AN EVALUATION OF PERFORMANCE OF WATER DISTRIBUTION NETWORKS IN LUSAKA CITY: A CASE FOR THE HILLVIEW SOUTH WATER PROJECT

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A dissertation submitted to the University of Zambia in partial fulfillment of the requirements for the degree of Master of Engineering in Project Management

THE UNIVERSITY OF ZAMBIA
LUSAKA

2017

DECLARATION

I, **Manengu Musambo** hereby declare that this work is my own, and that to the best of my knowledge, it has never been produced or submitted before at this university or any other institution for academic purposes, and that all sources of information have been duly acknowledged.

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Signature:………………………………….

Date:………………………………….

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CERTIFICATE OF APPROVAL

This dissertation by Manengu Musambo entitled '**An Evaluation of Performance of Water Distribution Networks in Lusaka City: A Case for the Hillview South Water Project**' is approved as partially fulfilling the requirements for the award of the degree of Master of Engineering in Project Management of the University Zambia.

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ABSTRACT

In the Vision 2030 Strategic Focus document, the Government of Zambia aims to provide wholesome water supply to all Zambians by the year 2030. Against this background, the Lusaka Water and Sewerage Company (LWSC) implemented a water distribution network (WDN) project in Hillview South in 2012 in order to improve service delivery in the area. In line with the principles of project management, this study sought to evaluate the performance of the WDN in Hillview South. This was done by assessing the effectiveness and efficiency of the WDN in delivering water with respect to project management processes vis-à-vis planning. It is envisaged that this study will form the basis for evaluating the performance of all future WDNs implemented by LWSC.

A case study approach was used, employing both qualitative and quantitative methods. Primary and secondary data were collected through questionnaires, in-depth interviews, observations and review of documentation. A questionnaire based survey was used to collect primary data from a total of 90 households that were purposively selected. Key informants from LWSC and the National Water and Sanitation Council (NWASCO) were also interviewed on aspects of the project implementation process and cost recovery. The data collected were analyzed using Statistical Package for the Social Sciences and Microsoft Excel spread sheets to bring out statistical representation of data in frequency tables and figures. Water samples were also collected from the boreholes supplying Hillview South as well as various points in the network and tested in order to determine its quality for use.

The study revealed that the WDN is performing according to its design, though some aspects of its design were inadequate resulting in frequent service disruptions due to insufficient water quantities being delivered at inappropriate pressure. The study also revealed that LWSC's cost recovery may not be very effective for the sustainability of the WDN in the long run. However, the implementation of the WDN was relevant because the Hillview South community can now access water they did not have before. It is important that LWSC enhances their due diligence before designing WDNs in order for the WDNs to perform effectively.

DEDICATION

To my beautiful wife and best friend in life,

Sharon:

Thank you for dedicating so much of your life to mine. I cannot imagine my life without you.

To my wonderful and awesome children,

Sepo and Busuma:

I am thankful to God for giving you to your mom and I.

ACKNOWLEDGMENTS

First and foremost, I would like to thank God Almighty for His grace. Without Him, all my efforts in putting this report together would have been futile. To Him alone belongs all praise, glory and honour.

Secondly, I wish to convey my heart felt gratitude to the following organisations and individuals, whose efforts and contributions enabled the compilation of this report:

Lusaka Water and Sewerage Company (LWSC) Limited, Ministry of Local Governement (MoLG), Mr Jilly H. Chiyombwe (LWSC), Mr Wilson Shane (LWSC), Mr Wycliff Kunda (LWSC), Mr Evaristo Musonda (LWSC), Mr Avitol Nkweendenda (LWSC), Mr Mununga Mungalu (LWSC), Mr Bruce Kabuka (LWSC), Mr Innocent Mututa (Ministry of Finance), Mr Mofwe Kapulu (UNZA), Mrs Chilala Kapulu (Social Development Specialist), Dr Balimu Mwiya (UNZA), Dr Erastus Mwanaumo (UNZA), all the respondents that granted me interviews and provided the Hillview South water distribution network raw data for analysis, and last but not least, my supervisor Dr Edwin Nyirenda.

Special thanks go to my wife, Sharon, and my sons, Sepo and Busuma, for their unwavering love, patience and ever present support throughout the duration of my research study.

Finally, several other people, too numerous to mention, also played a role in one way or the other in enabling the compilation of this report, and to all of them I extend my gratitude

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBREVIATIONS

AfDB	Africa Development Bank
AICD	Africa Infrastructure Country Diagnostic
AMCOW	African Ministers' Council on Water
CBNRM	Community Based Natural Resources Management
CEE	Civil and Environmental Engineering
CSO	Central Statistics Office
CU	Commercial Utility
DANIDA	Danish International Development Agency
DDT	Dichlorodiphenyltrichloroethane
DN	Distribution Network
ECZ	Environmental Council of Zambia
EIA	Environmental Impact Assessment
EMA	Environmental Management Act
ERB	Energy Regulation Board
FEMA	Federal Emergency Management Agency
GIZ	Gesellschaft für Internationale Zusammenarbeit
GR	Growth Rate
GRZ	Government of the Republic of Zambia
ICTs	Information and Communication Technology
IDEV	Independent Development Evaluation
LA	Local Authority
LCC	Lusaka City Council
LWSC	Lusaka Water and Sewerage Company
MLG	Ministry of Local Government
MLGH	Ministry of Local Government and Housing
MoF	Ministry of Finance
MoH	Ministry of Health
MDGs	Millennium Development Goals
MWDSEP	Ministry of Water Development, Sanitation and Environmental Protection
NESC	National Environmental Services Centre
NGO	Non-Governmental Organisation

NPTEL	National Programme on Technology Enhanced Learning
NRW	Non-Revenue Water
NUWSSP	National Urban Water Supply and Sanitation Programme
NWASCO	National Water Supply and Sanitation Council
PMBoK	Project Management Body of Knowledge
RTSA	Road Transport and Safety Agency
RWSS	Rural Water Supply and Sanitation
SARS	Severe Acute Respiratory Syndrome
SEA	State of the Environment Assessment
SPSS	Social Package for Social Sciences
SSA	Sub Saharan Africa
SSWM	Sustainable Sanitation and Water Management
UN	United Nations
UNICEF	United Nations Children's Education Fund
UNZA	University of Zambia
uPVC	ultra-Polyvinyl Chloride
UWSS	Urban Water Supply and Sanitation
WDN	Water Distribution Network
WHO	World Health Organisation
WRAP	Water Resources Action Plan
WRM	Water Resources Management
WWAP	World Water Assessment Programme
ZABS	Zambia Bureau of Standards
ZANACO	Zambia National Commercial Bank
ZEMA	Zambia Environmental Management Agency
ZICTA	Zambia Information and Communications Technology
ZMK	Zambian Kwacha (old denotation)
ZMW	Zambian Kwacha (rebased)

CHAPTER ONE: INTRODUCTION

1.1 Background

Water is absolutely essential for man, animals and plants. Without water, life on earth would not exist. Safe, adequate and accessible supplies of water, combined with proper sanitation, are basic needs and essential components of primary health care. The larger the quantity and the better the quality of water, the more rapid and extensive is the advancement of the public health.

Water supply systems are required in order to transport water for various demands to people. Each water supply system is strongly linked to a specific local condition. The demand for water differs substantially according to availability, climate, and the structure of houses, life style and living standards. Therefore, the demand and source of water supply is to be determined by the natural and socio-economic conditions of each community, which means planning and design approaches applicable to one system are never the same on another different system. The mere copying of a successful system in one area does not necessarily guarantee the same success in another area.

Lusaka City is characterized by erratic water supply services. This is a major concern because low coverage of reliable and safe water supply and sanitation services can result in outbreaks of communicable diseases such as cholera becoming endemic. Erratic water supply can lead to pressure differences in the distribution pipes and thus cause water hammer which damages the inevitable old water pipes. Most of the water supply and sewerage infrastructure in the urban areas of Zambia were constructed 50 to 60 years ago and have since been inadequately maintained and developed thus resulting in dilapidation of existing infrastructure and inadequate Urban Water Supply and Sanitation (UWSS) systems in new areas (MLGH, 2011). Lack of access to potable water is a global problem affecting nearly 800 million people. Although progress has been made toward addressing the problem, including through the Millennium Development Goal of halving the proportion of people without access to potable water by 2015, many countries still lag behind, Zambia included. Only a third of Sub-Saharan Africa’s (SSA) population has access to piped water within households (Seager, 2010). Neglect by and poor capacity of central government and municipal authorities complicate water provision (Kalulu & Hoko, 2010; Marston, 2014). Government utility agencies and private companies often have no financial incentives to provide water to both rural and poor peri-urban areas given the high upfront financial and infrastructural investments, with no guarantee of cost recovery. Terrain, unplanned settlements, and dispersed poor populations compound the problem and undermine economic viability. Therefore, private and public utility agencies tend to cherry-pick cities over rural areas, and wealthy urban over low-income and peri-urban neighborhoods where the poor pay more per unit of water and are often systematically marginalized and underserved even more than in rural areas (Swyngedouw, 2006; Bakker, 2013) lost in the socio-institutional and policy interstices between rural and urban. Some of these challenges reflect the unclear spatial boundaries of the 'peri-urban.' With the failure of both public and private water-supply systems to improve supply and access for poor urban/peri-urban communities, attention has turned to alternatives involving diverse partnerships among public, private, non-governmental organizations (NGOs), and water-user communities, including community-based natural resources management (CBNRM) approaches, with added neoliberal decentralization and 'good governance' goals (Kalulu & Hoko, 2010; Gutierrez, 2007).

Zambia has, through the years, moved from a time in the mid-1980's when abundant and fully subsidized water and sanitation services were available; to a time, in the 2000's when due to unprecedented urban growth and lack of sufficient infrastructure to accommodate this growth, has resulted in even the most basic of services not being universally available. Therefore, the provision of water and sanitation in the provinces remains a challenge (MoF, 2014).

Provision of water and sanitation services in Lusaka City is the responsibility of Lusaka Water and Sewerage Company Limited (LWSC). It is the only institution under the current regulatory systems licensed to provide water supply services throughout the city and townships. LWSC serves a population of more than 1.75 million people, with more than 65 percent of this population living in the peri-urban areas. Lusaka is currently supplied by groundwater sources (about 130,000 m^3/day) and from the Kafue River (about 95,000 - 96,000 m^3/day) through the Iolanda Treatment Works. The existing Kafue Town water supply system is based on abstraction from the Kafue River and has a design capacity of 24,000m^3/d. The current production capacity is 22,000m^3/d. In addition, there are two smaller water supply schemes in Chongwe and Luangwa, whose production capacities are 7,200m^3/d and 700 m^3/d respectively (Gauff, 2011).

Hillview South is the extended area of Hillview Park (also called Mwaiwake) on the Southern part of Kamwala in Lusaka City. This is a medium to high income residential area located on the southern part of Lusaka and shares boundaries with Hillview Park on the northern side, Rockfield on the Eastern side, and the Lilayi farming block area in the Northern and Southern directions.

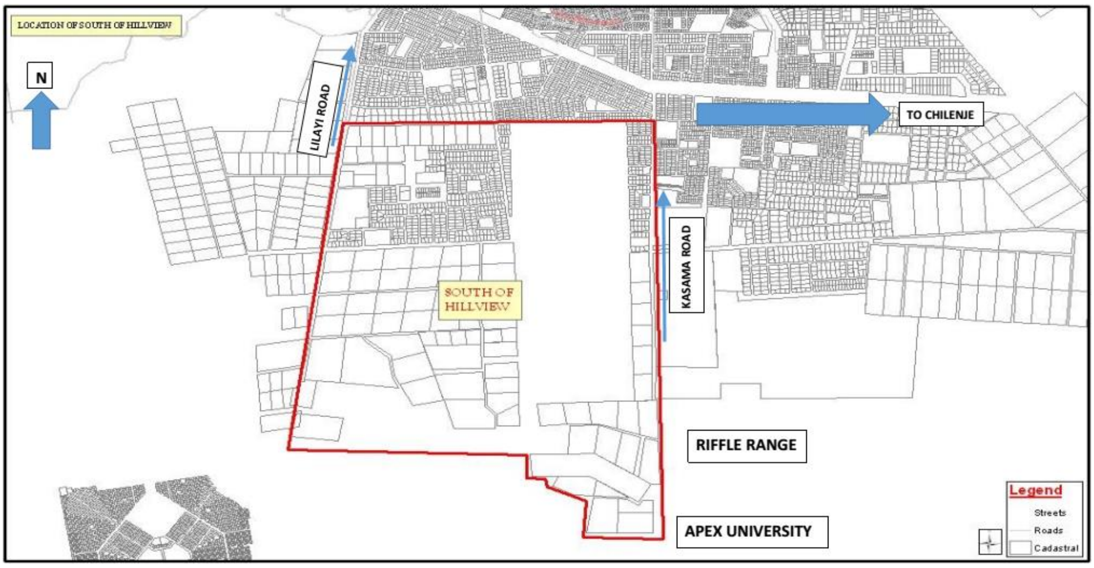

Figure 1-1: Location Map of Hillview South (Source: LWSC, 2017)

Hillview South is predominantly a rocky area. It was designated by the Lusaka Municipality for residential property development in the year 2000. The properties in the area can be characterised as medium to high cost. Lusaka Water and Sewerage Company (LWSC) started servicing the area from the year 2000 and has spent over ZMW 20 million since 2007 (LWSC, 2012) in trying to improve the water service provision to the Hillview Park area. In the year 2007, LWSC installed a water reticulation system in Hillview Park and also constructed a 250mm diameter water transmission pipeline which was meant to be the main source of water for the unserviced new development areas south of Lusaka including Hillview South. Further, in line with the Government of the Republic of Zambia (GRZ)'s Vision 2030 Strategic focus to provide clean and safe water supply to all Zambians by the year 2030, LWSC implemented a Water Distribution Network (WDN) project in Hillview South of Kamwala South in Lusaka City, in order to further improve the water service provision in the area at a cost of ZMK3, 998,172,736.06 (ZMW3, 998,172.74). The WDN project was an extension of the water reticulation project implemented in Hillview Park in 2007 and was implemented from 2011 to 2012. The total number of households designed by LWSC to be serviced by the Hillview South WDN project at the time of implementation was 2005 (LWSC, 2011). However, due to some challenges, LWSC managed to connect only a total of 573 households to the new WDN in Hillview South over a total length of 16.215km. Some of the challenges LWSC encountered in implementing the WDN project were increased project costs due to the slow pace of blasting rocks before excavation of trenches could commence. The water network installed in Hillview South was computed using EPANET Hydraulic and Design Software (LWSC, 2011). The selected material for the pipe work was the ultra-Polyvinyl Chloride (uPVC) of pressure type class 9.

With these water supply projects carried out in Hillview South to improve the provision of water service, this study sought to examine whether or not there has been significant and positive enhancements in the performance of the water distribution network in Hillview South.

1.2 Problem Statement

Despite the fact that LWSC installed a new WDN in Hillview South in order to improve service delivery in the area, the problem of erratic water supply still persists in that the installed WDN is:

i. Failing to adequately satisfy water requirements for various demands (domestic, commercial, fire-fighting, etc.).
ii. Not capable of providing satisfactory water pressure to meet the demands at all times.
iii. Not maintaining purity (quality) of the distributed water at all times.

The aim of installing a WDN is to supply a community with adequate quantity and quality of water, at satisfactory pressure to meet all the demands at all times (Almasri, 2008; Adeosun, 2014). A well designed water distribution network should adequately satisfy water requirements for a combination of various demands such as domestic, commercial, industrial and fire-fighting uses, as well as maintain purity (quality) of the distributed water (Feroze in WHO, 2012). This means that the WDN should be completely water-tight. However, this has not been the case with the Hillview South WDN.

Therefore, it is the aim of this research study to evaluate the performance of the installed water distribution network in order to highlight the nature and extent of the inadequacy in the provision of water service in Lusaka City by the Lusaka Water and Sewerage Company Limited.

1.3 Problem Justification

Health problems related to the inadequacy of water supplies are universal but generally of greater magnitude and significance in developing countries, Zambia included. Although population under the water supply coverage improved significantly during the Water Supply and Sanitation Decade and after the Decade, it has been estimated that about 25 percent of the population in developing countries still does not have access to safe water. As a result, millions of people in developing countries each year suffer from water-related diseases. The infant mortality rate is still very high in developing countries largely due to unsafe water supplies

Therefore, this research study seeks to highlight the critical underlying factors that continue to cause erratic and insufficient water supply in the townships of Lusaka City despite colossal sums of monies being spent on new water distribution network projects each year by water utility companies like Lusaka Water and Sewerage Company Limited.

1.4 Aim of the Research

The aim of this research is to evaluate the performance of the water distribution network in Hillview South of Lusaka City in line with project management principles.

1.5 Research Objectives

The objectives of this research were to assess the LWSC WDN in Hillview South for the following:

i. Quantity of water distributed by the network in Hillview.
ii. Effectiveness of the WDN in water service provision in Hillview South.
iii. The quality of the water distributed by the network in Hillview.
iv. Efficiency of cost recovery and sustainability of the WDN in Hillview.
v. Relevance of the implemented WDN in Hillview.

1.6 Research Questions

For the purpose of this study the following research questions have been formulated:

i. Does LWSC carry out comprehensive needs-assessments/due diligence before designing WDNs?
ii. What challenges does LWSC face in water service provision?
iii. How is LWSC maintaining the infrastructure that was constructed in order to mitigate rehabilitation costs?
iv. What lessons have been learnt from the implementation of the WDN project by LWSC in Hillview South?

1.7 Scope of the Research

The research study will focus on evaluating the performance of the Water Distribution Network implemented in Hillview South of Kamwala South in Lusaka City so as to establish the critical success factors for the performance of water distribution network projects.

1.8 Significance of the Study

This study is significant in that it gives an insightful appreciation of the importance of water distribution networks in the provision of water supply in Lusaka City. Additionally, the study is noteworthy in that:

i. It is the first evaluation of performance of a WDN in LWSC and thus, will assist LWSC to improve their designs of WDNs.
ii. It highlights the critical success factors for the performance of WDNs in meeting water requirements (quantity, pressure, continuity and quality) of a community.

iii. It underpins the importance of cost recovery of implemented WDN projects for the purposes of sustainability of the installed WDNs in Lusaka City.

1.9 Chapter Synthesis

This dissertation is divided into six chapters. Chapter one introduced the study on the evaluation of performance of water distribution networks in Lusaka City and presented a case study on Hillview South in Lusaka's Kamwala South area. It introduced the background to the problem, provided the justification, outlined the research problem, stated the research objectives and highlighted the significance of the study to the LWSC. It also stated the research questions, scope and relevance of the study. The third chapter discussed the methodology adopted for this research, this was accomplished by firstly discussing the research approach, design and target population, thereafter, the sample size was discussed as well as the sampling process and justifications employed this was important in ensuring representativeness of the research population methods of data collection and instruments used were discussed as well as research methodological reliability and validity. Chapter four outlines the actual findings as obtained from the interviews and questionnaires administered to relevant research samples in order to satisfy the set objectives of the research. Chapter five analyses and discusses the actual findings from the research study in view of the set research objectives. Chapter six provides the conclusion and offers recommendations of the research based on thorough literature review, findings from the field and their analysis, and consequently answers the research questions.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The World Health Organisation (WHO), in their publication on "The Right to Water," (WHO, 2003) asserted that water is the essence of life because it plays a vital role in nearly every function of the body, protecting the immune system (the body's natural defences) and helping remove waste matter. However, to do this effectively, water must be accessible and safe. Duflo *et. al.,* (2012), affirmed that access to safe water and sanitation is essential for health, security, livelihoods, and quality of life. Inadequate access to safe water and exposure to pathogens through the poor treatment of solid waste leads to adverse health consequences, particularly diarrhoeal diseases. Further, Duflo *et. al.,* (2012) argued that diarrhoea is responsible for an estimated 21 percent of under-five mortality in developing countries - 2.5 million deaths per year, and over 4 percent of the world's disease burden. However, the developing world (particularly Asia and Africa) is lagging in water and sanitation coverage (Duflo *et. al.,* 2012).

A water distribution network (WDN) is thus an integral part of water supply service in that it is the means of delivering or transporting water to individual consumers – it provides access to safe and reliable quantities and quality of water supplies for human communities. Adeosun (2014), as cited by the Water Online, (2017) argued that delivering or transporting sufficient water of appropriate quality and quantity has been one of the most important issues in human history. Further, Adeosun (2014) opined that the provision of drinking water is generally difficult in African cities because they are characterized by high rates of population growth. The Sustainable Sanitation and Water Management (SSWM, 2017) contends that cities are complex systems requiring special methods of prediction and management. The task of the city manager is made more complex by the fact that most of the rapidly growing cities are either located in water stress or water scarce regions, with diminishing per capita water availability or are confronted by issues of control and governance which affect improvement of water supply. It is thus imperative that WDNs be adequately designed and installed for them to perform to design specifications in order for them to be able to deliver safe and reliable quantities of water to meet increased user demands.

Onyenechere and Osuji (2012), in their study on “Water Service Provision in Owerri City, Nigeria,” argue that water must not only be adequate in quantity, it must also be adequate in quality. Onyenechere and Osuji (2012) further assert that there can be no state of positive health and well-being without safe water. For many urban areas the quality of water is becoming a major concern. This helps to explain the increasing demand for potable water in urban areas. In this regard, adequately designed WDNs play a key role in ensuring that adequate quantities and quality of water are reliably transported to communities or cities. Delivery of safe and reliable water to enrichen a community’s positive health and well-being can only be achieved by a good performing WDN. Additionally, SSWM (2017) affirms that water allocation of human settlements concerns both water quantity and quality. The World Health Organisation (WHO, 2017) asserts that maintaining good water quality in the distribution system will depend on the design and operation of the distribution network. Therefore, good water quality can only be maintained in the distribution system by well performing WDNs.

However, Stahre *et. al*., (2008) argued that effective performance of water distribution networks should be seen from the customers’ perspective with the following important aspects being considered; the quality of the drinking water, the frequency of water service interruptions and the pressure in the distribution network.

Therefore, in meeting the first, second and third research objectives which aimed at assessing; the sufficiency/adequacy of the quantity of water distributed by the WDN, effectiveness of the WDN in water service provision and the quality of the water distributed by the WDN, this chapter starts by defining water service, water supply and Water Distribution Network, before outlining the aim of installing a WDN. Then, the chapter gives an overview of water distribution services, before going on to discuss the requirements and components of an adequate WDN. Additionally, in line with the fourth and fifth research objectives, which were aimed at assessing the efficiency of cost recovery and sustainability of the WDN, and the relevance of the implemented WDN respectively, the chapter discusses the importance of WDNs in water service provision and challenges of providing improved urban water services.

Consequently, the aim of this literature review is to draw valuable lessons that are relevant to this research, from the existing body of knowledge on the subject.

2.2 Key Definitions

i. **Water Service**: Hickey (2008) as cited by FEMA (2008), defines water service as meters, facilities and equipment required to furnish service from the main to the property line and the billing for services supplied through the same to the consumer.

   Service delivery consists of a series of highly localized actions by agents in public agencies or private enterprises to provide needed goods and services to citizen beneficiaries "in a way that meets their expectations" (Kim, 2012). This definition draws on literature from a variety of disciplines (that is,, economics, behavioral economics, social sciences, and engineering) to provide a broader perspective to service delivery, rather than any discipline-centric view. Service delivery has a life-cycle span (that is,, plan, design, operate, maintain, and monitor) to sustain services such as nutrition or transport or goods such as electricity or water to citizen beneficiaries (Kim, 2012; Lockwood and Smits 2011). Getting (or delivering) these services or goods requires access by citizen beneficiaries, and the goods or services should meet the expectations of the beneficiaries, which implies taking into account their needs and demands (Kim 2012; Hodge 2007; Fiszbein *et. al.*, 2011).

ii. **Water supply** is the provision of water by public utilities, commercial organisations, community endeavors or by individuals, usually via a system of pumps and pipes. (Collins English Dictionary, 2012)

iii. A **Water Distribution Network** (WDN) is a system of pipelines and trenches providing the appropriate quality and quantity of water to a community (SSWM, 2017, Adeosun, 2014; WHO, 2011 and Almasri, 2008). The term **distribution system** is used to describe collectively, the facilities used to supply water from its source to the point of usage. Thus, a WDN is part and parcel of a distribution system and both are used in water service provision.

2.3 The Aim of Installing Water Distribution Networks

The aim of installing a water distribution network is to supply a community with the appropriate quantity and quality of water. WHO, (2011), Almasri (2008), and Adeosun (2014), cited by Water Online (2017) affirm that the purpose of a **water distribution network** is to **deliver water** to consumers **with appropriate quality, quantity** and **pressure**. It is important that the quality of the **distributed water** in a WDN should not get deteriorated in the **distribution pipes** so as to affect the health of the consumers. Further, the online Encyclopaedia Britannica (2017) asserts that a WDN must deliver adequate quantities of water at pressures sufficient for operating plumbing fixtures and fire-fighting equipment, yet it must not deliver water at pressures high enough to increase the occurrence of leaks and pipeline breaks. Pressure-regulating valves may be installed to reduce pressure levels in low-lying service areas.

2.4 An Overview of Water Distribution Networks

The SSWM (2017) asserts that water distribution networks are essential social infrastructure networks that directly affect public welfare and as such, water distribution has to be thought from the source to the consumer's tap. A correct water distribution network has to be well-planned and designed beforehand, and adapted maintenance performed while in use (SSWM, 2017). Many transportation systems are possible (piped with the use of different materials and techniques, or non-piped), and have to be carefully chosen, dimensioned, operated and maintained in order to use well-adapted, efficient, and safe solutions. Thus, a well-designed WDN should adequately satisfy water requirements at all times and at satisfactory pressure for a combination of various demands such as domestic, commercial, industrial and fire-fighting uses (Almasri, 2008, Adeosun 2014 and SSWM, 2017).

Hickey (2008), argues that a municipal water supply system cannot service its customers unless there is a continuous supply of water to meet domestic consumption needs in the broadest sense and water needs for structural fire protection. Water sources need to be selected carefully to make sure that this fundamental requirement is met. Hickey (2008) further points out that two main factors affect water supply selection and these are;

1) Quality of water: Water must be treated or purified to meet Regulatory Requirements. In Zambia, regulatory requirements for drinking water standards are set by the Ministry of Health (MoH) and Zambia Bureau of Standards (ZABS). The water quality standards adopted by the Ministry of Health are the World Health Organisation (WHO) standards for drinking water quality.
2) Quantity of water: The quantity of water must be adequate to meet consumer consumption and fire-flow demands at any time of the day, day of week, and week of the year. In Zambia, designs of water quantity or capacity for water distribution networks should conform to the Zambia Bureau of Standards for Water Supply Systems Demand Figures For Design – Guidelines of 2009 (ZABS, ZS361:2009).

2.5 Requirements of an Adequate Water Distribution Network

Adeosun (2014), cited by Water Online (2017) and Rhetella (2015), assert that an adequate water distribution network should meet certain requirements for it to be effective. This is affirmed by both the National Programme on Technology Enhanced Learning (NPTEL, 2017) and the Sustainable Sanitation and Water Management (SSWM, 2017), who assert that an adequate water distribution network should meet the following requirements for it to perform effectively:

i. Water quality should not deteriorate while in the distribution pipes. This means that the water in the distribution pipes should never at any one time be stagnant. It must be moving all the time to avoid stagnation and thus deterioration of its quality. Purity of distributed water should be maintained. This requires the distribution network to be completely water-tight.
ii. The system should be capable of supplying water to all the intended places with sufficient pressure head. The pressure must be adequate enough to push water to all the parts of the WDN.
iii. It should be capable of supplying the requisite amount of water during fire-fighting. Not only should the pressure be sufficient for fire-fighting purposes, but the quantity of water should be enough to cater for the residents' requirements as well as meet the demands of fire-fighting.

iv. Maintenance of the distribution system should be easy and economical. The layout should be such that no consumer is without water supply, during the repair of any section of the system. Water should remain available during breakdown periods of pipelines. System of distribution should not be such that if one pipe bursts, it leaves a large area without water. If a particular pipe length is under repair and has been shut down, the water to the population living in the down-stream side of this pipeline should be available from other pipelines.

v. All the distribution pipes should preferably be laid one metre from or above sewer lines.

vi. During repairs, a WDN should not cause any obstruction to traffic. In other words, the pipelines should not be laid under highways, carriage ways but below foot paths.

vii. It should be fairly watertight to keep losses (for example, due to leakage) to a minimum.

viii. A WDN should provide adequate water pressure at the consumer's taps for a specific rate of flow (that is, pressures should be great enough to adequately meet consumer needs). At the same time, pressures should not be excessive because development of the pressure head brings important cost consideration and as pressure increases leakages increase as well. In tower buildings, it is often necessary to provide booster pumps to elevate the water to upper floors.

2.6 Anatomy of a Water Distribution Network

Hickey (2008) defines anatomy as “separating or dividing a function into parts for detailed examination.”

According to Hickey (2008), the purpose of municipal water delivery systems is to transport potable water from a water treatment facility to residential consumers, for use as drinking water, water for cooking, water for sanitary conditions, and other water use in a domestic environment. In addition, water supply is essential for business and industry to operate in a municipal environment.

In addition, Hickey (2008) opined that of no less importance is the need to supply water to properly located fire hydrants to provide the public with an effective level of fire protection. Municipal water systems may also need to provide water for special services that include street cleaning, the selling of water to contractors for erecting buildings, parks and recreation, and miscellaneous uses.

A water system has two primary requirements:

i. First, it needs to deliver **adequate** amounts of water to meet consumer consumption requirements plus needed fire-flow requirements.
ii. Second, the water system needs to be **reliable**; the required amount of water needs to be available 24 hours a day, 365 days a year.

2.6.1 Components of an Adequate Water Distribution System

The SSWM (2017) opines that a water distribution system is analogous to the human circulatory system. The heart pumps blood through the arteries, veins, and capillaries to supply oxygen to all parts of the body. Similarly, a water pump supplies water through primary, secondary, and distributor water mains to supply water to consumers and for fire protection.

The SSWM (2017) thus states that the main elements of a water distribution system are:

i. **Water Source:** At the beginning of every water distribution system, there must be a raw water source such as a lake, river or groundwater source. To provide enough water for the network the water can be stored in a reservoir. In the case of the Hillview WDN, the water sources are boreholes (Lilayi and Shaft 5 boreholes).
ii. **Raw Water Pumping**: These pumps transport water from the source to the raw water storage facility. The water is filtered before being injected into the network in order to prevent corrosion. The water from the borehole sources for the Hillview WDN is not filtered, but pumped directly into the network.
iii. **Treatment (Purification):** At one stage of the distribution, the water is purified in order to reach the standard quality. The water supplied to the

Hillview WDN is treated for bacterial disinfection using on-line chlorination units only.

iv. **High Service Pumping:** Pumping stations may be needed to; pump water up to service areas that have higher elevations than other areas of a community and fill gravity tanks that float on the water supply distribution system. When pumping stations are used to distribute water, and no water storage is provided, the pumps force water directly into the network. This is the case with the Hillview WDN. The major disadvantages of pumping directly into the network are that energy costs tend to be high and also, there are service disruptions should the pump breakdown.

v. **Water Storage**: An extremely important element in a water distribution system is water storage. System storage facilities have a far-reaching effect on a system's ability to provide adequate consumer consumption during periods of high demand while meeting fire protection requirements. The two common storage methods are ground-level storage and elevated storage.

vi. **Piping/Distribution System:** At the end of the system, water is distributed via pipes to the consumer, who has to pay for the used amount. This is by far the most important component of a water distribution system as it is the only means of delivering wholesome water to the consumers. However, it is the most costly part of a distribution system as it accounts for up to 10 percent of the total cost of the distribution system (Hickey, 2008).

The other components of a water distribution system include; house service connections, meters and other appurtenances (fire hydrants, valves, valve chambers, etc.).

2.6.2 Hydraulics of a Water Distribution Network

According to Ainsworth (2004), the hydraulics of the network (adequate pressure and flow) is the main element of network dimensioning and design. Pressure occurs through gravity or pumps and is lost by the action of friction at the pipe walls. The pressure loss also depends on the water demand, pipe length, gradient and diameter. Several established empirical equations describe the pressure-flow relationship. These have been incorporated into network modelling software packages (for example, EPANET and WaterGEMS, as is the case with LWSC) to facilitate their solution and use (Ainsworth, 2004).

When designing a piped water supply system, the aim is to ensure that there is sufficient pressure at the point of supply to provide an adequate flow to the consumer (Ainsworth, 2004). For example, in Zambia, water utility companies are required to supply water to a single property at a minimum of 10m head of pressure at the boundary stop tap with a flow rate of 6.25 l/min (150lpcd) for medium-cost houses and 10.63l/min (255lpcd) for high-cost houses (ZABS, 2009). These minimum pressures increase as the number of properties supplied through a single service pipe (transmission main) increase (Ainsworth, 2004).

Further, Ainsworth (2004) opined that for the purpose of maintaining microbial quality, it is important to minimise transit times and avoid low flows and pressures in a water distribution network. Therefore, the requirements of adequate pressure and flow have to be balanced against the practicalities of supplying water according to the location of consumers and where pipes can be laid (Ainsworth, 2004).

2.6.3 Cost Considerations for Construction of WDNs

Construction costs depend on the chosen system (for example, lower costs for a dead-end system), on the used pipes and on the regional conditions (excavation depth, soil conditions, equipment, etc.), (SSWM, 2017). Gravity flow network are cheaper, because they require less pumping. More than half the cost of a municipal water supply system is for the distribution network and therefore careful consideration of the type of distribution network to choose should be made. The Hillview South WDN, for instance, cost ZMW3.9m whilst the total cost of the water distribution system cost over ZMW21m (LWSC, 2012).

2.6.4 Health Aspects Associated with Adequate WDNs

The SSWM (2017) argues that safety of drinking water depends on a number of factors, including quality of the water source, effectiveness of water purification and integrity of the whole distribution system that transports the water to consumers. At every stage in the production and delivery of drinking water, hazards can potentially compromise the quality of the water (Ainsworth, 2004). Piped distribution systems may be less vulnerable to contamination than open surface-water catchments; however, if piped systems become contaminated, there may be no treatment processes to reduce risks from the introduced hazards (Ainsworth, 2004). A leaking distribution system (Figure 1) increases the likelihood of safe water leaving the source or treatment facility becoming contaminated before reaching the consumer.

Figure 2-1: A damaged pipe causing water loss. (Source: GIZ, 2011)

The distribution system must be designed, managed and maintained to present a minimal level of leakage and be continuously under internal pipe pressure greater than the external hydrostatic pressure (SSWM; 2017). This will ensure delivery of water with reduced losses due to leaks, and minimisation of excess growth of pathogenic microorganisms. WHO (2006, 2011 and 2017) asserts that a certain level of free residual chlorine or chloramine disinfectant will reduce the risks of recontamination within the distribution system. Further, inflows of contaminated water during distribution are major sources of waterborne pathogens and contaminants (WHO, 2006, 2011 and 2017). In case the appropriate quality of the supplied water cannot be guaranteed, proper household water treatment and safe storage become necessary (SSWM, 2017).

2.6.5 Operation and Maintenance of WDNs

GONU (2009) affirmed that after a piped water system is installed it should be pressure tested, flushed to remove all dirt and foreign matter and disinfected (for example, chlorination). Following disinfection, the chlorinated water should be flushed to waste with potable water. Microbiological tests are required before the main is put into service (GONU, 2009).

2.6.6 Preventive Maintenance of Appurtenances in a WDN

Preventive maintenance of valves involves location, inspection and operation (GONU, 2009). Location of the valve box is confirmed by checking the measurements given on the map. Next, the valve box cover is removed and the interior inspected with a flashlight. Finally, the valve is fully closed, and the number of turns required to close it is recorded. The tightness of closure is checked through listening with a leak detector. Further, GONU (2009) argues that to avoid damage/failure of the stem, the applied torque using a power turning should not exceed the recommended limit specified by the manufacturer. Common defects requiring repair are broken stems, need for packing, and internal incrustation. Repair of a valve is a difficult task requiring isolation of that section of the pipe network, excavation, and removal of the valve. Either the damaged valve can be repaired and replaced or, if the overall conditions are good, new parts that need to be changed can be installed on site.

A WDN is a convenient access to fresh water. The chosen system depends on local conditions. An important part of a network is the piping. The SSWM (2017) affirms that water pipes are required almost everywhere, especially for drinking water distribution.

2.6.7 Advantages of using pipes in water distribution

i. Access to clean water if the system is properly designed and managed
ii. No more walking to water source or collecting water from open sources

2.6.8 Disadvantages of using pipes in water distribution

i. High investment and maintenance costs
ii. Recontamination of drinking water if the system is maintained poorly

2.7 Water Distribution Network Configurations

There are two configurations of water distribution networks. According to Bukhari (2017) asserts that water distribution networks may be classified as: Branching systems or Grid systems, or a combination of the two systems.

A grid system is usually preferred over a branching system, since it can furnish a supply to any point from at least two directions. The branching system has dead-ends, therefore, does not permit supply from more than one direction should be avoided where possible.

Bukhari (2017) affirmed that in locations where sharp changes in topography occur (hilly areas), it is common practice to divide the distribution system into two or more service areas. The configuration of a water distribution networks is thus dictated by:

i. Street patterns
ii. Topography
iii. Degree and type of development of the area
iv. Location of the treatment and storage works.

2.7.1 Types of Water Distribution Networks

According to GONU (2009) and Adeosun (2014), there are four types of water distribution networks and these are grid-iron, circular or ring, radial systems and dead-end. Further, GONU (2009 and Adeosun (2014) argue that investment costs for water distribution network construction (material, labour, planning for pipes and trenches) as well as maintenance costs (repair, pumping station, leakage control, and preventing recontamination) are high and so careful thought must be given to choosing the most suitable network type for any particular area or location.

2.7.2 Layouts of Water Distribution Networks

Adeosun (2014) states that distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads. There are, in general, four different types of pipe distribution networks for water supply; any one of which either singly or in combinations, can be used for a particular place. They are: Grid-Iron, Ring or Circular, Radial and Dead-End Systems.

2.7.2.1 Grid-Iron Distribution Network

Adeosun (2014) as cited by Water Online (2017) asserts that in the Grid-Iron distribution network, the main supply line runs through the centre of the area and sub-mains branch off in perpendicular directions. The branch lines interconnect the sub-mains. Further, Adeosun (2014) argues that this system is ideal for cities laid out on a rectangular plan or layout resembling a gridiron, where the water mains and branches are laid in rectangles. According to the SSWM (2017), the distinguishing feature of this system is that all of the pipes are interconnected and there are no dead ends. Moreover, the SSWM (2017) argues that in this system, water can reach a given point of withdrawal from several directions, which permits more flexible operation, particularly when repairs are required.

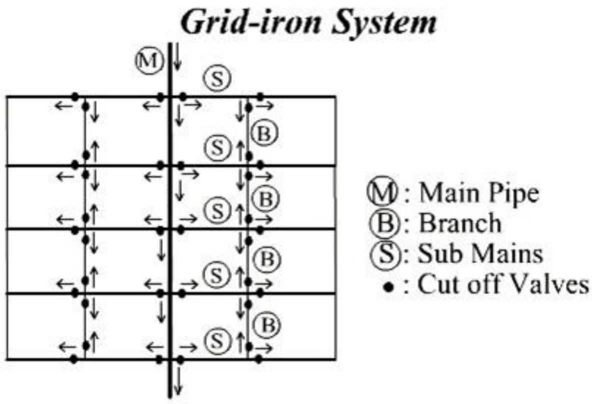

Figure 2-2: Grid-Iron WDN (Source: Adeosun, 2014)

Advantages of the Grid-Iron WDN:

i. Water is kept in good circulation due to the absence of dead ends. The free circulation of water, without any stagnation or sediment deposit, minimizes the chances of pollution due to stagnation.
ii. In the cases of a breakdown in some section, water is available at every point, from some other direction, with minimum loss of head because of the interconnections.
iii. Enough water is available at street fire hydrants, as the hydrant draws water from the various branch lines.
iv. During repairs, only a small area of distribution is affected.

Disadvantages of the Grid-Iron WDN:

i. Exact calculation of sizes of pipes is not possible due to provision of valves on all branches.
ii. A large number of cut-off valves are required.

iii. The system requires longer pipe lengths with larger diameters.

iv. The analysis of discharge, pressure and velocities in the pipes is difficult and cumbersome.

v. The cost of laying the pipes is higher.

2.7.2.2 Circular or Ring Distribution Network

Adeosun (2014) states that in a circular or ring distribution network, the supply main forms a ring around the distribution area. The supply main is laid all along the peripheral roads and sub-mains branch out from the mains. Further, Adeosun (2014) argues that the Circular distribution system also follows the grid-iron system with the flow pattern being similar in character to that of a dead-end system. Moreover, SSWM (2017) and Adeosun (2014), asserts that the branches in the circular distribution system are connected cross-wise to the mains and also to each other. This system is most reliable for a town with well-planned streets and roads.

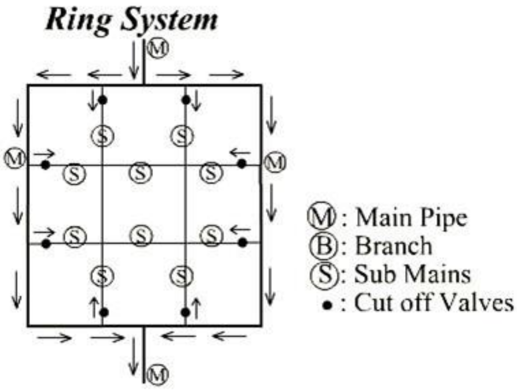

Figure 2-3: Circular or Ring WDN (Source: Adeosun, 2014)

Advantages of Circular or Ring Distribution Network:

i. Water can be supplied to any point from at least two directions.

ii. Determination of the size of pipes is easy.

iii. In case of fire, a larger quantity of water is available, and the length of the distribution main is much higher.

Disadvantages of Circular or Ring Distribution Network:

i. A large number of cut-off valves are required.

ii. The system requires longer pipe lengths with larger diameters.

iii. The analysis of discharge, pressure and velocities in the pipes is difficult and cumbersome.

iv. The cost of laying the pipes is higher.

2.7.2.3 Radial Distribution Network

According to SSWM (2017) and Adeosun (2014), the whole area in the Radial distribution network is divided into a number of distribution districts or zones. Each district has an elevated centrally located distribution reservoir from where distribution pipes run radially towards the periphery of the distribution district. Further, the SSWM (2017) and Adeosun (2014), argue that this system provides swift service without much loss of head and also, the design calculations are much simpler.

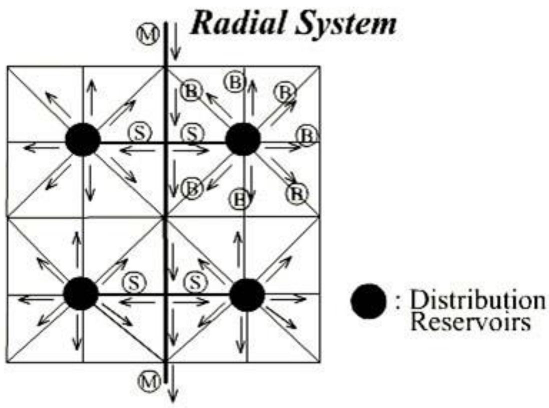

Figure 2-4: Radial WDN (Source: Adeosun, 2014)

Advantages of Radial WDN:

i. It gives quick service.
ii. Calculation of pipe sizes is easy.

Disadvantages of Radial WDN:

i. Radial WDNs cannot be used for cities with planned roads (that is, where a city does not have a system of radial roads emerging from different centres).

2.7.2.4 Dead End or Tree Distribution Network

According to the SSWM (2017), the dead-end distribution network (also called tree system), has one main pipeline running through the centre of the populated area and sub-mains branch off from both sides. The sub-mains divide into several branch lines from which service connections are provided.

Further, Adeosun (2014) and the SSWM (2017), argue that, the dead-end network is suitable for old towns and cities having no definite pattern of roads.

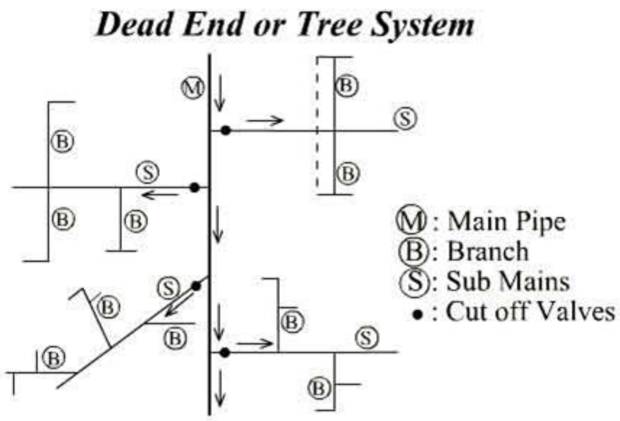

Figure 2-5: Dead-End or Tree WDN (Source: Adeosun, 2014)

Advantages of Dead-End or Tree WDN:

i. It is relatively cheap due to the smaller number of cut-off valves required and thus, the operation and maintenance cost is low.
ii. Determination of discharges and pressure easier due to less number of valves.
iii. The design calculation is simple and easy.
iv. Pipe laying is simple

Disadvantages of Dead-End or Tree WDN

i. Due to many dead ends, stagnation of water occurs in pipes.
ii. The system is less successful in maintaining satisfactory pressure in remote areas and is therefore not favoured in modern waterworks practice.
iii. One main pipeline provides the entire city, which is quite risky
iv. The head loss is relatively high, requiring larger pipe diameter, and/or larger capacities for pumping units. Dead-ends at line terminals might affect the quality of water by allowing sedimentation and encouraging bacterial growth due to stagnation. Water hammer could also cause burst of lines. A large number of scour valves are required at the dead ends, which need to be opened periodically for the removal of stale water and sediment.
v. The discharge available for fire-fighting in the streets is limited due to high head loss in areas with weak pressure.

2.8 The Importance of WDNs in Water Service Provision

Onyenechere and Osuji (2012), in their study on “Water Service Provision in Owerri City, Nigeria,” assert that human beings often settle close to water sources because they need water; and human settlements are sustainable only if they have access to potable water. Water resources are essential to human development processes and to achieve the Millennium Development Goals that seek, inter alia, to eradicate extreme poverty and hunger, achieve universal literacy, and ensure environmental sustainability. Thus, adequate water distribution networks play a vital role in transporting potable water from sources to human settlements in order to enhance development.

Further, Onyenechere and Osuji (2012) argue that there can be no state of positive health and well-being without safe water. For many urban areas the quality of water is becoming a major concern. This helps to explain the increasing demand for potable water in urban areas. Onyenechere and Osuji (2012) further affirm that water must not only be adequate in quantity, but in quality as well. Onyenechere and Osuji (2012) opine that the basic physiological requirement for drinking water has been established at about 2 litres per person per day. However, a daily supply of 140 - 160 litres per capita is considered adequate to meet all domestic needs. Water is not only vital for all forms of life; it also plays a great role in socio-economic development: domestic use, agricultural use, industrial use, power generation and recreational use. However, many urban dwellers do not have access to drinking water because of inadequate WDNs.

UN/WWAP (2003) asserts that lack of access to water decreases available time and resources for productive activities and thus reduces population welfare in developing countries while MacDonald (2005) and WHO (2006) argue that more than one billion people lack access to safe drinking water, most of whom are sub-Saharan Africans.

2.8.1 Benefits of Adequate WDNs in Water Supply

According to DANIDA (2006), the relationship between water, sanitation and poverty works in two directions; poverty constrains increases in access while improved access is a cornerstone of poverty alleviation. Further, DANIDA (2006) asserts that the primary and best-documented benefit of increased access to safe water, sanitation and the means of hygienic behaviours arises from a significant reduction in the incidence of water-related disease including diarrhoeal disease, trachoma, schistosomiasis, and hookworm infections. There is also growing evidence that improved hygiene, in particular handwashing, may have a significant positive impact on reducing transmission of upper respiratory tract infections including Tuberculosis and Severe Acute Respiratory Syndrome (SARS). These last two, along with reduced incidence of diarrhoeal disease, are of particular importance in congested urban environments.

Moreover, DANIDA (2006) opines that additional benefits to improved urban and low-income water supply, sanitation and hygiene include:

- improved attendance at school, particularly for girls;
- improved educational attainment (due largely to reductions in worm infestations);
- increased time and reduced drudgery associated with collecting water, open defecation, caring for sick family members and sickness itself;
- increased life-expectancy and therefore productive life-expectancy;
- increased worker productivity;
- opportunities for small-scale industry and market gardening;
- a reduction in expenditures on coping-costs at the household level (paying high rates for low-quality services for example); and
- reduced expenditures on curative health.

These gains are known to "stimulate a chain reaction of economic growth and poverty alleviation (Brocklehurst, C., 2004). Perhaps even more significantly, access to safe water and the means of safe disposal of excreta and hygienic behaviours confer dignity and reduce the burden and drudgery associated with income-poverty, insecure living and working environments and poor housing conditions and these benefits too, are particularly significant for disadvantaged urban households. DANIDA (2006) further opines that water, sanitation and hygiene are thus central to poverty alleviation, equity and empowerment of otherwise disadvantaged urban communities. It is clear, therefore, that water distribution networks play a key role in transporting water through pipes in order to reach communities thereby enabling access to safe water and the means of safe disposal of excreta and hygienic behaviours.

2.9 Institutional and Legal Framework for Water Service Provision in Zambia

2.9.1 Overview of the Water Sector in Zambia

In 1991, a change in the Government of the Republic of Zambia introduced general public service reforms and the liberalisation of the economy. This created a conducive environment for water sector reforms. In order to implement the reforms, a guide was required for the entire process. Thus, seven sector principles outlined in the 1994 National Water Policy were adopted as a first step to the implementation of the water sector reforms (National Water Policy, 1994), and these are:

1. Separation of water resources functions from water supply and sanitation;
2. Separation of regulatory and executive functions within the water supply and sanitation sector;
3. Devolution of authority to local authorities and private enterprises;
4. Achievement of full cost recovery for the water supply and sanitation services through user charges in the long run;
5. Human resource development leading to more effective institutions;
6. Technology appropriate to local conditions and
7. Increased GRZ spending priority and budget spending to the sector.

The Water Sector can be said to have two sub-sectors, namely: Water Supply and Sanitation (Urban and Rural) and Water Resources Management. In accordance with the Local Government Act, the National Water Policy and the Water Supply and Sanitation Act No. 28 of 1997, the Ministry of Local Government (MLG) and the Local Authorities (LAs) have the responsibility for Water Supply and Sanitation (WSS) - both urban and rural. The Ministry of Local Government provides policy guidance, technical and financial control, and facilitates mobilisation of foreign and local funds for capital development. The responsibility for the management of water resources falls under the Ministry of Water Development, Sanitation and Environmental Protection (MWDSEP).

2.9.2 Urban Water Supply and Sanitation (UWSS)

2.9.2.1 Oversight of Urban Water Supply and Sanitation Services in Zambia

The Ministry of Water, Sanitation and Environmental Protection (MWSEP) has the overall mandate to coordinate urban water supply and sanitation (UWSS) to all users through Local Authorities (LAs). All the LAs have devolved the authority for management of UWSS to private enterprises (Commercial Utilities (CUs)) which have been established by the formation of joint ventures among LAs.

The recognition of the importance of environmental management in the development process led to the establishment of the Ministry of Lands, Natural Resources and Environmental Protection (MLNREP). This ministry was also recently realigned with the functions of environmental protections being transferred to the Ministry of Water, Sanitation and Environmental Protection.

This Ministry of Water, Sanitation and Environmental Protection (MWSEP) is also responsible for regulating the use of water resources. The project area has a number of streams and water courses and as such the Ministry will be concerned with the pollution of water during the construction phase. Water pollution and the related matters are the responsibility of the Department of Water Affairs.

2.9.2.2 Water Supply and Sanitation Service Provision

There are currently eleven CUs licensed to provide WSS services in the urban areas of the 10 provinces of Zambia. Solid waste management and drainage remain the direct responsibility of the LAs. The LAs as shareholders appoint a Board of Directors to oversee the operations of the CU. The day-to-day running of the utility is the responsibility of the appointed management.

There are also six private schemes licensed to provide water supply and sanitation services as a fringe benefit to their employees. These are owned and run by companies whose core business is not water supply.

2.9.2.3 Regulation of Water Supply and Sanitation Service Provision

The National Water Supply and Sanitation Council (NWASCO) is responsible for regulation of water supply and sanitation service providers in Zambia, while the

Ministry of Health (MoH) is responsible for water quality regulation. The Zambia Environmental Management Agency (ZEMA) is responsible for environmental protection and the Zambia Bureau of Standards (ZABS) specializes in standardization, quality assurance, metrology and testing. All water supply systems for domestic water supply should comply with the set ZABS design standards for domestic water supply.

2.9.2.4 Water Supply and Sanitation Service Sector Development

The Government has developed a holistic and integrated National Urban Water Supply and Sanitation Programme (NUWWSP) to cover the period 2011 to 2030 for improved livelihood and health of the urban population in Zambia. The NUWWSP consists of a coherent set of institutional and sector support activities aimed at developing and sustaining water supply, sanitation, solid waste management and drainage infrastructure and services in the urban areas of Zambia.

The Urban population is served by various forms of WSS. NWASCO regards individual household connections, communal taps, water kiosks and public tabs served with treated water from the WSS provider’s network as acceptable water points. For sanitation, NWASCO considers service by offsite (main system/network) and septic tanks only for onsite as acceptable.

2.9.3 Water Resources Management (WRM)

Among the water sector guidelines enshrined in the National Water Policy of 1994 is the separation of Water Resources Management from Water Supply and Sanitation. The Ministry of Mines, Energy and Water Development, in early 2003, established the Water Resources Action Plan (WRAP) to develop a new legal and institutional framework for the efficient management of national water resources.

The Water Resources Management Authority was established by the Water Resources Management Act No. 21 of 2011. The function of the Authority is to promote and adopt a dynamic, gender-sensitive, integrated, interactive, participatory and multi-sectoral approach to water resources management and development that includes human, land, environmental and socio-economic considerations, especially poverty reduction and the elimination of water borne diseases, including malaria.

The Water Resources Act also provides for the management, development, conservation, protection and preservation of the water resource and its ecosystems. Further, the Act also provides for the equitable, reasonable and sustainable utilisation of the water resource, ensure the right to draw or take water for domestic and non-commercial purposes, and that the poor and vulnerable members of the society have an adequate and sustainable source of water free from any charge. Other provisions of the Water Resources Act No. 21 of 2011 include:

- creating an enabling environment for adaptation to climate change;
- provision for the constitution, functions and composition of catchment councils; sub-catchment councils and water users associations;
- provision for international and regional cooperation in, and equitable and sustainable utilisation of shared water resources;
- provision for domestication and implementation of the basic principles and rules of the international law relating to the environment and shared water resources as specified in the treaties, conventions and agreements to which Zambia is a State Party;
- repeal and replace the Water Act, 1949; and
- provision for matters connected with or incidental to, the foregoing.

2.9.4 National Water Supply and Sanitation Council (NWASCO)

The National Water Supply and Sanitation Council (NWASCO) regulates water providers for efficiency and sustainability of water supply and sanitation service provision. Established by the Water Supply and Sanitation (WSS) Act No. 28 of 1997, NWASCO is mandated to balance social and commercial interests, protect consumers from exploitation and providers from undue political interference. The regulator links water and sanitation prices to sustainability of systems and performance of providers. At the same time, NWASCO ensures that social interests are taken into account as well as preventing consumers from paying for the inefficiencies of the service providers.

Since commencement of operations in 2000, consistent and objective rules for regulation have been developed aimed at promoting long term efficient provision of water supply and sanitation services in line with the country’s national development agenda.

NWASCO's functions include:

- Licensing Service providers
- Developing sector guidelines
- Establishing and enforcing standards
- Advising government on WSS
- Advising Local Authorities on institutional arrangements
- Disseminating information to consumers

The Water Supply and Sanitation Act of 1997 stipulates the functions of NWASCO, among which is that of developing guidelines. The following mandatory guidelines for compliance by providers have been issued by NWASCO:

1. **Minimum Service Level Guidelines**

   These are standards which stipulate the acceptable minimum level of service which providers must achieve within a defined timeframe.

2. **Tariff Adjustment Guidelines**

   The Objectives of the Tariff adjustment guidelines are to ensure:

   - Sufficient revenues for the service providers to enable them to operate on a sustainable basis
   - Protection of consumers from being overcharged
   - Provision of efficiency incentives for the service providers
   - Conservation of treated water
   - Protection of the environment

3. **Water Quality Monitoring Guidelines**

   The objectives of the Water Quality guidelines include the following:

   - Ensure through regular monitoring that the quality standards set by the Zambia Bureau of Standards (ZABS) are being complied with and that the customers can have confidence that the water they consume is potable. In Zambia, the adopted drinking water standard guidelines are the World Health Organisation (WHO) standards.
   - Ensure that all water utilities will follow a systematic way of water quality monitoring so as to have uniformity of the process.

- Ensure that providers conduct risk assessments at all stages of water quality monitoring through water safety planning.

4. **Corporate Governance Guidelines**

Companies registered under the Companies Act, such as the Commercial Utilities (CU's) in the water supply and sanitation sector are autonomous entities whose decision making process is supposed to be free of external and specifically political influence. The main influence on the company should be the enhancement of shareholders value and delivery of the goods or services for which the company was established. The guidelines outline Good Corporate Governance principles that must be adhered to in terms of transparency, accountability and respect of the rights of stakeholders.

5. **Business Planning Guidelines**

A business plan provides a thought out and logical framework within which a business can develop and pursue business strategies over the planned period. It provides a benchmark against which actual performance can be measured and reviewed. The Business Planning guidelines outline the framework for preparing a business plan.

6. **Financial Projections Guidelines**

Providers have to submit their Financial Projections to NWASCO in order to fulfil the requirements as stipulated by the license. Financial projections do not stand-alone but are interconnected with the planning of all water supply and sewerage services of the provider. As a consequence it is required that Financial Projections have to be submitted as a complement to a 'Tariff Adjustment Proposal' or an 'Investment Plan'.

By issuing the guideline for "Financial Projections" NWASCO seeks to harmonize the practical steps in the financial planning process of the providers and to ensure the comparability of the statements among the providers. This guideline outlines the expected minimum standard for establishing financial projections.

7. **Annual Reporting Guidelines**

   The operating license stipulates that providers have to submit an annual report to NWASCO drawn up in accordance with guidelines issued by NWASCO. The annual reporting guideline specifies the content of the annual report to be submitted.

8. **Accounting Guidelines**

   The objectives of the accounting guidelines include the following:

   - To assist providers to periodically and timely deliver reliable and relevant financial information.
   - Minimise the number of alternative accounting treatments.
   - Harmonise the maintenance and reporting of financial information among providers.

2.9.5 Zambia Bureau of Standards (ZABS)

The Zambia Bureau of Standards (ZABS) is the Statutory National Standards Body for Zambia established under an Act of Parliament, the Standards Act, Cap 416 of 1994 of the Laws of Zambia for the preparation and promulgation of Zambian Standards. ZABS is a specialized organization of national importance serving the country in the field of standardization, standards formulation, quality control, quality assurance, import and export quality inspections, certification and removal of technical barriers to trade.

The core mandate of ZABS is to formulate National Standards, conduct quality assurance and calibration of measuring instruments (metrology) activities. Standards are documents developed by consensus with interested parties that describe good practices in the country. Some standards are compulsory while others are voluntary. Voluntary standards cannot be enforced by regulation while non-compliance to compulsory standards is a crime under the laws of Zambia. The Zambia Bureau of Standards is not in charge of enforcing all standards. Different sector specific regulators such as the Zambia Information and Communications Technology Authority (ZICTA) for Information and Communication Technologies (ICTs), Energy Regulation Board (ERB) for energy, Road Transport and Safety Agency

(RTSA) for road transport, and Zambia Environmental Management Agency (ZEMA) for chemicals and Lusaka City Council (LCC) for Public Health matters are also involved.

Some of the roles of ZABS include:

- preparing Zambian Standards and to promote their use;
- making arrangements or to provide facilities for the examination and testing of commodities, materials and substance from which commodities may be manufactured, processed, treated or finished;
- to provide quality control and quality assurance schemes for commodities in order to promote and improve trade;
- ZABS has Testing Laboratories for testing and analysis of products to national and international standards as well as client specifications. Among the products tested are
    - Water (for chemical and microbiological tests)
    - Environmental samples e.g. soil, water, (for DDT and other persistent organic pollutants)
    - Aldrin, dieldrin, chlordane, and other poisonous substances in drinking water

2.9.6 Zambia Environmental Management Agency (ZEMA)

The Ministry of Water, Sanitation and Environmental Protection (MWSEP) is the key institution entrusted with the formulation of environmental policies and pollution control. The Ministry carries out its mandate through the Zambia Environmental Management Agency (ZEMA), the Forestry Department and Department of Planning and Information.

The Zambia Environmental Management Agency (ZEMA), formally known as the Zambia Environmental Council (ECZ), was established under the Environmental Management Act (EMA) No. 12 of 2011. The Environmental Management Act (EMA) of 2011 was enacted by the Parliament of Zambia to regulate and coordinate environmental management, promote awareness, and ensure environmental protection through enforcement of regulations and the prevention and control of pollution in support of sustainable development, and also to provide for the health and welfare of persons, animals, plants and the environment of Zambia.

The functions of ZEMA are set out in section 9 of the Act, which states that the Agency's mandate is to 'do all things as are necessary to ensure the sustainable management of natural resources and protection of the environment and the prevention and control of pollution'. ZEMA's core functions include:

- Drawing up and enforcing regulations related to water, air and noise pollution, pesticides and toxic substances, waste management and natural resources management.
- Advising the Government on the formulation of policies related to good management of natural resources and environment.
- Advising (the general public) on all matters relating to Environment conservation, protection and pollution control, including necessary policies, research investigations and training.

ZEMA is the major environmental institution in Zambia and the main lead agency on matters pertaining to Environmental Impact Assessment (EIA). It is empowered by the EMA to identify projects, plans and policies for which EIA is necessary. ZEMA is the main authority for implementing environmental safeguards by ensuring development interventions are preceded by appropriate EIAs and/or State of Environment Assessment (SEAs) reports.

2.10 Design Standards for Residential Water Supply Systems

Before a WDN can be loaded with water to transport to the consumer, it must be designed to meet design standards for residential water supply systems. In Zambia, these standards include the Zambia Bureau of Standards for design of domestic water supply systems.

2.10.1 Basic System Requirements

The basic system requirements for a comprehensive residential water supply system are explained in the proceeding sections.

2.10.1.1 Water Demand

According to the World Bank (2012), the first step in designing a water system is to determine how much water is needed by the population to be covered. The water to be supplied should be sufficient to cover both the existing and future consumers. It must include provisions for domestic and other types of service connections. In addition to the projected consumptions, the World Bank (2012) opines that an allowance for Non-Revenue Water (NRW) that may be caused by leakages and other losses should be included.

The World Bank (2012) argues that water demands are influenced by the following factors:

i. Service levels to be implemented;
ii. Size of the community;
iii. Standard of living of the populace;
iv. Quantity and quality of water available in the area;
v. Water tariffs that need to be shouldered by the consumers;
vi. Climatological conditions;
vii. Habits and manners of water usage by the people.

Further, the World Bank (2012) states that water demand is a summation of all the consumptions for the various requirements (for example, drinking, cooking, washing, bathing, laundry, etc.) and will determine the capacity needed from the source/s. The average daily water demand, also known as the average day demand, is calculated (in m^3/day or lps) from the estimated water consumptions and the allowance for the NRW (expressed as a percentage). Additionally, the World Bank (2012) asserts that a municipality must recognize that the quantity of available water needs to be such that maximum daily consumption demands are satisfied at all times, even during periods of drought or after years of community growth. The water delivery system needs to expand as the municipality expands.

Once the consumption demands are defined, the next step is to determine the service level as part of the demand analysis.

2.10.1.2 Service Level Classifications

In Zambia, depending on the method by which the water is made available to the consumers, water service levels are categorised under the following:

i. High Cost Housing
ii. Medium Cost Housing
iii. Low Cost Housing
iv. Peri-Urban or Rural Housing

According to ZABS (2009), residential water demand is dependent upon the cost classification of housing. Housing categories in Zambia are generally classified as High Cost, Medium Cost, Low Cost and Peri-Urban housing, though there is no universally accepted definition of these categories.

In Zambia, all designs of residential water demands must comply with the Zambia Bureau of Standards for Water Supply Systems Demand Figures for Design Guidelines (ZS 361: 2009) indicated in Table 2-1.

Table 2-1: Zambian Residential Water Demand Figures (ZABS, ZS 361: 2009)

REQUIREMENTS	PERI-URBAN OR RURAL HOUSING (l/c/d)	LOW COST HOUSING (l/c/d)	MEDIUM COST HOUSING (l/c/d)	HIGH COST HOUSING (l/c/d)
Drinking	3	3	3	3
Bathing & Washing	15	25	50	90
W.C	-	30	30	40
Cooking & Cleaning	5	10	17	22
Laundry	5	10	20	30
Gardening	7	12	20	60
Other Uses	5	5	10	10
TOTAL	**40**	**95**	**150**	**255**

NOTES

1. The demand is expressed in litres per capita per day (l/c/d)
2. High and Medium Cost Housing based on main house occupants excluding servants quarters
3. For servants quarters, allow for Low Cost Housing demand figures
4. Water demand in Rural Areas is not explicitly covered, however the demand figures for Peri-urban Housing are recommended.
5. 'Other uses'inlude car washing, pet washing, etc

2.10.1.3 Design Flow/Capacity

The World Bank (2012) opines that the capacity is determined on the bases of local water needs plus fire-fighting demand. In Zambia, the capacity should comply with the guidelines for domestic water supply design standards set by the Zambia Bureau of Standards. Further, the World Bank (2012) asserts that pipe sizes should be selected to avoid losses due to high velocities.

2.10.1.4 Non-Revenue Water (NRW)

The World Bank (2012) defines Non-Revenue Water (NRW) as the amount of water that is produced but not billed as a result of leaks, pilferages, free water, utility usages, fire-fighting, etc.

Further, the World Bank (2012) asserts that designs of domestic water supply systems should include an allowance for non-revenue water; otherwise, the designed source capacity would not be sufficient to supply the required consumption of paying customers. In actual operation, the NRW should be a cause of concern and should be subject to measures to keep it as low as possible. For planning purposes, however, a conservative approach should be adopted. The water demand projection should assume that the NRW of a new system will be fifteen percent (15 percent) of the estimated consumptions (World Bank, 2012). The plan's figure can be increased up to a total of 20 percent at the end of 10 years. These assumed NRW figures require good maintenance of utilities, pro-active leakage prevention, and no illegal connections for 100 percent recovery of supplied water (World Bank, 2012).

Thus, all designs of WDN have to take into account the community consumption (demand) as well as the NRW percentage in order to give the average day demand.

According to the World Bank (2012), this can be computed mathematically, as:

$$\text{Average day demand, } Q_d = \frac{Qe}{1 - NRW} \qquad [1]$$

where; Q_d is the average day demand (lps)
Qe is the estimated demand of the population (lps)
NRW is the non-revenue water percentage

2.10.1.5 Water Pressure

- Pressure should be great enough to adequately meet consumer and fire-fighting needs.
- Pressure should not be excessive, but when determining the pressure required in a WDN, the following should be taken into account:
  - Cost consideration
  - Leakage and maintenance increase

2.10.1.6 Pipe Design

The National Environmental Services Center (NESC, 2010) asserts that to be able to design new water distribution pipelines or to analyze existing pipe networks, the head losses, pressures, and flows throughout the system need to be calculated. There are several formulas in hydraulics to do this, but one of those most commonly used is the Hazen-Williams equation. The Hazen-Williams equation (shown below) can conveniently be used for the hydraulic design of WDNs, regardless of the type:

$$Q = 0.28 \text{ x } C \text{ x } D^{2.63} \text{ x } S^{0.54} \qquad [2]$$

where; Q = flow rate [m^3/s]

0.28 = conversion factor from Imperial to SI units.

C = pipe roughness coefficient (dimensionless) can be found in prescribed values based on pipe material.

D = pipe diameter [m]

S = slope of hydraulic grade line, dimensionless; $S = h_L/L$

Where h_L is head loss in meters and L is the length of pipe in meters

2.10.1.7 Design Period

The World Bank (2012) affirms that in commercial utility models, the design period normally spans long periods involving decades within which the initial capital outlay and succeeding outlays for expansion and rehabilitation can be rationally recovered. For small water utilities, including those owned by the local governments, such large outlays are not available and cannot be matched by the population’s capacity to pay. For these reasons, the design period or horizon is set at 5 or 10 years. In fact, these are the design periods frequently decided by agreements among the funder, the implementing agency, and the community or the Local Authorities (LAs). Further, the World Bank (2012) asserts that in setting the design period, the designer should take into account the terms of the financing package and the potential consumers’ capability and willingness to pay the amounts needed to support repayment. The advantages and disadvantages for the 5- and 10-year options are:

i. **Five-year design period**
   - **Advantages** – Low initial capital cost. If the project is to be financed through a loan, the loan amortizations are lower due to the lower investment cost.
   - **Disadvantages** – Need for new capital outlays after five (5) years to upgrade system capacity. Most waterworks facilities, like reservoirs and pipelines are more viable to plan for a one stage 10-year period than to plan in two stages of 5-year period each.

ii. **Ten-year design period**
   - **Advantages** – The water system facilities are capable of meeting the demand over a longer period. No major investment cost is expected during the 10- year design period.
   - **Disadvantages** – The higher initial capital cost will require initial tariffs to be set higher.

2.10.1.8 Design Population

The World Bank (2012) affirms that the design population is the targeted number of people that the project will serve. Further, the World Bank (2012) asserts that there are two ways of projecting the design population:

1. Estimate the population that can be served by the sources. In this case, the supply becomes the limiting factor in the service level, unless a good abundant and proximate source is available in the locality.
2. Project the community population, and determine the potential service area (WDN area) and the served population. The historical population growth rates of the community are needed as the basis for population projections.

The year-by-year population projections for a community could then be computed by applying the basic equation:

$$P_n = P_0 (1 + GR)^n \qquad [3]$$

Where:

P_n = the projected population after nth year from initial year [count of people]

P_0 = the population in the initial year of the period concerned [count of people]

GR = the average growth rate between the two periods

n = number of years between P_n and P_0

In Zambia, the historical population growth rates are available at the Central Statistics Office (CSO). The latest national census in Zambia was conducted for the year 2010.

2.11 Challenges of Supplying Improved Urban Water Services

Ojo (2011), as cited in Gowela *et al.,* (2017), argues that most public water utilities in developing countries are faced with a number of challenges in improving service quality delivery. These challenges are linked to infrastructural, financial, environmental and health, social political and managerial issues. For over the past two decades, more efforts have been made on improving sustainable water supply by many countries. This has been made possible through the assessment of the performance of the public water utilities (Tiwari and Gulati, 2011; Zschille and Walter, 2012; Kalulu and Hoko 2010) and examination of the impact of public or private ownership on the performance of the water utilities (Kirkpatrick *et al.,* 2004; Kirkpatrick *et al.,* 2006). More studies have also focused on assessing the level of customer satisfaction with the service delivery (Jayaramu *et al.,* 2014; Zeraebruk *et al.,* 2014) in order to provide reliable information to policy makers. Further, Gowela *et al.* (2017) asserted that the access to water is affected by unreliable and intermittent water supply due to deterioration of water infrastructure (Mughogho and Kosamu 2012), poor revenue collection by the utility providers (Manda 2009; Kalulu and Hoko 2010), high levels of Non-Revenue Water (Harawa *et al.,* 2016) and rising urban population (Mpakati-Gama and Mkandawire 2015). Moreover, Mpakati-Gama and Mkandawire (2015), as cited in Gowela *et al.,* (2017), affirm that the rising population exerts pressure on water distribution systems and structures originally constructed for smaller populations.

The World Health Organisation (WHO), in their publication on “Guidelines for Drinking Water Quality,” (2011), states that natural disasters, including flood, drought and earth tremors, may significantly affect piped water distribution systems. Other conditions that may affect piped water distribution are:

- growing demands that cannot be met by the treatment plant;
- lack of adequate storage capacity;
- other communities drawing water from the same supply sources such as a lake or a river;
- a major commercial fire or wild land/urban interface fire that exhausts the water supply; and
- undetected underground leakage on the pipe distribution system

Therefore, maintaining a continuous or uninterrupted supply of water for municipal demands is a major challenge to many municipalities (Hickey, 2008). The water sources available to provide clean drinking water to Africa's population which stands at 1,269,063,417 (Worldometers, 2017), are limited. As demand for water grows, the impact on water management and the ability of urban centers, where access is much higher than in rural areas, to provide an adequate supply of water and sanitation is tremendous. While access to improved water sources has grown in urban areas, progress has stagnated at 85 percent (AMCOW 2012) as urban populations grow. AfDB (2015) opined that between 2000 and 2010, 84 million urban Africans gained access to improved water supply and 42 million to improved sanitation, an impressive 3.9 percent average increase in access over the decade, but at the same time, urban populations grew by an average of 3.9 percent.
AfDB (2015) argues that urban water infrastructure lags behind population growth for several reasons: rapid urbanization and population growth, a rising share of informal settlements, inadequate infrastructure, and institutional weaknesses including low cost recovery, inadequate governance, and deteriorating water sources.

Some of the challenges hindering improved urban water services (piped water supply services) are:

2.11.1 Rapid urbanization and poor urban planning

AfDB (2015) argues that Africa is urbanizing more quickly than any other region in the world and has faster growing urban slums. Over the next 20 years, its urban population is projected to double; growth rates will continue to be the world's highest. Currently, approximately 409 million Africans or 40 percent of the continent's population, lives in urban areas, more than twice the numbers in 1990 (AfDB, 2015). By 2030, that percentage will rise to half the continent's population, or some 654 million people (Jacobsen *et al.,* 2013). AICD (2011) affirms that approximately two-thirds of Africa's urban population is currently served by water utilities. Over the next quarter century, demand for water in Africa is projected to nearly quadruple - the world's fastest rate (Jacobsen *et al.,* 2013).

The AfDB Group (2015) affirms that rising industrial and commercial demand linked to industrialization and rising incomes for some have nourished expectations of higher quantities and better quality of water, increasing pressure for improved water management policies and implementation. Rapid urbanization is accompanied by poor urban planning and expanding slum populations. Africa's share of the global slum population rose from 14 percent in 1990 to 20 percent in 2005 (AfDB, 2015). Densely crowded slums create not only institutional and financial challenges but also technical challenges in accommodating the machines to build traditional sewer or water supply networks (AfDB, 2015).

By 2030, Africa's urban population is forecast to rise to 654 million people from 320 million people in 2010. Most of those who will be living in African cities in 2030 have yet to arrive, making it important for city planners to prepare now (Jacobsen *et al.*,2013) to make the best use of urban water planning principles.

2.11.2 Inadequate local investment and governance

According to an evaluation report on *"Water Supply and Sanitation in Africa: Findings, Lessons and Good Practices to Improve Delivery,"* by the Independent Development Evaluation (IDEV) of the African Development Bank (AfDB) Group, (AfDB, 2015), dilapidated and aging infrastructure of most African water utilities cannot meet the growing demand for water.

Further, the AfDB (2015) argues that African water utilities are unable to deliver continuous water service or adequate water quality because of their inefficient management. For African cities to provide water and sanitation services to meet social and economic demands, they need investments (AfDB, 2015). Yet most African countries lack adequate local funding to expand or renew their utilities and current investments in urban services are insufficient given urbanization rates. Gauff (2011) and MLGH (2011), exemplify the challenge of inadequate investment and governance of the water utilities by arguing that existing (old) Infrastructure is inadequately maintained and developed resulting in dilapidation of the infrastructure.

Moreover, Banerjee and Morella (2011), and the AfDB (2015), argue that low cost recovery and poor governance also thwart the expansion of water service coverage. For most utilities to fully recover their capital costs, tariff increases for consumers would be significant and affordable for only half of the population in Africa. Recovering full costs from existing customers and using the resulting cash flow to increase access for the poor would substantially increase equity, although associated political issues will be difficult to overcome (van Ginneken, *et al*., 2012).

The AfDB (2015) states that further complicating the picture of improving urban water services is the fact that urban water sources are being polluted by inadequate sanitation, poor wastewater management and human activities. The groundwater in most large African cities (for example, Dakar, Abidjan, Lomé, Lagos, and Dar es Salaam) is contaminated and polluted mainly by the discharge of untreated wastewater and unregulated industrial pollution (AfDB, 2015). Utilities must spend significant sums to treat the water whereas these resources could be used to provide basic services to citizens.

The World Bank's Africa Strategy (World Bank, 2011) sees an unprecedented opportunity for transformation and sustained growth in Africa, primarily in cities, the traditional engine of economic growth. This growth could place Africa on the cusp of an economic takeoff, much as China experienced 30 years ago or India 20 years ago.

The prevailing urban water challenges require improved water management, policies and service provision to be opportunities for African economic transformation.

2.12 Summary of Literature Review

Following the review of literature, the chapter established that the provision of safe and adequate quantities of water supply through water distribution networks is the cornerstone of wellbeing of a community. However, the chapter has also established that water distribution networks should meet certain requirements for them to be adequate in water service provision. It has been recognized that the performance of water distribution networks is hampered by a number of challenges which include; poor selection and design of the networks to suit a particular locality, rapid population growth and urbanisation which can supersede the services from the water distribution networks and lack of adequate funding resulting from low cost recovery. Lack of adequate funding tends to hinder maintenance or rehabilitation works needed to improve the performance of the water distribution networks. It was further established that the inability of a water utility company to collect sufficient funds from the water it produces and supplies its customers can be attributed to poor governance of the utilities and this contributes to poor performance of the water distribution networks.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Research Design

Research design is the preparation of situations for collection and analysis of data in a manner that aims to combine relevance to the research purpose with frugality in procedure (Kothari, 2004). Research design is thus the conceptual structure within which research is conducted. It establishes the proposal for the collection, measurement and analysis of data. The research study used a case study that employed both qualitative and quantitative methods. This was to get details and gain in-depth understanding on the performance of the water distribution network implemented in Hillview South in 2012 by LWSC. Tourki (2010) argues that a case study is a holistic inquiry whose goal is to gain insight, explore the depth and complexity inherent in a contemporary phenomenon.

3.2 Study Area

The research area was Hillview South of Kamwala South in Lusaka City, a predominantly a rocky area, which is the extended area of Hillview Park (also called Mwaiwake) on the Southern part of Kamwala in Lusaka City.

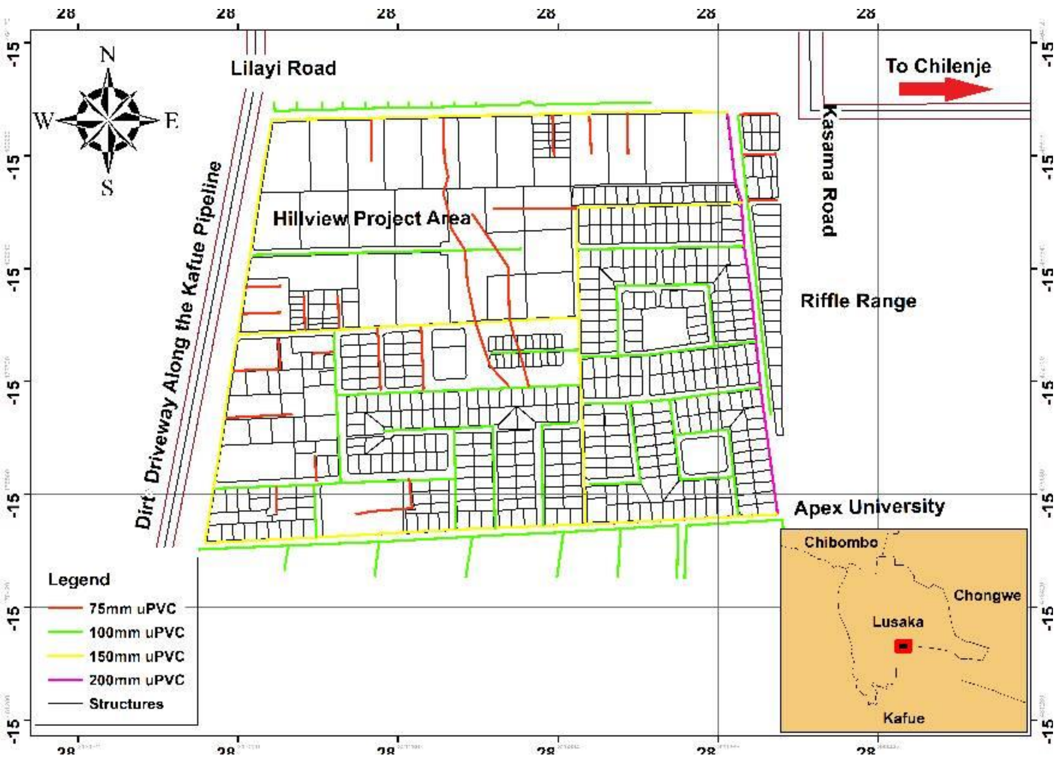

Figure 3-1: Overview of Hillview South WDN Project Area, Kamwala South, Lusaka (Source: LWSC, 2017)

The area is characterised as a medium to high income residential area without any low-cost housing, located on the southern part of Lusaka City and shares boundaries with Hillview Park on the northern side, Rockfield on the Eastern side, and the Lilayi farming block area in the Northern and Southern directions.

Hillview South stretches over an area of 2.412964 km^2 with a total of 2005 households. The LWSC WDN project, however, only covered a total of 573 households over a stretch of 16.215km. LWSC records (LWSC, 2011) indicated that the 16.215km length of the water network in Hillview South consists of the following lengths and sizes of ultra-Polyvinyl Chloride (uPVC) pipes:

- 4.080km of 75mm pipes
- 6.665km of 110mm pipes
- 4.715km of 160mm pipes
- 2.7355km of 200mm pipes

The type of WDN installed in Hillview South by LWSC in 2012 is the Ring or Circular Network, with four separate sources (Shaft 5 and Lilayi boreholes) of water supplying the network.

3.2.1 Reasons for Choosing Hillview South as a Research Study Area

The following reasons were advanced for choosing the Hillview South WDN as a research study:

i. **To explain a pattern in the performance of WDNs in Lusaka City –** since the WDN project was recently implemented, an explanation of the pattern in performance of WDNs installed by LWSC was sought because the problem of water shortages is prevalent in most communities in Lusaka. A pattern is a signal which explains what exactly what hinders optimal performance of WDNs installed by LWSC. Therefore, an informative explanation of multiple interrelated patterns (of aspects of performance of the WDN from the respondents' perspectives such as water quantity, quality, pressure and continuity) at once was sought.

ii. **To explain variation of performance of WDNs in the LWSC network -** The performances of WDNs is full of striking variation over different localities in Lusaka, over time, among individuals, populations and communities.

iii. **To highlight the consequences of the WDN design process in LWSC** – The key here was to develop and/or test hypotheses about the consequences of the design aspects of WDNs in LWSC.

iv. **To conduct laboratory tests on water samples in relation to the water quality requirements** – using the WHO guidelines as a basis for water quality standards, the water distributed in the Hillview WDN was tested for suitability for use.

v. **To show how performance of WDNs in the engineering field affects other fields in society** – ultimately, the optimal performance of WDNs caters for a wide range of fields for various purposes and this sought to be shown in the research study.

Additionally, the research study was also important for the purposes of:

i. better understanding the various parts/components of a WDN in order to determine what works well or not and thus recommend the best suited solutions regarding rehabilitation, replacement or repair.

ii. better communicating the value of the work put in by LWSC in installing WDNs for the purposes of securing more funding for new projects, advocacy or collaboration.

iii. enabling LWSC to adapt their designs of WDNs to respond to the requirements of a particular location and the needs of the residents in that location.

However, it should be noted that this study did not intend to make any generalization on the whole settlement, but to draw an understanding on the perceptions and opinions from the residents in Hillview South with regards to the water service provision through WDNs by LWSC.

3.2.2 Study Population

According to LWSC records, Hillview South has a total of 2005 serviced households (LWSC, 2011), but the WDN implemented in 2012 only covered 573 households. In their proposal to the financiers (ZANACO) for installation of the WDN in Hillview South, LWSC design figures indicated that the required water demand for the area at peak flow was $80m^3/h$ for a population of 6,180 people over a ten-year period from 2011 (LWSC, 2011). Records at LWSC (LWSC, 2011) indicated that the population figures used for the design of the Hillview South WDN by LWSC were obtained from the Central Statistics Office (CSO).

This study sought to verify if LWSC's designed water demand of $80m^3/h$ was sufficient for the indicated population by using a 10 year design period for a WDN. In this method of design, the community population is projected over ten years for the potential WDN service area using historical population growth rates of the community (World Bank, 2012). The historical population growth rates of Lusaka District for the year 2010 (CSO, 2010) was used as the basis for the population projection over the ten year design period. The year-by-year population projection for Hillview South was then computed by applying the geometric progression method (World Bank, 2012; Ahmed and Rahman, 2000) because it is the same method used by LWSC in their design of the Hillview South WDN in 2011:

$$P_n = P_0 (1 + GR)^n \qquad [1]$$

Where:

P_n = the projected population after the tenth year from the year 2012

P_0 = the population in the initial year of the period concerned

GR = the average growth rate between the years 2010 and 2020 (for Lusaka district, the growth rate is 4.6 percent per annum; CSO, 2012)

n = number of years between P_{2022} and P_{2012} (that is, 10 years)

3.3 Research Methods

The study employed both qualitative and quantitative research methods. Qualitative methods were used for in-depth understanding (Kothari, 2004) and quantitative methods (Creswell, 2006) to establish trends and patterns in the study site of Hillview South. An inductive approach was used to examine and discover patterns that reflect the relevant literature (Eisenhardt, 1989) for in-depth analysis. Qualitative methods (secondary data sources) were explanatory and involved literature review, interviews, water samples laboratory tests and field observations, whereas Quantitative methods (primary data sources) were descriptive and involved the use of household based questionnaire surveys.

3.4 Quantitative Methods

Quantitative methods were used to conduct key informant interviews, which involved consultations with key personnel at Lusaka Water and Sewerage Company Limited that were directly involved with the implementation of the water distribution network project in Hillview South or are currently involved with it in its operations. Key informant interviews were also conducted at NWASCO in order to get an unbiased perspective from the regulator's side concerning the performance of the WDN. Household questionnaire based surveys were also used to collect quantitative data. The interviews commenced as soon as a comprehensive literature review was completed.

3.4.1 Primary Sources of Data

Primary sources provided data through the use of questionnaires, semi-structured interviews and field observations.

3.4.1.1 Questionnaires

These were used on households as a way of understanding the residents of Hillview's perception and trends in order to understand the residents' levels of satisfaction with regards to the quality and quantity of water supplied by LWSC to their area.

3.4.1.2 Semi-Structured Interviews

Semi- structured interview guides were used to get insights from the perspective of the service providers and implementers. This tool was to enable the researcher to get in-depth information (Kothari, 2004) as a way of getting an understanding from the professionals' point of view. These were used for key informants from LWSC. This was to understand the water distribution network from the point of view of the LWSC. Other key informants were from NWASCO, the regulator of the water utility companies. This was for the purposes of getting a non-biased perspective from the regulator on the performance of the WDN installed by LWSC.

3.4.1.3 Field Observations

This was used for purposes of triangulation. This was done through observations and pictures. This was to verify the data obtained from the households and the suppliers of the water to Hillview. Field observations were used in addition to household based questionnaire surveys, in order to make the respondents' tacit knowledge explicit through scrutiny of the actual prevailing conditions of the Hillview South WDN. This was important because it validated some of the findings from various parts of the area.

3.4.1.4 Sampling of Water Points

Sampling of water points was done in order to test water samples from various points within the Hillview South water distribution network. This was necessary in order to determine the quality of the distributed water for domestic use by the residents.

Sampling points were selected such that the samples taken were representative of the different sources from which the water reaches the users or enters the system (from the borehole sources). These points included samples representative of the conditions at the most unfavourable sources or places in the supply system, particularly points of possible contamination such as at interconnections with personal borehole pipelines, loops or branches (within the distribution network), low-pressure zones (sloppy part of the network), and ends of the system. Sampling points were uniformly distributed throughout the piped distribution network, taking population distribution into account.

The sampling points were proportional to the number of branches in the network. The points chosen were generally representative of the Hillview South water distribution network as a whole and of its main components. The Hillview South water distribution network has two borehole water sources, and these were both sampled. The sampling points for the borehole sources were located just after the outlets from the boreholes.

The sampling sites in the distribution network were agreed with LWSC as well as chosen randomly. The water samples were collected in brand new and disinfected

750ml water bottles which were clearly labelled. Thereafter, the water samples were then packed in a clean cooler box and transported to the Civil and Environmental Engineering laboratory at the University of Zambia for analysis within two hours of sampling.

3.4.1.5 Sampling of Respondents

The study sampled household members from the Hillview South community members as a way of understanding “parts of that population” (Field, 2005: 67). According to LWSC records, Hillview South had a total of 2005 households at the time of implementing the WDN project (LWSC, 2011) but the study area under review was a stretch of 16.215km, catering for 573 housing units spread throughout the area.

In order to sample the population, Raosoft Online Sample Size Calculator (Raosoft, 2017) was used to determine the number of respondents required. The confidence level was 95 percent, which refers to the amount of uncertainty that can be tolerated and had a margin of error of 10 percent. The reason for selection this margin of error was because of the high number of non-responses when the field work began. Also, some snowball sampling technique was employed. This is a non-probability sampling technique to get to the required respondents because most of the households in the area were using personal boreholes as their main source of water. According to Raosoft Online Sample Size Calculator (2017), the sample size was 83 but a total of 90 households were interviewed because a section of the community not intended to be on the water distribution network were also benefiting from the WDN. Thus, a total of seven (7) extra households were interviewed to see if there were any variations in their water service provision from the WDN.

In other instances some households did not have any person who could answer the questions and therefore, in such instances telephone interviews were conducted from the respondent’s house. The selection of key informants from LWSC in the study was purposive in that the respondents had worked on the Hillview South WDN project from planning through implementation and were aware of what took place from the onset of the project in the area. Other key informants were from NWASCO in order to provide a perspective from the regulator of the water utility on the performance of the WDN installed by LWSC. All respondents selected were willing to participate and they were assured that the data collected would be treated with utmost confidentiality, but it was stated that the findings would be used to improve performance of similar WDNs implemented by LWSC in future.

3.5 Qualitative Methods

A qualitative method of research is a method of investigation used in many different academic disciplines, though more traditionally in the social sciences. It is used for explanatory purposes. Qualitative research can thus be defined as an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem (Creswell, 2014). The process of research involves emerging questions and procedures, data typically collected in the participant's setting, data analysis using a particular set of facts or ideas to build from particulars to general themes, and the researcher making interpretations of the meaning of the data. Further, Creswell (2014) opines that those who engage in this form of inquiry support a way of looking at research that honours an inductive style, a focus on individual meaning, and the importance of rendering the complexity of a situation.

Qualitative research explores attitudes, behaviour and experiences through such methods as interviews, focus groups or key informants. It attempts to get an in-depth opinion from participants. Dawson, (2007) argues that fewer people take part in qualitative research because their attitudes, behaviour and experiences are important considerations. However, contact with these people tends to last a lot longer.

3.5.1 Secondary Data Sources

Secondary data sources were drawn from already existing literature so as to compliment and supplement the primary data. This data was used to help fill in the gaps in the existing body of knowledge from the field data collected. Secondary data sources were cardinal for gathering information and thus were used to develop a strategy for execution of the study. This process involved researching and extracting relevant information from various documents. Examples of documents that were reviewed include documents from Lusaka Water and Sewerage Company Limited (LWSC) (for example, Project Reports, Project Design Literature and Hillview South Water Project Proposal Report for funds solicitation), the Ministry of Local

Government and Housing (MLGH) (for example, the National Urban Water Supply and Sanitation Programme (NUWSSP)). Other documents were obtained from the National Water Supply and Sanitation Council (NWASCO), World Health Organisation (WHO), World Bank (WB), Africa Development Bank (AfDB), Water Online, Sustainable Sanitation and Water Management (SSWM) and various journal publications from several researchers on water supply, particularly on water distribution networks. The aim of the desk study was to:

- get acquainted with the evaluation criteria used by NWASCO in evaluating WDNs.
- get acquainted with water distribution networks design by gathering and reviewing available documents from the World Bank, Africa Development Bank (AfDB) and various journal publications on the subject matter.
- establish the critical success factors for the effective performance of water distribution networks by reviewing journals and other similar documents from various scholars on all aspects of performance of water distribution networks
- establish the challenges that hinder improvements to piped water supply service provision by reviewing available documents from the World Bank, Africa Development Bank (AfDB), World Health Organisation (WHO) and various journal publications relevant to the subject matter and evaluate the performance of the Hillview South water distribution network from the residents' perspective and field observations

3.6 Data Analysis and Presentation

The data collected was coded and transcribed in order to maintain confidentiality of the respondents. Thereafter, Social Package for Social Sciences (SPSS) was used to analyse the data in order to establish trends and patterns in the settlement through counts, frequencies and percentages. Qualitative data was analysed through thematic analysis which involved organizing text data into categories and labelling those categories into themes. Thereafter, these themes were used to understand the reasons behind the numbers that the respondents gave.

3.7 Limitations of the Study

The limitations with this study were firstly, the use of a case in that generalization cannot be made on other areas similar to that of Hillview. The data collection was done during the rainy season, thus leakages from broken pipes were difficult to see and in some cases, pools of water found in the area were assumed to have collected due to the heavy rains. Thus, some leakages and broken pipes could not be seen on the network.

CHAPTER FOUR: FINDINGS, DATA PRESENTATION AND ANALYSIS

4.1 Introduction

The data obtained from respondents during the field research is presented and analysed in this chapter in order to draw conclusions and recommendations for the research.

4.2 Characteristics of the Population

The study interviewed a total 90 households in ascertaining the performance of the water distribution network in Hillview South in Kamwala South of Lusaka City. From the population interviewed, 63 percent were female while 37 percent were male as depicted in Figure 4-1 below.

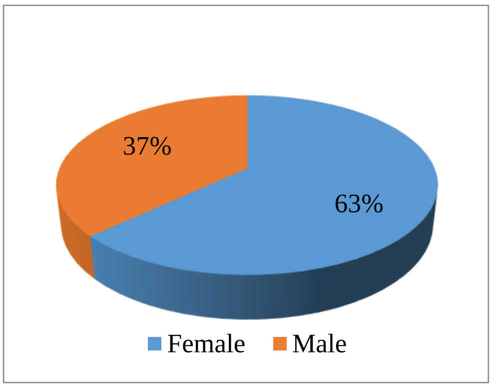

Figure 4-1: Gender of Sampled Population in Hillview South (Source: Field Survey, 2017)

The results further showed that 54 percent of the respondents were house owners while the remaining 46 percent were either tenants or caretakers in places were landlords were absent. This is shown in Figure 4-2.

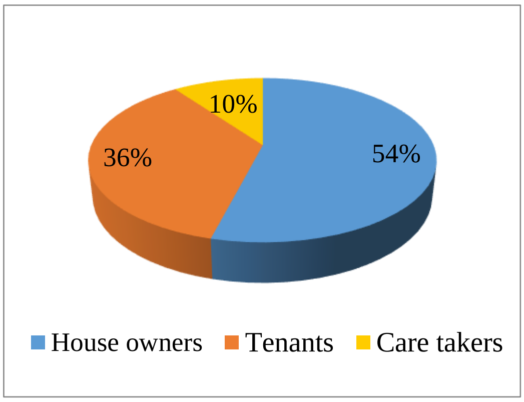

Figure 4-2: House ownership in Hillview South (Source: Field Survey, 2017)

In determining how long the respondents had lived in the area, the results showed that 61 percent of the population had lived in the area for less than 5 years while 28 percent had lived there for a period between 5 to 10 years while only 11 percent had lived in the area for more than 10 years. When aggregated, results show that about 78 percent of the respondents had lived in the area between 1 and 5 years. The average number of household members among the households interviewed was five, with the minimum household members being one and the maximum being twenty-four.

4.3 Hillview South Water Sources

Hillview South is supplied with water from four borehole sources in the LWSC satellite network from what are commonly referred to (by LWSC) as the Lilayi boreholes (Figure 4-3). One other borehole from the Shaft 5 boreholes (Shaft 5B borehole) is on standby to supply water to the area in case of a breakdown with any one of the four Lilayi boreholes. All the borehole sources have on-line chlorination treatment systems installed in the delivery pipelines for purification of the water.

Figure 4-3: Shaft 5 and Lilayi Boreholes, respectively (Source: Field survey Pictures, 2017)

The field survey results further revealed that 98 percent of households interviewed were connected to the LWSC distribution network because most personal boreholes in the area had dried up.

4.4 Respondents' Perception of the WDN Service Provision by LWSC

The respondents had various views on how they rated the performance of LWSC on water service provision.

The indicators for satisfaction or dissatisfaction were based on location within the area, length of stay as well as the availability of water, use of personal/private boreholes and storage facilities such as tanks. The results revealed that 51 percent of the respondents were satisfied with the water supplied from LWSC. However, 37 percent of the respondents felt that the supply could be classified as average and 11 percent were dissatisfied with the service provision. Figure 4-4 shows the respondents' rating on the WDN's water service provision.

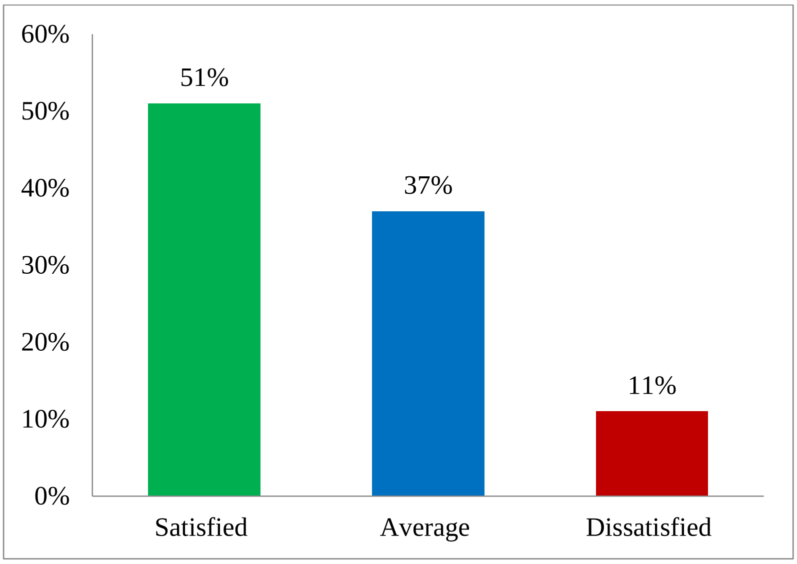

Figure 4-4: Respondents' comments on the WDN service provision by LWSC (Source: Field Survey, 2017)

Field observations revealed that the fifty one percent that were satisfied with the water service provision from LWSC had installed water storage tanks and also used private boreholes as a backup to the LWSC WDN supply.

Field observations further revealed that the 37 percent of the respondents that classified the supply as average, also had installed water storage tanks and therefore were able to store enough water from the network (when available) and used it when there was service interruption. The 11 percent that were dissatisfied with the service provision were solely dependent on the LWSC WDN and had neither private boreholes nor storage tanks.

In meeting the research objectives set forth in chapter one, the following were the findings:

4.5 Coverage of the Hillview South water distribution network

Two aspects were investigated here, and these are; accessibility of the residents to water from the WDN and secondly, the quantity of water distributed by the WDN.

4.5.1 Accessibility of the residents to water from the WDN

Households that had storage facilities were happy with the service due to the fact that it was difficult to notice the non-availability of water because of the storage. The study results revealed that 90 percent of respondents had water available from the taps up to 24 hours in a day with the remaining 10 percent mentioning that the water supply was available up to at least 6 hours in a day.

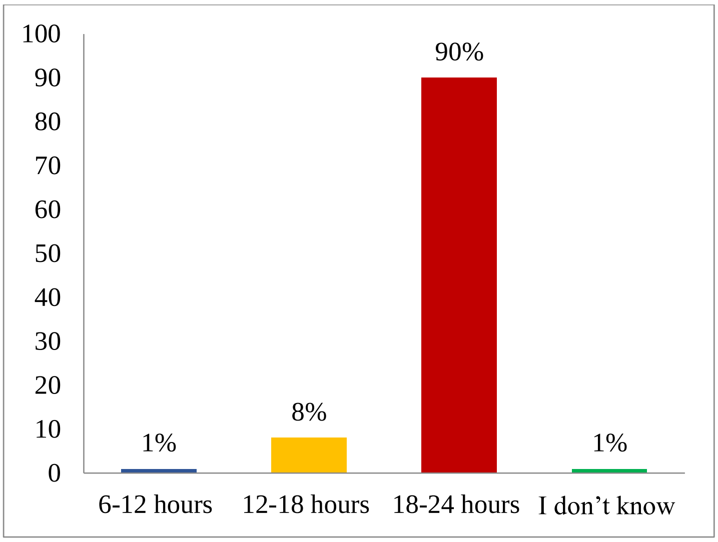

Figure 4-5: Availability of the water from the WDN (Source: Field Survey, 2017)

It was noted through field observations that the 24-hour availability of water (accessibility to the water) was as a result of storage facilities that most residents in the area had (Figure 4-6). The need for storage was necessitated by erratic supply from the LWSC distribution network in the past. The available water was used for various daily activities and even gardening in some cases.

Figure 4-6: Overhead and surface storage water-tanks, and booster pump housing that most households have (Source: Field Survey Pictures, 2017)

4.5.2 Quantity of water distributed by the LWSC WDN

Study results reveal that 88 percent of the respondents indicated that the water was sufficient, while only 11 percent of the respondents mentioned that the water was not sufficient for their daily needs.

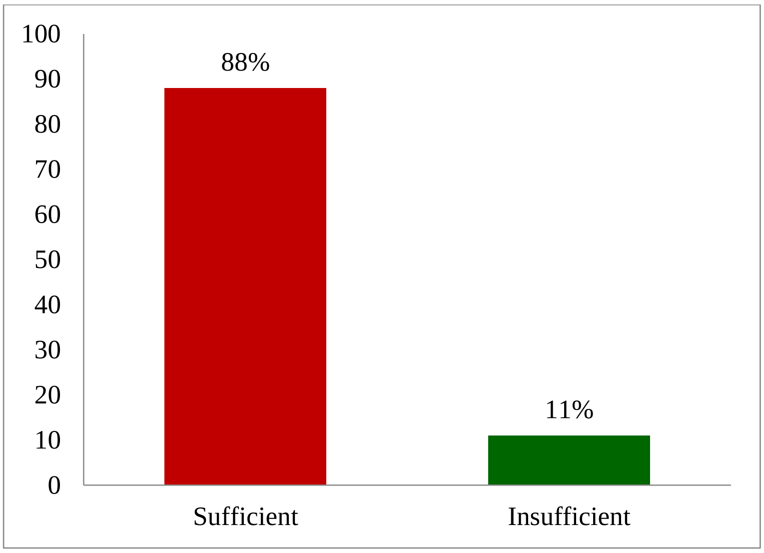

Figure 4-7: Sufficiency of quantity of water distributed by the WDN (Source: Field Survey, 2017)

It was also noted through field observations that the quantity of water from the installed WDN was not sufficient for the residents' daily needs and as such, in order to meet their daily water needs the respondents resorted to installing water storage tanks.

To size any water system or its component parts, an estimate of the amount of water the water system expects its customers to use must be made (Hickey, 2009 and, Ahmed and Rahman, 2000).

Usually, a water supply system is designed for a future population. The total quantity of water required by a community is computed by:

$$Q_f = P_f \times q \qquad [3]$$

where; Q is the quantity of water requirement per day (m^3/d or m^3/h)

P_f is the projected population estimated at the end of the design period and,

q is the rate of water consumption per capita per day (lpcd).

In their project proposal report to the financiers of the Hillview project, Zambia National Commercial Bank (ZANACO), LWSC stated that a daily peak demand of $80m^3/h$ (LWSC, 2011) was sufficient to meet the requirements 6,180 people in Hillview South.

The following are the findings from actual computations of the water quantity requirements. Note that all assumptions used in the design are the same assumptions made by LWSC in their design of the Hillview South WDN and the method of population projection used is the same as that used by LWSC in their design.

Therefore;

Hillview Population = 2005 households (LWSC, 2011)

For effective designs, future population projections of 10 years from time of implementing the WDN project should be considered (World Bank, 2012). Hence,

$$P_n = P_0 (1 + GR)^n$$

where:

P_n = the projected population after n-th year from initial year

P_0 = the population in the initial year of the period concerned

GR = the average growth rate between the period 2012 and 2022
(Lusaka district growth rate = 4.6 percent per annum, CSO, 2012)
n = number of years between P_n and P_0

Therefore,

$P_{2022} = (6,180)(1 + 0.046)^{10} = 9,689.588203 \approx$ **9,690 people**, which is the projected population for Hillview South for a design period of 10 years from the time of implementation of the WDN in 2012.

Now, assume 50 percent of the households are medium cost and the other 50 percent high-cost houses.

Therefore, population in medium cost houses = 9,690 /2 = **4,845 people**

This implies that the population in the high cost houses is also **4,845 people**

Now, applying the ZABS ZS 361:2009 design standards for domestic water supply, we have the following:

ZS 361:2009: 150l/c/d for medium cost houses, implying that;

$Q_{mc} = P_f \times q = (4,845) \times 150$l/c/d = 726,750 l/c/d = 726.75m^3/d = **30.28m^3/h**

ZS 361:2009: 255l/c/d for high cost houses, hence;

$Q_{hc} = P_f \times q = (4,845) \times 255$l/c/d = 1,235,475l/c/d = 1,235.48m^3/d = **51.48m^3/h**

Therefore, total demand, $Q_t = Q_{mc} + Q_{hc}$ = (30.28 + 51.48)m^3/h = **81.76m^3/h** (2dp)

Now consider the non-revenue water component in order to cater for fire-fighting and other incidentals. Non-revenue water for a new WDN is assumed to be 15 percent (World Bank, 2012). Thus,

Q = 81.76/(1-0.15) = **96.19m^3/h** > 80m^3/h designed by LWSC

Clearly, the LWSC design capacity is not sufficient to meet the requirements of the targeted population. It falls short by about 17.65 percent of the desired demand. For a larger population of 2005 properties for the entire Hillview South, the water requirement would even be much higher.

To determine if the sources have sufficient capacity to meet the demands of the Hillview South community, we determine their combined yields and compare with the computed design capacity. According to LWSC records (LWSC, 2017), the four Lilayi borehole sources have the following yields:

i. Lilayi Road 1 = 110m^3/h
ii. Lilayi Road 2 = 100m^3/h
iii. Lilayi 3 = 35m^3/h
iv. Lilayi 4 = 20m^3/h

Combined Total Yield = 265m^3/h

Thus, the boreholes' total combined yield is **265m^3/h**. This value is clearly greater than the design capacity of **96.19m^3/h** and even if the boreholes were being operated at 50-70 percent of their total combined yield (to allow for borehole recovery), their capacity would still be sufficient to cover the Hillview South community demand.

Therefore, the findings reveal inadequate design of the WDN by LWSC. However, there is a possibility that the four Lilayi boreholes may not be solely dedicated to supplying water to the Hillview South WDN and may be supplying water to other areas of Lusaka City. This could be affecting optimal performance of the WDN in Hillview South.

4.6 Continuity in Water Service Provision

In ascertaining the continuity in service provision needed in order to mitigate the risk of people using contaminated water sources, frequency of service interruptions or disruptions, alternative water sources available to the residents, water pressure in the WDN and leakages in the network were looked at.

4.6.1 Frequency of Service Interruptions

Respondents were asked on the continuous availability of the water in the area and whether they ever had disruptions in the water supply service from the LWSC WDN.

Respondents were clear that they did have days were they had no water (up to 3 days), especially in the dry season. Other times when they had disruptions in the system were when LWSC carried out maintenance works in the area. From the population interviewed, 47 percent indicated that they could go for a number of days without water service from the LWSC WDN. Twenty-three percent acknowledged that water shortages were there at times and 28 percent mentioned as never having water shortages or no supply at all since they were connected to the LWSC distribution network.

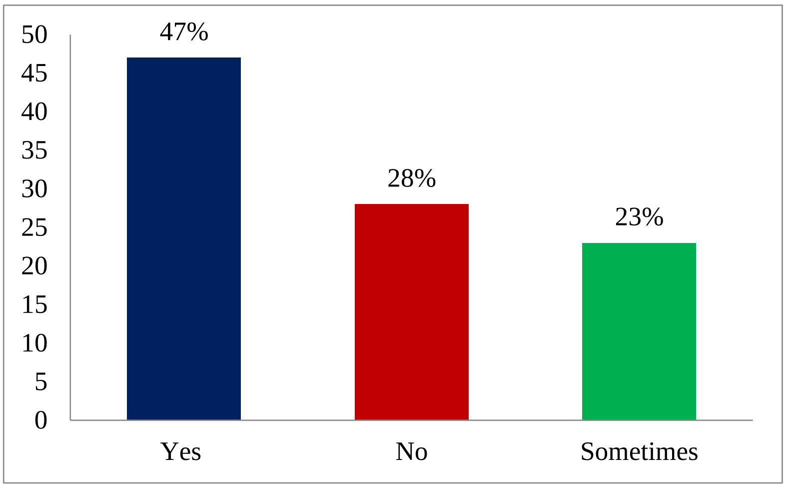

Figure 4-8: Frequency of service interruptions in the WDN (Source: Field Survey, 2017)

4.6.2 Alternative sources of water supply

Arising from confirmation of water disruptions, respondents were asked were they got the water from during such times. Of the 90 respondents, 39 percent mentioned using personal boreholes and connecting them to overhead and/or ground tanks with the use of booster pumps. 32 percent of the respondents mentioned that they draw water at a fee from neighbours with personal boreholes, while 29 percent indicated that they fetch water from water vendors. Therefore, all respondents had an alternative source of water due to the fact that the supply from LWSC WDN had been intermittent in the past (Figure 4-9).

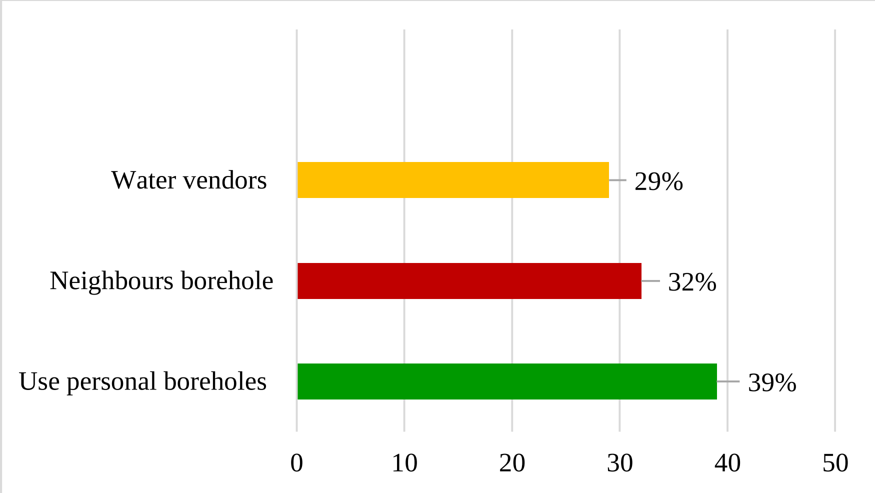

Figure 4-9: Alternative sources of water during interruptions (Source: Field Survey, 2017)

4.6.3 Water Pressure in the WDN

The water pressure in the WDN was investigated by asking the respondents to comment on how they found the water pressure at their taps to be.

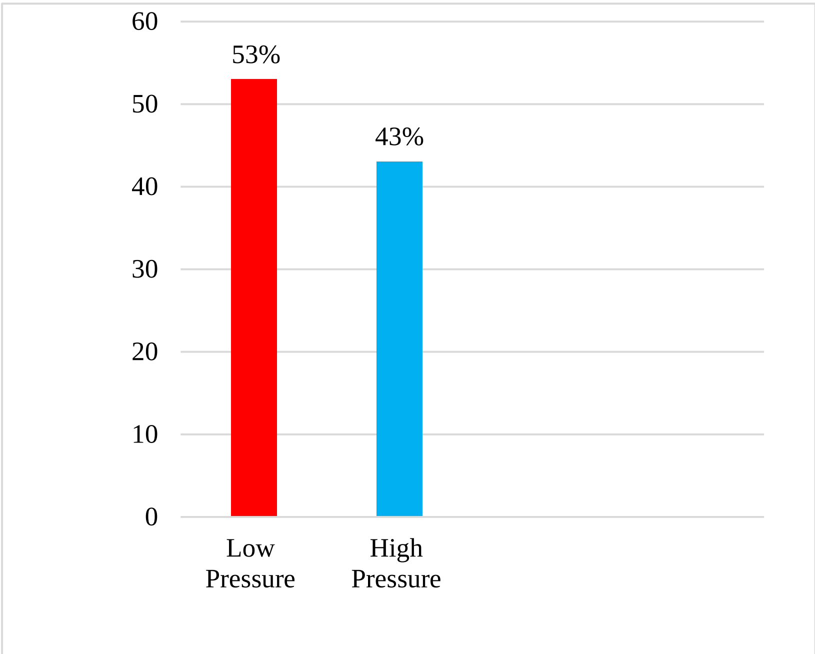

Figure 4-10: Household water pressure at the taps (Source: Field Survey, 2017)

53 percent of the respondents indicated that the pressure was low while 43 percent mentioned that water pressure was high. Field observations revealed that those who enjoyed high pressure were the ones with installations of overhead water tanks or ground tanks with booster pumps.

4.6.4 Leakages in the WDN

As a result of low water pressure and service interruptions in the WDN, respondents were asked if they had any leakages in the network even though the network had been in use for less than five (5) years and whether they knew were to report such cases. The study revealed that 72 percent of the respondents did not have any leakages in the past two years, while 26 percent mentioned having experienced leakages but that these were worked on promptly by LWSC. Only 2 percent said they were not sure of having leakages in the network.

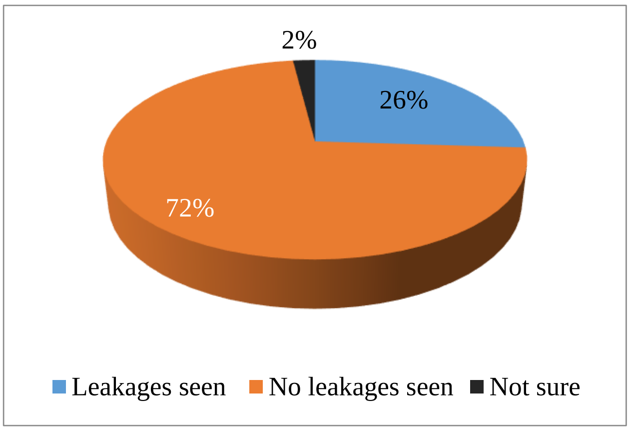

Figure 4-11: Percentage of leakages and faults in the WDN (Source: Field Survey, 2017)

Field observations revealed leakages at two valve chambers in the network.

Figure 4-12: Heavy leakages at valve chambers at the Lilayi borehole (left) and in the WDN (right) (Source: Field Survey Picture, 2017)

The study revealed that in as much as the people did not have cases of leakages or faults to report, they were aware of where to report cases related to pipe bursts and leakages. Study results revealed that 75 percent of the respondents knew where to report cases of such a nature with others being unsure of where exactly to go. In spite of them knowing where to report the cases, 53 percent of them have not experienced any such cases that they need to report, but 38 percent of the respondents had reported such cases and they felt the response from the LWSC maintenance team was slow and needed improvement on their promptness to attend to pipe bursts and meter faults as many were forced to pay bills that could have been avoided if repair and maintenance were done on time.

4.7 The Quality of Water Distributed by the WDN

There were three aspects of quality investigated in the study and these were; the respondents' perception of the water quality from the WDN, the quality of water from the borehole sources supplying Hillview South and finally the quality of the water distributed by the WDN. The findings for each are highlighted as follows:

4.7.1 Respondents' Perception of Water Quality as Supplied by LWSC

The study revealed that 93 percent of the respondents were happy with the quality of water because the water "clear and clean." 7 percent indicated being unhappy with the quality of the water because it had high calcium content and this made it difficult to drink.

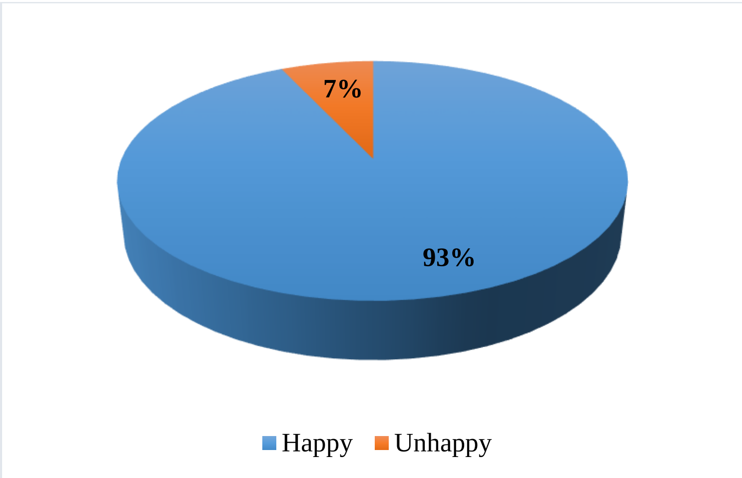

Figure 4-13: Respondents' perception of the quality of water supplied by LWSC (Source: Field Survey, 2017)

4.7.2 Water Source Quality

Water samples obtained from the borehole sources (Lilayi and Shaft 5 boreholes) supplying Hillview South were tested at the University of Zambia (UNZA) Civil and Environmental Engineering (CEE) Laboratory in order to determine its quality for domestic use.

The results revealed that sources have Nitrate concentration in excess of the World Health Organisation (WHO) stipulated guidelines values for drinking water (Appendix D).

4.7.3 Water Quality from the WDN

Water samples obtained from the Hillview WDN were tested at the University of Zambia (UNZA) Civil and Environmental Engineering (CEE) Laboratory in order to determine its quality for use and the results revealed that parts of the network have bacterial contamination (Appendix C).

Contamination could be due to interconnections between the WDN with private boreholes that are close to soakaways in the area, unrepaired leakages at interconnections of the WDN with the old network and unrepaired leakages at valves or other sections in the WDN (Figure 4-14).

Figure 4-14: Ponding due to leakages at interconnection between old and new networks (left) and at gate valve within the network (right) (Source: Field Survey Picture, 2017)

4.8 Efficiency of cost recovery and sustainability of the WDN

Cost recovery refers to the method to recovering an expenditure which a business takes on. Generally, cost recovery is simply recapturing the costs of any given expense. WDNs are expensive investments and as such, LWSC should have a well-defined method/mechanism of recouping all the monies they invest in installing WDNs. This is important because collection of revenue determines the sustainability or expansion of the WDN in the long term.

In order to determine the mode of payments that were used by the residents, results show that there were basically three main ways in which people in the area were required to pay for the water (Figure 4-15);

- 41 percent of the respondents were not metered but paid a fixed monthly charge that varied from ZMW148 with the highest being ZMW300.
- The study also revealed that 33 percent were on a pre-paid metering system while 24 percent were on a post-paid metering system.
- It was also noted that 2 percent of respondents were not paying for water they used.

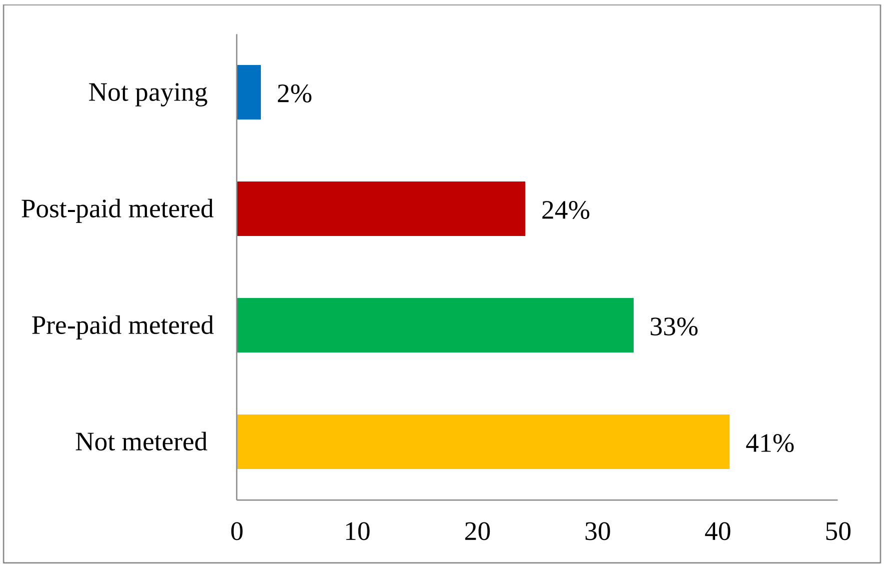

Figure 4-15: Mode of payment for water bills (Source: Field survey, 2017)

It can be seen from the results that a huge proportion of the respondents (41 percent) are not metered but are placed on a fixed monthly charge regardless of the amount of water they consume. This is definitely a bottleneck in revenue collection for the utility and thus has a negative impact on performance and consequently, sustainability of the network. There is a likelihood that the respondents actually consume/use up more water than they actually pay for and vice versa. This is of great concern to LWSC as it is difficult to determine how much water the utility actually gets paid for from the unmetered households. This may imply that the cost recovery for the project is very low as LWSC cannot really recover the actual revenue they are supposed to from the WDN.

It is thus very important that LWSC aims at metering most, if not all, of their customers in order to increase their revenue collection as this is the only way the utility will be able to enhance the performance of the WDN in Hillview South.

4.8.1 Accountability for the distributed water

To determine if LWSC actually determines or knows how much water they supply to the residents and how much to bill for, the respondents were asked how much water they actually used per month. It was difficult to determine because 79 percent of the respondents were unsure of how much water they used and the data found on this was insufficient to determine the actual consumption per month. The overriding factor was that 41 percent of the respondents (Figure 4-15), were not metered and so both LWSC and the respondents did not know how much water was used and billed for per month. However, when asked how much they pay for water, the range was wide; from not paying at all to ZMW1,500 being the highest payment for water bills per month, with the average payment being ZMW250, and ZMW150 in cases where only 20 percent of the respondents were paying.

4.9 Relevance of the installed WDN in Hillview South

To determine the WDN's relevance to the Hillview community, respondents were asked if there was any change in the supply hours from the past to meet their daily requirements and thus impact their livelihoods and also if they had been invited to stakeholder meetings before the project was implemented so as to get their views and contributions. Also, the respondents were asked about how they valued the WDNs in relation to their daily water needs.

4.9.1 Change in supply hours from the WDN to meet daily requirements

The study results revealed that, 56 percent of the respondents indicated that they had observed a change in the supply hours.

The change noted was in two categories. The first category noted a change in water supply from the past in that the area was not supplied with water and now it has water. This was for respondents that had lived in the area for more than 5 years. The second category noted that ever since they were put on the new network, water supply was problematic since the commissioning of the WDN, but the supply had since improved in terms of supply hours to the area.

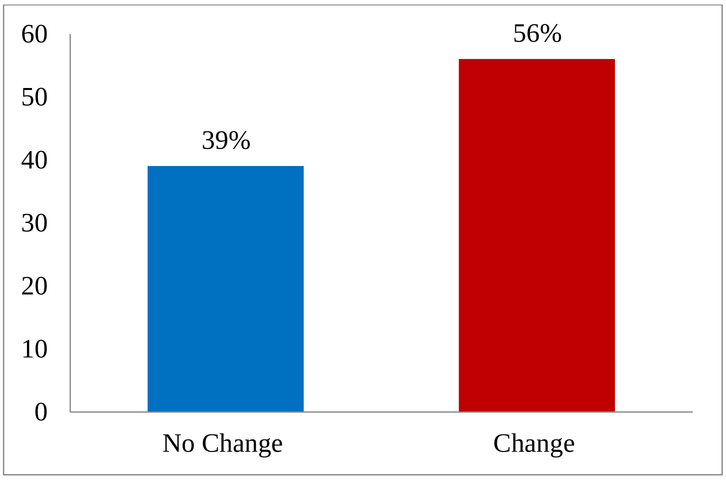

Figure 4-16: Change in supply hours from the past (Source: Field Survey, 2017)

However, for those that had lived in the area for a year or less, they mentioned not noticing any change and felt the supply had been the same.

Field observations however, revealed that respondents that mentioned noticing a change in the water supply hours meeting their daily requirements were the ones who had installed various water storage tanks and booster pumps, and thus could access the stored water at any given time.

4.9.2 Stakeholder and Communication Management during Project Implementation

Respondents were asked if they were invited for any community meetings before the project was implemented. This question was only applicable to respondents that had been in the area for more than 5 years because from the 90 households surveyed, 51 percent mentioned not having been invited to any stakeholder meeting while 24 percent mentioned that meetings were held during the promotion of the WDN project as a marketing strategy and therefore never thought the project would ever kick-off.

The results indicate that the implemented project had very little input from the community (51 percent were not invited to stakeholder meetings before implementation of the project) and thus it can be seen that the needs of the community may not have been taken into account before the project was implemented.

4.9.3 Respondents' perspective on the value of the WDN as a whole

Respondents were asked to comment on how they perceived the LWSC WDN as a whole, regarding the following aspects; tariffs, water quality, pressure, and availability of water in their area (Figure 4-17).

The first aspect regarding tariffs showed that 49 percent of respondents were happy with the water tariffs, while 29 percent were seen to have been very happy and 13 percent were very unhappy with tariffs and complaints were associated with false or inaccurate meter readings, leaking meters and high bills even in dry seasons when water supply was extremely erratic.

Of the 90 respondents, 61 percent indicated being very happy and 31 percent being happy with the water quality in that the water was clear and clean. However, 3 percent mentioned not being happy and 4 percent not being very happy. The reason associated with their displeasure included the high calcium content in the water which made it difficult to drink.

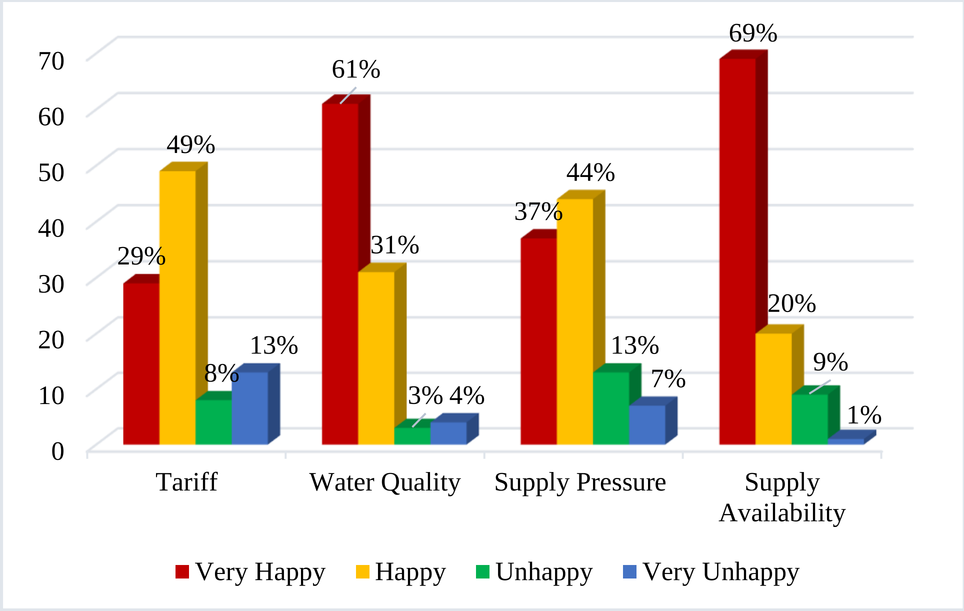

Figure 4-17: General feeling on households concerning different aspects of the WDN (Source: Field survey, 2017)

When asked whether the pressure of water pleased them 44 percent said they were generally happy while 37 percent were very happy but at least 20 percent mentioned being unhappy at 13 percent and 7 percent being very unhappy.

With regard to water availability 69 percent mentioned being very happy and 20 percent being happy, while 9 percent were unhappy and 1 percent being very unhappy.

4.10 Summary of Findings, Data Presentation and Analysis

An evaluation of performance of water distribution networks in Lusaka City: A Case for the Hillview South Water Supply Project established that the performance of the installed water distribution network in Hillview South is inadequate to meet all the requirements of the Hillview South community. However, the general feeling from the respondents (Figure 4-17) is that of satisfaction with the performance of the WDN since it has provided them with water they did not have before the project was implemented.

CHAPTER FIVE: DISCUSSION OF FINDINGS

5.1 Introduction

This chapter discusses and analyses the findings in collaboration with the existing body of knowledge on the performance of water distribution networks in water service provision. Discussion of findings with literature was important in determining how this research fits in the existing body of knowledge on the subject. It further provides a basis for comparison on how the research has contributed to the filling of the previous missing gaps in the body of knowledge. This was carried out in liaison with the research objectives and questions. As opined by Kim, (2012); Lockwood and Smits (2011), service delivery has a life-cycle span (that is, plan, design, operate, maintain, and monitor) to sustain services such as nutrition, transport or goods such as electricity or water to citizen beneficiaries. Getting (or delivering) these services or goods requires access by citizen beneficiaries, and the goods or services should meet the expectations of the beneficiaries, which implies taking into account their needs and demands (Kim 2012; Hodge 2007; Fiszbein *et. al.,* 2011).

Therefore, picking up from chapter four where the findings were presented and analysed, this chapter strives to provide an explanation and implication of the results.

5.2 Coverage of the Hillview South Water Distribution Network

5.2.1 Accessibility to the water from the WDN

The study results revealed that sinking of personal boreholes and installation of water storage tanks was necessitated by intermittent supply from the LWSC distribution network. As asserted by Kim (2012); Hodge (2007); Fiszbein *et. al.,*(2011), delivering services or goods requires access by citizen beneficiaries, and the goods or services meeting the expectations of the beneficiaries, which implies taking into account their needs and demands. Clearly, the citizens of Hillview South do not enjoy the benefits of the installed WDN as their water demand expectations are not met. Therefore, their access to the water from the WDN is limited and only enhanced through installation of water storage tanks. According to Adeosun (2014) and Almasri (2008), the aim of installing a WDN is to supply water to a community in adequate quantity and quality at appropriate pressure, at all times. This is in stark contrast to the research findings on the performance of the WDN in Hillview South.

5.2.2 Quantity of water distributed by the WDN

According to Adeosun (2014) and Almasri (2008), the aim of installing a WDN is to supply water to a community in adequate quantity and quality at appropriate pressure, at all times. The quantity of water distributed by the WDN in Hillview has not been adequate and therefore defeats the purpose or aim of installing a WDN, which in turn hinders optimum performance of the WDN in Hillview South.

5.3 Continuity in Water Service Provision

5.3.1 Frequency of Service Interruptions

A WDN should transmit water to the consumers 24 hours a day continuously in order to avoid stagnation within the pipe system. A water distribution network should be based on a pipe layout that is suitable and have no or less water stagnation within the pipe to avoid tuberculation, encrustation and sediment deposits. According to Hickey (2008), and the Sustainable Sanitation and Water Management (SSWM, 2017), a water system has two primary requirements:

i. First, it needs to deliver **adequate** amounts of water to meet consumer consumption requirements plus needed fire-flow requirements.
ii. Second, the water system needs to be **reliable**; the required amount of water needs to be available 24 hours a day, 365 days a year.

From the foregoing, it is clear that the LWSC WDN in Hillview South is not reliable since it cannot deliver **adequate** amounts of water to meet consumer consumption requirements 24 hours a day for 365 days a year.

5.3.2 Alternative Sources of Water Supply

All respondents confirmed having an alternative source of water due to the fact that the supply from the LWSC WDN had been disruptive. As asserted by Hickey (2008), and the Sustainable Sanitation and Water Management (SSWM, 2017), a water system needs to deliver **adequate** amounts of water to meet consumer consumption requirements as well as being **reliable** so as to deliver the required amount of water 24 hours a day, 365 days a year.

In contrast to the existing body of knowledge on the subject of WDNs, the results indicate that the respondents have alternative sources of water due to the fact that the LWSC WDN does not meet their expectations or water demands (Kim 2012; Hodge 2007; Fiszbein *et, al.,* 2011).

5.3.3 Water Pressure in the WDN

According to the National Programme on Technology Enhanced Learning (NPTEL, 2017) and the Sustainable Sanitation and Water Management (SSWM, 2017), a WDN should provide adequate water pressure at the consumer's taps for a specific rate of flow, that is, pressures should be great enough to adequately meet consumer needs. The system should be capable of supplying water to all the intended places with sufficient pressure head. The pressure must be adequate enough to push water to all the parts of the WDN. Further, the online Encyclopaedia Britannica, (2017), asserts that a WDN must deliver adequate quantities of water at pressures sufficient for operating plumbing fixtures and fire-fighting equipment. In this regard, the LWSC WDN in Hillview South falls short of these requirements.

5.3.4 Leakages in the WDN

According to the National Programme on Technology Enhanced Learning (NPTEL, 2017) and the Sustainable Sanitation and Water Management (SSWM, 2017), one of the requirements of an adequate WDN for it to perform effectively is that the WDN should be fairly watertight to keep losses (for example, due to leakage) to a minimum. Field observations revealed leakages at two valve chambers within the network and therefore it is fair to say on this aspect, LWSC has done well.

5.4 The Quality of Water Distributed by the WDN

According to the World Bank (2012), water quality is a measure of how good the water is, in terms of supporting beneficial uses or meeting its environmental values. Potable water is water suitable for drinking and cooking purposes. Potability considers both the safety of water in terms of health, and its acceptability to the consumer - usually in terms of taste, odor, color, and other sensible qualities. Further, WHO (2017) asserts that the safety and accessibility of drinking-water are major concerns throughout the world. Health risks may arise from consumption of water contaminated with infectious agents, toxic chemicals, and radiological hazards. Improving access to safe drinking-water can result in tangible improvements to health. Thus, WHO, (2017) affirms that water safety and quality are fundamental to human development and well-being. Therefore, providing access to safe water is one of the most effective instruments in promoting health and reducing poverty.

5.4.1 The Quality of Water from the Borehole Sources

The study results revealed that both borehole sources supplying water to Hillview South have amounts of Nitrates in excess of the World Health Organisation (WHO) stipulated guidelines for drinking water standards, as shown in Table 5-1.

Table 5-1: Water Source Quality (Source: UNZA CEE Lab. Test Results, 2017)

Parameter	**Lilayi Boreholes**	**Shaft 5 Boreholes**	**WHO Guideline (Maximum permissible value for drinking water)**
Nitrates (NO3-N mg/l)	**14.40**	**15.13**	10

5.4.2 The Quality of the water distributed by the WDN

The study results revealed that part of the network has bacterial contamination as can be seen in Table 5-2.

Table 5-2: DN Water Quality (Source: UNZA CEE Lab. Test Results, 2017)

Bacteriological Results	**Water Sample A (Plot 4354)**	**Water Sample B (Plot 26194)**	**Water Sample C (Plot 43504)**	**WHO Guideline (Maximum permissible value for drinking water)**
Total Coliforms (#/100ml)	**38**	**85**	0	0
Feacal Coliforms (#/100ml)	**20**	**60**	0	0

According to Onyenechere and Osuji (2012), water must not only be adequate in quantity, it must also be adequate in quality. There can be no state of positive health and well-being without safe water. Further, Adeosun (2014) affirms that water quality should not deteriorate while in the distribution pipes. This means that the water in the distribution pipes should never at any one time be stagnant. It must be moving all the time to avoid stagnation and thus deterioration of its quality. Purity of distributed water should be maintained. This requires the distribution network to be completely water-tight. WHO (2011) affirms that total coliforms should be absent immediately after disinfection, and the presence of these organisms indicates inadequate treatment. The presence of total coliforms in distribution systems and stored water supplies can reveal regrowth and possible biofilm formation or contamination through ingress of foreign material, including soil or plants. The Sustainable Sanitation and Water Management (SSWM, 2017), states that the safety of drinking water depends on a number of factors, including quality of the water source, effectiveness of water purification and integrity of the whole distribution system that transports the water to consumers. Further, SSWM affirms that at every stage in the production and delivery of drinking water, hazards can potentially compromise the quality of the water. Piped distribution systems may be less vulnerable to contamination than open surface-water catchments; however, if piped systems become contaminated, there may be no treatment processes to reduce risks from the introduced hazards (Ainsworth, 2004).

From the foregoing, it is seen that in as much as the borehole sources (Lilayi and Shaft 5 boreholes) have nitrates in excess amounts of the WHO recommended guidelines; the purification system at the sources is effective because the water in the WDN in Hillview South does not show any indication of excess amounts of nitrates. Disinfection is of unquestionable importance in the supply of safe drinking-water (WHO, 2011). However, parts of the WDN in Hillview South indicate that water is contaminated with bacteria (total and feacal coliforms contamination). Onyenechere and Osuji (2012), state that water must be adequate in quality because there can be no state of positive health and well-being without safe water. Further, the WHO (2011) states that maintaining good water quality in the distribution system will depend on the design and operation of the system and on maintenance and survey procedures to prevent contamination and to prevent and remove the accumulation of internal deposits. The protection of the distribution system is essential for providing safe drinking-water. Because of the nature of the distribution system, which may include many kilometres of pipe, storage tanks, interconnections with industrial users and the potential for tampering and vandalism, opportunities for microbial and chemical contamination exist (WHO, 2011, 2012 & 2017). When contamination by enteric pathogens or hazardous chemicals occurs within the distribution system, it is likely that consumers will be exposed to the pathogens or chemicals (WHO, 2011, 2012 & 2017). In the case of pathogen ingress, even where disinfectant residuals are employed to limit microbial occurrence, they may be inadequate to overcome the contamination or may be ineffective against some or all of the pathogen types introduced. Therefore, the destruction of pathogenic microorganisms is essential and very commonly involves the use of reactive chemical agents such as chlorine (WHO, 2011, 2012 & 2017). Disinfection is an effective barrier to many pathogens (especially bacteria) during drinking-water treatment and should be used for surface waters and for groundwater subject to feacal contamination.

The bacteriological contamination in the Hillview WDN can thus be attributed to a number of factors:

i. Lack of maintenance of the WDN and repair of cracks or breakages in the pipes or appurtenances causing leakages in the WDN can lead to build up of deposits and ingress of pathogens.
ii. interconnections of the WDN with borehole pipelines that are very close to soakaways
iii. the potential for tampering and vandalism leading to cracks and breakages in the WDN and thus causes leakages. A leaking distribution system increases the likelihood of safe water leaving the source or treatment facility becoming contaminated before reaching the consumer (SSWM, 2017). The distribution system must be designed, managed and maintained to present a minimal level of leakage and be continuously under internal pipe pressure greater than the external hydrostatic pressure. This will ensure delivery of water with reduced losses due to leaks, and minimisation of excess growth of pathogenic microorganisms. A certain level of free residual chlorine or chloramine disinfectant will reduce the risks of recontamination within the distribution system WHO (2006, 2011, and 2017) and SSWM (2017). Inflows of contaminated water during distribution are major sources of waterborne pathogens and contaminants (WHO 2006, 2011 and 2017; and SSWM (2017).

5.5 Efficiency of Cost Recovery and Sustainability of the WDN

A large proportion of the respondents were not metered (41 percent) and as such there is a likelihood that LWSC actually bills for less than what is actually used by the consumers in Hillview South. As opined by Kalulu and Hoko (2010), financial limitations are a detriment to the development of new water sources and thus affect the quality of urban water supply services. Further, Kalulu and Hoko (2010) argue that, water utilities need to continuously minimize costs and maximize revenue to ensure affordability and consequently access to safe water.

5.6 Relevance of the installed WDN

5.6.1 Change in Water Supply Hours from the WDN

Water service delivery, like any other service, requires that the citizen beneficiaries access the services. The services should meet the expectations of the beneficiaries, which implies taking into account their needs and demands (Kim 2012; Hodge 2007; Fiszbein *et. al.,* 2011). Therefore, from the foregoing, it is clear that the installed WDN was a relevant project as can be seen by the fact that people in Hillview South now have access to water that they did not have before the implementation of the project. The only downsize is that their expectations may not have been met.

5.6.2 Improvement in Water Supply to Enhance Livelihoods

According to Kim (2012), Hodge (2007) and Fiszbein *et. al.,* (2011), the accessibility by the residents of Hillview South to the water distributed by the WDN in order to improve their livelihoods establishes that the project was relevant even though its design and implementation may not have been up to speed. The fact that the residents now have access to water they never had before shows that indeed the installation of the WDN was relevant as it has improved the general cleanliness and health of the community.

5.7 Summary of Discussion of Findings

The Hillview WDN project presented interesting lessons on project management. The evaluation of this project established that project planning is a very important aspect of project management which cannot be hastened. As has been established in evaluation of performance of the Hillview South WDN, a poorly designed WDN cannot meet its objectives of supplying a community with adequate quantities of safe water at appropriate pressure all the time. A good design of a WDN is only possible with good project initiation and planning. According to the PMBoK (2013), the preparation of a detailed project scope statement which is critical to project success, builds upon the major deliverables, assumptions, and constraints for a project which are documented during project initiation. During project planning, the project scope is defined and described with greater specificity as more information about the project is known. Existing risks, assumptions, and constraints are analyzed for completeness and added or updated as necessary. Part of the project scope involves the design of the WDN. The design process should be a thorough engagement of all the project staff or team. The PMBoK (2013) states that although specific roles and responsibilities for the project team members are assigned, the involvement of all team members in project planning and decision making is beneficial. Participation of team members during planning adds their expertise to the process and strengthens their commitment to the project. As much as the WDN project was relevant to the people of Hillview South, careful planning and design of the WDN project should have been given priority and due attention. The water demand should be thoroughly determined beforehand and then a suitable source able to meet the demand adequately should be selected. Periodic maintenance of the network is also lacking and should be embarked upon by LWSC in order for the utility to be able to continuously supply water of the best quality to their customers.

Project management is not just about implementing of projects, it is also about monitoring/reviewing the performance of the project and controlling any defects that may arise. As established in the evaluation of performance of the Hillview South WDN, performance monitoring should be carried out periodically on the installed WDN so as to determine bottlenecks that may need remedying. The study also established that the system may not be sustainable because of the fact that a large proportion of the people in the project area are placed on fixed billing as opposed to metered billing which enables the utility to invoice for exactly what is used.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

Chapter six is the culmination of the "Evaluation of Performance of Water Distribution Networks in Lusaka City: A Case for the Hillview South Water Project." It concludes the study and offers recommendations. The foregoing chapters highlighted the importance and necessity for LWSC to be evaluating the performance of water distribution networks in Lusaka City. The preceding chapters also touched on the effects of poorly designed WDNs on the welfare and livelihoods of consumers. Various literature sources have been reviewed focusing on the aim or need for WDNs in water service provision, requirements of adequate WDNs, benefits of having adequate WDNs in water supply, types of WDNs and their suitability to various topographical locations, challenges encountered by water utility companies, particularly LWSC, in trying to improve urban water supply and the need to adhere to set standards for designs of domestic water supply guidelines. This was necessary in order to provide an up-to-date understanding of the subject of WDNs and its significance to water service provision by LWSC. This final chapter aims at delineating the conclusions from the research as well as making appropriate recommendations on the challenges affecting piped water supply in Lusaka City. The first section of this chapter gives a reiteration of the unabridged study followed by reviewing of the research questions. Thereafter, the last part offers the conclusion as well as recommendations with regards to the problems identified from the research findings and analysis.

6.2 Review of the Research Questions

6.2.1 Does LWSC carry out comprehensive needs-assessments before designing WDNs in order to ensure communities are supplied with safe and reliable water?

From the computed water demand figures, it is clear that the water demand for Hillview is much higher than that designed by LWSC. This is the reason the water supply service is erratic in the area as the WDN supply adequate quantities of water to meet the demand in the area. To be able to design an adequate WDN, a thorough needs assessment must be carried out in order to collect all the relevant information needed for the design of the WDN. A thorough needs assessment enables a careful study of the project area and its requirements to be made and thus aids in also selecting the most suitable type of WDN for the area.

6.2.2 What challenges does LWSC encounter in providing safe water to the people of Lusaka City?

The major hindrance to LWSC in its efforts to provide safe water supplies to Lusaka City is lack of adequate funding to implement their projects comprehensively. This is exacerbated by low cost recovery for improved WDNs. To be able to rehabilitate or expand the WDNs, LWSC must collect revenue for the water supplied to their customers. However, as seen in the findings in Hillview South, a huge portion of the customers are placed on fixed billing rates thereby increasing the possibility of LWSC billing and collecting revenue that is not reflective of the actual amount of water supplied. It is very important for LWSC that the majority, if not all, of the customers be metered in order to enhance revenue collection which is crucially important for the improving the water service provision in Lusaka.

6.2.3 How is LWSC maintaining the infrastructure that was installed in Hillview South in order to mitigate rehabilitation costs?

LWSC's efforts to adequately maintain the existing infrastructure is greatly limited by lack of adequate resources (funding, human resources, equipment, etc.). Field observations indicated that some major leakages at the Lilayi boreholes supplying Hillview South have not been repaired due to the fact that the utility lacks adequate resources. As such, the rate of deterioration or dilapidation of the installed WDN is accelerated thereby reducing the efficiency of the WDN. Consequently, the lack of adequate resources means LWSC fails to periodically maintain their infrastructure and is thus forced to only be reactive to pipe bursts, breakages and any other faults in the WDNs as opposed to being proactive. This can be an expensive venture as unplanned or unbudgeted expenditure is directed towards rectification of the WDNs instead of their expansion.

6.2.4 What experiences and lessons have been learnt on the WDN project implemented in Hillview South by LWSC?

As opined by Kim, (2012); Lockwood and Smits (2011), indeed service delivery has a life-cycle span (that is, plan, design, operate, maintain, and monitor) to sustain services such as water to citizen beneficiaries. If the service (from the WDN) is not meeting the expectations of the beneficiaries, then a review of the situation must be made so as to pinpoint the cause of the lack of service and thus rectify the problem.

The process of monitoring and controlling the performance of the WDNs must be a continuous one that should be adhered to thoroughly if the LWSC customers in Hillview South are to enjoy the benefits of adequate WDNs in the area. Only through monitoring and controlling can the performance of WDNs be improved to meet all expectations of the LWSC customers. Planning of the WDN projects should include aspects of continuous review of the performance of the WDNs after commissioning, in order to determine pitfalls of the implemented systems and how best to remedy the situations.

Adeosun (2014) pointed out that it is very important that a water distribution network to be based on a pipe layout that is suitable (depending on topography, street patterns, degree and type of development of the area, location of the treatment and storage works) and have no or less water stagnation within the pipe to avoid tuberculation, encrustation and sediment deposits. This means that LWSC should carefully select and appropriately design the type of WDNs suitable to each locality they desire to install the WDNs.

In addition, regulators (NWASCO and ZABS) and policy makers should require water utilities to do periodic water audits and regularly publish detailed water distribution system data, which can then be independently audited. This way, LWSC and all parties concerned would know exactly how much effort would be required to remedy the inadequate service.

6.3 Summary of Review of the Research Questions

The study set to evaluate the performance of water distribution networks in Lusaka City, by evaluating the performance of the Hillview South Water Distribution

Network in Kamwala South of Lusaka, installed by Lusaka Water and Sewerage Company Limited in the year 2012. Among the aspects covered in the evaluation were:

i. Quantity of water distributed by the network in Hillview – This refers to the coverage or level of access the people in Hillview South have to the water distributed by the network (is the quantity of water distributed sufficient to meet the people's daily needs?).
ii. The continuity in water service provision – is the service from the WDN continuous without interruption 24 hours a day? How effective is the WDN in water service provision in Hillview?
iii. The quality of water distributed by the network against acceptable standards for human consumption (as per WHO drinking water guidelines).
iv. Efficiency of cost recovery and sustainability of the WDN in Hillview South. Is the cost recovery effective? Is LWSC's revenue collection in Hillview South at 100%?
v. The relevance of the implemented WDN project in Hillview South (was the project really necessary in view of the other requirements of the Hillview South community?).

With inference to the above research objectives, the conclusions arrived at in this chapter are based on the literature review and the results of the study obtained from the data that was collected and analysed in the previous chapters. The following conclusions are thus made:

i. "An Evaluation of Performance of Water Distribution Networks in Lusaka City: A Case for the Hillview South Water Supply Project," established that even though the installed WDN in Hillview South of Kamwala South in Lusaka performs well, its performance is inadequate to meet the community's demands. Some aspects of the design of the WDN were found to be inadequate. The water distribution network that was installed by LWSC in Hillview South in 2012 does not supply adequate quantities of water to the community of Hillview South and this is evidenced in frequent service interruptions leading to most of the residents sinking private boreholes and using pressurised booster pumps in a bid to have uninterrupted supply of water at appropriate pressure at their premises.

ii. It was also established that parts of the water distribution network had bacterial contamination as is evidenced in the water sample test results from the distribution network. The importance of having domestic water for drinking free of bacteria cannot be over emphasized as bacterial contamination in drinking water can have grave consequences if not checked. However, the exact source of the contamination could not be ascertained as there are a number of possibilities:

a) Intermittent supply of water may result in low water pressure and consequently allow the ingress of contaminated water into the system through breaks, cracks, joints and pinholes or contamination through ingress of foreign material, including soil or plants. In many cases, intermittent supply of water is frequently associated with contamination. Therefore, water supply interruptions are not desirable but unfortunately, this is very common in the Hillview South WDN. The control of water quality in intermittent supplies represents a significant challenge, as the risks of infiltration and backflow increase significantly. It is very important therefore, that the WDN in Hillview South distribute water continuously in order to avoid contamination of the water through cracks or breakages.

b) Total coliforms should be absent immediately after disinfection, and the presence of these organisms indicates inadequate treatment or disinfection. The presence of total coliforms in distribution systems and stored water supplies can reveal regrowth and possible biofilm formation.

c) Bacterial contamination in the Hillview South WDN is also possibly due to the interconnections of some of the customers' borehole supply pipelines with the LWSC WDN. The boreholes are very close to soakaways within the premises and thus could be contaminated with bacteria. Since some of the borehole pipelines are connected to the LWSC WDN, it is possible that concentrated "slug" of contaminated water can flow through the distribution network when charging the system after supply is restored and may increase risks to consumers.

iii. The literature review evaluated the challenges faced by water utility companies in improving urban water supply services. From the literature review, the research study established that LWSC faces the following challenges;

a) **Rapid urbanisation and poor urban planning** – literature review established that configuration of a water distribution network is dictated by; street patterns, topography, degree and type of development of the area and location of the treatment and storage works. LWSC faces a huge challenge in that it is failing to keep up with the rapidly expanding city of Lusaka and its increasing demand for water services. The utility’s inability to keep up with the rapid urbanisation is exacerbated by poor urban planning as this hinders proper selection and layout of distribution networks. For instance, in locations where sharp changes in topography occur (hilly or mountainous areas such as Hillview South), the distribution network should be divided into two or more service areas.

b) **Inadequate investment and governance** – Due to the fact that LWSC has a low cost recovery, the utility lacks adequate local funding to expand or maintain existing infrastructure thereby resulting in dilapidation of the infrastructure. The inability of the utility to collect sufficient funds from the water it produces and supplies can be attributed to poor governance of the utility which in turn thwarts the expansion of water service coverage. Cost recovery is definitely very important for sustainability of the installed system. However, from the results of the study, up to 41 percent of the respondents were placed on fixed billing and therefore, there is a possibility that LWSC invoices or bills this particular group of customers in Hillview South for less water than they actually supply (or is used by the customers) and this can have a negative impact on improving the network in order to cater for an ever increasing population (more consumers) in Lusaka City.

iv. The research study also established that LWSC does not carry out comprehensive due diligence to enable them design adequate WDNs to meet the water demand requirements of the communities they serve.

v. The study established that the implemented WDN project was relevant. This is evidenced by the fact that the implementation of the WDN project brought water to the Hillview South community when the community did not have it (the water) before its implementation. Clearly, this shows that the WDN was relevant because it addressed a basic human need. Water is vital for the basic survival of human beings and improves their livelihoods. However, the study has revealed that aspects of design of the WDN were not adequately addressed hence leading to inadequacy of performance of the WDN in so far as water quantity, quality, continuous supply and appropriate pressure are concerned.

6.4 Recommendations

In view of the foregoing conclusions, the following are the recommendations made for improved performance of the WDNs installed by LWSC:

i. LWSC should implement operational monitoring in order to safeguard the quality of the distributed water at all times. Operational monitoring is the conduct of planned observations or measurements to assess whether the control measures (for example, mode of treatment or disinfection) in a drinking-water system are operating properly. It includes observing or testing parameters such as turbidity, chlorine residual or structural integrity of the water distribution network. Operational monitoring is usually carried out through simple observations and tests, in order to rapidly confirm that control measures are continuing to work. Control measures are actions implemented in the drinking-water system that prevent, reduce or eliminate contamination and are identified in system assessment. It is possible to set limits for control measures, monitor those limits (as set by ZABS, ZEMA or MoH) and take corrective action in response to a detected deviation before the water becomes unsafe. Operational monitoring would include actions, for example, to rapidly and regularly assess whether the turbidity of water following filtration is below a certain value or the chlorine residual after disinfection or at the far point of the distribution network is above the recommended value. If monitoring shows that a limit does not meet specific actions, then there is the potential for water to become unsafe.

ii. LWSC must be carrying out comprehensive needs-assessments or due diligence before designing WDNs. Needs-assessments, also called gap-analyses, would greatly assist LWSC in determining the steps needed to be taken in order to design adequate water distribution networks for communities with little or no water service to the desired future state of adequate quantities of safe water supplies. Comprehensive needs-assessments/due diligence should consist of; (1) listing of characteristic factors (such as attributes, competencies, and performance levels) of the present situation in LWSC; (2) listing factors needed to achieve future objectives of supplying sufficient safe water quantities at appropriate pressure all the time, and then (3) engaging the community (community participation) in order to highlight the gaps that exist in the water service to the communities. This is very important as it will enable LWSC to determine how best to meet the water requirements of the communities they serve. This third step is particularly important because engaging the community would enable LWSC to collect the information necessary to determine the water requirements of the communities and thus lead to designs of WDNs that are inclusive of the communities' needs.

iii. LWSC must be carrying out periodic maintenance of WDNs in order to maintain or improve on the quality of water in the distribution networks. Periodic maintenance is also important in helping keep water losses through leakages to a minimum and thus enhance the performance of WDNs.

iv. LWSC must train their design engineers sufficiently in order to build their capacity to plan and design adequate WDNs that would be able to meet the demands and requirements of the communities they supply water to.

REFERENCES

Adeosun, O.O (2014): Water Distribution System Challenges and Solutions [Online] Available at: www.wateronline.com/doc/water-distribution-system-challenges-and-solutions-0001 [Accessed 12 May 2017].

AICD (2011): Africa's Infrastructure: A Time for Transformation, The International Bank for Reconstruction and Development /The World Bank, NW Washington, DC, USA; (https://openknowledge.worldbank.org/handle/10986/2692; Retrieved on 4th May, 2017).

Ahmed M. Feroze and Mujibur Rahman (2000): Water Supply and Sanitation - Rural and Low Income Urban Communities. First ed. Dhaka: ITN Bangladesh.

Ainsworth, R. (2004): Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems. London, UK.: IWA Publishing.

Almasri, M. (2008): Optimal Design of Water Distribution Networks. s.l.:An Najah National University, Palestine.

AMCOW (2012): A Snapshot of Drinking Water and Sanitation in Africa – 2012 Update Report, WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, Egypt (https://www.wssinfo.org/fileadmin/user_upload/resources/Africa-AMCOW-Snapshot-2012-English-Final.pdf; Retrieved on 14th May, 2017).

Bahri, A.; Brikke, F and Vairavamoorthv, K (2015): Managing Change to Implement Integrated Urban Water Management in African Cities, Stockholm, Sweden.

Bakker, K. (2013): Neoliberal versus Post Neoliberal Water - Geographies of Privatization and Resistance.

Banerjee, S., and E. Morella, (2011): Africa's Water and Sanitation Infrastructure: Access, Affordability and Alternatives, The World Bank, Washington DC, USA (https://openknowledge.worldbank.org/bitstream/handle/10986/2276/608040PUB0Afri10Box358332B01PUBLIC1.pdf?sequence=1; Retrieved on 2nd June, 2017).

Bukhari, A. A. (2008): Water Distribution System; http://faculty.kfupm.edu.sa/CE/abukhari/Courses/CE370/Lectures/Waterpercent20Distributionpercent20System.pdf; Retrieved on 8th April, 2017)

Cain, A and Mulenga, M (2009): Water Service Provision for the Peri-Urban Poor in Post-Conflict Angola, IIED, London, UK

Collins English Dictionary - Complete and Unabridged, Digital Edition, (2012); (http://www.dictionary.com/browse/water-supply); Retrieved on 20th February, 2017.

Creswell, J. (2009): Research Design - Qualitative and Quantitative Approaches, Sage Publication, Thousand Oaks California, USA.

DANIDA (2006): Water Supply and Sanitation for Low-Income Urban Areas, Technical Advisory Services, Denmark.

Department of Public Utilities (2005): Water Distribution System Design Guidelines, Standard Specifications and Details, VA, USA.

Duflo E; Galiani, S and Mobarak, M (2012): Improving Access to Urban Services for the Poor - Open Issues and a Framework for a Future Research Agenda, Colombo.

Encyclopaedia Britannica (2017): (https://www.britannica.com/technology/water-supply-system/Effluent disposal#toc286139; Accessed on 17th May, 2017)

Field, A. (2005): Discovering Statistics using SPSS, Second Edition, Sage Publication, London.

Fiszbein, A; Ringold, D and Rogers, F.H. (2011): Making Services Work - Indicators, Assessments, and Benchmarking of the Quality and Governance of Public Service Delivery in the Human Development Sector, Policy Research Working Paper 5690, World Bank, Washington, DC.

Gauff, H.P (2011) Water Supply Investment Master Plan Lusaka, Lusaka: Millennium Challenge Corporation.

GIZ (2011): Guidelines for Water Loss Reduction - A Focus on Pressure Management, Eschborn; Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH: (https://www.giz.de/fachexpertise/downloads/giz2011-en-guideline-water-loss-reduction.pdf; Retrieved on 14th April, 2017).

GONU (2009): Technical Guidelines for the Construction and Management of Drinking Water Distribution Networks, Khartoum: Government of National Unity (http://www.bebuffered.com/downloads/TechGuidelinesforImprovedconstructionandmanagementofHafir_2009.pdf; Retrieved on 10th February, 2017).

Gowela J. J.; Alleyne T and Chinopfukutwa G.L. (2017): Service Quality Gap Analysis to Improve Public Water Service Delivery in Lilongwe City - Tapping Customer's Voice, Malawi.

Gutierrez, E. (2007. Delivering Pro-Poor Water and Sanitation Services, the Technical and Political Challenges in Malawi and Zambia. Geoforum 38 (5).

GRZ (2006): Zambia Vision 2030, Government of the Republic of Zambia, Lusaka, Zambia.

Harawa, M.M; Hoko Z; Misi S. and Maliano S. (2016): Investigating the management of unaccounted for water for Lilongwe water board, Malawi. Journal of Water Sanitation and Hygiene for Development. Available at: http://washdev.iwaponline.com/content/early/2016/07/08/washdev.2016.013.abstract

Hickey, H.E. (2008): Water Supply Systems and Evaluation Methods, Volume I: Water Supply System Concepts. Emmitsburg: U.S. Fire Administration (http://www.sswm.info/sites/default/files/reference_attachments/HICKEYpercent20 2008percent20Waterpercent20Supplypercent20Systemspercent20Volumepercent20I .pdf; Retrieved on 14th February, 2017).

Hickey, H.E. (2008): Water Supply Systems and Evaluation Methods. Volume II: Water Supply Evaluation Methods. Emmitsburg: U.S. Fire Administration (http://www.sswm.info/sites/default/files/reference_attachments/HICKEYpercent20 2008percent20Waterpercent20Supplypercent20Systemspercent20Volumepercent20I _0.pdf; Retrieved on 14th February, 2017).

Hodge, G. (2007): Regulatory Frameworks for Urban Services - Background Discussion Paper, OECD. (http://www.oecd.org/gov/regulatory-olicy/39218313.pdf; Accessed on 10th November, 2017).

IDEV/AfDB Group (2015): Water Supply and Sanitation in Africa - Findings, Lessons and Good Practices to Improve Delivery, Abidjan, Côte d'Ivoire.

Independent Evaluation Group Working Paper 2016/No 3, (2016): Introducing a Framework for Evaluating Service Delivery in Sector Evaluations: Urban Transport, Water and Sanitation, and Nutrition, The World Bank Group, Washington, USA.

IWRMC and UNZA (2014) Final Report on Review of the Performance of Community Contributions towards Rural Water Supply Infrastructure Development in Zambia, Lusaka

Jacobsen, M; Webster, M and Vairavamoorthy, K (2012): The Future of Water in African Cities, World Bank Group, Switzerland.

Jayaramu, K.P., Kumar, B.M. and Prasanna, R.K.K. (2014): Customer Satisfaction with Domestic Water Supply in India – A Study in Hubli city. Journal of Environment and Earth Science, 4(9), pp.105–117, NaN-948.

JICA (2009): The Study on Comprehensive Urban Development Plan for the city of Lusaka, Lusaka: JICA.

Kalulu, K. and Hoko, Z. (2010): Assessment of the Performance of a Public Water Utility: A case Study of Blantyre Water Board in Malawi. Physics and Chemistry of the Earth, Parts A/B/C 35, pp. 13-14. Available at: http://dx.doi.org/10.1016/j.pce.2010.07.017; Accessed on 25th May 2017.

Kasonde-Ng'andu, S. (2013): Writing a research Proposal in educational reaserch. Lusaka: University of Zambia Press.

Kirkpatrick, C.; Parker, D. and Zhang, Y.F (2004): State Versus Private Sector Provision of Water Services in Africa: A Statistical, DEA and Stochastic Cost Frontier Analysis

Kirkpatrick, C.; Parker, D. and Zhang, Y.F (2004): An empirical analysis of state and private-sector provision of water services in Africa. World Bank Economic Review, 20(1), pp.143–163.

Kim, J. K. (2012): Delivering on Development - Harnessing Knowledge to Build Prosperity and End Poverty, World Bank, World Knowledge Forum, Seoul, Korea. (http://www.worldbank.org/en/news/speech/2012/10/08/delivering-development-harnessingknowledge-build-prosperity-end-poverty; Retrieved on 11th March, 2017)

Lockwood, H. and S. Smits. (2011): Supporting Rural Water Supply - Moving Toward a Service Delivery Approach, Practical Action Publishing: Rugby, UK.

LWSC (2011): Project Implementation Plan - Water Distribution Network in Hillview South, Kamwala South, Lusaka Water and Sewerage Company Limited (LWSC), Lusaka, Zambia.

MacDonald, A. M. (2005): Developing Groundwater - A Guide for Rural Water Supply, ITDG Publishing, New York, USA

Manda, M.A.Z. (2009): Water and sanitation in urban Malawi: Can the Millennium Development Goals be met? A study of informal settlements in three cities, Available at: http://books.google.com/books?hl=en&lr=&id=-KnEhFyRzKwC&oi=fnd&pg=PR5&dq=Water+and+sanitation+in+urban+Malawi+:+Can+the+Millennium+Development+Goals+be+met+?+A+study+of+informal+settlements+in+three+cities&a mp;ots=NvR0KsG9l3&sig=.

Mpakati-Gama, E. and Mkandawire (2015): Coping with Water Supply Shortages in Major Cities of Malawi Effiness. CSID Journal of Sustainable infrastructure Development, 2008, pp.14– 22.

Marston, A. (2014): The Scale of Informity: Community-Run Water Systems in Peri-Urban Cochabamba, Bolivia.

MLGH (2011): National Urban Water Supply and Sanitation Programme (NUWSSP) 2011-2030, Lusaka, Zambia: Ministry of Local Government and Housing (MLGH).

MoF (2014): Revised Sixth National Development Plan, Lusaka: Ministry of Finance, Zambia.

Mughogho, B.U.G. and Kosamu, I.B. (2012): Water supply arrangements in developing countries: A Case Study of Blantyre City, Malawi. African Journal of Environmental Science and Technology, 6(2), pp.94–103.

NESC (2010): Fundamentals of Hydraulics Flow, Vol. 10, Issue 1 (www.nesc.wvu.edu/techbrief.cfm; Accessed on 12th May, 2017)

NPTEL (2014): Water Distribution Systems, National Programme on Technology Enhanced Learning, Chennai, India (http://nptel.ac.in/; Accessed: 15th January, 2017).

Ojo, V.O. (2011): Customer Satisfaction - A Framework for Assessing the Service Quality of Urban Water Service Providers in Abuja, Nigeria, Loughborough University, Loughborough, UK.

Onyenechere, E. C. and Osuji, S.C. (2012): Water Service Provision in Owerri City, Owerri, Nigeria.

Pinto F.S.; Costa A.S; Figueira J.R and Marques R.C (2016): The Quality of Service - An Overall Performance Assessment for Water Utilities, Lisbon, Portugal.

Raosoft Online Sample Size Calculator (2017): (https://www.researchgate.net/deref/http%3A%2F%2Fwww.raosoft.com%2Fsamplesize.html; accessed on 9th March, 2017)

Rhetella (2015): (cited on https://www.coursehero.com/file/10596443/Water-Distribution-System/; Accessed on 12th May, 2017)

Seager, J. (2010): Gender and Water: Good Rhetoric, But It Doesn't "Count". Issue 1, pp. 1-3. Available at http://dx.doi.org/10.1016/j.geoforum.2009.07.006, Accessed on 26th May 2016.

SSWM, (2017): Sustainable Sanitation and Water Management: http://www.sswm.info/; Accessed on 12th February, 2017).

Stahre P; Adamsson and Mellstrom G (2008): A New Approach for Assessment of the Performance of Water Distribution and Sewerage Networks, Malmo, Sweden

Swyngedouw, E. (2006): Power, Water and Money: Exploring the Nexus. s.l.:United Nations Development Programme.

Tiwari, P. and Gulati, M. (2011): Efficiency of urban water supply utilities in India. International Journal of Water Resources Development, 27(2), pp.361–374. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-79957522407&partnerID=40&md5=7fbb44221076e9fc98f77547fdaf7516.

Tourki, T. (2010): Implementation of Lean within the Cement Industry (Doctoral Dissertation, University of De Montfort)

UN/WWAP (2003): Water for People, Water for Life, United Nations/World Water Assessment Programme; Retrieved on 27th October 2016 from: (http://www.un.org/esa/sustdev/publications/WWDR_english_129556e.pdf;)

Van Ginneken, M; Netterstrom, U and Bennett, A (2011): More, Better, or Different Spending? Trends in Public Expenditure on Water and Sanitation in Sub-Saharan Africa; Retrieved on 16th October 2016 from: (http://www.ppa.pt/wp-content/uploads/2012/06/Water-access-in-Africa.pdf)

Worldometers (2017): www.worldometers.info/world-population/africa-population/ Accessed on 26th November, 2017.

WHO (2003): The Right to Water, World Health Organisation, Geneva, Switzerland (http://www.who.int/water_sanitation_health/en/righttowater.pdf; Retrieved on 10th May, 2017).

WHO (2005): Water Recreation and Diseases, IWA Publishing, World Health Organization London.

WHO (2006): Health Aspects of Plumbing; World Health Organisation, Geneva. http://www.sswm.info/sites/default/files/reference_attachments/WHOpercent202006percent20Healthpercent20Aspectspercent20ofpercent20Plumbing.pdf. Retrieved on 14th December, 2016.

WHO (2011): Guidelines for Drinking - Water Quality, Fourth Edition, Geneva, Switzerland.

WHO (2017): Guidelines for Drinking - Water Quality, Fourth Edition incorporating the first addendum, Geneva, Switzerland.

World Bank (2012): Rural Water Supply Design Manual, Vol. 1, Manila, Philippines.

Zeraebruk, K.N; Mayabi, A.O; Gathenya, J.M. and Tsige, Z (2014): Assessment of Level and Quality of Water Supply Service Delivery for Development of Decision Support Tools : Case Study Asmara Water Supply. International Journal of Sciences: Basic and Applied Research (IJSBAR), 14(1), pp.93–107. Available at: http://gssrr.org/index.php?journal=JournalOfBasicAndApplied&page=article&op=view&path[]=1341&pat h[]=1597.

Zschille, M. and Walter, M. (2012): The performance of German water utilities: a (semi)-parametric analysis. Applied Economics, 44(29), pp.3749–3764.

APPENDICES

APPENDIX A: HOUSEHOLD QUESTIONNAIRE

THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

HOUSEHOLD QUESTIONNAIRE

AN EVALUATION OF PERFORMANCE OF WATER DISTRIBUTION NETWORKS IN LUSAKA CITY: A CASE FOR THE HILLVIEW SOUTH WATER PROJECT

Introduction

Good morning/afternoon. My name is ____. I am student from the University of Zambia in the School of Engineering and currently undertaking a study to try and evaluate the water supply projects carried out in Hillview South to improve the provision of water service. I am here to learn whether or not there has been any significant change and or improvement with regard to the water supply as a result of the projects undertaken in the area.

I would like to assure you that the information collected from this study will be treated with utmost confidentially, but findings may be used to improve future water supply projects as a way of ensuring more effective and efficient public service delivery.

With your permission, I would like to interview you so that I can understand how the water supply projects have benefited the community. Please note that your participation in this research is voluntary.

Do you have any questions for me? You may ask questions about this study at any time during the interview.

"May I begin the interview now?”

☐ **Yes** ☐ **No**

PERSONAL INFORMATION

1.1	Interviewer name	
1.2	Date	
1.3	Respondent’s gender	☐ 1. Male ☐ 2. Female
1.4	Is respondent house owner?	☐ 1. Landlord ☐ 2. Tenant ☐ 3. Caretaker
1.5	How many people are living in this household	No. of HH members.................... Male........... Female............

1.6	How long have you lived in this house/ area?	☐ 1.less than one year ☐ 2.1-5 years ☐ 3. 5- 10 years ☐ 4. More than 10 years ☐ 5. Other specify………………………..
ACCESS AND PERFORMANCE OF SERVICE PROVIDER		
2.1	What is your main source of drinking water?	☐ 1. LSWC ☐ 2. Bowsers ☐ 4. Self – borehole ☐ 5. Other, specify …………………………………..
2.2	How long have you been using this source of water?	☐ 1. Less than one year ☐ 2. 1-5 years ☐ 3. 5-10 years ☐ 4. Don't know ☐ 5. Other, specify ……………………………………….…………
2.3	Have you ever used more than one source of water since you moved to this area?	…………………………………………………… …………………………………………………… ……………………………………………………
2.4	What is your comment on your suppliers' service provision to your household?	☐ 1. Satisfactory ☐ 2. Average ☐ 3. Unsatisfactory ☐ 4. Other specify …………………………… ☐ 5. I do not know
2.5	Explain your response in 2.3 above	………………………………………………… ………………………………………………… ………………………………………………….
2.6	On average how many hours do you have running water in a day?	☐ 1. 0 hours per day ☐ 2. 1-6 hours per day ☐ 3. 6- 12 hours per day ☐ 4. 12-18 hours per day ☐ 5. 18 -24 hours per day ☐ 6. I do not know
2.7	Are the supply hours sufficient to meet all your household needs (drinking, bathing, washing, etc.)	☐ 1. Yes ☐ 2. No ☐ 3. Don't know Explain: …………………………………………
2.8	Have these supply hours always been this way in the past? *Depending on how long one has lived the area* ***If yes, proceed to question 2.10***	☐ 1. Yes ☐ 2. No ☐ 3. Don't know ☐ 4. Other specify …………………………….
2.9	If not, what were they like?	Explain: …………………………………………………

		………………………………………………… ………………………………………………….
2.10	Are there days you do not have water flowing into your household?	☐ 1. Yes ☐ 2. No ☐ 3. Sometime ☐ 4. Don't know
2.11	If Yes, were do you get your water on such days?	☐ 1. In house storage ☐ 2. Bowsers ☐ 3. Drawing from neighbours with boreholes ☐ 4. Other, specify ……………………………….
2.12	How is the water pressure into your household?	☐ 1. Very high ☐ 2. High ☐ 3. Normal ☐ 4. Low ☐ 5 Other specify ………………………………
QUALITY AND QUANTITY OF WATER		
3.1	What type of meter does your household have?	☐ 1. Metered post-paid ☐ 2. Metered pre-paid ☐ 3. Not metered
3.2	If not metered, how do you pay for your water?	Specify……………………………………… …………………………………………………
3.3	How much water do you consume per month? **(To be computed from the bill)**	....
3.4	How much is your average monthly bill?	....
3.5	Do you consider amount of water supplied to be sufficient to meet your household's requirements each day?	☐ 1. Yes ☐ 2. No ☐ 3. Don't know ☐ 4. N/A
3.6	How happy are you with your main water supply system in terms of…	*3.6a – tariff?* ☐ 1. Very happy ☐ 2. Happy ☐ 3. Unhappy ☐ 4. Very unhappy
		3.6b - water quality (taste, colour, etc.)? ☐ 1. Very happy ☐ 2. Happy ☐ 3. Unhappy ☐ 4. Very unhappy
		3.6c - water pressure? ☐ 1. Very happy ☐ 2. Happy ☐ 3. Unhappy ☐ 4. Very unhappy
		3.6e - availability (continuity of supply, opening

		hours, etc.)? ☐ 1. Very happy ☐ 2. Happy ☐ 3. Unhappy ☐ 4. Very unhappy
3.7	Since you started staying here have you noticed any change in the water supply system?	☐ 1. Yes ☐ 2. No ☐ 3. Don't know ☐ 4. Specify……………………………………
3.8	Explain response above	…………………………………………………… …………………………………………………… ……………………………………………………
3.9	Have you ever had any faults/leakages with your household connection in the past two years?	☐ 1. Yes ☐ 2. No ☐ 3. Don't know ☐ 4. N/A
3.10	If yes, What did you do about it?	………………………………………………… ………………………………………………..
3.6	Do you know where to report cases related to water supply.	…………………………………………………… …………………………………………………… ……………………………………………………
3.7	Have you ever reported any such case in the past two years?	☐ 1. Yes ☐ 2. No ☐ 3. Don't know ☐ 4. N/A
3.8	What was the complaint about?	………………………………………………… ………………………………………………...
3.9	What was the response and or action you got from the service provider	………………………………………………… ………………………………………………… …………………………………………………
3.10	Where you happy with the response you received?	☐ 1. Yes ☐ 2. No ☐ 3. Don't know ☐ 4. N/A
3.11	Explain above	………………………………………………… ………………………………………………..
IMPACT		
4.1	Were community members invited for stakeholder meetings before the implementation of the projects?	☐ 1.Yes ☐ 2. No ☐ 3. Don't know ☐ 4. N/A
4.2	***If yes, what can you tell me about the community involvement to the project?***	…………………………………………………… …………………………………………………… …………………………………………………… ……………………………………………………
4.3	Are you aware of any rehabilitation that has been	☐ 1.Yes ☐ 2. No

	undertaken in your water supply system and by whom?	☐ 3. Don't know ☐ 4. N/A
4.4	***If yes what exactly do you know?***	……………………………………………………… ……………………………………………………… ………………………………………………………
4.5	If yes, did the project improve accessing water supply?	☐ 1. Yes ☐ 2. No ☐ 3. Don't know ☐ 4. N/A
4.6	Explain your answer in 4.3	……………………………………………………… ……………………………………………………… ………………………………………………………
4.7	In your view, do you think the project achieved its goal?	……………………………………………………… ………………………………………………………
4.8	What advice would you give to your service provider?	……………………………………………………… ………………………………………………………
4.9	Do you have any general comments on the water supply system in your area?	……………………………………………………… ……………………………………………………… ………………………………………………………

End of the interview.

Thank you for your cooperation!

APPENDIX B: INSTITUTIONAL KEY INFORMANT GUIDE

THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

INSTITUTIONAL KEY INFORMANT GUIDE

AN EVALUATION OF PERFORMANCE OF WATER DISTRIBUTION NETWORKS IN LUSAKA CITY: A CASE FOR THE HILLVIEW SOUTH WATER PROJECT

Introduction

Good morning/afternoon. My name is ______________________________. I am student from the University of Zambia in the School of Engineering and currently undertaking a study to try and evaluate the water distribution network project carried out in Hillview South to improve the provision of water service. I am here to learn whether or not there has been a significant change and or improvement with regard to the water supply as a result of the water supply projects undertaken in the area.

I would like to assure you that the information collected from this study will be treated with utmost confidentially, but findings may be used to improve future water distribution network projects as a way of ensuring more effective and efficient public service delivery.

With your permission, I would like to interview you so that I can understand how the water supply projects were implemented. Please note that your participation in this research is voluntary.

PERSONAL INFORMATION		
1.1	Interviewer name	
1.2	Date	
1.3	Respondent's gender	☐ 1. Male ☐ 2. Female
1.4	Name of Institution	
1.5	Position at work	

1) Could you please enlighten me on how South of Hillview was selected for the water supply projects that have been under taken in the area?

   Probe:

   i. Identification of the area;
   ii. Target population the project was targeting;
   iii. Funders of the project;
   iv. Percentage of population that had water before and after implementation;
   v. Process on how the project was carried out;
   vi. Planning of the project;
   vii. If Environmental Impact Assessment was done.

2) Is the design of the project in Hillview as intended or where they changes to the plan?

   Probe:

   i. Did the project achieve the set outcomes and results during the implementation period?
   ii. To what extent were expected and estimated project results achieved?
   iii. Which were the unintended outcomes?
   iv. Which factors contributed and hindered achieving outcomes?
   v. Did the project improve water supply services in the targeted areas? In what sense? What indicators are you using to measure this? Populations reached?
   vi. Are there any partnerships which were established?
   vii. Who were the stakeholders involved in this project. Was the participation of stakeholders as intended? If not, what was the cause for failure to participate in project implementation?
   viii. Who is in charge of repairs and maintenance works?

3) Who were the funders of the project?

Probe:

i. Was it a grant or loan?
ii. Are there any modalities in place for cost recovery? If loan what are cost recovery plans and if grant were there any condition?
iii. Are the water tariffs charged in the beneficiary communities cost reflective?
iv. Who is supposed to manage the facility?

4) Did the project benefit the targeted population socio-economically? (for example, creation of jobs; Improved public health) In your view, do you think it was a good investment?

Probe:

i. Capital investment?
ii. Social benefits?
iii. Environmental Impacts?
iv. Were resources used in an appropriate and economical way to achieve results? (Was the budget used efficiently and adhered to? Has the project obtained value for money?)

End of the interview.

Thank you for your cooperation!

APPENDIX C: DISTRIBUTION NETWORK WATER SAMPLE TEST RESULTS

SCHOOL OF ENGINEERING
CIVIL ENGINEERING DEPARTMENT
ENVIRONMENTAL ENGINEERING LABORATORY

P.O Box 32379, Lusaka

PHYSICAL/CHEMICAL EXAMINATION OF WATER

Attn : Manengu Musambo
Lusaka
Sampled by : Client
Sampling date : 03.03.2017
Report date : 05.03.2017

Laboratory Results

Parameter	Water sample A plot 4354	Water sample B plot 26194	Water sample C plot 43504	WHO Guideline (Maximum Permissible value for drinking water)
pH	7.41	7.52	7.60	6.5- 8.5
Turbidity (NTU)	0.82	0.89	0.40	5.0
Conductivity (µs/cm)	719	718	770	1500
Total Dissolved Solids (mg/l)	360	359	384	1000
Total Suspended Solids (mg/l)	<1.0	<1.0	<1.0	-
Total hardness (as mg $CaCO_3$/l)	422	404	416	500
Calcium hardness (as mg $CaCO_3$/l)	392	332	362	500
Alkalinity (as mg $CaCO_3$/l)	412	400	405	500
Iron (mg/l)	<0.01	<0.01	<0.01	0.30
Ammonia (as NH_4-Nmg/l)	<0.01	<0.01	<0.01	1.50
Sulphates (mg/l)	0.16	0.33	17.95	250
Chlorides (mg/l)	20.0	17.0	27.0	250
Nitrites (as NO_2–N mg/l)	<0.001	<0.001	<0.001	0.100
Nitrates (as NO_3–N mg/l)	2.05	1.87	5.56	10.0
Acidity (as mg $CaCO_3$/l)	Nil	Nil	Nil	500
Total phosphates (mg/l)	<0.01	<0.01	<0.01	5.0
Magnesium (mg/l)	7.20	17.28	12.96	-
Calcium (mg/l)	156.8	132.8	144.8	200
Fluorides (mg/l)	0.52	0.41	0.36	1.50
Potassium (mg/l)	4.22	3.59	5.70	-
Sodium (mg/l)	13.20	11.22	17.82	200
Manganese (mg/l)	<0.01	<0.01	<0.01	0.50
Bacteriological Results				
Total coliforms (#/100ml)	38	85	0	0
Feacal coliforms (#/100ml)	20	60	0	0

Tests carried out in conformity with " Standard Methods for the Examination of water and Wastewater APHA, 1998".

Comment: On the day of sampling the bacteriological quality of the water was bad at plot 4354 and 26194, the water needs to be treated before drinking i.e. Boiled, chlorinated, UV etc.
The chemical tests were within the WHO standards for drinking.

J. Kabika
Co-ordinator- Environmental Engineering Laboratory

UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
05 MAR 2017
DEPT OF CIVIL ENGINEERING
P O. BOX 32379, LUSAKA

APPENDIX D: BOREHOLE SOURCES WATER SAMPLE TEST RESULTS

SCHOOL OF ENGINEERING
CIVIL ENGINEERING DEPARTMENT
ENVIRONMENTAL ENGINEERING LABORATORY

P.O Box 32379, Lusaka

PHYSICAL/CHEMICAL EXAMINATION OF WATER

Attn : Manengu Musambo
Lusaka
Sampled by : Client
Sampling date : 31.03.2017
Report date : 02.04.2017

Laboratory Results

Parameter	Lilayi boreholes	Shaft 5 boreholes	WHO Guideline (Maximum Permissible value for drinking water)
pH	8.1	7.6	6.5- 8.5
Turbidity (NTU)	0.31	0.41	5.0
Conductivity (µs/cm)	734	747	1500
Total Dissolved Solids (mg/l)	367	375	1000
Total Suspended Solids (mg/l)	<1.0	<1.0	-
Total hardness (as mg $CaCO_3$/l)	366	334	500
Calcium hardness (as mg $CaCO_3$/l)	292	264	500
Alkalinity (as mg $CaCO_3$/l)	358	252	500
Iron (mg/l)	<0.01	<0.01	0.30
Ammonia (as NH_4-Nmg/l)	<0.01	<0.01	1.50
Sulphates (mg/l)	105.40	61.48	250
Chlorides (mg/l)	25.0	27.0	250
Nitrites (as NO_2–N mg/l)	<0.001	<0.001	0.100
Nitrates (as NO_3–N mg/l)	**14.40**	**15.13**	10.0
Acidity (as mg $CaCO_3$/l)	Nil	Nil	500
Total phosphates (mg/l)	<0.01	<0.01	5.0
Magnesium (mg/l)	17.76	16.80	-
Calcium (mg/l)	116.8	105.6	200
Fluorides (mg/l)	0.41	0.38	1.50
Potassium (mg/l)	5.28	5.70	-
Sodium (mg/l)	16.50	17.82	200
Manganese (mg/l)	<0.01	<0.01	0.50
Bacteriological Results			
Total coliforms (#/100ml)	0	0	0
Feacal coliforms (#/100ml)	0	0	0

Tests carried out in conformity with " Standard Methods for the Examination of water and Wastewater APHA, 1998".

Comment: On the day of sampling the bacteriological quality of the water was good.
The chemical tests were within the WHO standards for drinking water except for Nitrates which can be reduced by Reverse osmosis (RO).

J. Kabika
Co-ordinator- Environmental Engineering Laboratory

UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
02 APR 2017
DEPT OF CIVIL ENGINEERING
P O. BOX 32379, LUSAKA