic value) Creusen & Schoormans (2004). In (Tanks overground (design), 2024) RWH storages are made to blend with the houses architectural design, the colour of the house, as well as the functional purpose of storing rain.

4.19 Rainwater harvesting education and training

In the interviews, key senior management team participants emphasized that RWH installation in WIS will have educational impact and not only environmental impacts, it showed promising as an educational model to raise awareness about RWH and water conservation. This addressed the third research question about the strategies that can be used by WIS to promote RWH installation. In a study by Chanan *et al.*,(2014), about rainwater tanks in schools project, the educational element resulted in enhancements in the knowledge, attitudes, and conduct of both students and teachers within the schools, aiding in the transition towards attaining sustainability. Rainwater harvesting project in schools demonstrated cost savings, learning opportunities as well as the environmental benefits. Economically, it offers savings on water expenses, raises awareness of external costs, and avoiding the necessity for additional infrastructure development. Socially, it entails crafting and implementing policies, empowering students with knowledge, and fostering a sense of ownership among them. Environmentally, RWH advocates for the efficient utilization of resources, particularly water, upholds resource integrity, and contributes to environmental health preservation Chanan *et al.*,(2014).

4.20 Potential limitations of the study

The primary limitations of this study revolved around time constraints and logistical challenges. Initially intended to encompass research across six government schools equipped with Rainwater Harvesting (RWH) systems but underutilizing them, the study faced setbacks due to the lengthy process of obtaining research permits in Botswana, which typically requires six months. Consequently, the scope of the study had to be narrowed, reducing the number of schools under investigation. This limitation inherently diminishes the breadth of the study's findings, potentially impacting the comprehensiveness of the conclusions drawn. Additionally, time constraints prevented comprehensive interviews with the entire WIS community, further limiting the depth of data collection and potentially skewing the study's outcomes. Furthermore, the ongoing drought in Botswana during the study period posed a significant obstacle, as the absence of substantial rainfall impeded the researcher's ability to conduct hands-on observations and data collection, hindering the study's accuracy and applicability.

4.21 How the results and conclusions influence the knowledge or understanding of the problem examined

Mostly in Africa and other countries focus is always on the parameters of function only (catchment area, conveyance, storage, treatment). But for certain users like WIS, though agreeing with all the benefits that come with RWH, it may not be an option for them due to certain issues as mentioned above. This problem is addressed by the researcher where an optimised system design (a dual system) was modelled to show that in the case of WIS, a few surface storage tanks can be constructed on the surface, the size of these tanks will not be determined by the potential of rainwater that can be harvested but rather would serve as an educational model to raise awareness about RWH and to teach the concept to the students just as the school needs. Whatever the message that the school needs to push forward with regards to RWH can be illustrated in these tanks. The underground tanks will serve the purpose of harvesting rainwater that could not be collected by the surface storage tanks. Constructing these storage tanks underground will be addressing the emerging issues of availability of space and crowding the student's space with big tanks of water. Therefore, with this design adopted, RWH can be practiced fully at WIS.

The results show that RWH is not only about function to users. Especially users who have multiple sources of water, their eagerness to install RWH is different from users who do not have water sources at all. In raising awareness and promoting it, all factors should be considered looking at the need of the user. Ignoring that aspect will prove why countries like Botswana who have little rainfalls do not harvest at the intensity at which they should. People are aware of RWH as seen in the results above, but how the system can fit into their environment is where the disconnection is.

The researcher demonstrated the promising prospects of Rainwater Harvesting (RWH) at WIS by showcasing its potential benefits across economic, social, and environmental dimensions. Optimisation of the system is also a possibility as seen in the model proposed.

CHAPTER V: SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

Following the findings outlined in the preceding chapter, the focus of this chapter is to provide a concise overview of the study's objectives, methodologies, and significant findings. Additionally, it offers conclusions and recommendations. The initial part presents a summary, emphasizing the main findings of the study. Subsequently, a brief conclusion is provided in the second section, followed by recommendations for future actions in the final part.

5.2 Summary

The study investigated the potential of rooftop rainwater harvesting (RWH) systems in addressing water scarcity and resource management issues in Gaborone, with a focus on Westwood International School (WIS). The objectives were to assess the current state of RWH awareness and adoption at WIS, design an optimized RWH system for the school, and propose strategies for RWH implementation in Botswana.

Through interviews conducted with the WIS community, it was found that there is a general awareness of RWH, primarily gained from experiences in participants' home environments. They expressed belief in the benefits of RWH for WIS and noted that the school's existing environmental initiatives align well with RWH adoption. However, challenges were identified, including limited space for storage tanks and Botswana's low rainfall patterns.

The methodology involved designing a customized RWH system tailored to WIS's needs and evaluating its potential using water bills to determine consumption and costs. This approach aimed to provide insights into the feasibility and efficiency of RWH at WIS. A design was proposed suitable for WIS needs that can ensure full utilisation of RWH in the school taking into consideration their intention about the system and their concerns.

In addressing the third research question that looked into strategies that can be proposed for implementation of RWH in WIS, inclusion of the system in the school curriculum was proposed and raising awareness through the school initiatives were suggested as suitable means for the school.

Overall, the findings suggest that while there is awareness and potential interest in RWH at WIS, challenges related to infrastructure and environmental factors need to be addressed for

successful implementation. The proposed strategies aim to overcome these challenges and promote the adoption of RWH not only at WIS but also in broader contexts within Botswana, contributing to sustainable water management practices in the region.

5.3 Conclusion

The decline in dam levels in Botswana underscores the urgent need for proactive measures to address water scarcity challenges. Rainwater Harvesting (RWH) emerges as a sustainable solution to augmenting water supply, diversifying water sources, and enhancing resilience against drought and water shortages. By integrating RWH initiatives with traditional water management approaches, Botswana can secure a reliable and sustainable water future for its citizens.

Integrating RWH systems with existing water infrastructure offers a holistic approach to water management in Botswana. By incorporating RWH technologies into urban and rural development plans, authorities can diversify water sources and reduce reliance on centralized water supply systems. This decentralized approach empowers communities to become more self-sufficient in water provisioning, particularly in areas where access to traditional water sources is limited.

RWH initiatives can play a pivotal role in addressing the multifaceted challenges posed by water scarcity in Botswana. By promoting RWH awareness campaigns, providing incentives for RWH adoption, and implementing supportive policies and regulations, the government can foster a culture of water conservation and resilience. Moreover, investing in RWH infrastructure, such as rooftop rainwater collection systems and storage tanks, can enhance water availability and reliability, particularly during dry seasons or periods of prolonged drought.

The adoption of RWH aligns with principles of sustainability and resilience, offering long-term benefits for Botswana's water management strategy. By harnessing rainwater, communities can reduce their environmental footprint, minimize water wastage, and adapt to changing climatic conditions. Furthermore, RWH promotes self-reliance and empowers communities to actively participate in water stewardship efforts, fostering a sense of ownership and responsibility towards water resources.

5.4 Recommendations

Moving forward, strategies for overcoming challenges and promoting RWH adoption need to be developed. These may include exploring alternative storage solutions, enhancing public awareness campaigns, and advocating for policy support to incentivize RWH implementation. By addressing these challenges and leveraging existing environmental initiatives, WIS and other institutions in Botswana can contribute to sustainable water management practices and mitigate the impacts of water scarcity in the region. By prioritizing these recommendations, Botswana can leverage Rainwater Harvesting (RWH) as a key strategy for enhancing water security, resilience, and sustainability across the country. To facilitate the widespread adoption of rooftop rainwater harvesting (RWH) systems, several key strategies are recommended: Firstly, the development and implementation of RWH policies and regulations are essential to ensure compliance and promote adoption across various sectors. Secondly, financial incentives, subsidies, and technical support should be provided, particularly targeting rural and underserved areas, to facilitate the installation of RWH infrastructure. Thirdly, public awareness campaigns and educational programs are crucial for promoting the benefits of RWH and fostering community engagement. Additionally, collaboration with local communities, NGOs, and international partners is vital to share best practices, knowledge, and resources for effective RWH implementation. Lastly, continuous monitoring and evaluation of RWH initiatives impact on water availability, quality, and sustainability are necessary, enabling adjustments to strategies as needed to maximize effectiveness.

The researcher recommends the use a dual system see Figure 4.1, especially in cases of balancing the need for the system to be visible but not that visible and an in-depth study in to this topic, measuring actual rainfall over a long period of time and a full cost benefit analysis to find out the true cost benefit of investing in RWH at WIS. The analysis was not done because of time restrictions.

The researcher also recommends further studies on the factors affecting the utilisation of RWH as a practice and how they can be addressed.

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APPENDICES

Appendix 1: Interview Guide for WIS participants

INTERVIEW GUIDE

A. INTRODUCTION

My name is Tebogo Vivian Siphambe, a Master of Science degree student at the Pan African University Institute of Water and Energy Sciences including Climate Change, enrolled in Water Engineering. As part of my study, I am conducting research titled, “**The potential of rainwater harvesting for improved water security and sustainable management in semi-arid regions. A case study of Westwood International School Gaborone, Botswana**”. I would like to ask for your participation in this interview. Information collected will remain confidential and will be used for the purpose of this research only.

SECTION A

Research Question I (What is the state of RWH awareness and adoption in Westwood International School?)

Interview questions:

- a. Are you familiar with the term rainwater harvesting (RWH) systems? If yes, kindly describe what it is in your opinion. If no, are you open to making quick research about it to find out more about it? Also, if no, perhaps you know what it is but not as the term RWH.

- b. Is this system in place at your school? If yes, describe how it functions and utilized.

- c. What do you perceive are the benefits and challenges of implementing RWH systems in Westwood International School?

Research Question II: What RWH optimized rooftop system is at Westwood international School?

Interview questions:

- a. Can you describe the current condition of the rooftop rwh at Westwood International School?

- b. What are the expected water demands or usage requirements within the school premises?
- c. Are there any specific preferences or priorities regarding the design and functionality of the RWH system at Westwood International School?

Research Question III: What strategies are proposed for the implementation of RWH in Westwood International School?

Interview questions:

- a. What are the strategies in place for the implementation of RWH in Westwood International School?
- b. What strategies do you believe would be effective in increasing awareness and fostering support for the implementation of RWH systems among stakeholders at Westwood International School?
- c. Are there any specific educational or training programs that you think would be beneficial in preparing staff and students for the adoption of RWH systems? If affirmative, please state or highlight some of the programmes. If no, what training programmes do you suggest should be in place?
- d. How would you prioritize the allocation of resources and funds for the implementation of RWH systems within Westwood International School?

THANK YOU!

Appendix II: Informed consent form

PROJECT TITLE: THE POTENTIAL OF RAINWATER HARVESTING FOR IMPROVED WATER SECURITY AND SUSTAINABLE MANAGEMENT IN SEMI-ARID REGIONS. A CASE STUDY OF WESTWOOD INTERNATIONAL SCHOOL GABORONE, BOTSWANA

Principal Investigator: Tebogo Vivian Siphambe

Phone number(s): +267 74426900

What you should know about this research study:

Please read this informed consent form carefully in order to understand the purpose, risks, and benefits of this research study. You have the right to refuse to take part, or to withdraw at any point during the study. Kindly review this consent form carefully and ask any questions or raise any concerns before you make a decision. Your participation is voluntary and there is no monetary compensation associated with this study. Interviews will be recorded with a tape recorder in order to aid in the analysis of data.

Purpose

The purpose of this mixed study is to investigate the viability of rainwater harvesting and its implementation as a strategy for mitigating water scarcity and promoting sustainable water management in semi-arid regions such as Botswana. This study focuses on an institution like Westwood International School.

Procedures and duration

Once you provide consent to participate, you will be offered the opportunity to partake in an interview, which can be conducted either in person or over the telephone. The interview is expected to last between 20 and 30 minutes, during which we will inquire about your perspectives and experiences related to rainwater harvesting.

Risks and discomforts

One potential risk associated with this study is that the raw data collected may mistakenly get to the wrong hands. Although the interviews will be recorded with a tape recorder, the researcher will however ensure the confidentiality of the collected data. Your anonymity will be maintained throughout the study. Respondents will be tagged with alphabets and numbers.

Benefits

The results and significance of this research will be shared with relevant stakeholders to facilitate enhancements in the implementation of rainwater harvesting practices in Botswana. Dissemination will occur through seminars and publications. Please be aware that there is no financial compensation provided for participation in this study.

Confidentiality

The information collected from this inquiry will be safeguarded with strict confidentiality measures, ensuring that recorded audio and other documentation are securely stored by the

researcher. Under no circumstances will any of the gathered data be utilized for commercial purposes.

Voluntary participation

Participation in this study is voluntary. Declining to participate will not impact your future interactions with the Pan African University Institute of Water and Energy Sciences including Climate Change, University of Botswana, its staff, or affiliated institutions. Should you choose to participate, you have the right to withdraw your consent and cease participation at any time without facing any consequences. Failure to adhere to scheduled appointments with the principal investigator will be considered as an implicit withdrawal, leading to the termination of your participation without prior notice. If you are unable to fulfill your agreed-upon obligations, your participation in the study will be terminated without requiring your consent. Please be aware that the interview will be recorded using a voice recorder.

Authorization

By signing your signature, you have read and understood the information provided above, have had all your questions in relation to the study answered, and you have agreed to participate in the study.

Name and signature of Research Participant

Date

You will be given a copy of this consent form to keep. If you have any questions concerning this study or consent form beyond those answered by the investigator, including questions about the research, your rights as a research participant; or if you feel that you have been treated unfairly and would like to talk to someone other than a member of the research team, please feel free to contact Dr. Piet Kenabatho, Cell: +267-73930993, kenabatho@ub.ac.bw

Appendix III: Letter of support



Faculty of Science

Department of Environmental Science

Corner of Notwane
and Mobuto Road
Gaborone, Botswana

Pvt Bag 00704
Gaborone
Botswana

Tel : (267) 355 2527
Fax : (267) 355 2908
Email: hod-environmentalscience@ub.ac.bw

February 19, 2024

To: The School Head/Principal
Westwood International School
P O Box 2446
Gaborone, Botswana
Mmankgwedi Rd

Dear Sir/ Madam

RE: Formal Request for Information for Master's Thesis Research on Rainwater Harvesting at Westwood International School, Gaborone, Botswana

I am writing on behalf of one of my Master's students, **Tebogo Vivian Siphambe**, who is currently conducting research for her thesis titled "**The Potential of Rainwater Harvesting for Improved Water Security and Sustainable Management in Semi-Arid Regions: A Case Study of Westwood International School, Gaborone, Botswana.**" The aim of her research is to comprehensively investigate this subject matter and contribute valuable insights to the field.

To ensure the accuracy and depth of her study, I am formally requesting specific information from your organization, which we believe would greatly enhance the quality of her research. The requested information includes:

1. Total school population, inclusive of both students and staff members, to ascertain the overall water demand.
2. Monthly water consumption data, which will enable an assessment of potential water savings achievable through the adoption of rainwater harvesting practices.
3. Documentation or resources where rainwater harvesting is taught, promoted, or integrated into planning, such as sections of the school policy, curriculum, or displayed posters within the school premises.
4. Opportunity to interview staff members across the organisational setup (upper management, middle management, auxiliary etc) to obtain information needed to address certain study objectives.

We understand that providing this information may require some time and effort on your part, but your cooperation would be immensely valuable in contributing to academic research aimed at advancing our understanding of climate change mitigation, sustainable development, and integrated water resource management. Your cooperation and assistance are greatly appreciated.

We assure you that any information provided will be handled with the utmost confidentiality and used solely for academic purposes.



Thank you for your consideration and participation.

Yours Faithfully



Professor Piet Kebuang Kenabatho (Ph.D.)

Department of Environmental Science, UB

Tel: +267-3552509

Cell: +267-73930993

Email: kenabatho@ub.ac.bw

Appendix IV: Water Utilities bills

December 2022



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE		TAX INVOICE		WUC VAT REGISTRATION No: C03896701113													
CUSTOMER DETAILS <div style="border: 1px solid black; padding: 5px; width: fit-content;"> [REDACTED CUSTOMER NAME] BOX 2446 GABORONE, 22978/0/0 </div>			INVOICE DATE: 31-01-2023 DATE PRINTED: 04-05-2023 CUSTOMER NO: 6563 INVOICE NO: 2052162016 CUSTOMER VAT REG. NO:														
TRANSACTION DESCRIPTION			AMOUNT (Pula)														
Consumption charges for the period: 07.12.2022 - 06.01.2023 Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00 <table border="1"> <thead> <tr> <th>From</th> <th>To</th> <th>Meter no.</th> <th>Prev. MR</th> <th>New MR</th> <th>Cons (Kl)</th> </tr> </thead> <tbody> <tr> <td>07.12.2022</td> <td>06.01.2023</td> <td>B-KZR0615</td> <td>12,113</td> <td>12,268</td> <td>155</td> </tr> </tbody> </table> Water Charge For Consumption Period: 07.12.2022 - 06.01.2023 Waste Water Charge For Consumption Period: 07.12.2022 - 06.01.2023 Late Payment Charge: Sub-tot: VAT @ 12%:			From	To	Meter no.	Prev. MR	New MR	Cons (Kl)	07.12.2022	06.01.2023	B-KZR0615	12,113	12,268	155	5,855.40 1,011.60 0.00 6,867.00 824.04		
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)												
07.12.2022	06.01.2023	B-KZR0615	12,113	12,268	155												
			7,691.04														
Balance B/F 22,162.17		Payments 0.00		Current Charge 7,691.04													
				Total Due 29,853.21													
IMPORTANT INFORMATION																	
Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.																	

February 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE	TAX INVOICE	WUC VAT REGISTRATION No: C03895701113																																																	
CUSTOMER DETAILS <div style="border: 1px solid black; padding: 5px; margin: 5px auto; width: 80%;"> <p style="text-align: center;">XXXXXXXXXXXXXXXXXXXX</p> <p>BOX 2446 GABORONE,</p> </div>	INVOICE DATE: <input type="text" value="31-03-2023"/> DATE PRINTED: <input type="text" value="04-05-2023"/> CUSTOMER NO: <input type="text" value="0503"/> INVOICE NO: <input type="text" value="2023002353"/> CUSTOMER VAT REG. NO: <input type="text"/>																																																		
PLOT NO. <input type="text" value="22978/0/0"/>																																																			
TRANSACTION DESCRIPTION		AMOUNT (Pula)																																																	
Consumption charges for the period: 07.02.2023 - 06.03.2023 Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00 <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">From</th> <th style="text-align: left;">To</th> <th style="text-align: left;">Meter no.</th> <th style="text-align: left;">Prev. MR</th> <th style="text-align: left;">New MR</th> <th style="text-align: left;">Cons (El)</th> <th></th> </tr> </thead> <tbody> <tr> <td>07.02.2023</td> <td>06.03.2023</td> <td>B-K2R0615</td> <td>12,542</td> <td>12,710</td> <td>168</td> <td style="text-align: right;">6,416.48</td> </tr> <tr> <td colspan="6">Water Charge For Consumption Period: 07.02.2023 - 06.03.2023</td> <td style="text-align: right;">1,107.28</td> </tr> <tr> <td colspan="6">Waste Water Charge For Consumption Period: 07.02.2023 - 06.03.2023</td> <td style="text-align: right;">0.00</td> </tr> <tr> <td colspan="6">Late Payment Charge:</td> <td style="text-align: right;">7,523.76</td> </tr> <tr> <td colspan="6">Sub-tot:</td> <td style="text-align: right;">902.85</td> </tr> <tr> <td colspan="6">VAT @ 12%:</td> <td></td> </tr> </tbody> </table>		From	To	Meter no.	Prev. MR	New MR	Cons (El)		07.02.2023	06.03.2023	B-K2R0615	12,542	12,710	168	6,416.48	Water Charge For Consumption Period: 07.02.2023 - 06.03.2023						1,107.28	Waste Water Charge For Consumption Period: 07.02.2023 - 06.03.2023						0.00	Late Payment Charge:						7,523.76	Sub-tot:						902.85	VAT @ 12%:							
From	To	Meter no.	Prev. MR	New MR	Cons (El)																																														
07.02.2023	06.03.2023	B-K2R0615	12,542	12,710	168	6,416.48																																													
Water Charge For Consumption Period: 07.02.2023 - 06.03.2023						1,107.28																																													
Waste Water Charge For Consumption Period: 07.02.2023 - 06.03.2023						0.00																																													
Late Payment Charge:						7,523.76																																													
Sub-tot:						902.85																																													
VAT @ 12%:																																																			
		8,426.61																																																	
Balance B/F	Payments	Current Charge	Total Due																																																
28,778.15	0.00	8,426.61	17,204.76																																																
IMPORTANT INFORMATION																																																			
<p>Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.</p>																																																			

March 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION
 SEDIBENG HOUSE
 PRIVATE BAG 00276
 GABORONE

TAX INVOICE

WUC VAT REGISTRATION No: C03895701113

CUSTOMER DETAILS

BOX 2446
 GABORONE,

PLOT NO.

INVOICE DATE

DATE PRINTED

CUSTOMER NO:

INVOICE NO:

CUSTOMER VAT REG. NO:

TRANSACTION DESCRIPTION	AMOUNT (Pula)
Consumption charges for the period: 07.03.2023 - 06.04.2023	
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00	
From To Meter no. Prev. MR New MR Cons (Kl)	
07.03.2023 31.03.2023 B-KZR0615 12,710 13,076 366	
Water Charge For Consumption Period: 07.03.2023 - 31.03.2023	14,962.16
Waste Water Charge For Consumption Period: 07.03.2023 - 31.03.2023	2,564.56
Late Payment Charge:	0.00
Sub-tot:	17,526.72
VAT @ 12%:	2,103.21
01.04.2023 06.04.2023 B-KZR0615 13,076 13,165 89	
Water Charge For Consumption Period: 01.04.2023 - 06.04.2023	3,006.84
Waste Water Charge For Consumption Period: 01.04.2023 - 06.04.2023	525.84
Late Payment Charge:	0.00
Sub-tot:	3,532.68
VAT @ 14%:	494.58

23,657.19

Balance B/F	Payments	Current Charge	Total Due
<input type="text" value="37,204.76"/>	<input type="text" value="0.00"/>	<input type="text" value="23,657.19"/>	<input type="text" value="60,861.95"/>

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

April 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE	TAX INVOICE	WUC VAT REGISTRATION No: C03895701113																																																	
CUSTOMER DETAILS	INVOICE DATE: <input type="text" value="31-05-2023"/> DATE PRINTED: <input type="text" value="12-07-2023"/> CUSTOMER NO: <input type="text" value="6563"/> INVOICE NO: <input type="text" value="205334668"/> CUSTOMER VAT REG. NO: <input type="text"/>																																																		
[Redacted Customer Name] BOX 2446 GABORONE, PLOT NO. <input type="text" value="22978/0/0"/>																																																			
TRANSACTION DESCRIPTION		AMOUNT (Pula)																																																	
Consumption charges for the period: 07.04.2023 - 05.05.2023 Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00 <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">From</th> <th style="text-align: left;">To</th> <th style="text-align: left;">Meter no.</th> <th style="text-align: left;">Prev. MR</th> <th style="text-align: left;">New MR</th> <th style="text-align: left;">Cons (Kl)</th> <th style="text-align: right;">Amount</th> </tr> </thead> <tbody> <tr> <td>07.04.2023</td> <td>05.05.2023</td> <td>B-KZR0615</td> <td>13,165</td> <td>13,558</td> <td>393</td> <td style="text-align: right;">16,127.48</td> </tr> <tr> <td colspan="6">Water Charge For Consumption Period: 07.04.2023 - 05.05.2023</td> <td style="text-align: right;">2,763.28</td> </tr> <tr> <td colspan="6">Waste Water Charge For Consumption Period: 07.04.2023 - 05.05.2023</td> <td style="text-align: right;">0.00</td> </tr> <tr> <td colspan="6">Late Payment Charge:</td> <td style="text-align: right;">18,890.76</td> </tr> <tr> <td colspan="6">Sub-tot:</td> <td style="text-align: right;">2,644.71</td> </tr> <tr> <td colspan="6">VAT @ 14%:</td> <td style="text-align: right;">21,535.47</td> </tr> </tbody> </table>		From	To	Meter no.	Prev. MR	New MR	Cons (Kl)	Amount	07.04.2023	05.05.2023	B-KZR0615	13,165	13,558	393	16,127.48	Water Charge For Consumption Period: 07.04.2023 - 05.05.2023						2,763.28	Waste Water Charge For Consumption Period: 07.04.2023 - 05.05.2023						0.00	Late Payment Charge:						18,890.76	Sub-tot:						2,644.71	VAT @ 14%:						21,535.47	
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)	Amount																																													
07.04.2023	05.05.2023	B-KZR0615	13,165	13,558	393	16,127.48																																													
Water Charge For Consumption Period: 07.04.2023 - 05.05.2023						2,763.28																																													
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Sub-tot:						2,644.71																																													
VAT @ 14%:						21,535.47																																													
		21,535.47																																																	
Balance B/F	Payments	Current Charge	Total Due																																																
<input type="text" value="46,437.60"/>	<input type="text" value="0.00"/>	<input type="text" value="21,535.47"/>	<input type="text" value="67,973.07"/>																																																
IMPORTANT INFORMATION																																																			
<p>Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.</p>																																																			

May 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION
SEDIBENG HOUSE
PRIVATE BAG 00276
GABORONE

TAX INVOICE

WUC VAT REGISTRATION No: C03895701113

CUSTOMER DETAILS

~~XXXXXXXXXXXXXXXXXXXX~~

BOX 2446
GABORONE,

PLOT NO.

INVOICE DATE

DATE PRINTED

CUSTOMER NO:

INVOICE NO:

CUSTOMER VAT REG. NO:

TRANSACTION DESCRIPTION	AMOUNT (Pula)												
Consumption charges for the period: 06.05.2023 - 06.06.2023													
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00													
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;">From</td> <td style="width: 15%;">To</td> <td style="width: 15%;">Meter no.</td> <td style="width: 15%;">Prev. MR</td> <td style="width: 15%;">New MR</td> <td style="width: 15%;">Cons (Kl)</td> </tr> <tr> <td>06.05.2023</td> <td>06.06.2023</td> <td>B-KZR0615</td> <td>13,558</td> <td>13,894</td> <td>336</td> </tr> </table>	From	To	Meter no.	Prev. MR	New MR	Cons (Kl)	06.05.2023	06.06.2023	B-KZR0615	13,558	13,894	336	
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)								
06.05.2023	06.06.2023	B-KZR0615	13,558	13,894	336								
Water Charge For Consumption Period: 06.05.2023 - 06.06.2023	13,667.36												
Waste Water Charge For Consumption Period: 06.05.2023 - 06.06.2023	2,343.76												
Late Payment Charge:	0.00												
Sub-tot:	16,011.12												
VAT @ 14%:	2,241.56												
18,252.68													

Balance B/F	Payments	Current Charge	Total Due
67,973.07	0.00	18,252.68	86,225.75

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

June 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION
SEDIBENG HOUSE
PRIVATE BAG 00276
GABORONE

TAX INVOICE

WUC VAT REGISTRATION No: C03895701113

CUSTOMER DETAILS

~~XXXXXXXXXXXX~~

BOX 2446
 GABORONE,

PLOT NO.

INVOICE DATE

DATE PRINTED

CUSTOMER NO:

INVOICE NO:

CUSTOMER VAT REG. NO:

TRANSACTION DESCRIPTION

AMOUNT (Pula)

Consumption charges for the period: 07.06.2023 - 06.07.2023

Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00

From	To	Meter no.	Prev. MR	New MR	Cons (Kl)
07.06.2023	06.07.2023	B-KZR0615	13,894	14,203	309

Water Charge For Consumption Period: 07.06.2023 - 06.07.2023

12,502.04

Waste Water Charge For Consumption Period: 07.06.2023 - 06.07.2023

2,145.04

Late Payment Charge:

0.00

Sub-tot:

14,647.08

VAT @ 14%:

2,050.59

16,697.67

Balance B/F

39,788.15

Payments

0.00

Current Charge

16,697.67

Total Due

56,485.82

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

July 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE	TAX INVOICE	WUC VAT REGISTRATION No: C03895701113
CUSTOMER DETAILS	INVOICE DATE: <input type="text" value="31.08.2023"/>	DATE PRINTED: <input type="text" value="26.09.2023"/>
[Redacted Customer Name] BOX 2446 GABORONE, 22978/0/0	CUSTOMER NO: <input type="text" value="6563"/>	CUSTOMER NO: <input type="text" value="2055203253"/>
PLOT NO: <input type="text" value="22978/0/0"/>	INVOICE NO: <input type="text"/>	CUSTOMER VAT REG. NO: <input type="text"/>

TRANSACTION DESCRIPTION	AMOUNT (Pula)												
Consumption charges for the period: 07.07.2023 - 04.08.2023													
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00													
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;">From</td> <td style="width: 15%;">To</td> <td style="width: 15%;">Meter no.</td> <td style="width: 15%;">Prev. MR</td> <td style="width: 15%;">New MR</td> <td style="width: 20%;">Cons (Kl)</td> </tr> <tr> <td>07.07.2023</td> <td>04.08.2023</td> <td>B-KZR0615</td> <td>14,203</td> <td>14,468</td> <td>265</td> </tr> </table>	From	To	Meter no.	Prev. MR	New MR	Cons (Kl)	07.07.2023	04.08.2023	B-KZR0615	14,203	14,468	265	
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)								
07.07.2023	04.08.2023	B-KZR0615	14,203	14,468	265								
Water Charge For Consumption Period: 07.07.2023 - 04.08.2023	10,603.00												
Waste Water Charge For Consumption Period: 07.07.2023 - 04.08.2023	1,821.20												
Late Payment Charge:	0.00												
Sub-tot:	12,424.20												
VAT @ 14%:	1,739.39												

14,163.59			
Balance B/F	Payments	Current Charge	Total Due
<input type="text" value="56,485.82"/>	<input type="text" value="0.00"/>	<input type="text" value="14,163.59"/>	<input type="text" value="70,649.41"/>

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

August 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE	TAX INVOICE	WUC VAT REGISTRATION No: C03895701113
CUSTOMER DETAILS		
<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;"> [Redacted Customer Name] BOX 2446 GABORONE, 22978/0/0 </div>	INVOICE DATE: <input style="width: 100%;" type="text" value="30.09.2023"/> DATE PRINTED: <input style="width: 100%;" type="text" value="26.09.2023"/> CUSTOMER NO: <input style="width: 100%;" type="text" value="6563"/> CUSTOMER NO: <input style="width: 100%;" type="text" value="2055672025"/> INVOICE NO: <input style="width: 100%;" type="text"/> CUSTOMER VAT REG. NO: <input style="width: 100%;" type="text"/>	
PLOT NO. <input style="width: 100%;" type="text"/>		

TRANSACTION DESCRIPTION	AMOUNT (Pula)												
Consumption charges for the period: 05.08.2023 - 06.09.2023													
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00													
<table style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: left;">From</th> <th style="text-align: left;">To</th> <th style="text-align: left;">Meter no.</th> <th style="text-align: left;">Prev. MR</th> <th style="text-align: left;">New MR</th> <th style="text-align: left;">Cons (Kl)</th> </tr> <tr> <td>05.08.2023</td> <td>06.09.2023</td> <td>B-KZR0615</td> <td>14,468</td> <td>14,657</td> <td>189</td> </tr> </table>	From	To	Meter no.	Prev. MR	New MR	Cons (Kl)	05.08.2023	06.09.2023	B-KZR0615	14,468	14,657	189	
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)								
05.08.2023	06.09.2023	B-KZR0615	14,468	14,657	189								
Water Charge For Consumption Period: 05.08.2023 - 06.09.2023	7,322.84												
Waste Water Charge For Consumption Period: 05.08.2023 - 06.09.2023	1,261.84												
Late Payment Charge:	0.00												
Sub-tot:	8,584.68												
VAT @ 14%:	1,201.86												
9,786.54													

Balance B/F	Payments	Current Charge	Total Due
30,861.26	0.00	9,786.54	40,647.80

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

September 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION
 SEDIBENG HOUSE
 PRIVATE BAG 00276
 GABORONE

TAX INVOICE

WUC VAT REGISTRATION No: C03895701113

CUSTOMER DETAILS

[Redacted Customer Name]

BOX 2446
 GABORONE,
 22978/0/0

INVOICE DATE: 31.10.2023

DATE PRINTED: 28.11.2023

CUSTOMER NO: 6563
 4695896756

INVOICE NO:

PLOT NO:

CUSTOMER VAT REG. NO:

TRANSACTION DESCRIPTION

AMOUNT (Pula)

Consumption charges for the period: 07.09.2023 - 06.10.2023

Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00

From	To	Meter no.	Prev. MR	New MR	Cons (Kl)
07.09.2023	06.10.2023	B-K2R0615	14,657	14,898	241

Water Charge For Consumption Period: 07.09.2023 - 06.10.2023

9,567.16

Waste Water Charge For Consumption Period: 07.09.2023 - 06.10.2023

1,644.56

Late Payment Charge:

0.00

Sub-tot:

11,211.72

VAT @ 14%:

1,569.64

12,781.36

Balance B/F

40,647.80

Payments

0.00

Current Charge

12,781.36

Total Due

53,429.16

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

October 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE		TAX INVOICE	WUC VAT REGISTRATION No: C03895701113
CUSTOMER DETAILS <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <p style="text-align: center;">XXXXXXXXXXXXXXXXXXXX</p> <p>BOX 2446 GABORONE, 22978/070</p> </div>		INVOICE DATE <input type="text" value="30.11.2023"/>	DATE PRINTED <input type="text" value="28.11.2023"/>
PLOT NO. <input type="text" value="22978/070"/>	CUSTOMER NO: <input type="text" value="6563"/>	INVOICE NO: <input type="text" value="4005954850"/>	CUSTOMER VAT REG. NO: <input type="text"/>

TRANSACTION DESCRIPTION	AMOUNT (Pula)														
Consumption charges for the period: 07.10.2023 - 06.11.2023															
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00															
<table border="0" style="width: 100%;"> <tr> <td style="text-align: left;">From</td> <td style="text-align: left;">To</td> <td style="text-align: left;">Meter no.</td> <td style="text-align: left;">Prev. MR</td> <td style="text-align: left;">New MR</td> <td style="text-align: left;">Cons (Kl)</td> <td></td> </tr> <tr> <td>07.10.2023</td> <td>06.11.2023</td> <td>B-KZR0615</td> <td>14,898</td> <td>15,067</td> <td>169</td> <td style="text-align: right;">6,459.64</td> </tr> </table>	From	To	Meter no.	Prev. MR	New MR	Cons (Kl)		07.10.2023	06.11.2023	B-KZR0615	14,898	15,067	169	6,459.64	
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)										
07.10.2023	06.11.2023	B-KZR0615	14,898	15,067	169	6,459.64									
Water Charge For Consumption Period: 07.10.2023 - 06.11.2023	1,114.64														
Waste Water Charge For Consumption Period: 07.10.2023 - 06.11.2023	0.00														
Late Payment Charge:	7,574.28														
Sub-tot:	1,060.40														
VAT @ 14%:															
8,634.68															

Balance B/F	Payments	Current Charge	Total Due
<input type="text" value="12,781.36"/>	<input type="text" value="0.00"/>	<input type="text" value="8,634.68"/>	<input type="text" value="21,416.04"/>

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

November 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION
SEDIBENG HOUSE
PRIVATE BAG 00276
GABORONE

TAX INVOICE

WUC VAT REGISTRATION No: C03895701113

CUSTOMER DETAILS

~~XXXXXXXXXXXXXXXXXXXX~~
 BOX 2446
 GABORONE,

PLOT NO. 22978/0/0

INVOICE DATE 31-12-2023

DATE PRINTED 08-03-2024

CUSTOMER NO: 6563

INVOICE NO: 2057856304

CUSTOMER VAT REG. NO:

TRANSACTION DESCRIPTION	AMOUNT (Pula)
Consumption charges for the period: 07.11.2023 - 06.12.2023	
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00	
From To Meter no. Prev. MR New MR Cons (Kl)	
07.11.2023 06.12.2023 B-KZR0615 15,067 15,256 189	
Water Charge For Consumption Period: 07.11.2023 - 06.12.2023	7,322.84
Waste Water Charge For Consumption Period: 07.11.2023 - 06.12.2023	1,261.84
Late Payment Charge:	0.00
Sub-tot:	8,584.68
VAT @ 14%:	1,201.86

9,786.54

Balance B/F	Payments	Current Charge	Total Due
<u>21,416.04</u>	<u>0.00</u>	<u>9,786.54</u>	<u>31,202.58</u>

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

December 2023



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE		TAX INVOICE	WUC VAT REGISTRATION No: C03895701113
CUSTOMER DETAILS <div style="border: 1px solid black; padding: 5px; text-align: center;"> XXXXXXXXXXXXXXXXXXXX BOX 2446 GABORONE, </div>		INVOICE DATE: 31-01-2024	DATE PRINTED: 06-03-2024
PLOT NO: 22978/0/0	CUSTOMER NO: 6563	INVOICE NO:	CUSTOMER VAT REG. NO:

TRANSACTION DESCRIPTION	AMOUNT (Pula)														
Consumption charges for the period: 07.12.2023 - 05.01.2024															
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00															
<table border="1"> <thead> <tr> <th>From</th> <th>To</th> <th>Meter no.</th> <th>Prev. MR</th> <th>New MR</th> <th>Cons (Kl)</th> <th></th> </tr> </thead> <tbody> <tr> <td>07.12.2023</td> <td>05.01.2024</td> <td>B-KZR0615</td> <td>15,256</td> <td>15,449</td> <td>193</td> <td>7,495.48</td> </tr> </tbody> </table>	From	To	Meter no.	Prev. MR	New MR	Cons (Kl)		07.12.2023	05.01.2024	B-KZR0615	15,256	15,449	193	7,495.48	
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)										
07.12.2023	05.01.2024	B-KZR0615	15,256	15,449	193	7,495.48									
Water Charge For Consumption Period: 07.12.2023 - 05.01.2024	1,291.28														
Waste Water Charge For Consumption Period: 07.12.2023 - 05.01.2024	0.00														
Late Payment Charge:	8,786.76														
Sub-tot:	1,230.15														
VAT @ 14%:															

10,016.91			
Balance B/F	Payments	Current Charge	Total Due
31,202.58	0.00	10,016.91	41,219.49

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

January 2024



WATER UTILITIES CORPORATION

Committed to: PROVIDING A QUALITY WATER SERVICE

WATER UTILITIES CORPORATION SEDIBENG HOUSE PRIVATE BAG 00276 GABORONE	TAX INVOICE	WUC VAT REGISTRATION No: C03895701113
CUSTOMER DETAILS		
<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;"> <p style="text-align: center;">[REDACTED]</p> <p>BOX 2446 GABORONE,</p> </div>	INVOICE DATE: <input type="text" value="29.02.2024"/> DATE PRINTED: <input type="text" value="09.03.2024"/> CUSTOMER NO: <input type="text" value="6543"/> INVOICE NO: <input type="text" value="2057958966"/>	CUSTOMER VAT REG. NO: <input type="text"/>
PLOT NO: <input type="text" value="22978/0/0"/>		

TRANSACTION DESCRIPTION	AMOUNT (Pula)												
Consumption charges for the period: 06.01.2024 - 06.02.2024													
Contract: 6563 Plot: 22978/0/0 Security deposit: 300.00													
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;">From</td> <td style="width: 15%;">To</td> <td style="width: 15%;">Meter no.</td> <td style="width: 15%;">Prev. MR</td> <td style="width: 15%;">New MR</td> <td style="width: 20%;">Cons (Kl)</td> </tr> <tr> <td>06.01.2024</td> <td>06.02.2024</td> <td>B-KZR0615</td> <td>15,449</td> <td>15,708</td> <td>259</td> </tr> </table>	From	To	Meter no.	Prev. MR	New MR	Cons (Kl)	06.01.2024	06.02.2024	B-KZR0615	15,449	15,708	259	
From	To	Meter no.	Prev. MR	New MR	Cons (Kl)								
06.01.2024	06.02.2024	B-KZR0615	15,449	15,708	259								
Water Charge For Consumption Period: 06.01.2024 - 06.02.2024	10,344.04												
Waste Water Charge For Consumption Period: 06.01.2024 - 06.02.2024	1,777.04												
Late Payment Charge:	0.00												
Sub-tot:	12,121.08												
VAT @ 14%:	1,696.95												
Total	13,818.03												

Balance B/F	Payments	Current Charge	Total Due
19,803.45	0.00	13,818.03	33,621.48

IMPORTANT INFORMATION

Note: All outstanding balances on your bill must be settled within 30 days of the invoice date. If not paid, your water service may be disconnected without further notice and a late payment charge of P88.00 will be charged to your account. Payments may be made in cash, by cheque or ATM at any Water Utilities Revenue Office. Please refer to the back of this bill for contact information.

Appendix V: Plagiarism report

The screenshot shows a web browser window displaying a Grammarly plagiarism check report. The document being checked is titled "Tebogo Siphambe Plagiarism check" and contains text about water management in Botswana. The report indicates a 4% plagiarism score, with one match identified: "Regional workshop on water quality monitoring ..." from the URL <https://cbit.org/workshop-water-quality-monitoring/>. The text in the document includes: "and treatment processes (Abdulla, 2019). In water management, there is a clear need for change as an adaptability for integrated water management. Sustainable management of water resources and the implementation of Integrated Water Resources Management (IWRM) cannot be realized unless current water management regimes undergo a transition towards more adaptive water management" is one of the logic discourses towards water management as highlighted by (Pahl-Wostl , Kabat, & Moltgen, 2008). It is therefore necessary to establish the correlation between implementing rooftop rainwater harvesting systems within institutions and addressing issues related to water scarcity and the management of water resources in Gaborone, Botswana. This study was motivated by poor rate of sustainable water management practices like RWH in Botswana, even though Botswana is known for its water scarcity and its aridity. Therefore, the researcher aims to determine the potentiality of institutional rainwater harvesting in Gaborone, Botswana. In particular, this study aims to determine the potential of institutional RWH at Westwood International School, Gaborone, Botswana focusing on a specific technique that ensures optimum sustainable water". The report also shows a list of other sources that were checked, including "Managing the socio-ecology of very large rivers: Collect...", "VISION 2036 | Statistics Bots...", "6.4 by 2030, substantially increase ...", "International Rainwater Catchment Systems Experiences", "Fostering Safe Spaces | Indigenous Ori...", and "National Cleaning Week - Zeph...". The overall score is 81, and the report includes a sidebar with options for "Generative AI", "All suggestions", "Correctness", "Clarity", "Engagement", "Delivery", and "Get Expert Writing Help". The document is 9,691 words long.

Tebogo Siphambe Plagiarism check

and treatment processes (Abdulla, 2019).
In water management, there is a clear need for change as an adaptability for integrated water management. Sustainable management of water resources and the implementation of Integrated Water Resources Management (IWRM) cannot be realized unless current water management regimes undergo a transition towards more adaptive water management" is one of the logic discourses towards water management as highlighted by (Pahl-Wostl , Kabat, & Moltgen, 2008). It is therefore necessary to establish the correlation between implementing rooftop rainwater harvesting systems within institutions and addressing issues related to water scarcity and the management of water resources in Gaborone, Botswana.
This study was motivated by poor rate of sustainable water management practices like RWH in Botswana, even though Botswana is known for its water scarcity and its aridity. Therefore, the researcher aims to determine the potentiality of institutional rainwater harvesting in Gaborone, Botswana. In particular, this study aims to determine the potential of institutional RWH at Westwood International School, Gaborone, Botswana focusing on a specific technique that ensures optimum sustainable water

4% Plagiarism Back to all suggestions

1% of your text matches this source:

Regional workshop on water quality monitoring ...
<https://cbit.org/workshop-water-quality-monitoring/>

Click to copy reference
Regional workshop on water quality monitoring - LCBC. <https://cbit.org/workshop-water-quality-monitoring/>

1 MATCH

- Managing the socio-ecology of very large rivers: Collect...
- VISION 2036 | Statistics Bots... — www.statsbots.org/bw
- 6.4 by 2030, substantially increase ... — [indicators.report](#)
- International Rainwater Catchment Systems Experiences.
- Fostering Safe Spaces | Indigenous Ori... — [hopetoolkit.ca](#)
- National Cleaning Week - Zeph... — www.zephyrimg.com

81 Overall score

Goals

Generative AI

All suggestions

Correctness

Clarity

Engagement

Delivery

Get Expert Writing Help

4.5 Plagiarism

9,691 words

