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SUSTAINABLE URBAN WATER MANAGEMENT: Case study of Athiriver Township, Mavoko Municipality.

BY

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Declaration

I, Bonventure Kaliti, hereby declare that this thesis proposal is my original work. To the best of my knowledge, the work presented here has not been presented for a proposal in any Institution of Higher Learning.

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Abbreviations and Acronyms

ACA	Athiriver Catchment Area
AWR	Alternate Water Resource
CBD	Central Business District
COK	Constitution of Kenya
CoW	City of Windhoek
DMA	District Metered Areas
DPR	Direct portable reuse
IBR	Inclining Block Rate
IPR	Indirect potable reuse
IWA	International Water Association
JMP	Joint Monitoring Programme
KNBS	Kenya National Bureau of Statistics
LVNCA	Lake Victoria North Catchment Area
LVSCA	Lake Victoria South Catchment Area
MAVWASCO	Mavoko Water and Sewerage Company
MCM	Million Cubic Meter
MDG	Millennium Development Goals
MWSI	Ministry of Water, Sanitation and Irrigation
NEMA	National Environmental Management Authority
NRW	Non-Revenue Water
NWHSA	National Water Harvesting and Storage Authority
NWMP	National Water Master Plan
OECD	Organisation for Economic Co-operation and Development

PLP	Peak-Load Pricing
RVCA	Rift Valley Catchment Area
RWH	Rain Water Harvesting
SDG	Sustainable Development Goals
SIWI	Stockholm International Water Institute
SPA	Service Provision Agreement
SPSS	Statistical Package for Social Science
SSA	Sub Saharan Africa
TCA	Tana Catchment Area
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization.
UNICEF	United Nations Children's Fund
UWCS	Urban Water Cycle Systems
WASREB	Water Services Regulatory Board
WHO	World Health Organization
WRMA	Water Resource Management Authority
WSB	Water Service Board
WSP	Water Service Provider
WSTF	Water Sector Trust Fund
WT	Water Tribunal
WWDA	Water Works Development Agencies

Abstract

Water sustainability refers to the ability to provide clean water to residents and commercial businesses easily and efficiently. The lack of a sustainable water supply in cities is a major issue that water service providers, planners, city managers, and policymakers must address. Athi river town is no exception, as it is experiencing rapid urbanization, rapid population growth, and insufficient water supply. The town's water resources are under stress, and if unsustainable use continues, the town may face water scarcity in the future.

The major reason why this study was carried out is to discover a solution to challenges facing the management of water sources and their infrastructure in Athiriver Township by evaluating water supply, water demand management, Non- revenue water and water governance in households and business. According to the study, MAVWASCO provides piped water in the town, and its primary water sources are the Kasuitu dam and two boreholes. According to the findings, rainwater harvesting and wastewater recycling are not considered alternative water sources. MAVWASCO provides water services in informal settlements through public water kiosks. Non-revenue water is very high at 44 percent, compared to WASREB's annual standard of 20 percent.

According to this study, the most common water demand management strategy is turning off water taps when not in use (34%). The findings revealed that MAVWASCO does not have a clear set of strategies for managing water demand, but does practice water rationing during dry seasons. Because of the public awareness campaign, residents are well informed about the importance of water conservation. Water is a devolved function under the County Government Act of 2012, but there is no clear role in water resource development because most water development activities are carried out by National government parastatals; thus, the Water Act of 2016 needs to be reviewed.

The study concluded by recommending strategies for ensuring sustainable water supply in Athi river town, such as developing alternative water sources like rainwater harvesting, wastewater recycling, aquifer recharging, and the construction of the proposed Mto Mawe dam. Conducting water audits and leak detection programs to reduce non-revenue water. Water demand management strategies include encouraging the use of water-saving technologies and behaviour change. Policy development for rainwater harvesting, wastewater reuse, and aquifer recharge.

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SUSTAINABLE URBAN WATER MANAGEMENT: The case of Athiriver Township, Mavoko Municipality.

CHAPTER 1

1.0 Introduction

"*Urbanization brings opportunities for more efficient water management and improved access to drinking water and sanitation. At the same time, problems are often magnified in cities, and are currently outpacing our ability to devise solutions." Ban Ki-moon (UN Secretary General, 2014).*

Water is a vital natural resource, especially in the urban regions where we have dense populations. In these urban areas, there are commercial, industrial, and residential users who are in great need of water to run their daily activities. As cities expand in size, the competition in the watersheds keeps growing as agriculture and industries simultaneously grow. By 2050, the demand for water is expected to double, and thus the already existing competition for water in peri-urban and rural areas will become worse (Akica Bahri, 2012).

Water becomes increasingly scarce due to urbanization and increased competition between land uses and economic sectors (Tim van Hattum et al., 2016). The climate change currently being experienced in the world has increased the risk of floods, drought, and heat waves. These are problems that need to be addressed in urban planning and water management through a systematic approach and transition.

Cities around the globe have been struggling to provide their populations with a reliable supply of clean water as required. This is an aspect that has been brought about by several factors, among them the insufficient investment of funds in the water sector, the inability of the water authorities to charge poor people for the consumption of water, and the incapacity of the public sector to provide efficient water services, (Anand Chiplunkar et al., 2012).

In Africa, only a minimal amount can currently be used as usable freshwater. In addition, several rivers and lakes have suffered significant decreases in their discharge and surface area. Groundwater wells are also under constant threat from desertification and subsequent depletion. (UNECA, 1999). Human encroachment into forested areas and indiscriminate logging of forests has led to soil erosion, leading to deterioration in water quality and a reduction in the storage capacity of reservoirs and their useful life.

African cities have similar water problems. The similarity of water problems includes the loss of water through distribution networks, the tap water quality, intermittent supply, the sources and uses of raw water (Anand Chiplunkar et al., 2012). The excessive use of groundwater has led to some cities experiencing severe environmental problems such as land subsidence, depletion of groundwater, and the deterioration of water quality. In addition to that, most African cities do not have adequate sewerage networks or efficient wastewater treatment systems and therefore still depend on septic tanks and other onsite sanitation facilities. Due to this situation, water pollution is a common occurrence as the dirt loads in the groundwater sources and freshwater bodies.

Although Africa has grown in urbanization over the last few years, the rate of water service delivery has not been improved, thus leading to high pressure on the already existing water resources, creating a water deficit. Urbanization heightens the relationship between available quality and quantity of water (Bahri et al., 2015). African cities are faced with high costs as they try to develop new water sources, cater for water treatment, and have systems in place to counter water shortages. This is despite the limited means available and the growing need not only to expand the supply of water to meet the increasing demand due to population and industry growth but also to ensure that the water quality is maintained.

An added major challenge to the populations in urban areas is to create designs that are resilient to climate change and population growth (Butler & Maksimovic, 1999). This can be done in an effort sustainably manage the water resources and go further into protecting the natural environment (Newman, 2001). It is now widely recognized that the traditional approach to urban water management is grossly inadequate to address current and future sustainability issues (Ashley et al., 2003).

To reorient urban areas towards sustainability and resilience, it is recognized that different aspects of urban water systems need to be seen about each other. This would require the adoption of an integrated approach to water system management, planning, and provision in the urban areas should be adopted as proposed by Mitchell, (2006). Urban water management has its main goal of ensuring that the urban areas have access to clean drinking water and sanitation services. Other than that, urban water management also ensures the management of storm water, rainwater, and works to reduce other water-related risks such as water-borne diseases and floods, and landslides.

Making African cities more sustainable and resilient requires a major socio-technical overhaul of traditional approaches. This complexity has been reduced in the past by the water managers through optimization and focusing on single sections of the water system, especially the supply security. This is

done in separation and not in any consideration of any other dimension of the water cycle. As a result of this, most of the urban water management objectives and best practices are compromised (Brown & Wong, 2009).

Natural disasters such as floods and droughts are common in Kenya, these disasters pose a challenge to scarce water resources. The number of premises in Kenyan urban areas with piped water services has been declining. In 1990, the percentage stood at 56% while in 2000, the number declined to 50%. By 2010, the percentage of households in the Kenyan urban areas stood at 46% (UNICEF, Joint Monitoring Programme, 2012). The fact that informal settlements in urban areas keep growing adds to the challenge of sufficient water supply in the urban regions. Providing water in informal settlements in urban centers is difficult for the service providers as the government rarely gives priority to such areas. UNDP (2011) gathered information that indicates that the residents in informal settlements have no title deeds and therefore risk being evicted. The realization that these residents risk being evicted at any time makes it hard for the government and other private investors to input water infrastructure. Other than that, the laying down of water infrastructure in informal settlements would also prompt further eviction to facilitate pipe laying (UNDP, 2011).

The performance of the water and sanitation utilities in Kenya is generally low. Services in Kenyan cities and towns are characterized by irregular supplies, insufficient pressure, constant customer complaints, frequent breakdowns, inefficient operations, poor maintenance and low finance levels. Evidence of poor water management practices in urban areas includes the extensive use of public taps. In developed countries where there are better management practices, there are no public taps since the public already has 100%water coverage. Public taps are an indication of lower levels of service as well as high water wastage. The concept of sustainable development has emerged as a globalized and holistic means of solving problems of this nature. Management of water resources would imply the use of environmentally friendly means for the extraction, treatment, improvement and distribution of water. (Sullivan et al., 2003).

According to the Kenya constitution 2010, Kenya is a democratic nation governed under two government spheres: National and County. According to Article 6 of the Kenyan constitution, the country is divided into 47 counties, with every county operating under a county government. From Article 174-200 of Chapter 11 of the Kenyan constitution, it is provided that devolved governments shall appoint city and urban areas boards, which are units of decentralization under the counties. The two major legislations

are the County Governments Act of 2012 and the Urban Areas and Cities Act of 2011. The Machakos County Assembly in 2018 approved the establishment of Mavoko municipality in accordance with section 9 of the Urban Areas and Cities Act of 2011.

Mavoko municipality has water scarcity struggles due to the increased population and the increased economic activities. Urbanization brings along population growth which has, in turn, put pressure on the existing local water sources resulting in the shortage of water in recent years. With projected water demand of 570,000 M^3 per month, the utility company is able to supply approximately 145,000 M^3 per month (MAVWASCO, 2020).

Any strategy for addressing urban water scarcity should involve the building of sustainable and resilient water services that can be able to deal with water scarcity, increased demand, and current and future climatic change (UNICEF, 2012).

This study explores water management in Mavoko from a social and technical view set within a framework of potential changes toward sustainable urban water management. It will also explore the different household, industrial, and commercial enterprises' water management practices currently in place in the municipality, their drivers, and how these de\rivers can be remodeled to fit more sustainable water management modes.

1.1 Problem statement

Batten (2016) explains water sustainability as the ability to make clean water easily and efficiently available to residents as well as commercial businesses. Batten further explains that water sustainability goes further into the protection of waterways from pollution as well as making sanitation services easily accessible to the residents. In addition to that, sustainability in relation to water means that there is resilience to extreme weather conditions that might result in conditions such as flooding or scarcity.

Batten (2016) argues that water sustainability in cities can be measured in three elements; resiliency, efficiency, and quality. According to Batten, a city that is water resilient is always prepared to handle challenges relating to too little or too much water. With this being the case, the resident of an area is protected from disasters caused by too much water, such as flooding, and also problems caused by the lack of water, such as drought. This is while ensuring that the water supply still continues uninterrupted. Water management is vital for the functioning as well as the moving forward of a community, for with efficient water management, production and distribution of goods and services can go on uninterrupted, and the water can still be reserved for the preservation and continuity of future generations.

A city that can be termed as water-efficient rarely has instances of water leakage and has high accountability for water usage because of the aspect of metering (Batten, 2016). A city with a high-quality water supply has low instances of water-related diseases, good sanitation, and less water pollution. High-quality water promotes city competitiveness, business investments, and recreational water activities.

Athiriver Township has over decades experienced water shortage mainly because of rapid urbanization and high population growth due to its proximity to Nairobi City County. The town lacks enough water sources which can sustain supply to the ever increasing demand. The demand for water currently stands at 570,000M^3 per month, this is way beyond the water sources capacity of supplying 145,000M^3 of water per month (MAVWASCO, 2019). Population growth has created an imbalance between the supply and demand for water in the town. This has resulted in a water crisis and people are unable to meet their water needs. (Mulwa F. et.al, 2021). The fact that there is a growing need for water with the growing population and economic activity in the municipality, coupled with the scarcity of water, has further put pressure on the available water resources to continuously supply quality water to the people of Athi River town.

Aging and inadequate water infrastructure have contributed to scarcity as well as the inefficiency of supply in Athiriver town. Athiriver urban water systems have been superseded by time due to irregular maintenance schedules that hinder upgrading. This has resulted in poor performance in water distribution from different sources to end users. Inadequate water infrastructure has led to high non-revenue water of 44% annually (MAVWASCO, 2019).

The management of urban water services is mainly challenged by the fragmentation of institutions and the lack of coordination across sectors. Policy implementation is slowed down by the fragmented institutions divided between the state, municipal and devolved governments, which in most instances make service management in urban areas inefficient. There is, therefore, a lack of coordination between the municipal, county, and national levels, which creates undefined tasks and responsibilities, which results in the poor implementation and enforcement of water regulations.

Unsustainable water supply has impacted urban development in Athiriver by reducing its competitiveness as an industrial town, minimizing productivity, and deterring business investments. Conventional urban water management plans have been unable to meet the people's water needs, as well as industrial water, wastewater treatment, and other water-related services. Planning for water

sustainability in Athiriver is inevitable in order to ensure the town gains a competitive edge and attracts business investments that will increase productivity.

In view of the above, this research is designed to understand factors which hinder sustainable supply and demand management of water and will propose recommendations on the management strategies to promote sustainable urban water management.

1.2 Research objectives

The major reason why this study was carried out is to discover a solution to challenges facing the management of water sources and their infrastructure in Athiriver Township.

The sub- objectives are:

1. To evaluate the existing water and infrastructure management issues in Athi River Township, Mavoko municipality.
2. To investigate success factors and successful water and infrastructure management case studies around the world.
3. To recommend working water and infrastructure management solutions in Athi river township, Mavoko municipality.

1.3 Research Questions

1) What is the state of water and infrastructure management in Athi River Township, Mavoko municipality?
2) What are the best practices for water and infrastructure management in the world?
3) What are the appropriate policies and strategies to improve management of water sources and infrastructure in Athi River Township, Mavoko municipality?

1.4 Significance of the study

The water sources available in the municipality are slowly depleting, and this problem is worsened by the high rate of population increase. With the growing population, there is an increase in the need for water as a resource, therefore creating a strain. This, therefore, means that there is a possibility for the municipality to be considered in a 'Water Stress' in the next ten years. Larger populations do demand larger portions of water, and with insufficient water supply, there will be a severe scarcity of water in the municipality. Sustainable solutions are required to reduce the vulnerability of Athi river town to these sudden changes in water demand.

Water sources in the community rely on rainfall to replenish both surface and underground sources. With unpredictable climate change, water sources will become scarce in the near future. Mavoko, as a semi-arid area, will be equally affected, which is why an action plan is needed to prevent foreseeable water shortages due to climate change.

The quality and reliability of water services in the municipality are threatened by poor water infrastructure. High water leakage leads to the loss of large water volumes and increases the chances of water infiltration and ex-filtration. Through the case studies, this study will help MAVWASCO to understand how other countries have been able to reduce non-revenue water.

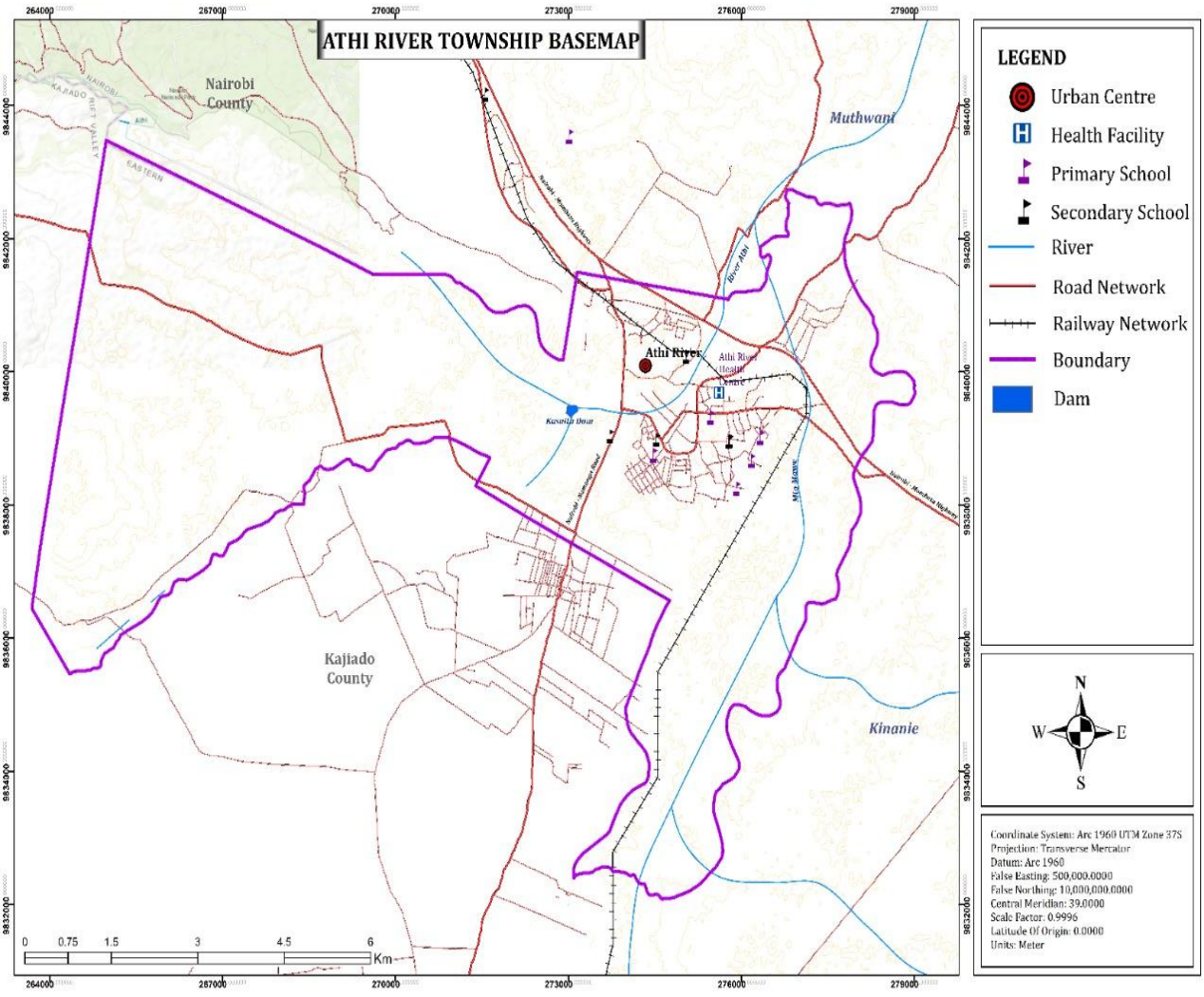
Understanding the water management structure in Kenya and the functions of various institutions will help in identifying various gaps in implementing the numerous water laws and policies. This will help the national government and county government to harmonize the laws and policies to ensure efficient water management in municipalities.

1.5 Scope of the study

Studying the whole of Mavoko municipality would be time consuming and expensive. In this respect, the study will sought to examine water infrastructure management issues in Athi river township Mavoko municipality, Machakos County, Kenya. The study will be conducted within the boundaries of Athiriver ward. The scope of the study is limited to water management in Athiriver Township. As shown in the map 1 below.

Athiriver Township Base Map

MAP 1: ATHIRIVER TOWNSHIP BASE MAP



(Source author)

The study will examine domestic, commercial and institutional water uses. The research will sought to evaluate water sources, water supply infrastructure and demand management. The study will not entail waste water management. It would further look into policy, legislative and institutional measures in place for sustainable water management.

The focus of data collection will be households, commercial enterprises, institutions and government agencies in the water sector. Secondary data will be collected from Mavoko water and Sewerage Company.

1.6 Limitations of the study.

Inadequate technical information due to limited studies on urban water management in Mavoko municipality. Financial constraints which prevented collection of adequate data. Some government institutions were not willing to respond to the questionnaires or participate in interviews.

1.7 Organization of the study

The study is structured into six chapters. Chapter 1 comprises of introduction to urban water management which entails description of water supply situation in cities around the globe and the country. The problem statement, research objectives, research questions these sections give details of the problem description in the study area and the objectives which will guide the study. It also has the research questions which are arising from the objectives.

Chapter 2 is literature review covers global perspective of urban water management and the dimensions of sustainability which will be considered in this study. The chapter also gives urban water management parameters of water supply and water demand. Three case studies with best practices across the globe are analyzed in this chapter and a summary of lessons learned discussed. Theoretical framework and conceptual framework are explained in this chapter.

Chapter 3 is research methodology, in this chapter the research design of the study is discussed. The instruments of data collection, data analysis methods and presentation techniques are discussed. Chapter 4 on study area analyzes the Athiriver Township its location, climatic conditions, demographic profile and economic activities. Water governance and legal framework are discussed in this chapter. General Water supply and demand situation in the country are discussed in this chapter.

Chapter 5 entails data analysis, data presentation and discussion on field findings. Chapter 6 entails summary of study findings, conclusions, recommendations, and areas of further research and implementation matrix of proposed strategies in the study.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Background

Global water consumption is anticipated to rise as populations and countries develop, leading to issues like water scarcity and declining water quality. This poses an objection to the experimental and technical group to develop new strategies for better regulating water supplies (Antigoni, 2017). Based on the impact on society as a metric of devastation, the water crisis is the top global danger (World Economic Forum, 2015). Water should indeed be seen as a resource with enormous potential to boost city dwellers' life satisfaction.

Since water is intimately connected to many major global concerns, water is at the center of sustainable development (UN, 2012). Antigoni, (2017) explains that water is critical to reducing the global burden of disease and improving the health, well-being and productivity of populations. Additionally, it plays a crucial role in creating and maintaining a range of advantages and services for individuals. Water is the vital link between climatic changes, humankind, and the environment and is also at the center of adaptability to climate change (Antigoni, 2017).

The UN announced the "Water for Life" decade from 2005 to 2015 (UNDESA, 2015). Its objective was to support global initiatives to fulfill international obligations by 2015. These dedications are helping to achieve MDG 7: guarantee environmental sustainability, with emphasis on objective 7c: Reduce by half 2015 the percentage of persons without reliable access to basic sanitation and clean water; this goal was achieved in 2010. (WHO, 2019). In order to accomplish the water targets of the Millennium Declaration, the Johannesburg Plan of Execution of the World Summit for continuous advancement, and Agenda 21, they attempted to build stronger partnerships between governments and various stakeholders, between countries and ethnic communities, and between commercial advantages and the needs of ecosystems and the poor.

The UN congress approved a resolution in July 2010 recognizing the right to access clean water for drinking and sanitary facilities as a fundamental human right necessary for the enjoyment of life to the fullest and of all other rights. The General Assembly eventually decided on a water goal in September 2015 to guarantee accessibility and efficient access to water and hygiene for everyone.

Water quality can equally affect how much is available to meet specific needs; thus, availability is not solely a function of quantity. Poor wastewater treatment is a significant contributor to the degradation of urban water resources, which has adverse effects on ecosystems, human health, and water-dependent livelihoods. Throughout history, the success of urban communities has depended on having a reliable water supply and the ability to manage garbage (Akica, 2012).

Improper water management causes serious financial, environmental, and social problems, and the appropriate use of these water supplies is becoming more and more crucial. This situation emphasizes the necessity of developing alternate water supplies, regulating demand, and, most importantly, taking the durability of all these water sources into account (Kumudu Rathnayaka et al., 2016). Various water sources, including desalination, recycled water, storm water, and rainfall have been developed and are used in many places of the world due to technological breakthroughs and the growing need for alternative water resources. Water is cleaned using the right technology for the intended use and delivered to satisfy various water requirements, including drinking, other domestic end users, agriculture, industrial, corporate, institutional, and recreational.

In African cities, governments and urban communities operate largely within the traditional paradigm of urban water management. In this approach, large, centrally managed water infrastructure systems seek to provide safe, reliable, and cost-effective water supply, drainage, and wastewater management services. These services are delivered separately and are reflected in the urban water cycle as each infrastructure is developed and managed as a distinct component. While traditional approaches have provided urban populations with access to safe drinking water, flood control, and public health protection, the provision of such services results in several negative impacts, including water pollution, ecosystem disruption, high energy and chemical consumption, and costly maintenance (Mitchell, 2006). Traditional practices have also been criticized for creating rigid institutional frameworks that are unable to respond to the complexity and uncertainty of emerging challenges. (Brown and Keath, 2008).

2.1.2 Global perspectives on water supply and demand

According to Boretti & Rosa (2019), when water needed exceeds water available supplies is known as a "water shortage." If a nation's annual water availability per person is less than 1700 m3, the nation is considered to be under water stress. With a yearly per capita supply of fewer than 1000 m3, Kenya is one of the water-scarce nations in the world (Jones, J.A.A. 2014).

In 2015, 844 million people were still denied access to even the most basic drinking water services, with an anticipated 2.1 billion missing access to safely managed services (WHO/UNICEF, 2017). There will be 2.5 billion additional people living in cities worldwide between 2018 and 2050, with approximately 90% of that growth occurring on the continents of Asia and Africa (UN DESA, 2019). Water demand is anticipated to rise as the population grows, threatening the world's limited supply.

It was expected that the total annual water consumption in the world in 2010 was 4,600 Km^3, and that need will rise to 5,800 Km^3 in 2050. (Burek et al., 2016). In 2010, the African continent's water requirement accounted for 5% of the total global consumption; by 2050, it is expected to escalate to 8%. Asia continues to be the world's largest consumer of water on a significant level, particularly for agricultural usage.

Water availability is decreasing due to declining supplies despite rising water demand. The amount of water available in 2010 was 53,900 Km^3 per year, and the projected available water in the year 2050 will be 53,300 Km^3 per year (Burek et al., 2016).

2.1.3 Global administrative perspectives of water management.

Various international bodies, Non-Government Organizations, professional societies, donor agencies, and research institutions have prepared documents and literature concerning water issues. Several conferences on the global stage have been held to discuss water as a natural resource. Institutions of higher learning and research have conducted a great deal of research to find solutions to the issue of water as a resource.

Organizations and networks involved in global water management use various methods to create and carry out initiatives. The national and local water governance structures and critical stakeholders are empowered, involved in problem-solving, and able to support implementation efforts on the ground thanks to these action routes. Setting international water treaties and laws, funding water resource operations and service distribution efforts, establishing and popularizing minimal level and best strategies for water implementation of strategies, enabling technology, knowledge exchange, conducting learning and awareness programs, and gathering, tracking, and analyzing water-related information are the main avenues that have historically been sought to resolve global water hurdles (Heather et al., 2013).

The Millennium Development Goals (MDGs) from 2000, the Global Decade for Action, "Water for Life" from 2005 to 2015, and the 2030 Agenda for Sustainability all make significant recommendations on regulations, pushing the new Goal of Sustainable development, remain to be crucial to the global

water industry's agenda to increase access. The MDG 7 on ecological responsibility aimed to reduce the sum of people lacking better connection to clean water for consumption by 2015. The only areas that did not meet their targets were Sub-Saharan Africa (SSA) and Oceania, even though the global MDG objective on the water was met by 2010, five years ahead of schedule. With rare exceptions, most SSA countries fell short of the water goal's rural and urban benchmarks. The United Nations officially stated in a resolution from 2010 that "pure consumption water and hygiene are vital to the fulfillment of every single civil freedom" during the "Water for Life" Decade, which ran from 2005 to 2015. The SDGs affirm hygiene and sewage as a separate goal number 6, which includes more expanding targets focusing on other aspects of water like management and governance, sewage, and ecosystem resources, in contrast to the MDGs, which absorbed water and sewage under Goal 7 to ensure sustainable development (UN-Water, 2015).

One of the most decisive necessities of human civilization is connection to pure, safe, and dependable water for consumption. As such, all partners must work together in collaboration and with an integrated strategy (IWA, 2004). In a secure water future, water use for human life and welfare is prioritized alongside its intrinsic worth. One-fifth of the global population lacks access to clean drinking water, and service issues predominantly impact developing countries' poorest areas of society (Global Water Partnership, 2000).

Sound water management improves countries' economic and social well-being. In addition, the ability of water utilities to utilize a wide range of alternative supply and service procurement options also improves water security, stimulating economic growth and sustainable development. Improved water supply, sanitation and better management of water resources drive countries' economic growth and contribute significantly to poverty eradication.

The quantity and quality of water sources have been under tremendous strain due to unsustainable development strategies and governance breakdowns, which has compromised their capacity to produce benefits for society and the economy. The need for water in towns is often raised by rapid urbanization, growing industrialization, and improving living standards.

The UN-Water strategy for 2050 is a globe where everyone has access to enough water in sufficient amounts, of reasonable quality, and from maintainable sources to satisfy their basic requirements and maintain their wellness and development. It imagines a society where fair ingress to water supplies and

amenities for all people will promote greater social participation, and access to water will no longer be a gendered burden.

Strong collaboration and coordination among various government agencies within a nation and across international borders, the creation of policies and incentives to deter people from uncontrolled groundwater extraction, the balancing of water rights, and providing critical players with correct information to engage in decision-making are essential components of establishing good governance (Binaya et al., 2020).

2.2 Dimensions of sustainable urban water cycle systems.

The sustainability idea was initially described in the context of Urban Water Cycle Systems (UWCS) as " being one of those water basic systems that are designed and managed to completely support the community's goals both now and, in the future, while maintaining its environmental sustainability, and hydrological reliability (ASCE & UNESCO, 1998). The UWCS sustainability components that Rui and Kees (2012) propose to include environmental, social, economic, infrastructural, and governance

Regarding the social aspect, continuous UWCS should provide ingress to town water initiation, and these operations precondition successfully meet the requirements and expectations of the present consumers. Social sustainability is a cooperative effort between society and the water utility to increase resource efficiency. Contrary to what occurred in the past, urban water utilities are now blatantly customer-focused, and the goals go beyond merely ensuring that the service is available. People predisposed to conserve water often recognize the value of water resources, see conservation as a moral imperative, and are likely to incorporate effective water-use habits (Pearce et al., 2014).

Moreover, sustainability should mean that the UWCS is accepted and its community contributions are significant. The UWCS environmental component focuses on how UWCS affects living and non-living biological ecosystems. It includes maximizing the use of water, energy, and materials while minimizing any adverse effects that may arise afterward (effluents, emissions, and waste).

In UWCS economic sustainability advocates for use of water as a natural resource to satisfy present consumption needs without compromising future water needs. Exponential consumption of water resources in cities without plans for conservation can lead to economic challenges to water utilities. To achieve economic sustainability water utilities have to develop strategic plans which promote water conservation and make adequate investments to develop the available water sources for present needs

and future needs .Water production can be increased by having rain water harvesting and water recycling policies in cities. Prevention of water pollution will help to protect the existing water supply sources.

In agreement with (Organization for Economic Co-operation and Development (OECD), 2011), water governance is a collection of bureaucracy with a primary focus on both state structures (laws, official policies) and institutional arrangements (power relations and practices), as well as coordination mechanisms and their effectiveness. Three water governance models—hierarchical, market, and network—can be identified at the metropolitan level. The market model relies on a more significant approval of stakeholders for water administration and ownership of water belongings. The hierarchical system depends on top-down methodologies in decision-making and execution for water access with centralized government authorities, vertical responsibility, and poor consultation. The network model also relies on decentralized management techniques and the collaboration of private, social, and public actors (Oriana & Aziza, 2019). Beyond the theoretical approaches, hybrid governance approaches are used in practice.

Good governance should help define and carry out policy objectives at the lowest feasible charge to the public (efficiency) while also ensuring that all stakeholders are included (trust and engagement).
Policies, people, and places are three elements that impact governance.

Policy: urban water administration influences the usage, quality, and safety of water resources and can be impacted by a variety of fundamentally connected policies, including land use, spatial planning, transportation, fuel, waste products, ecology, and agriculture (Oriana and Aziza, 2019). When policies are coordinated, inter-sector complementarities are favored while resources are assigned effectively.

People: Numerous individuals, including urban designers, water network operators, regulators, advisers, and members of civil society, have a stake in or a part to play in town water management. These individuals come from the public, private, volunteers, and water consumers. They all support dynamic and comprehensive approaches to the management of water resources. Assuring the responsibility of city administrators to citizens and terminal users, fostering trust and possession among stakeholders, securing the ability to pay for water services, establishing convergent goals across policy regions, and preventing and resolving disputes over water distribution are all possible benefits of stakeholder involvement (OECD, 2015). In order to increase public understanding of current and prospective water dangers and to increase the sociopolitical acceptability of changes, stakeholder involvement is crucial (Oriana & Aziza, 2019).

Places: Boundaries are erased by water. Because of this, overcoming geographical incompatibilities and promoting cooperation between cities and their environs necessitates developing location knowledge (rural and watersheds). In this situation, urban-rural collaborations offer win-win outcomes that benefit cities, populations, distributaries, and environments (Oriana & Aziza, 2019).

The term "infrastructural dimension" refers to a system's infrastructure facilities and can refer to characteristics of the system's functionality, sturdiness, dependability, flexibility, and adaptability (Ashley et al., 2002). The structure should be strong enough to adjust to demand and deal with ongoing or sporadic difficulties. Infrastructure will need to perform and respond more quickly due to population increase (or decline), severe rules, climate change, technology advancements, and higher consumer expectations. A workable structure for the gathering, transportation, purification, preservation, and circulation of water for both public and private usage in household, industrial, commercial, and agricultural regions is necessary to build a viable water supply system.

The provision of drinkable water is unquestionably the most crucial municipal requirement. Residents rely on water for personal requirements. Urban water delivery systems, however, must also quantitatively include all additional public, corporate, and manufacturing operations (Antigoni, 2017). Given current challenges related to population expansion, climate variability, and environmental effects of conventional practices, the delivery and administration of these services have grown more challenging (Wong & Brown, 2009). Figure 1 below highlights sustainability dimensions of UWCS.

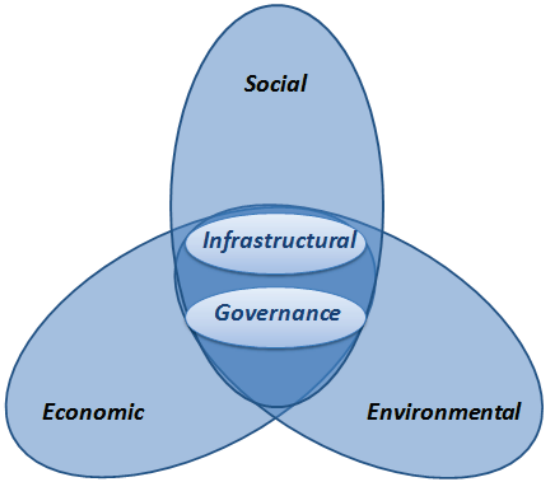


Figure 1 DIMENSIONS OF SUSTAINABILITY

(Rui and Kees, 2012).

2.3 Urban Water Management Challenges

Urban water administration presents a variety of difficulties in developing nations. The system is complicated due to the many elements and stakeholders that must be considered and the wide range of socioeconomic conditions.

i. **Water scarcity:** Regarding urban water distribution and sanitation, water shortages offer both a difficulty and a chance. It is difficult since there are generally no new water origins that could be created cost-effectively for large urban areas in underdeveloped countries (Biswas, 2006)

ii. **Rapid and unplanned urbanization**: Currently, metropolitan regions house 54 percent of the global total (3.9 billion people); by 2050, that figure is expected to rise to 66 percent, with over 90 percent of that expansion happening in Asia and Africa (UN, 2014). Urban areas in developing nations are already strained to prepare for and house the current population sustainably. Urban sprawl makes it more difficult to deliver essential services because unrestrained urban growth has raised the demand for infrastructure and resources (land, energy, water, and transportation) at unfavorable densities (Prietoa, 2010). Water resources, the ability of the water distribution system to give water in both quality and quantity to everyone, and the ability to treat rising amounts of sewage and fecal waste are all under strain due to escalating water demand and shortage. Additionally, due to urbanization, shifting urban landscapes are impacting the local hydrology and ecology by diminishing options for natural infiltration and causing quick peak stormwater runoff flows (Jacobsen et al., 2012).

iii. **Insufficient Capital investment:** To operate and keep the sewage and water systems that are now in place in urban areas of growing countries, appropriate funding must be made available and released promptly. Lack of funding frequently restricts the operation and upkeep of current water and sewage sanitation services and the development of new ones (Biswas, 2006). It would be essential to identify the financing or investment gap that must be closed as precisely as possible to establish a pertinent funding approach. Additionally, it would be crucial to make a clear distinction between capital expenses and ongoing expenses, as each of them requires a different financing strategy (Earl et al., 2019)

iv. **Inefficient water management**: Today, metropolitan water management practices are still sector-specific and lack the requisite breadth to effectively address the multifaceted water-related issues facing cities in emerging nations. When they do exist, watershed methods for metropolitan water management are frequently dispersed and poorly organized with the delivery of many other

urban services. Poor management is one of the leading causes of water systems' ineffectiveness and subpar performance. Unattractive pay and frequent political meddling in management processes and decisions at the water companies are the primary causes of the poor administration (Biswas, 2006).

v. **Climate change adaptation**: The increasing fluctuation in water accessibility resulting from the climate crisis, including rising global temperatures, altered changes in precipitation, and weather variability, must be considered while managing urban water resources. According to estimates, 150 million individuals live in cities that consistently lack water; by 2050, population density might increase to 1 billion (McDonald et al., 2011). Additionally, the majority of the significant environmental risk are potent in urban areas due to high rates of urbanization and fast expansion of large cities, as well as an increment in highly vulnerable urban communities that live in informal establishments, most of which are located on the shoreline that is especially disclosed to climate advance effects like the increasing sea level and other severe climate (Revi, 2014). Water infrastructure and supplies are anticipated to be impacted by climate change in quantity and quality, primarily due to flood destruction, rising treatment costs, and decreased operational capacity. Many slums miss drainage systems, or the existing ones are clogged with trash. Overflow from raw sewage from leaking sewers can be caused by heavy rain (Twumasi & Asomani-Boateng, 2002).

vi. **Ageing and deterioration of existing infrastructure:** The equipment for metropolitan water systems (storing, purification, delivery, and distribution) is nearing or has already exceeded its planned lifetime in most African cities. These resources have not gotten the required attention for replacement and preservation due to a lack of routine maintenance cycles, inadequate information on the investment projects worth (and extent), and a lack of effective decision-support instruments.

vii. **Water governance:** One of the most pressing issues affecting the water industry in developing nations is the poor implementation of policies and plans, which results from insufficient governance systems (Remmert, 2016). The entities handling stormwater management, water supply, hygiene, and resource provision are not coordinated enough. The low governance performance also mentions the difficulties with decentralization and the lack of essential governing tools. Organizational and legislative adjustments are necessary to avoid constricting sectoral views and support an integrated strategy. (Vairavamoorthy and Bahri, 2015).

2.4 Urban water management parameters

The main parameters which will be looked at in urban water management are water supply and demand management.

2.4.1 Water supply systems

Cities need to have a reliable and resilient water supply that uses conventional and alternative water sources with minimal energy consumption. Alternative water management practices such as incorporating water recycling and reuse, rain water harvesting, desalination, groundwater storage, and demand-side management measures such as efficiency and water conservation can bring greater flexibility and resilience to local and regional water systems. These concept of portfolio approach in water management can be considered by utilizing water from various sources. The alternate water sources are discussed below.

a) Surface and ground water supply

For urban water supply needs, groundwater and surface waters are essential sources. Because most bacteria are cleaned out by the soil and rocks through which groundwater travels, groundwater is less prone to infectious contamination than surface water (Antigoni, 2017).

Lakes, rivers, marshes, dams, water pans, and the ocean serve as surface water supplies for Kenya. Five catchment areas—the Lake Victoria basins, Tana, Rift Valley, Ewaso Ngiro and Athi—contain the surface water resources. Dams built in rivers and valleys that serve as reservoirs are used to extract surface water. Water pumping systems can be installed to extract it directly from the rivers and lakes.

b) Rain Water Harvesting (RWH)

"Rain water harvesting refers to collection and storage of rain water" (Devon et.al 2015). It's collected from rooftops and stored in a tank. Rainwater is a promising Alternate Water Resource (AWR) due to its low treatment requirements compared to other AWR, low environmental impact, and additional benefits of runoff and peak flow reduction, rainwater is a good option water resource. Despite the benefits of RWH, its development is restricted, most likely due to misconceptions about the quality of rainwater and inconsistent water supplies caused by seasonal change. The gap between our present understanding and future requirements is being closed by scientific innovation, albeit there are some excellent RWH examples. (Devon et al., 2015)

Uneven rainfall distribution across the year is among the obstacles to adopting rainwater to maximum. Because there are not enough rains during the drought, rainwater is not seen as a dependable water

source. Having multiple storage tanks that can store water and be used during the dry season can solve this problem. RWH offers great promise to make metropolitan waterworks more resilient. Rainwater can serve as reserves when the distribution of water is suddenly cut off due to an unexpected power outage, a pipe breakage, or a natural disaster. RWH can help reduce floods without adding to the sewer system's volume, and stored narrowly rainwater can be used to supply fire-extinguishing water to fight fires.

Although effective RWH initiatives have raised public knowledge of the advantages of RWH worldwide, more has to be done to increase public awareness and encourage the implementation of RWH systems (Devon et al., 2015) Adding lessons on water conservation, harvesting, and reuse in school curricula can raise attention, especially among young people.

c) Water Reuse and Recycling

"Municipal water reuse is the process of treating gray or residual water from showers, bathtubs and sinks (in some cases washing machines) appropriately to meet non-potable needs" (Butler et al, 2009).

Water reuse increases the possibility of conserving the available freshwater supply, which is frequently exploited beyond sustainable limits. Reusing recycled water for potable purposes is gaining popularity. The exceedingly minimal risk of sickness from contaminants is a crucial factor in many uses. To reduce the risk of dispersing potentially dangerous contaminants, additional alternatives should be installed at all operations that are intended to reuse water, whether explicitly or implicitly (Rietveld et al., 2011).

After being released into a groundwater or surface reservoir, reclaimed water is subjected to indirect potable reuse (IPR), which involves treating it to drinking standards. Before reaching the ecosystem, wastewater may receive either sophisticated or essential purification; however, it must be thoroughly purified before it is released into the communal supply (Leverenz et al., 2011).

Reclaimed water is cleaned to drinking-water standards and then blended directly with the water supply in a process known as direct potable reuse (DPR). Redeemed water DPR is frequently regarded as a viable choice for the time ahead. It lessens the burden on currently used outside water resources and does away with the requirement for a different distribution infrastructure when collecting water for non-potable uses (Devon et al., 2015). The concentrations of dangerous contaminants in water can be decreased to deficient levels that do not endanger human health thanks to ongoing advancements in water treatment technology.

Because DPR allows for local water reuse rather than long-distance transportation, it may also be cheaper, less fuel, and simpler to install than other water resource solutions (Leverenz et al., 2011).

Community acceptance is a significant obstacle to water reuse, especially potable reuse, as many people are fundamentally wary of drinking or utilizing recycled water.

Reusing non-potable water is significant to recycled water since it can be used in place of potable water to save the overall supply. Non-potable recovered water can be used for various purposes, such as industrial processing, street cleaning, flushing toilet, and horticulture. In order to save freshwater and increase supply, it may be necessary to expand non-potable water reuse techniques and increase system effectiveness (Kalavrouziotis et al., 2015).

d) Desalination

Desalination is a method used to remove minerals from saltwater. In arid and semi-arid areas, desalination can significantly lessen or totally solve water scarcity problems (El Saliby et al., 2009). Making desalination technology viable and available in coastal locations or atop saline groundwater sources could assist a compelling section of the global community in attaining their water demand. Regrettably, classical desalination methods still have high financial, energy, and ecological impacts. These expenses include emissions of greenhouse vapor, disturbance of sea life during planning and construction and at absorption points, and the discharge of saline liquid that contains chemicals and is hazardous to submerged organisms (Lattemann & Höpner, 2008; Baten & Stummeyer, 2013). Investigating cost-effective and efficient techniques is necessary to lessen these effects and enable desalination, a less expensive alternative water supply.

2.4.2 Water demand management

"Water demand management is the adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability" (Department of Water Affairs and Forestry, South Africa (DWAF, 1999).

Metropolitan water resource management has changed from supply to demand management globally as a consequence of rapid population growth, prolonged dry spells, rising water demand, rising energy costs, the need to delay the building of large-scale water supply due to budget constraints, and hot and dry or semi-arid weather conditions (Magnusson, 2004).

Demand management seeks to alter how businesses and industries utilize water to boost efficiency and lessen the need for costly infrastructure expansion. It has been recognized as a potential substitute for or enhancement of the traditional strategy of boosting supply by investing in infrastructure (UNEP, 2006).

Urban water need management prioritizes management of water resource usage and alternate water supply (Binaya et al., 2020). The subsequent must be put into consideration in order to regulate water demand. Utilizing projections, the first stage is to evaluate the present and forecast water needs based on projected population increase, urbanization, and water usage rates (Rathnayaka et al., 2016). The second phase analyzes the water management and supply infrastructure in its existing status. Analysing water wastage (non-revenue water) using widely accepted indicators in the evaluation is crucial (Binaya et al., 2020). Water tariff reforms also offer a means to encourage water conservation and apply fines for wasteful behaviour (Raj, 2016). The final step in attaining efficient demand-side management is raising knowledge about water reuse and recycling, water purification at the place of use, and rainwater harvesting through social media, networking websites, door-to-door campaigns, or community outreach (Binaya et al., 2020).

Implementing urban water demand management advances the creation and uptake of new technologies, lowers water losses, promotes water-efficient use, improves water quality, rises billing (financial sustainability), upholds the high efficiency of the water system, and raises public awareness of water conservation among citizens (Baki et al., 2018).

Increased surface and underground removal rates have historically been the standard response in traditional water management situations to rising water demand brought on by population and wealth increases. Environmental deterioration and excessive exploitation of several freshwater resources result from this. Municipalities and corporations use various measures to manage water demand, including monetary incentives, water-saving equipment, metering, awareness raising, and leak repair.

a) Water Pricing

According to economic theory, water price demand flexibility is the most crucial factor to comprehend if water managers adjust prices to manipulate water demand. This is because, when everything else is constant, a rise in the price of water results in a decline in demand (Olmstead & Stavins, 2009).

Incentive structures can be utilized in a few ways that are generally highly effective in lowering water demand. They include increasing water prices to reflect total selling price, providing deduction on water expenses in exchange for implementing specific water distribution best custom, or providing explicit

refunds on appliances that conserve water (Biswas et al., 2009). Utility credits are given for good practices for managing the water cycle, such as watershed management, RWH, water reuse, and others. Offers of monetary incentives, tax exemptions, and other benefits are made for adopting AWR and water-saving equipment. These rewards are intended to motivate people to limit water use, lowering water demand.

According to brandes et al., (2010) water utilities use various pricing structures to control water consumption, such as:

Uniform rate- Price per unit is constant as consumption increases.

Inclining block rate- Price increases in steps as consumption increases.

Declining block rate- Price decreases in steps as consumption increases.

Excess use rate -Price is significantly higher for any consumption above an established threshold.

Seasonal surcharges- Price is higher during peak periods.

Zonal rates -Users pay for the actual cost of supplying water to their connection.

Scarcity rates- Price per unit increases as available water supply decreases.

Lifeline block- A first block of water is provided at low or no cost beyond the fixed charge to ensure everyone has a minimum amount of water to meet basic water needs

In order to conserve water during the dry seasons, prevent overuse in the vacation industry, and ensure complete restoration of all expenses involved in the acquiring, purification, and dispensation of water solutions, a dynamic pricing framework incorporating an inclining block rate (IBR) and extra peak-load pricing (PLP) is necessary (Molinos-Senante, 2014). Water usage has decreased for utilities that have employed a mix of these pricing structures.

Families with lower incomes react to water charge hikes stronger and more favorably than wealthy household groups, both in terms of basic water costs and earnings (Renwick et al., 1998).

b) Water saving technologies

In the near and intermediate term, the desire for household appliances and gadgets that save water may increase due to increased awareness of saving water and rising water costs. Smart meters, low- energy rate lavatory, faucets, water savers cleaning equipment, shower heads and dishwashers are a few examples of water-saving technology that can be implemented at various scales, from homes to significant industrial and commercial structures (Devon et al., 2015).

A smart meter is a unit of cutting-edge technology used to gather more precise and detailed data on usage of water (Beal et al., 2013; Liu et al., 2016). Thanks to high- tech advancements, household may quickly learn about water usage (Seyranian et al., 2015). In contrast to traditional regularly meters, current intelligent water meters help homeowners collect data on water consumption in intensively information (Liu et al., 2015). A crucial step into urban water conservation is deploying creative ways to assess water consumption.

c) Reduction on Non-revenue water

The total amount of water generated for distribution minus the total amount billed to consumers is known as non-revenue water (NRW) (MWSI, 2019). High NRW levels can cause water scarcity during times of high demand, lowering the degree of service offered to consumers, causing erratic supply, and compromising the economic viability of water systems through lost profits and increased operating expenses (alexander et al. 2010).

UN-Habitat cites the following advantages of NRW reduction: -

I. A cleaner dataset and higher sales.
II. More drinkable water is now available.
III. Cost reduction—using fewer chemicals and electrical resources—and improved production.
IV. Postponed investment requirements to boost production capacity.
V. Accurate demand forecasts.
VI. Distribution system operation that is optimized.

Water losses, which include natural and noticeable losses, can happen at any point in the water cycle, including during removal, purification, distribution, and usage. A WSP with a high degree of NRW typically lacks the administrative and technical expertise required to deliver dependable service and exemplary leadership, autonomy, and responsibility (MWSI, 2019).

The attempts of Kenya's utility companies to reduce water losses have not been successful since rates of NRW have primarily remained stable for the past ten years, between 41 and 47 percent. Sector criteria are established by the Water Services Regulatory Board (WASREB); NRW levels under 20% are considered desirable, 20–25% are considered acceptable, and over 25% are considered unacceptable. The accepted level of NRW on a global scale is 10%.

If NRW levels remain as high and nearly unchanged as they have for the past 10 years, Kenya will confront a 30 percent shortfall between the available water and the projected need by 2030. (MWSI, 2019).

Water providers can lower NRW by locating leaks and charging customers correctly. They will earn more money; as a result, increasing their independence. The lowest-priced and most efficient way to guarantee the sufficiency of the water system is frequently water loss reduction.

Figure 2 below shows graphical presentation of NRW trend in the country from 2010 to 2018.

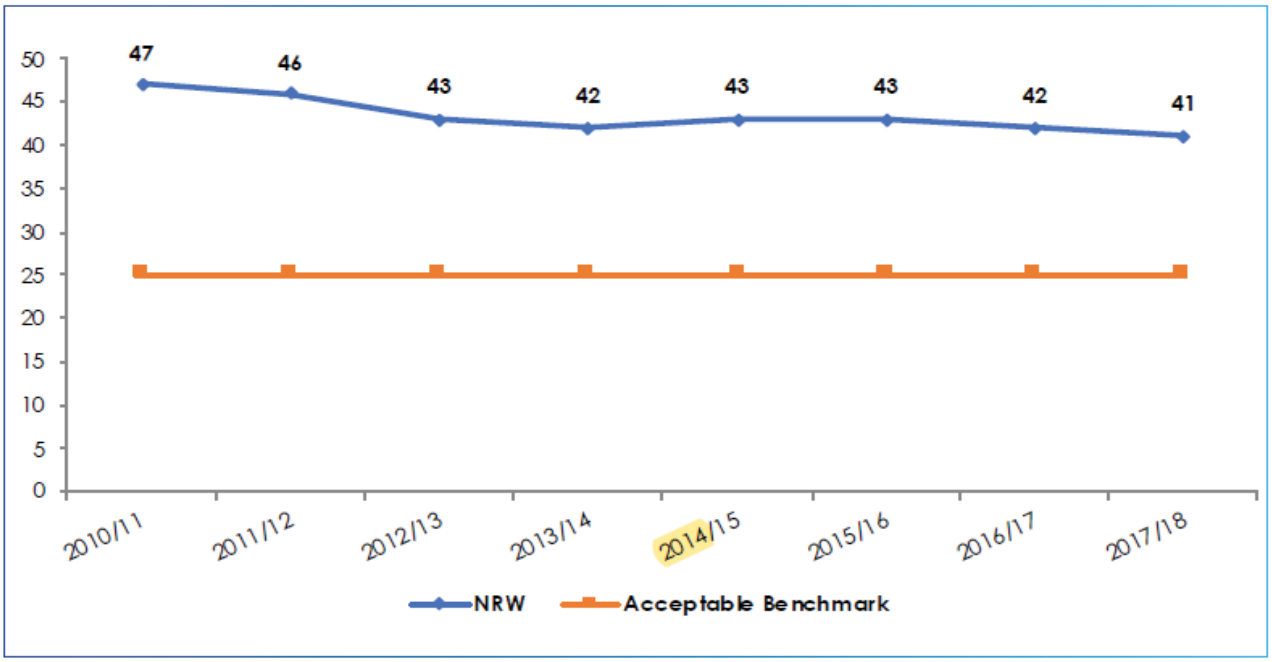


Figure 2 National Trend of NRW Ratio in Kenya

Source (WASREB, Impact Report 11)

Two prime approaches of leak administration are: reactive and active. Pipe rupture and tension decreases are occurrences that trigger passive leaking management. Active management entails frequent distribution system surveys and spill monitoring (Devon et al., 2015). Intelligent metering, area metering, and batch metering systems can be used to show the continuation of water losses. By combining these data, utilities may more accurately assess leakage and analyze overnight flow rates to enhance water loss control tactics.

An encouraging high-tech for keeping on track and reducing actual mislaying in water dispensation structure is the execution of automated meter perusal for service tubes, which accordingly accumulates expenditure data and convey it to a main dataset, doing away with the manually inspect meters which take a lot of time (Waldron, 2007).

a) Water metering

Fixed meters do not immediately contribute to water conservation, but they aid in evaluating conservation efforts' success. Lacking meters makes it impossible to impose conservation measures like forced water restrictions and prices. Metering thus serves this purpose (Christos et al., 2012).

Water metering offers more responsibility to a customer who buys water based on actual consumption and to providers who are paid based on the amount they provide. It provides the most effective method for lowering household water consumption (alexander et al. 2010). District Metered Areas (DMA) supervision is frequently used in leakage control techniques. Based on the water supply system's topology and geography and the number of users, the system is split into numerous zones called District Metered Areas (DMA). Each of which is served by a separate (or more) pipe(s) on which a flow rate is mounted (Covas & Ramos, 1999). Controlling all outflows and inflows in the region, as well as pressure change during the day, utilizing volumetric approaches or the lowest night flow, are crucial duties of DMA installation. Only in this manner is it feasible to regulate the network's hydrodynamic conductivity, calculate the loss volume, and ultimately pinpoint the locations of leaks using step analysis or any other technique (Christos et al., 2012).

This division of the distribution network into zones that can be separated from one another and whose volumes can be monitored with the proper metering is a crucial prerequisite for DMAs (USEPA, 2010).

d) Public education and awareness.

Giving consumer's information concerning water shortages and encouraging them to conserve water with direct rationalizing advice is a typical strategy for improving water conservation (Seyranian et al., 2015). Lowering the water ultimatum can be accomplished by raising consciousness about environmental problems and water shortage. In addition to more indirect methods like educational efforts, corporate responsibility programs, or consumer recognition schemes, behaviour change may also be achieved by direct acts like raising tariff rates, pushing remodeling programs, or enacting legislative limits (alexander et al. 2010)

Programs for conserving water at the school level, announcements on the radio and television, and information via mailings, seminars, or newspaper advertising are a few forms of this. Even though this technique does not result in long-term demand decreases, there are few drawbacks to including it in any supply control approach (Devon et al., 2015). Reduced knowledge gaps concerning water usage preservation are the end objective of information supply, eco-friendly measures, and water maintenance campaigns (used by water organizations and government agencies) (Schultz, 2002; Seyranian et al., 2015).

Public participation is essential to ensure that overall strategy, policies and individual actions are fully based on people's perceptions, needs and abilities

2. 5 urban water management case studies

2.5.1 Case study 1; Bangkok, Thailand

Thailand's capital, Bangkok, is located on the Chao Phraya River's level deltaic plain, which reaches the Gulf of Thailand (Babel et al., 2010). Around 10 million people live in the city. Bangkok has a monsoon-type climate with three distinct seasons: wet (May to October), cold (November to January), and scorching (February to May) (February–April). It receives around 1,500 mm of rain each year, over 25% of the total falling in September. In the dry season, from November to April, there is little or no rain (Thai Meteorological Department). Both surface and groundwater are the primary sources of water supply. Metropolitan Waterworks Authority (MWA) was founded as a governmental corporation through the Metropolitan Waterworks Authority Act of 1967. It had a duty to survey, find, and get raw water while distributing purified water to Bangkok residents. Bangkok's sustainable water supply has been ensured using the following criteria.

2.5.1.1 Water Supply management

The primary water supply source in Bangkok are Chao Phraya, Mae Klong Rivers, and groundwater aquifers (Mukand & Aldrin, 2012). Groundwater mining has been monitored to reduce adverse effects such as groundwater exhaustion, quality deterioration, and land use (Babel et al., 2007). As of 2009, MWA had four therapeutic companies with a total manufacturing capacity of 5.52 mcm/day. The treated water is supplied to the distribution system through 16 filling stations in distinct branch offices (Mukand &Aldrin, 2012).

MWA has invested much in service expansion over the years, resulting in an increased service area of 1,182.8km2 as of 2008 (Mukand &Aldrin, 2012). The remarkable increase in service handling is due

to the obligation of the utility to expound its services as directed by its principal plan. MWA has primarily hinged on a distribution-oriented approach in attaining the increased water claim in Bangkok.

i) Metering connections

An essential part of water distribution monitoring is using meters to control and measure water usage. The establishment of meters is a vital part of the typical procedures for fixing new links in Bangkok. From 1998 to 2008, service influences increased by 36%, indicating the extent of the increased coverage (Mukand &Aldrin, 2012). To uphold the efficacy of water meters, the Water Meter Sector of MWA and its subdivision offices substitute meters after eight years.

ii) Non-revenue water reduction

MWA was capable of decreasing unexplained water by making water transmission losses one of its policies. MWA undertook a variety of steps, such as: Improving the distribution network and dissipation rate by routinely replacing outdated pipes to maintain a pipeline's age range of 20 years; creating the Water Broadcast and Delivery Control Centre to improve the effectiveness of water allocation; establishing District Metering Areas (DMAs) throughout the region and implementing the Water Seepage Submission Scheme for combined water leakage supervision (Babel et al., 2010).

iii) Master plans

It is an essential component of service development. MWA service exposure in 2008 was nearly 99% of the populace in its responsible area. This is owing to the asset programs and development or growth projects founded on the MWA primary strategy of 1990. MWA also rescripts its principal strategy to suit probable future petition and supply situations.

2.5.1.2 Water Demand management

i) Water pricing

Although ineffective, MWA has utilized water price as a demand strategic framework. Since 1981, a continuous tariff structure has been put in place. Because lesser use is paid at a reduced rate, the tariff system is intended to encourage people to save water (Mukand &Aldrin, 2012).

ii) Public education and water conservation

MWA promotes water conservation via the media, the web, leaflet distribution, and a variety of public awareness initiatives carried out as part of the state of community relations enterprises and other schemes (MWA, 2000; Babel & Rivas, 2009).

iii) Financial resource management

Assuredly a tax system (nominal prices for up to 30 m3 usage) cannot cover manufacturing and supply expenses; a state-run water company may have a positive financial result. Reduced O&M expenses and effective revenue collection can help with this. Since 2001, MWA has remained a financially self-sufficient utility and has not received budget help from the government.

iv) Corporate governance

Remarkable outcomes and accomplishments are made possible by the use of practical corporate governance standards. Due to its significant autonomy in carrying out its duties, MWA has, among other things, taken risky actions and implemented transparent management.

2.5.2 Case study 2; Water management in Israel

Israel is among the world's top countries facing extreme water stress. Israel is a rapidly growing economy, and this thus means that the country has had an increased water need. To cater to the increased water needs in the country, the Israeli government has implemented policies that integrate regulatory and institutional reforms alongside vast investments in water infrastructure. Israel's geography is composed of the subtropical region, between the tropical and temperate zones, while the Mediterranean climate characterizes the coast's geography. The country experiences rainy seasons, which start from October to May, with the high rainy seasons being experienced from December to February (Israel Science and Technology Directory)

With the policies integrating the regulatory and institutional reforms and the vast investments that Israel has implemented comes six elements that drive the implementation and the effective working of the policies investments. These are:

2.5.2.1 Water supply

Israel mostly sources its water from the ground, desalination, reusing wastewater treated, and from the surface. The country has had the integrated use of groundwater and surface water which first started in 1964 and transported water from Galilee to the Negev desert in the South of Israel, where the major population was. This was done through a giant pipeline, Israel’s first water carrier developed by Mekorot (Marin et al., 2017). Through this massive infrastructure, Israel has been able to distribute large volumes of water from one resource, store them in other resources to aid supply to the rising water demands, and regulate water use according to the hydrological conditions.

i) Desalination

Israel has developed desalination plants with a production of 585 million cubic meters, located along the Mediterranean coast. These plants provide water supply for municipal consumption to ensure the country's water security (Marin et al., 2017). The desalination water from these plants supplies 85% used domestically in the urban areas and 40% of the total water used in the country. The desalination facilities in the nation are vital to sustaining portable water because Israel has limited natural water resources. Therefore, desalination water supplements Israel's potable water demands.

ii) Reuse of treated wastewater for irrigation

Israel has been setting the pace in the world as a water reclamation and treatment leader. Israel treats 92% of its wastewater, while 75% of the reused water is used in irrigation (Nir & Frank, 2014). Farmers in Israel largely depend on reclaimed water as the water is used in more than 40% of Israel's irrigation schemes; 87% of the wastewater is reused (Marin et al., 2017). Reclaimed water in irrigation has made it possible to release scarce fresh water for domestic uses, reducing pressure on the freshwater sources. The utilization of wastewater as a new resource is an effective way of closing the gap between Israel's growing water demands and the available supply. Climate fluctuation affects natural water resources, but wastewater is an exception, which means that wastewater is a constant water source.

iii) Using aquifers as reservoirs

Israel has made a remarkable innovation in water management where the previously overexploited aquifers are now being used as storage reservoirs (Marin et al., 2017). In the low-demand months, the aquifers are refilled with wastewater that has been treated as they also capture the flash floods which occur occasionally. The aquifers operate as buffers as they minimize the rate of water evaporation which would have otherwise happened if the water was left in open storage (Marin et al., 2017).

2.5.2.2 Water demand management

In efforts to achieve water security, Israel has incorporated demand management as a vital component. Demand management involves the reduction of domestic consumption, the embracement of aquifers and water abstraction, the improvement of water efficiency, and the directing the shift of water to high-value crops.

i) **Water pricing**.

Over the last decade, Israel has been trying to implement reforms in the water sector which has led to its financial viability upon recovery from tariffs (Marin et al., 2017). Meters and pricing have enhanced

demand management (Zaide, 2009). MUA, under IWA and incorporated in 2009, brought about the tariff increase, increasing the price of portable and sanitation services. This was necessary to ensure that the corporatized utilities could run independently from local governments by efficiently covering all their revenues (Marin et al., 2017).

ii) Water saving technologies

Regulations had long been placed in Israel, requiring new constructions to have low-flow and dual toilets. 35% of the total household water usage in Israel is accounted for as water used while flushing toilets (Israel Water Authority, 2012c). Between 2010 and 2011, a campaign was held in the country that aimed at reducing the overall household water use by distributing water-saving faucet attachments. The Water Authority, which carried out that campaign estimated that devices such as the water-saving faucet attachments reduce water consumption in households by a least 30% (Israel Water Authority, 2012c). The agriculture sector in Israel has continued to thrive despite a major reduction in the availability of fresh water (Marin et.al 2017). This occurrence has been made possible by irrigation technologies, which have been proved efficient and increased access to treated wastewater.

iii) Public Information and Awareness Raising Campaigns

Topics related to public awareness of water shortages in Israel are prevalent as every child is taught and the media also makes this information widely available (Nir & Frank, 2014). From 2008-2010, an intense campaign was carried out where the media educated the Israelites on water use. This campaign ran for 18 months continuously and resulted in a rapid reduction of water by 76 million cubic meters. Reports indicate that the campaign only costs $0.10 per cubic meter to free the water (Marin et al., 2017). Although pricing and use of restrictions are effective water management strategies, public awareness campaigns are more effective tools for water management. This is because, unlike restrictions and pricing, awareness campaigns do not receive public or political resistance.

iv) Institutional reforms

Financial sustainability has been promoted in the Israeli water sector by the implementation of institutional reforms, and this has created the aspect of independence for the infrastructure from political decisions. This has been facilitated by establishing a strong national regulator and corporatizing service providers, which makes them responsible for the entire water chain and setting water tariffs (Marin et al., 2017).

2.5.3 Case study 3; water management in Windhoek Namibia

Among the driest countries in the world is Namibia, which houses two deserts; the Kalahari and Namib, which make 80% of the country a desert or semi-desert. The city under analysis in this paper is Windhoek, Namibia's capital city, located 1540 meters above sea level in the country's central highlands. The city receives an annual rainfall of 370mm (Department of water affairs, 2019).

2.5.3.1 Water supply

Windhoek currently depends fully on the surface, and underground water as all water sources within a radius of 500km have been completely exploited (Lahnsteiner & Lempert, 2007). The only source of bulk water in Windhoek is Namibia's Central region. The city's main source of drinking water is "Grootfontein–Omatako Eastern National Water Carrier" and three cenotes named Von Bach, the Omatako dam, and the Swakoppoort dam (Earl et al., 2019). Boreholes are also vital to Windhoek's water provision, which brings forth underground water. The city also operates by reclaimed water from the Goreangab Water Reclamation Plant, under the management and ownership of the city of Windhoek (Earl et al., 2019).

i) Windhoek aquifer

An aquifer recharge scheme has been created to serve as the water bank for Windhoek city, where water collected from the treated surface is collected and safely stored in the aquifer for use when needed (Murray et al., 2018). Water stored underground is not affected by evaporation; therefore, the recharge project is fully effective in seeing Windhoek's water supply sufficiency. This is unlike past times when the water meant to be used in Windhoek was reserved in open water bodies prone to quick vaporization (Earl et al., 2019). The recharge water is mainly sourced from the three dams, which make up 75% of the water, while the remaining 25% is reclaimed water. Before the water is distributed, it is treated to drinking standards through a system that prevents the clogging of the boreholes and the deterioration of the water quality (Murray et al., 2018).

Some plans are underway to expand the aquifer's storage to exploit its full capacity. The full capacity of the aquifer currently stands at 90 million cubic meters, which is three times Windhoek's water demand (Earl et al., 2019). In the exploitation of its full capacity, the water aquifer is expected to act as the buffer when Windhoek suffers from a water shortage. After the full development of the aquifer, it is expected to be the sole water source in Windhoek for 2-3 years of drought (Earl et al., 2019).

ii) Direct portable reuse

The natural sources of water in Windhoek dried up due to an increase in the usage of water, direct potable reuse (DPR) was established in the city in 1968 as the first treatment plant, and thus the city is known as a pioneer in DPR (Gross, 2016). The Gammams Waste Water Treatment, alongside the New Goreangab Water Reclamation plants, can supply the city's water demand through sewage treatment and water reclamation. Currently, 7% of already used water is treated as partially used in watering parks, cemeteries, and sports fields (Lahnsteiner & Lempert, 2007).

iii) Non-revenue water reduction and metering connections

Technical measures in Windhoek are mainly to control water leakage and the proper watering of gardens. Water audits and leakage detection are continuously done to reduce water loss through leakages further, accompanied by pipe replacements and repairs for better water management (Lahnsteiner & Lempert, 2007). Since all these measures have been implemented, water loss in Windhoek is the lowest in Southern Africa, with only 10% of the water being lost. This is a very low percentage even for cities in developed countries in continents such as Europe.

iv) Institutional reform

Water reform in Namibia started in the late 1990s, where the main goal was emulating the separation of roles between the institutions rendering services to the citizens and the government (Government of Namibia 2008). The management of water resources, as well as the drinking and water supply, is currently under the Ministry of Agriculture, Water and Forestry, under which the department of water resources management operates. The water supply in Windhoek falls under NamWater, a state-owned water supplying company that also means the dams, treatment plants, and pipelines. NamWater is also responsible for getting the water to households and businesses and selling it (Earl et al., 2019). Having few institutions with specific roles in the water sector has enabled the government to have efficient water provision services.

2.5.3.2 Water Demand Management

The number of people moving to Windhoek keeps increasing, putting more pressure on the existing water resources. This, added to the drought experienced in 1993, prompted the CoW to declare water demand management as an effective way of conserving water. This, therefore, led to the initiation of the water demand management policy in 1994, which had its main aim as improving the efficiency of water

use and reducing water consumption, mainly in the population that identified as high income, by imputing several measures, (Earl et al., 2019).

i) Water pricing

The block tariff structure was one of the ways that were used to control water consumption in Windhoek, with water prices going up as the volumes of water being used increased. After these measures were put across, there was a rapid decrease in the volumes of water used between 1994 and 1999, when the volumes of water used decreased by 71 l/c/. The tariff structure named the block structure ensures that the water usage habits of Windhoek residents were changed, leading to the making of savings that exceeded 30%, d (van der Merwe, 1999).

An announcement by CoW put down measures of a new tariff for all households that ran under the consumption of more than 50 cubic meters per month back in 2015. However, the penalty tariff threshold was later lowered to 40 cubic meters in 2016, and in the same year, there was also an increment for the residents' basic water tariff by 10% (Haidula 2015).

ii) Water saving technologies

"Since 1996 the city of Windhoek introduced policy measures to enforce use of water saving technologies. Some of the measures are; Metering taps must be used in hostels, taps outside non-residential buildings must be self-closing or lockable, only low flow showers are allowed, toilet cisterns must be 6/3 liter dual flush units, automatic flushing devices without activation by the user are prohibited and Retrofitting of existing inefficient water devices is compulsory within 3 years" (Van der Merwe, 1999).

iii) Public awareness campaigns

To increase both the awareness of water saving and the acceptance of the direct reuse of drinking water, the city of Windhoek has organized appropriate educational programs in schools, on radio and television, and in the print media (J. Lahnsteiner and G. Lempert, 2007). Strong emphasis was placed on customer advice, public participation and distribution of pamphlets on the efficient use of water.

2.6 Summary Lessons learned from the three case studies

2.6.1 Reuse of treated water

From the secondary data review on the three selected case studies reuse of treated wastewater is one of the best practice which is carried out in Israel and Windhoek, Namibia. 92% of the wastewater in Israel

is treated, and over 75% is reused in irrigation. Reclaimed wastewater is a major source of water for farmers, supplying more than 40 percent of the country's needs for irrigation. In Windhoek, water reclamation plants produce water for direct portable reuse.

2.6.2 Using aquifers as reservoirs

The research found out that arid countries like Israel and Namibia use aquifers as reservoirs. Israel has made a remarkable innovation in water management where the previously overexploited aquifers are now being used as storage reservoirs. During low-demand months, aquifers are recharged with treated wastewater, and flash floods are captured on occasion. Windhoek has created an aquifer recharge scheme that serves as a water bank. Evaporation does not affect underground storage, preventing losses that would have occurred if this water had been stored in open reservoirs.

2.6.3 Water saving technologies

From the case studies it was established that policy measures to enforce use of water saving technologies were implemented in the three case studies.

2.6.4 Non- revenue water reduction strategies

The research found that strategies were developed in the case studies to reduce non-revenue water. The technical measures carried out are mainly related to the control of leaks and the appropriate irrigation of the gardens. To reduce water losses, both leak detection and water audits are carried out on an ongoing basis. In addition, systematic pipe repair and replacement programs have been implemented and proper water meter management is performed in all case studies.

2.6.5 Public awareness campaigns

The three case studies promote water conservation through the media and the internet, through the distribution of brochures, and the implementation of a range of public awareness activities such as: Educational programs in schools, on radio and television, and in the print media. This increases awareness of water conservation and acceptance of the use of treated water.

2.6.6 Institutional reforms

Having few institutions with specific roles in the water sector has enabled the three case studies to have efficient water provision services. Implementing institutional reforms to promote financial sustainability of the water sector as a whole, and separate political decisions from infrastructure planning and operations.

2.6.6 Development of master plan

The research found out that the three case studies have prepared a water master plan which guides investments and programmes to be implemented. Implementation of the water master plans has enabled the countries to achieve water sustainability. The master plans are reviewed after some time to suit projected future demand and supply conditions.

2.7 Theoretical framework

2.7.1 Sustainable Development Theory

Everything a person or people do on earth affects the well-being of the human race, the environment, and the economy. Human activities lead to the creation of three interconnected spheres that explain the relationship between the environment, the economy, and the people's social life in relation to sustainable development (Justice, 2019). The three spheres are interrelated concepts and form the core of human decisions, which are important in influencing sustainable development (Wanamaker, 2018). The making of proper decisions toward sustainability will positively influence the community. Sustainability-oriented decisions prompt good land use, good water management and sustainable agricultural practices, proper energy management, effective and efficient techniques in building and design, and the making of laws that bring sustainable growth. The common argument is that when the three spheres of sustainability are enforced properly in people's day-to-day lives, everybody is set to win (Kaivo-oja et al.,2013). The idea of sustainable development depends on the pillars of a sustainable economy, environment, and social sustainability (DESA-UN, 2018)

Sustainable Economy

The sustainability of the economy implies a balance between production and consumption which thus means that future needs are not compromised (Lobo, Pietriga, & Appert, 2015). In previous years, economies have operated by assuming an unlimited supply of natural resources and, therefore, resources could not be efficiently allocated in the market (Du & Kang, 2016). Other than that, these economists also believed that with economic growth came technological advancement, which would rekindle the natural resources that had been previously destroyed (Cooper & Vargas, 2004). This perspective is against the new view that natural resources are limited and that some natural resources cannot be replenished. With the rapid economic growth, natural resources have been overstretched, causing a changed direction over economic assumptions (Basiago, 1996, 1999; Du & Kang, 2016).

Social sustainability

In the pillar of social sustainability comes the aspects of cultural identity, empowerment, participation, equity, and participation (Daly, 1992). Social sustainability is built on the importance of people because growth is centered on human beings (Benaim & Raftis, 2008). Fundamentally, sustainability in the social sphere is the connection between the social conditions; an example is a relation between poverty and the environs (Farazmand, 2016). The social sustainability theory, therefore, suggests that the mitigation of poverty would not lead to the environment or the economy is negatively affected (Kumar, Raizada, & Biswas, 2014), but should happen to leave the environment and economy as they were (Scopelliti et al., 2018).

Environmental sustainability

Sustaining an environment revolves around having the natural environment remain fruitful and strong to support life. The integrity of the ecosystem and the environment's carrying capacity are the main aspects of environmental sustainability. Environmental sustainability needs the natural resources should be used properly as inputs in the economy (Goodland & Daly, 1996). This results in natural resources not being exploited quicker than they can regenerate, nor should waste materials be produced quicker than they can be destroyed (Evers, 2018) since the earth has an existing equilibrium (Diesendorf, 2000).

Principles of sustainable development

The attainment of sustainable development depends on several principles, but the most vital of all is centred on the environment, the economy, and society. These three major parts of SD lead to the conservation of biodiversity and ecosystem, the control of the human population, and the management of human resources. Other than that, the principles go further into conserving human culture and managing human resources (Ben-Eli, 2015; Molinoari et al., 2019).

Ecosystem conservation is among the major principles of sustainable development. For living organisms to keep existing, ecosystems need to be conserved. The limited resources on earth cannot meet the needs of unlimited people. Therefore, the overexploitation of natural resources is bound to cause adverse effects on the natural surroundings meaning that even as we exploit the earth's natural resources, we must always consider its carrying capacity (Kanie & Biermann, 2017). Therefore, having alternative natural resources such as harvesting rainwater instead of entirely depending on dams and groundwater. Environmental sustainability is engineered by biodiversity, ecology conservation, proper land use, and physical planning. Sustainable development is concerned with managing to realize development without

limiting the future generation's ability to meet their needs. Water provision and proper sanitation are achieved in most cities, as these two aspects have been key elements in the international development discourse since the '70s (Falkenmark, 1977). Water provision in the cities and mainly in the informal settlements and rural areas households (ASCE & UNESCO, 1998) and settlements is an issue that has gained importance over the last decades (Satterthwaite, McGranahan, & Mitlin, 2005).

2.7.2 Behavioral change theory

According to behavioral theory, people think about the consequences of their actions before doing things (Herek, 1986; Zanna & Rempel, 1988). Thinking and beliefs shape attitudes, behaviors, and actions toward water conservation (Kim and Hunter (1993). Choices involving behaviors are triggered by emotional reactions and are not focused on cognition and rationality (Stef Koop & Stijn Brouwer, 2020). Behaviour change can be caused by acquiring knowledge or relevant experiences. The knowledge of water conservation can be spread through the use of advertisements and media campaigns in water to raise awareness of water scarcity. More knowledge about water scarcity makes people more likely to change their behaviors affecting water efficiency.

Pushing for behavioral change and showing the relationship between the state of the environment and the attitude and behaviors of the residents of a particular area can help improve water conservation in Mavoko Municipality.

2.7.3 Ecological Modernization

The theory of ecological modernization explains that institutions and social actors attempt to integrate environmental issues into their daily operations, relations with other institutions, and their attachment to the natural world (Mol et al., 2009). Sustainable development and the theory of ecological modernization share common features like the fact that they function within the existing economic structures but encourage innovation, individual behaviour, and technological embracement (Bell, 2020). It is argued that the only way to get away from the current ecological crisis is by embracing modernization by the sociological theory (MoI, 1995). The state, markets, industrialism, and technology are the forces of modernization that can move the world from degradation to sustainability (MoI, 2002).

Policies related to ecological modernization have been identified in the water management systems, (Debaere et al., 2014), such as in the metering of the water and the trading of water rights (Giurco, White, & Stewart, 2010). To achieve water sustainability in urban areas, engineers should develop resource- and economically efficient systems. Research has established that people in the cities as individual

consumers are more concerned about water information related to pricing (Koutiva & Makropoulos, 2016). Causing a change in human behaviour without directly touching on economic costs mainly draws from social marketing (Hurlimann, Dolnicar, & Meyer, 2009) behavioural psychology, and social psychology (Walton & Hume, 2011). Water demand can be reduced through providing information, adopting positive behaviour with the right motivation, and adopting effective and efficient technologies (Hurlimann et al., 2009). Under the modernist ecological model, portable reuse and desalination techniques meet water shortages when they are economically feasible (Asafu-Adjaye et al., 2015). The ecological modernisation theory guides how technological and behavioural change capabilities can be exploited to create a sustainable water supply in Mavoko municipality.

2.8 Conceptual framework

The study is based on a sustainability framework that allows MAVWASCO to meet the needs of all of its water users consistently and provides the flexibility to adapt to future needs. The frameworks will be an essential guidance tool for management practices so that economic losses caused by water supply shortages due to climate change, population growth, or infrastructure damage can be avoided. It will talk about three important parts of urban water management: the demand for water, the way water is governed, and supply of water.

Traditional water supply portfolios include surface water, imported sources, and groundwater supplies that must be shared among many users. Because of this, looking at the hydrologic records of utilities' main supply sources from the past will tell us a lot about how reliable the current supplies are and if there are any underlying trends. The study will look at how reliable supplies are based on two things: how vulnerable existing supplies are and how many kinds of supplies there are. When a supply portfolio relies on just one water source, the water's availability depends on the supply source. Supply diversity is evaluated by relative abundance and how many different sources are available. Diversifying supply portfolios would aid relieve stress on existing sources, making water resources more reliable, resilient and flexible.

Management of water effectively can make water supplies last longer and lessen the effects of a water shortage, even if the water supplies themselves are really not reliable. The amount of water a community needs depends on how people use water, how many people live there, what industries they have, how much water they need for outdoor irrigation, and so on (Hornberger et al., 2015). This framework will be used to examine how water is used in different societies. As a result, it determines how much room

there is for more effective methods of decreasing demand while also increasing the security of current supply.

Managing water demands effectively can extend availability of water supplies and limit the potential impacts of water shortage, even when the reliability of the supplies themselves is uncertain. Water demand is a result of intrinsic water use behaviors in a community, as well as a function of land use, population density, industrial activities, outdoor irrigation needs, etc. (Hornberger et al., 2015). This framework will assess how different communities use their water. It also analyses how much room there is for improved demand management practices and conservation strategies to help decrease consumption and consequently improve the reliability of existing supplies.

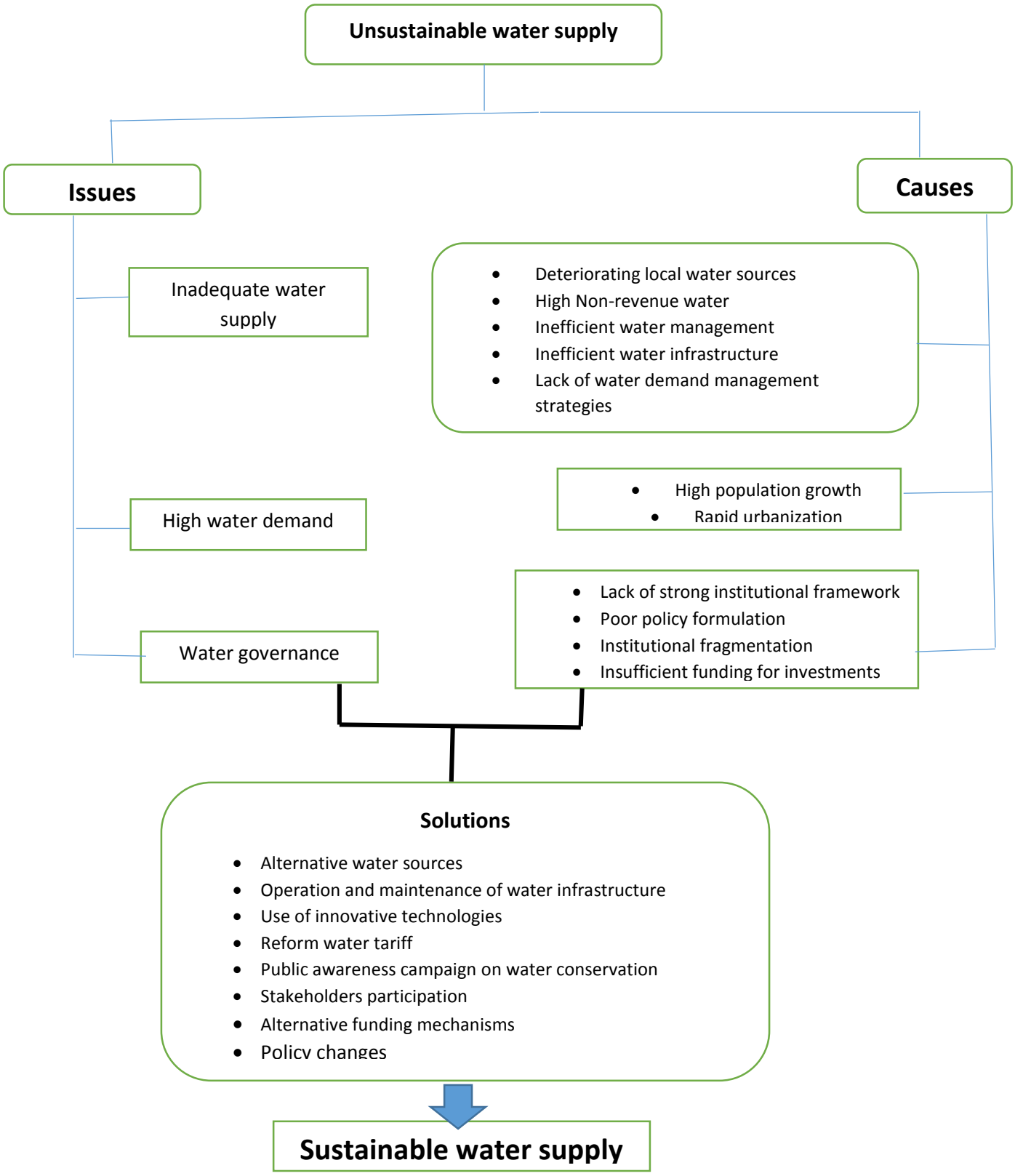
For water supplies to be able to last for a long time, they need to be flexible and strong enough to adapt to changing needs and possible problems (Milman and Short, 2008). The framework has three major ways to improve the ability to adapt that can be done at distinct intervals. Short-term water conservation methods can be used by water utilities in order to better utilize their present water resources. Over the long term, water suppliers may increase supply by adding new sources. In the end, utilities may be able to use these alternative sources more effectively to meet the needs of different sectors for high-quality water. Socio - economic factors affect how people use water, like how much they use, how willing they are to try new supplies and technologies, and how they respond to conservation and adaptation incentives when water is scarce (Hornberger et al., 2015).

The term "water governance" refers to the wide range of administrative institutions in place which create and preserve water resources and offer water services at all societal levels (Global water partnership, 2003). Water policies, laws, and regulations, as well as organizational structures, are evaluated based on how well they work to ensure a steady supply of water. Effectiveness (how policy goals are met), efficiency (how much it costs society), and inclusivity of stakeholders (trust and involvement) will be evaluated in the research region.

Successful water and infrastructure management are analyzed from three case studies of Bangkok Thailand, Israel and Windhoek Namibia. The best practices such as reuse of waste water, using aquifers as reservoirs, reduction of non-revenue water, public awareness and development of water master plan are identified as strategies which will ensure sustainable water supply in Athi River Township.

Figure 3 below shows conceptual framework of the study.

Figure 3: Conceptual framework



CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This chapter explains the research methods used. It includes data gathering methods, data presentation, data analysis and the study design.

In this case study, methods for managing urban water demand focus on both demand and supply-sides and the management solutions. Strategical approaches have been made to show the role of the stakeholders, institutions, and community in reducing the demand for and lack of water (Hamlat et al.2013). Sustainable development theory and political science literature are both considered in the strategy creation phase. Water is regarded as a natural resource in sustainable development theory, and limiting its unsustainable usage is an important aspect of the plan. In political science literature, the institutional framework plays a crucial role in designing diverse methods (Mishra et al. 2017).

Data was gathered from annual government reports, MAVWASCO annual report, the country's water master plan, and reports by an international organizations, and interviews with MAVWASCO officials, households, businesses, and government officials.

3.1 Research Design

The research adopted a descriptive research approach, which means that interviews, observations, and a review of documents were utilized to accurately depict the features of a certain scenario or community (M.Abir, 2008). The study employed this research design because the researcher wanted to understand the current status of water supply in Athiriver Township. The research design was selected to enable the researcher to understand the behaviors, traits, opinions and attitudes of the participants towards water use and conservation. Quantitative observations allowed in- depth analysis and chance to validate the existing water management conditions. The selected area of study Athiriver Township will be discussed in depth in chapter four of study area.

3.2 Methods and instruments of data collection

The research depended on both primary and secondary sources of data for its findings. Data from households was gathered with the assistance of research assistants. They were trained and a pilot data collection was conducted to help them understand the questionnaire and study area before commencing on the assignment.

The following data was gathered and evaluated in order to meet the study's goals.

Table 1 below shows the instruments of data collection.

Data collected and instruments of data collection.

Objectives	**Data needed**	**Methods of data collection**	**Data analysis methods**	**Data presentation**
1. To evaluate existing water management issues.	**Water supply** 1. Sources of water 2. Nature of water distribution network 3. Amounts of water available 4. Amount of water supplied 5. Frequency of supply 6. Modes of water storage 7. Methods used to measure consumption 8. Strategies to ensure efficient water supply 9. Development plans to increase supply 10. households connected to water 11. water conservation strategies	Interviews, observation, photography, questionnaires, documents review and archive retrieval.	Qualitative and quantitative data analysis	Pie charts, bar graphs and pictorials.
	Water demand management 1. Amount of water demanded 2. Demand management	Interviews, observation, photography, questionnaires		

	3. water pricing tariffs 4. strategies to reduce demand 5. water saving technologies used 6. water conservation strategies 7. non-revenue water reduction strategies 8. number of meters installed 9. nature of public awareness campaigns	,documents review and archive retrieval		
	Water governance 1. Policies in place to ensure sustainable water supply 2. Policies in place to reduce water demand 3. Reforms initiated to ensure financial sustainability of water utilities 4. Development plans to improve water sector 5. Water conservation policies 6. The role of various institutions in water sector	Interviews, questionnaires, observations, archival retrieving.		

Table 1: INSTRUMENTS OF DATA COLLECTION

(Source: Author)

3.2.1 Primary data sources

The following tools and techniques were utilized to gather primary data:

3.2.1.1 Observation

This means looking at things like objects, land uses, water supply coverage, water sources, and water color. The nature of the respondents' homes was also looked at. Observation guides were used to record the physical details that were important to the study. Later, the information was used to check the respondent's verbal claims.

3.2.1.2 Interviews

Interview schedules are used to acquire data from key informants in face-to-face interactions. They may be given in a formal or informal setting. Structured interviews were conducted with specialists in the field of water. The Mavoko Water and Sewerage Company, the Water Resource Management Authority, NEMA, the Ministry of Water, the Machakos County Government, and Mavoko Municipality officials and community leaders were some of the most important sources of information and expertise in this project.

3.2.1.3 Questionnaires

A questionnaire is a form that each person in a study fills out to give information about themselves. The questionnaire was administered to selected household, commercial enterprises and institutions. The questionnaires were divided into various categories of households, business enterprises, water service providers, Machakos county government, ministry of water and other institutions in water sector. The questionnaires are annexed as appendix 1-4.

3.2.1.4 Photography

Photographs were taken throughout the data collection process in order to document various aspects of the research region, such as the state of water sources and the number of people at a certain water point.

3.2.2 Secondary data sources

Data considered to be secondary are those that have already undergone statistical analysis after being gathered by someone else (Kothari, 2004). Before collecting primary data, a desk study review was undertaken by studying books, journals, magazines, newspaper articles, development plans, environmental reports, strategic plans, master plans, and survey maps.

3.3 Target population

The research's primary focus was homesteads, commercial firms, and chosen industries in the study region. The key resource persons were from various institutions such as; Mavoko Water and Sewerage Company, Municipal Council of Mavoko, Water Resource Management Authority (WRMA), The

County Government of Machakos, ministry of water and irrigation, and the National Water Harvesting Authority.

3.4 Sample size

The area of Athiriver is approximately 37 square kilometers in size. According to the 2019 KNBS housing and population census, 55,464 people live in 20,513 households in the area. It is divided into Athiriver North, Athiriver Township and Oloshaiki sub locations with 1,789; 52,997 and 678 people respectively.

The study adapted random sampling for the household questionnaires which mainly targets residents, enterprises and industries. To calculate sample size, the Yamane 1967 formula was applied as follows:

$$\mathbf{n= \frac{N}{1+N(e)^2}}$$

Where n= is the sample size,

N= is the population size, and

e = is the level of precision (0.05)

A 95% confidence level and precision of 0.05 are assumed.

Based on the above formula and using N as 20,153

$$n= \frac{20{,}153}{1+20{,}153(0.05)^2}$$

$$n= \frac{20{,}153}{51.3825}$$

n= 392

Therefore 392 household and business questionnaires were to be administered.

(Adapted from Yamane, 1967)

3.5 Data analysis and presentation

The information from the household and business surveys was assessed using the Statistical Package for the Social Sciences (SPSS). To ensure that the data gathered in the field is accurate, it was necessary to sort, code, organize, and clean/cross-check it before it could be compared and verified. Developing themes from Key Informant Interviews and secondary information were used to examine the qualitative data. Pie charts and graphs were used to make it easier to understand the data. An additional set of data

derived from secondary sources was used to supplement the information obtained from the survey of homes and businesses.

3.6 Ethical considerations

A research permit was obtained from University of Nairobi, Department of Architecture and my supervisors prior to field work and data collection. A consent was also obtained from the participants by informing them the findings of the study are purely for academic purposes.

3.7 Research assumptions

The research project is based on the assumptions that:

MAVWASCO has not developed water resources and infrastructure to cater for the growing demand of its services.

Water management strategies employed are inadequate. Sustainable water supply can increase urban development and growth.

CHAPTER 4

STUDY AREA

4.0 Mavoko Municipality water and infrastructure management

4.1.1 Water management in Kenya

The right to clean and safe water in sufficient quantity for all people living in Kenya is enshrined in Article 43 (1) (d) of the Kenyan Constitution (2010). In addition, the Fourth Schedule of the Constitution (2010), Part 1, Section 22(c) defines the role of the national government concerning water as "protecting water, ensuring sufficient drainage, hydraulic engineering, and dam safety". Part 2 of the Constitutional Calendar, Section 11(b), lists water and sanitation as one of the responsibilities of the county government (COK, 2010). This means that the national government is in charge of water development, while decentralized governments are in charge of overseeing water service providers and sanitation companies. Numerous government agencies and boards have been established to ensure the proper implementation of multiple water-related policies.

4.1.2 Water supply in Kenya

Surface and groundwater are Kenya's primary water sources. Renewable water sources are defined as the largest amount of water resources that are theoretically available (National Water Master Plan 2030). (NWMP). Surface runoff and aquifers recharge are examples of renewable water resources that can be determined through rainfall-runoff analysis. The term "available water resources" refers to the sum of annual surface water runoff and the sustainable yield of groundwater resources (NWMP 2030).

Table 2 below depicts the estimated water resources available for the six drainage basins.

Kenya's Available Water Resources by drainage Basin

Table 2 WATER RESOURCE CATCHMENT AREAS IN KENYA (Unit: Million Cubic Meter (MCM/year)

Catchment area	Area (km^2)	2010	2030	2050
LVNCA	18,374	4,742	5,077	5,595
LVSCA	31,734	4,976	5,937	7,195
RVCA	130,452	2,559	3,147	3,903
ACA	58,639	1,503	1,634	2,043
TCA	126,026	6,533	7,828	7,891
ENNCA	210,226	2,251	3,011	1,810
Total	**575,451**	**22,564**	**26,634**	**28,437**

(SOURCE NWMP, 2030)

From the above table Athiriver Catchment Area (ACA) where mavoko municipality, Nairobi and Mombasa city are located will have available water of 1,634 mcm/yr in 2030. This is both surface and ground water sources which can be developed.

Due to the uneven distribution of water resources in the country in terms of time and space, actual available freshwater resources are regarded as limited and below the total water resources.

4.1.3 Water demand in Kenya

Kenya has both surface and groundwater resources, according to the National Water Master Plan 2030 (NWMP). However, the nation is categorized as a water-scarce, with shrinking freshwater resources in the face of ever-increasing and competing water needs. The country's renewable water resources are estimated to be 42.1 billion m3 per year, with surface water accounting for 20.6 billion m3 and groundwater recharge accounting for 21.5 billion m3 (NWMP, 2030).

As per water demand forecasting per catchment area, by 2030, water demand is predicted to exceed 21 MCM/y, which will be consumed by the following sub-sectors: irrigated agriculture (84%), household (14%), manufacturing (1.3%), and wildlife and fisheries (0.7%) (NWMP, 2030).

Table 3 shows projected water demand from 2010 to 2050.

Water Demand per Region

Table 3 WATER DEMAND PROJECTIONS PER CATCHMENT AREA ***(Units in MCM/yr.)***

Catchment area	**Area (sq. Km)**	**2010**	**2030**	**2050**
Lake Victoria north catchment area	18,374	228	1,337	1,573
Lake Victoria south catchment area	31,374	385	2,953	3,251
Rift valley catchment area	130,452	357	1,494	1,689
Athiriver catchment area	58,639	1,145	4,586	5,202
Tana Catchment Area	126,026	891	8,241	8,476
Ewaso Ng'iro North Catchment Area	210,226	212	2,857	2,950
Total	**575,451**	**3,218**	**21,468**	**23,141**

Source: National Water Master Plan (NWMP, 2030)

From the above table Athiriver catchment area where Mavoko municipality, Nairobi and Mombasa city are located water demand is estimated to be 4,586 mcm/yr in 2030. In Kenya domestic water demand in

2010 was 1,186 mcm/yr and its projected in 2030 it will be 2,561 mcm/yr also the industrial water demand was 125 MCM/year in 2010 and its projected in 2030 it will be 280 mcm/yr, in ACA the projected domestic water demand in 2030 will be 941mcm/yr while the industrial water demand will be projected to be 153 mcm/yr (NWMP 2030).

4.1.4 Administrative, Coordination and Water Governance in Kenya

In Kenya, water administration is shared by two levels of government. County governments play a more active role in water functions such as drinking water supply and drainage, while the national government plays a prominent responsibility for policy-making and regulatory functions.

Kenya's water sector is governed by the Water Act of 2016. Several institutions at the national, regional, and local levels work together to ensure that water services are delivered smoothly.

The Ministry of Water and Irrigation is in charge of the formulation of policies and resource mobilization in the sector. Water Resources Management Policy, Water and Sewerage Services Management Policy, Waste Water Treatment and Disposal Policy, Water Catchment Area Conservation, Control, and Protection, Water Quality and Pollution Control, Restoring the Water Balance of Rivers and Lakes, Sanitation Management of Public Water Schemes and Community Water Projects, Water Harvesting for Domestic and Industrial Use, and Flood Control Management are the Ministry's functions.

***Water Resource Authority* :** The Water Act of 2016 mandates the Water Resource Authority as the lead agency to regulate the management and use of water resources, both surface and groundwater, in terms of quality and quantity. The authority's functions include: developing and enforcing standards, procedures, and regulations for the management and use of water resources and flood mitigation; receiving water permit applications for water abstraction, water use, and recharge, issuing, and varying water permits, as well as enforcing the conditions of those permits; collecting water permit fees; and providing information and advice to the Cabinet Secretary. Water resource management takes place at the river basin level. Lake Victoria North Catchment Area (LVNCA), Lake Victoria South Catchment Area (LVSCA), Rift Valley Catchment Area (RVCA), Athi Catchment Area (ACA), Tana Catchment Area (TCA), and Ewaso Ng'iro North are the six major catchment areas in the country.

Water Services Regulatory Board (WASREB) – The Water Services Regulatory Board (WASREB) was established by the Water Act of 2016, to regulate the provision of water and sewerage services. The primary goal of the board is to protect consumers' interests and rights in the delivery of water services.

The board's main functions are: determining and prescribing national standards for the provision of water services and asset development for water service providers; evaluating and recommending water and sewerage tariffs to county water service providers; setting license conditions and accrediting water service providers; monitoring compliance with standards, including the design, construction, operation, and maintenance of facilities for the provision of water services.

Regional Water Works Development Agencies (WWDAs) - Are created by Section 68 of the Water Act 2016 to develop, maintain, and manage national public water works within their jurisdiction**.**

Water Sector Trust Fund (WSTF) - Created by the Water Act of 2016, the WSTF provides conditional and unconditional grants to counties in addition to the Equalization Fund, to aid in the development and the management of water services in marginalized and rural area.

The National Water Harvesting and Storage Authority (NWHSA)- was created under Section 30 of the Water Act of 2016, with a nationwide mandate to construct national public water works infrastructure for water resources storage and flood mitigation on behalf of the central government, as well as to maintain and manage national water supply infrastructure for water resources storage.

Water Tribunal (WT) - Is created under Section 119 of the Water Act of 2016 to listen and make a decision on any conflict involving water resources or water services where a business contract exists, unless entities have otherwise consented to an alternative dispute-resolution process.

Water service providers - Section 77 of the Water Act 2016 gives the county government the power to create water service providers. Water service providers' functions include providing water services within the license area and developing county assets for water service delivery.

Figure 4 depicts a diagrammatic representation of the management structure of Kenya's water sector.

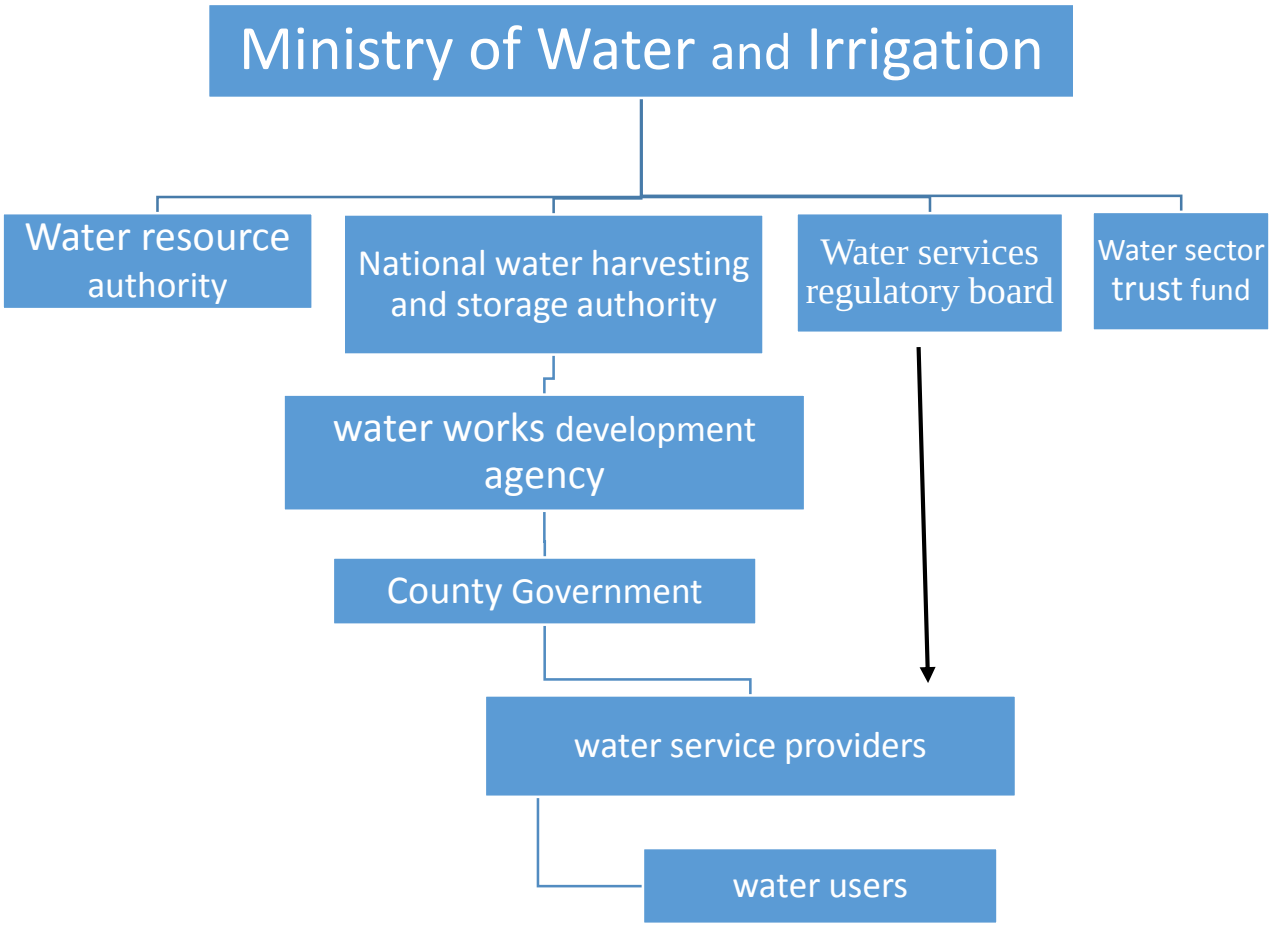


Figure 4 Organizational structure in water sector Kenya.

(Source, author)

4.2 Mavoko municipality Background

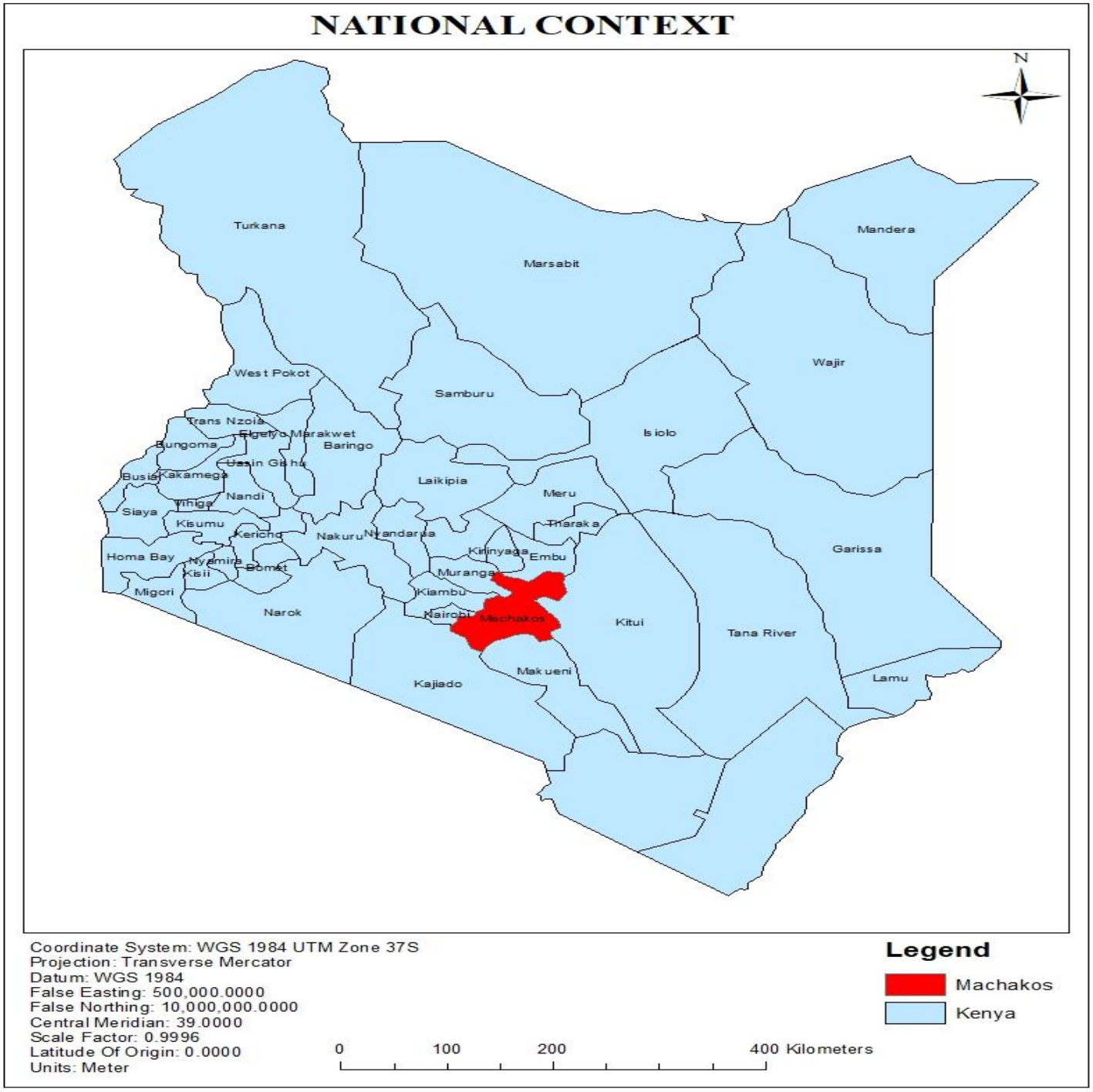
MAVWASCO provides water services in the town. The company is a limited liability company that was established in accordance with water sector reforms outlined in the Water Act of 2002. The Tanathi Water Service Board (WSB), which has jurisdiction over water service provision, has granted the company a Service Provision Agreement (SPA) and a license. The company is responsible for the management of the water supply network, water sources, and water kiosks within its jurisdiction.

4.2.1 Location and size

Mavoko Municipality is in Machakos County and has an eastern border with Nairobi City County. The Municipality extends to Muthwani-Lukenya and Makutano (Kyumbi) to the east, where it borders Machakos sub-County, and covers Katani and Joska on Kangundo road. It extends from the Kapiti plains in the southwest to the Kitengela area, where it borders Kajiado East Municipality, and to Embakasi, which borders Nairobi City County.

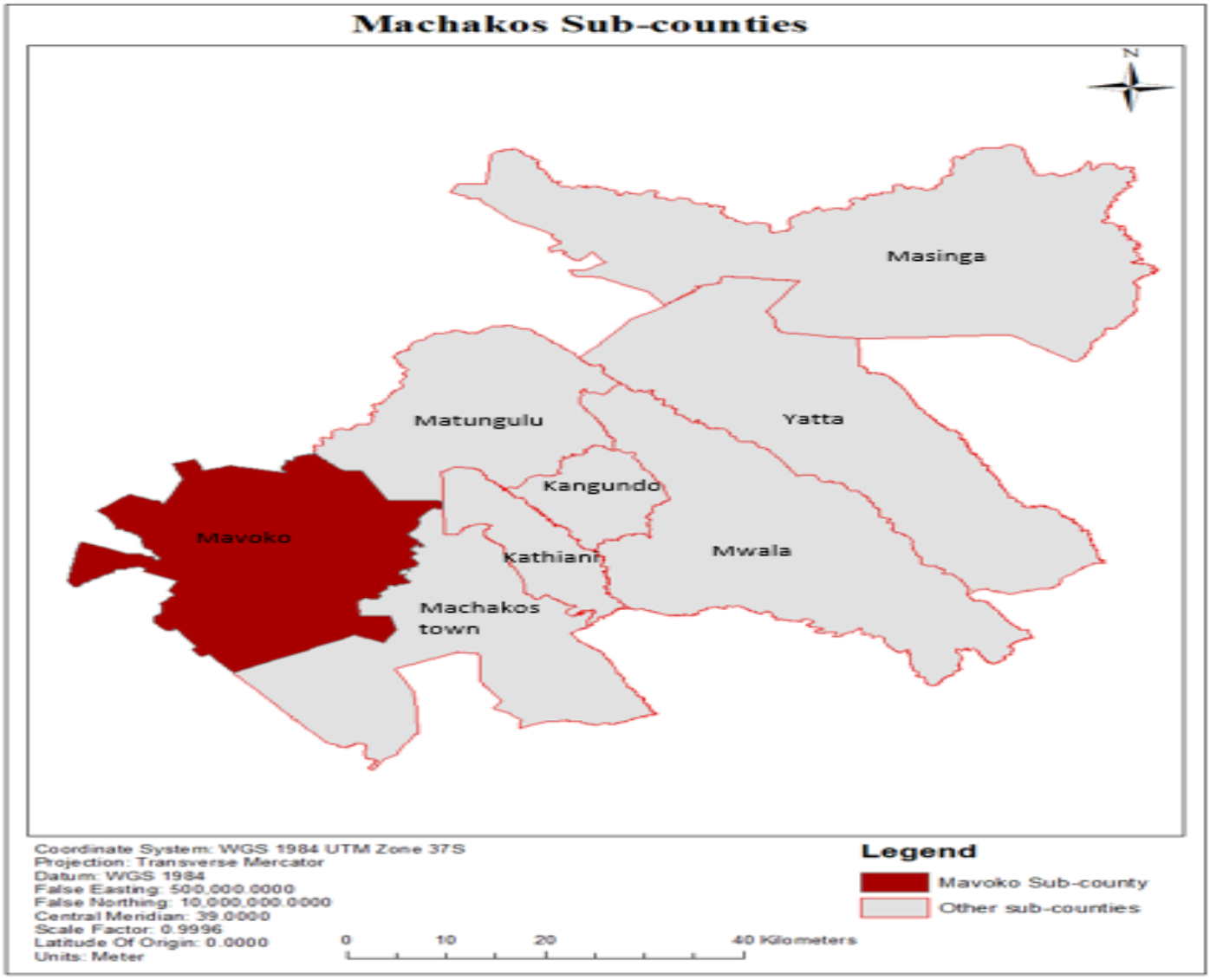
Map 2 depicts Machakos in a national context, while Map 3 depicts Mavoko in relation to Machakos County.

MAP 2: MACHAKOS COUNTY IN NATIONAL CONTEXT



Source Vision IR, 2018.

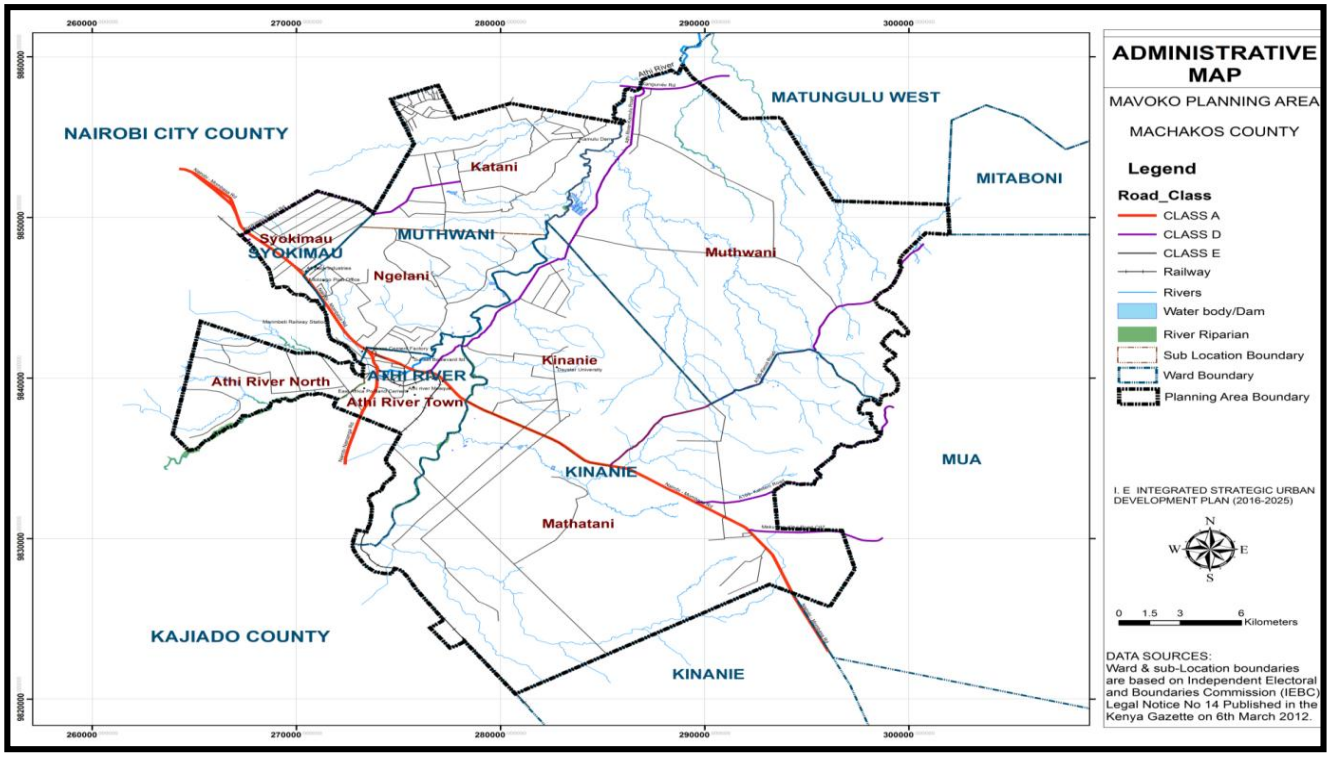
MAP 3: LOCATION OF MAVOKO MUNICIPALITY IN MACHAKOS COUNTY.



Source Vision IR, 2018.

Athi River Township, is the major urban center and headquarters of Mavoko Municipality. The town is located 25 km southeast of the nation's capital Nairobi along the Nairobi-Mombasa Highway. Other major urban centers include Utawala, Joska, Katani, Mlolongo, Syokimau, Kyumbi (Makutano) among other upcoming centers dotting the Municipality. It has an area coverage of 827.2 Km^2 administratively, it is divided into 4 wards namely Athi River, Kinanie, Syokimau/Mlolongo and Muthwani. Map 4 below shows the electoral wards in the study area.

MAP 4: MAVOKO MUNICIPALITY WARDS



Source Vision IR, 2018.

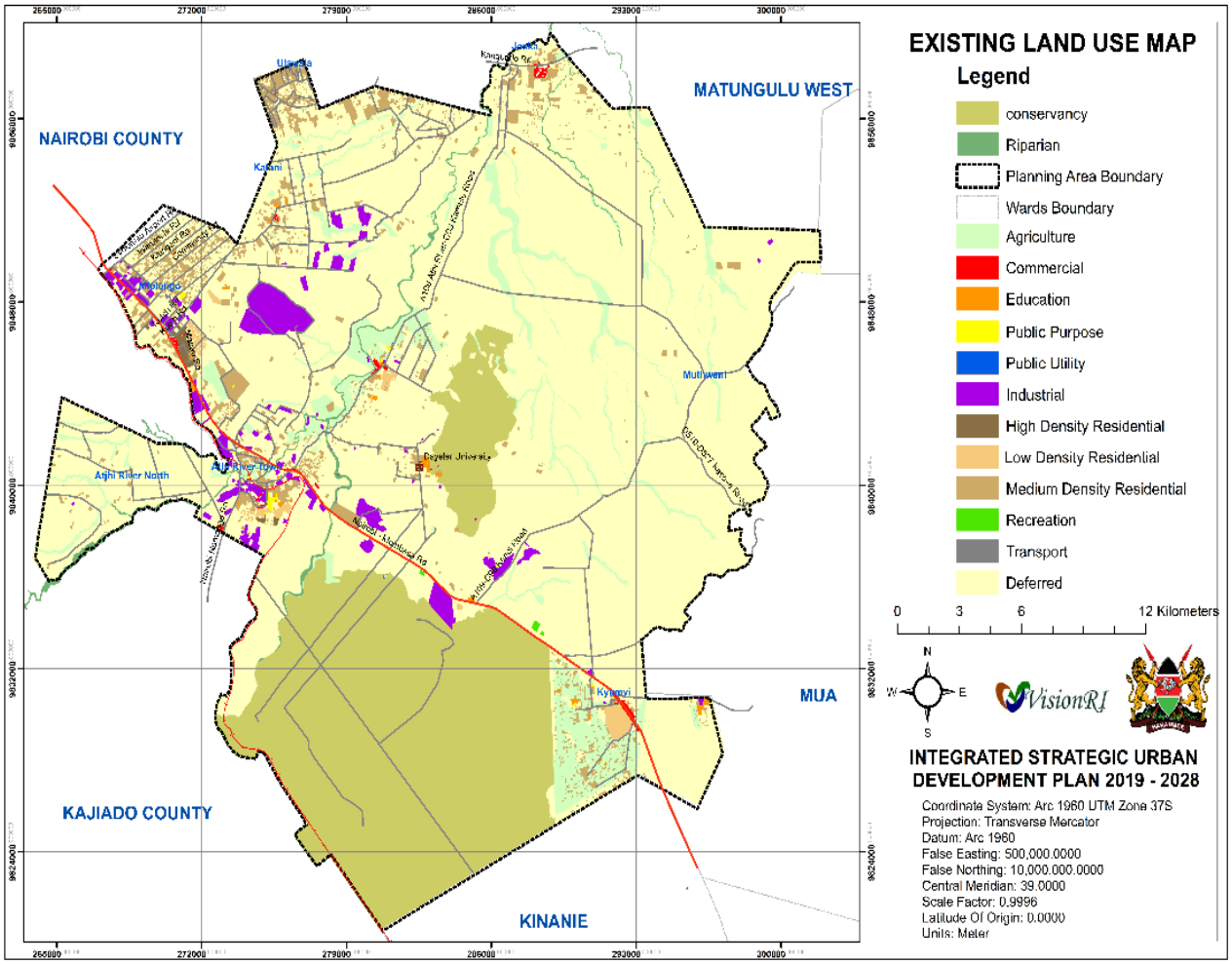
4.2.2 Land uses

Mavoko's land use pattern is characterised by intense urban growth in areas beside Nairobi City, an industrial corridor along Mombasa Road, sprawling residential areas that transition into the vast open areas at its periphery. Urban growth is particularly intense at Athi River, Mlolongo, and Syokimau, where mixed land uses; for instance, industrial with commercial and residential developments may be found.

The Municipality's CBD is Athi River Township. It is characterised by a mixture of commercial, residential, institutional and industrial uses. The latter is highlighted by the various manufacturing factories, and the Export Processing Zone. Land in Mavoko falls in two main categories; public and private. There is no communal land in the Municipality. In the early years of Mavoko, land was mainly accessed through public allocation processes.

Map 5 showing Mavoko existing land uses is shown below:

MAP 5: EXISTING LAND USES IN MAVOKO



(Source vision IR, 2018)

The Mavoko municipality's Integrated Strategic Urban Development Plan 2019-2028 proposes various land uses by calculating the acreage needed in the future. These new land uses will result in a significant impact on the area's infrastructure and natural resources.

Table 4 below shows the major land use categories and the proposed required land:

Table 4 EXISTING AND PROPOSED LAND USES IN MAVOKO in acreage.

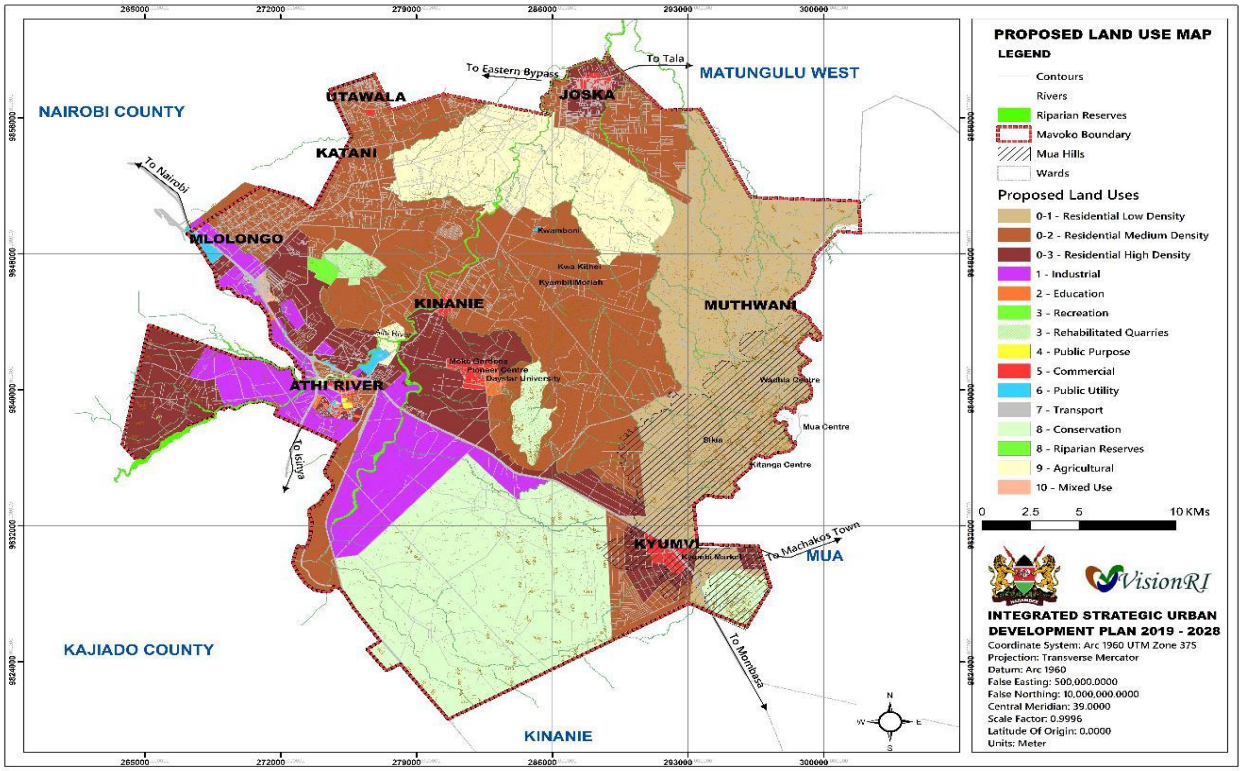
No.	User	Existing		Proposed	
		Area in Hectares (Ha)	Percentage (%)	Area in Hectares (Ha)	Percentage (%)
0	Residential				
	Residential - High	3,615.36	4.28%	9,141.20	10.83%
	Residential – Medium			22,870.03	27.10%
	Residential – Low			14,453.15	17.13%
	Total	**3,615.36**	4.28%	**46,464.94**	
1	Industrial	1,758.10	2.08%	6,996.49	8.29%
2	Educational	144.67	0.17%	253.48	0.30%
3	Recreational	19.29	0.02%	170.37	0.20%
	Rehabilitated Quarries	438.08	0.52%	438.08	0.52%
4	Public Purpose	61.53	0.07%	27.04	0.03%
5	Commercial	148.56	0.18%	910.11	1.08%
6	Public Utility	1.03	0.00%	250.62	0.30%
7	Transportation	2,418.59	2.87%	3,975.81	4.71%
8	Conservation Areas				
	Conservancy	15,929.53	18.88%	15,929.53	18.88%
	Riparian Reserves	782.8	0.93%	1,540.26	1.83%
	Total	**21,702.18**	25.72%	**30,491.79**	**20.72%**
9	Agriculture	5,188.44	6.15%	7,330.39	8.69%
10	Mixed Use	-		102.28	0.12%
11	Undeveloped Land	53883.42	63.85%	0	0.00%
	Total	84,389.41	100.00%	84,389.41	100%

(*Adapted from Mavoko municipality Integrated Strategic Urban Development Plan 2019- 2028 MISUDP*)

According to draft integrated strategic urban development plan for Mavoko 2019- 2028 residential land has the highest percentage of 55.06% of total land area. Conservation area covers 20.72% of total land, industrial land covers 8. 29% and agricultural land will cover 8.69%.

Map 6 below shows the proposed land uses in Mavoko 2019-2028:

MAP 6: PROPOSED LAND USES IN MAVOKO MUNICIPALITY



(MISUDP 2019-2028)

4.3.0 Physical and Climatic conditions

4.3.1 Climatic conditions

The climate of Mavoko Municipality is semi-arid. It has two rainy seasons, long and short (bimodal rainfall pattern). The long rain season begins at the end of March and lasts until May, while the short rain season begins at the end of October and lasts until December. The annual rainfall average ranges from 500mm to 1300mm. The average annual temperature in the area is 26^{o}C, with temperatures ranging from 20.4^{o}C in the upper highlands to 34^{o}C in the midlands Mavoko area. July and August have the lowest temperatures, while January, February, and March have the highest temperatures.

4.3.2 Geology and soils

The study area is mainly located on a plateau by the name of Kapiti plains that stretches from Konza to Athi River Town with hills like Mua and Lukenya. The Municipality at the eastern border zone of Rift Valley. The geological history of the area has been dominated by volcanic activities and mainly comprises of thick succession of lavas (volcanics) and sediments of Kainozoi cage. The geology of the area is comprised of Tertiary Volcanic underlain by Basement Complex of Precambrian rocks. The

oldest of these rocks is the Kapiti Phonolite, which covers a vast area to the east and northeast of Machakos.

There is a close relationship between geological formation, topography and soils. The Corridor lies in an area of predominantly black cotton soil. The thickness of these soils varies with the geological sequences of the area. The weathering process of the Kapiti Phonolite results to the formation of the orange-brown lateritic soil below the dark grey black cotton soil. They are poorly drained, have low infiltration rate and low permeability and are capable of significantly upholding any released contaminants to the groundwater.

4.4 Demographic

According to the 2019 Kenya Population and Housing Census, the municipality has a total population of 322,499 people, a population density of 390 people per km2, and 109,735 households (KNBS, 2019). Over the last 20 years, the study area's population has grown dramatically.

Table 5 below shows population growth from 1999 to 2019.

Table 5: POPULATION GROWTH IN STUDY AREA 2009-2019

Ward	Population			% Pop. Change
	1999	2009	2019	
Athi River	23,034	51,293	84,906	268.61%
Kinanie	9,801	17,538	28,479	190.57%
Muthwani	10,031	28,517	35,522	254.12%
Syokimau/Mlolongo	5,984	42,154	173,592	2800.93%
Total	48,850	139,502	322, 499	560.182%

Source: KNBS 1999, 2009 and 2019 Population Census Reports

4.5 Economic activities

Mavoko is one of the Kenyan towns experiencing rapid urban sprawl as Nairobi's industrial area expands along the Nairobi-Mombasa highway towards the Athi River. Mavoko's employment patterns have shifted significantly from cattle ranching in the 1950s to industrial and commercial activities today. A sizable proportion of the population works in the area's various manufacturing industries. Other economic activities include transportation, as the area serves as a logistical hub on the Mombasa-Nairobi highway, construction, and tourism.

4.6 Current water sources

The main surface water sources are the Mbagathi River and the Stone Athi River, which meander through the municipality. The study area includes the Syokimau stream, which is part of the Athiriver tributaries. Boreholes piped water from MAVWASCO, rainwater, and water vendors are Mavoko's primary water sources.

MAVWASCO provides water to the majority of Athi Town residents. The Company provides water services through individual connections, but it also operates water kiosks, primarily in low-income neighborhoods and informal settlements.

CHAPTER 5

DATA ANALYSIS AND DISCUSSIONS

5.0 INTRODUCTION

This chapter analyzes the findings and discusses the data gathered to achieve the study's objectives. It is divided into the following sections:

1. Evaluation of the existing water and infrastructure management issues in Athi River Township, Mavoko municipality. The water and infrastructure management issues which have been evaluated in this section included: water sources, water supply, water pricing, Non-Revenue water, strategies for demand management and challenges faced by service providers.
2. Investigation of success factors and successful water and infrastructure management case studies around the world. Three case studies will be analyzed in this section and best practices which can be applied in Athiriver Township will be identified.
3. Recommendation of working water and infrastructure management solutions in Athi River Township, Mavoko municipality. The recommendations in this section will include: strategies which will promote sustainable water supply and water demand management.

5.1 **Response rate**

Only 350 of the 392 questionnaires distributed to households and businesses in the study area were returned, representing 89 percent response rate.

5.2 Existing water and infrastructure management issues in Athi River Township, Mavoko municipality.

5.2.1 Water sources for households and business enterprises

Water vendors selling water to residents on hand-pulled carts or donkey carts were the primary source of water for the majority of households in the study area. Water vendors were identified as the primary source of water by 26% of those polled in the household survey. Private boreholes were the second most common source of water in the study area, with 24 percent of respondents citing them as their primary source of water. Piped water from Mavoko water and sewerage company (MAVWASCO) was named as the primary source of water by 10% of respondents. 19% of respondents identified public boreholes

constructed by the county government of Machakos or the national government as their primary source of water. Figure 5 below shows the various water sources in the study area. None of the surveyed households used surface water sources such as rivers or streams as the main source of water. This was attributed to high pollution of the available streams making the water unfit for human consumption.

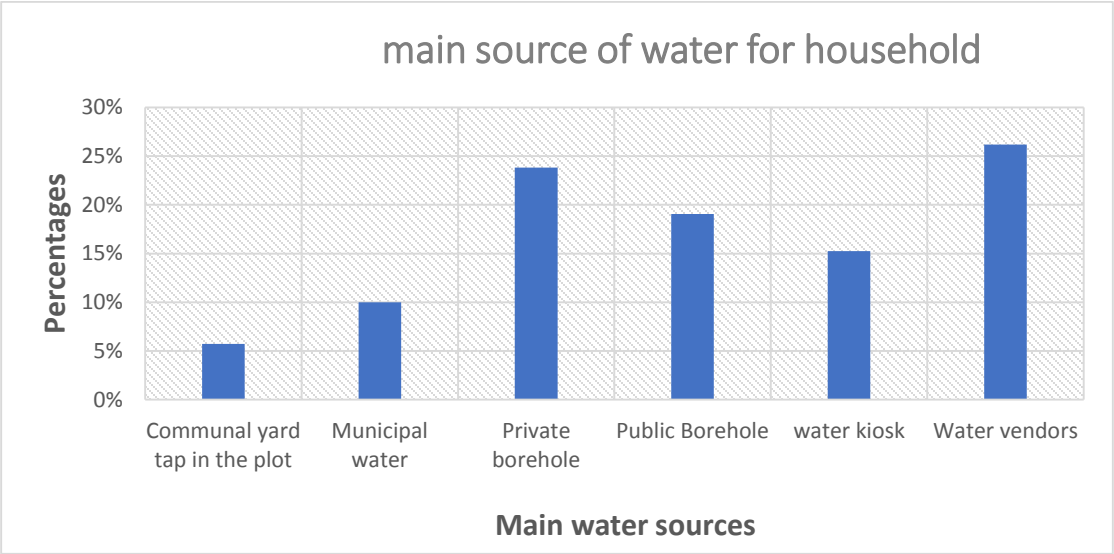


Figure 5: Main water sources for 250 household respondents

Source field survey December, 2021

For the business enterprises the 54% of surveyed business identified water vendors as the main water source. Piped water from MAVWASCO was identified by 14% hence being the second large source to business enterprises. Some business indicated to using water sources from two sources as shown in figure 6 below.

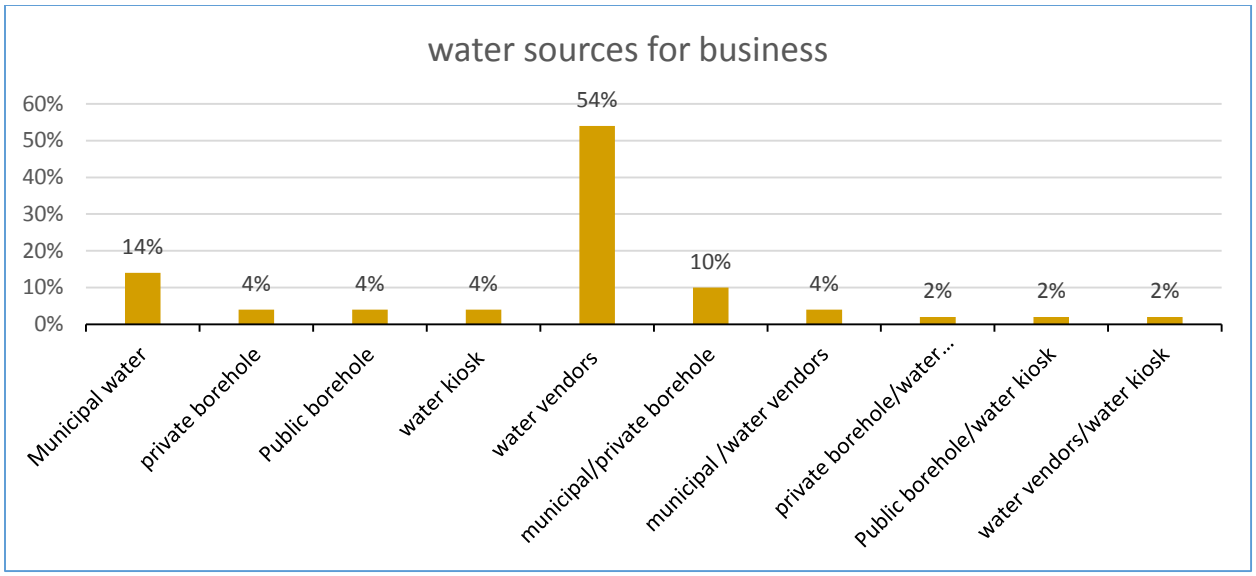


Figure 6: Main water sources for 100 business respondents

Source field survey December, 2021.

According to the above analysis of both household and commercial enterprises, its clear water vendors serve a larger population in the study area. MAVWASCO's piped water has also been connected to more businesses than households. Private boreholes play an important role in the supply of water in the study area.

The Kasuitu dam, located at the confluence of the rivers Mbagathi and Ngong, was MAVWASCO's primary source of water. This was established during the interview with the company's technical manager. The company has built a 2-meter-high wall barrier across the river to serve as a reservoir (as shown in figure 7 below). They also have two boreholes which they use to supplement the water from the dam. The water from the reservoir is pumped into a treatment plant for purification before being distributed to the residents.

Figure 7 below shows Kasuitu water reservoir.

Figure 7 kasuitu reservoir

Source field survey December, 2021

It was also established 74% of the household respondents had alternative water sources in the event the main water sources developed challenges as shown in fig. 6. 38% of the respondents identified reserve tanks as their alternative sources of water while 13% indicated the alternative source was wells (fig. 8 and 9).

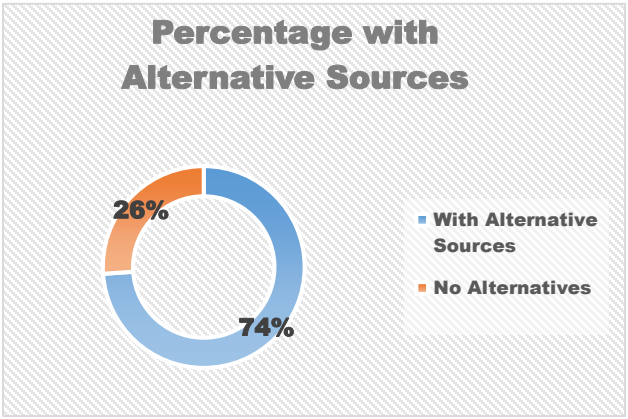


Figure 8. Alternative sources of water for 250 household respondents

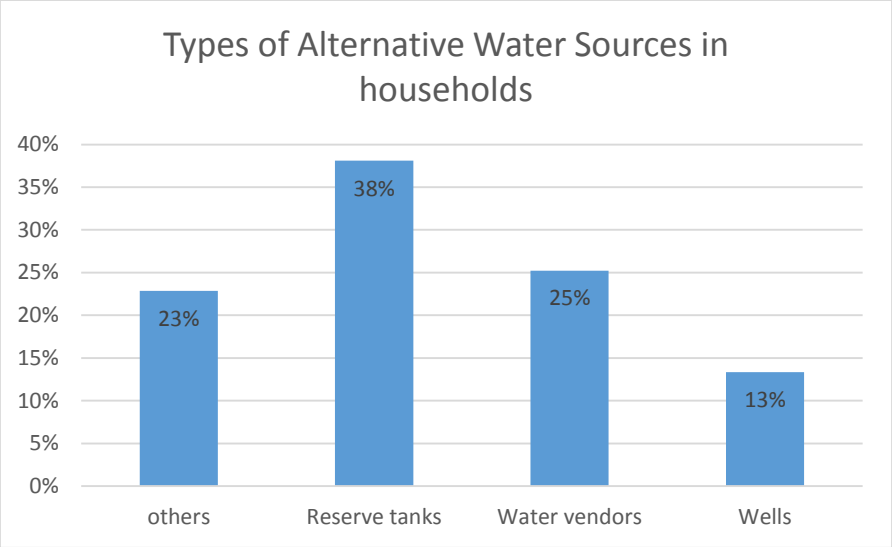


Figure 9 Types of alternative sources of water for 250 household respondents

In the business enterprise sector it was established 54% of the respondents don't have alternative sources of water (as shown in figure 10 below).This indicate that when there is water shortage business incur huge losses as they can't operate to optimum.

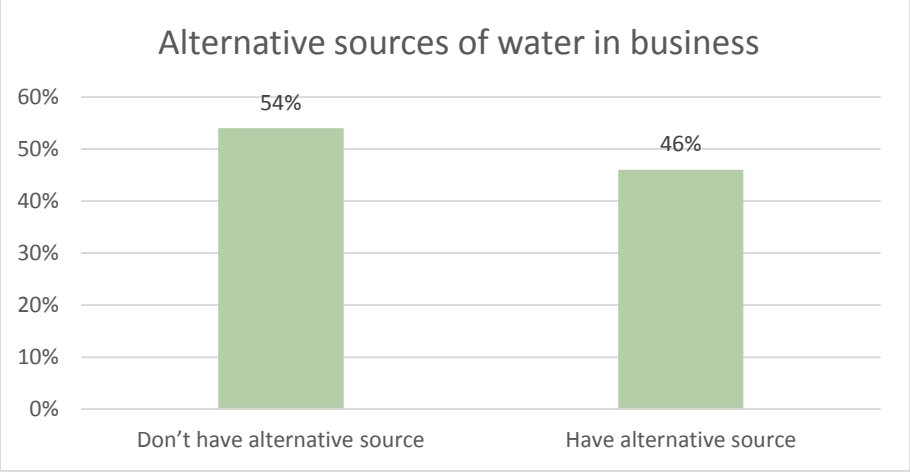


Figure 10 alternative water sources for 100 business respondents

The study discovered that only 31% of households harvested rainwater during rainy seasons (as shown in figure 11 below). Drums and buckets were commonly used to store harvested rainwater. It was discovered that the primary reason respondents do not harvest rainwater is that they believe the water is polluted and thus unfit for human consumption. Those who own the home in which they leave preferred to collect rainwater and use it to clean cars or water kitchen gardens and flowers during the dry season.

It was determined from the responses on rainwater harvesting that middle-income and high-income respondent's value rainwater as an alternative source of water, whereas low-income respondents do not.

For business people 92% of the respondents don't harvest rain water in their business premises (as shown in figure 12 below). The respondents identified poor state of roofs and pollution as the reasons which hinder them from harvesting rain water. The field survey established most of the buildings in the study area don't have rain water harvesting facilities such as gutters and storage tanks. Most of the respondents both in household and business sector view rain water as of poor quality hence not alternative source of water.

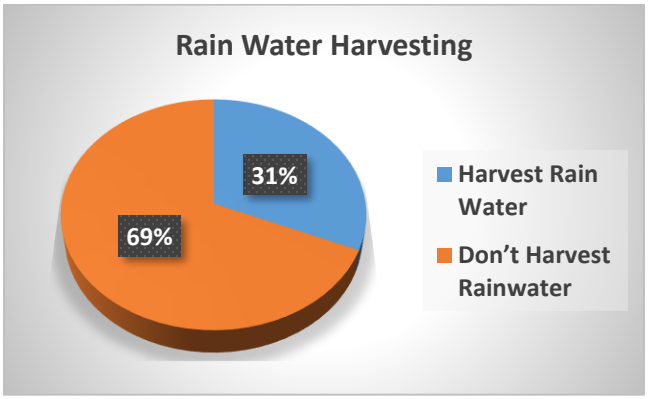


Figure 11 Rain water harvesting for 250 household respondents

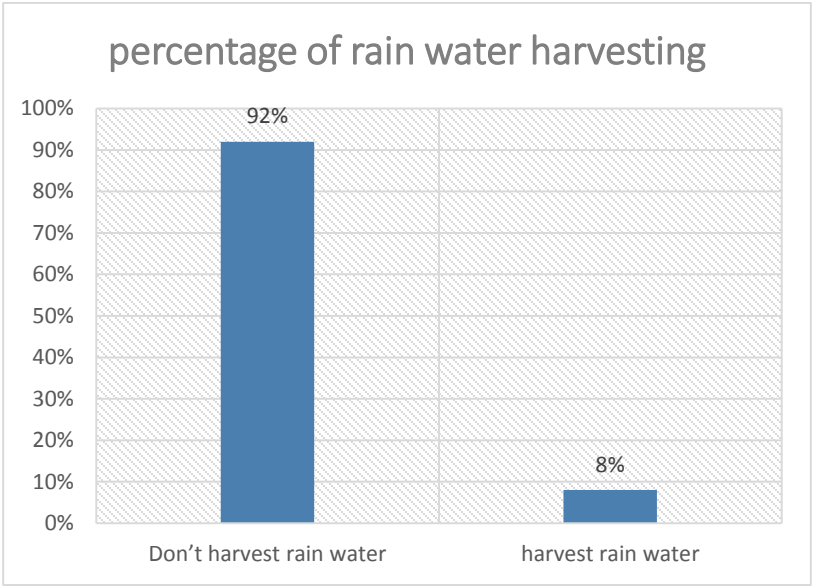


Figure 12 Rain water harvesting in 100 business respondents

The research found out both households and business enterprises don't use recycled water as alternative source of water. It was established that MAVWASCO doesn't have a water recycling plant hence recycled water is not alternative source of water to the company.

5.2.2 Water supply system for households and business

Water supply services in Athiriver Township are provided by MAVWASCO and other private entities. MAVWASCO is the public entity licensed to provide water services in Athiriver Township. The company sources its water from Kasuitu dam and 2 boreholes. The water distribution network in the municipality totals to 214,000 Km^2 . There is one treatment plant in the township where all the water from the dam and borehole is purified to recommended standards. The network has 5 pumping stations which help to keep the water pressure at the recommended standards to ensure smooth flow. There are 7 storage tanks in the distribution network. The research found out that MAVWASCO has connected 5,000 households to piped water in its distribution network. It was also established that the company has constructed and manages 49 water kiosks which they supply with water. Only one kiosk which is managed by MAVWASCO sources its water from a borehole.

Private entities which provide water services in the township source their water from private boreholes and Nairobi water and sewerage company through water bowsers. The field study established that private entities buy fresh water from Nairobi water and Sewerage Company in Nairobi County and sell to the residents of Athiriver Township. Majority of fresh water vendors sell up to 5,000 litres per day. MAVWASCO supplies 5,000m^3 of water per day to its customers.

5.2.3 Water pricing tariff for business and households.

The price of water influences demand, low prices leads to increased demand while high prices leads to low demand. The research found out that 39% of the household respondents spend between 500 – 1000 Ksh to purchase water per month. When the respondents were asked to rate the water price 41% identified it as affordable while 37% rated the price as expensive (as shown in figure 13 below).

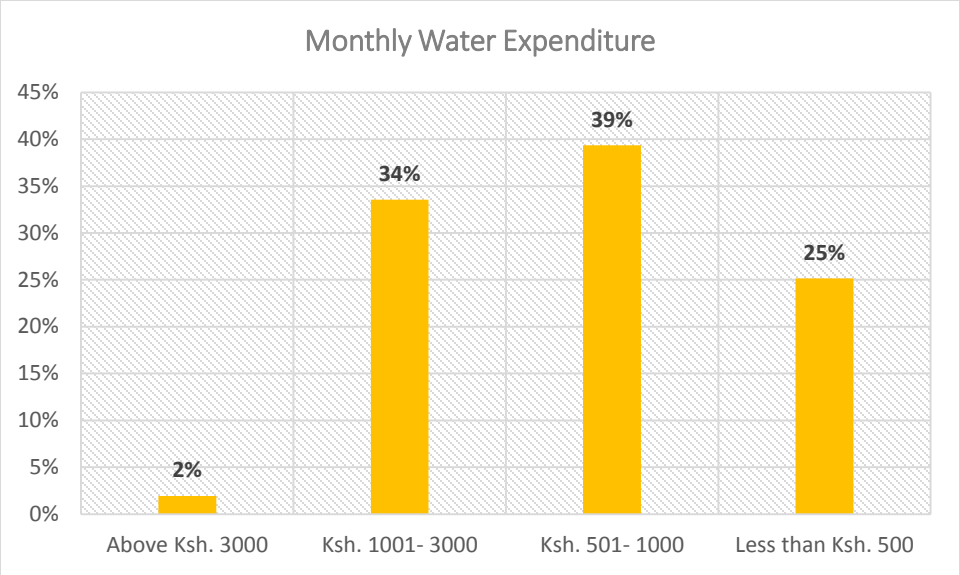


Figure 13 Monthly water expenditure for 250 household respondents.

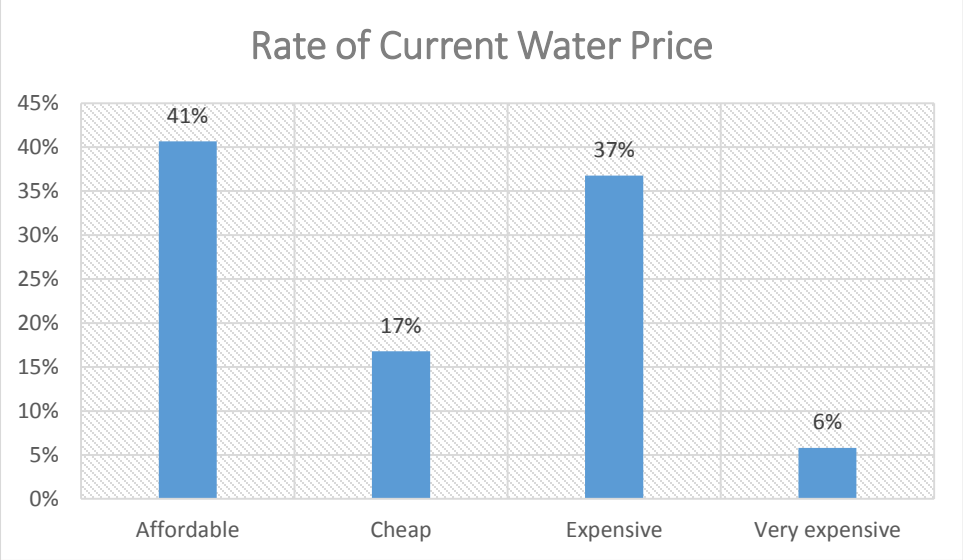


Figure 14 Rate of current water price for 250 household respondents.

In the business enterprises it was established that 72% of the respondents spend less than 5,000 ksh. On water bills per month. When asked to rate the water price 46% of the respondents said the water price was expensive while 36% identified the water price as affordable (as shown in figure 15 and 16 below).

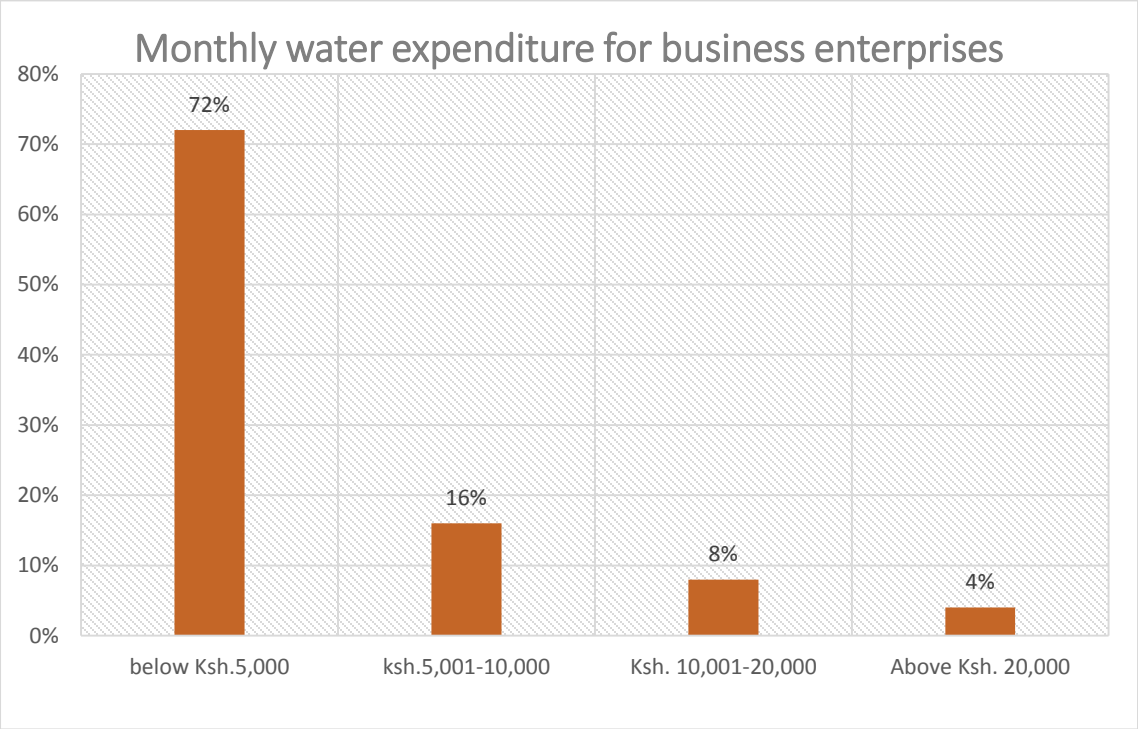


Figure 15 Monthly expenditure on water for 100 business respondents

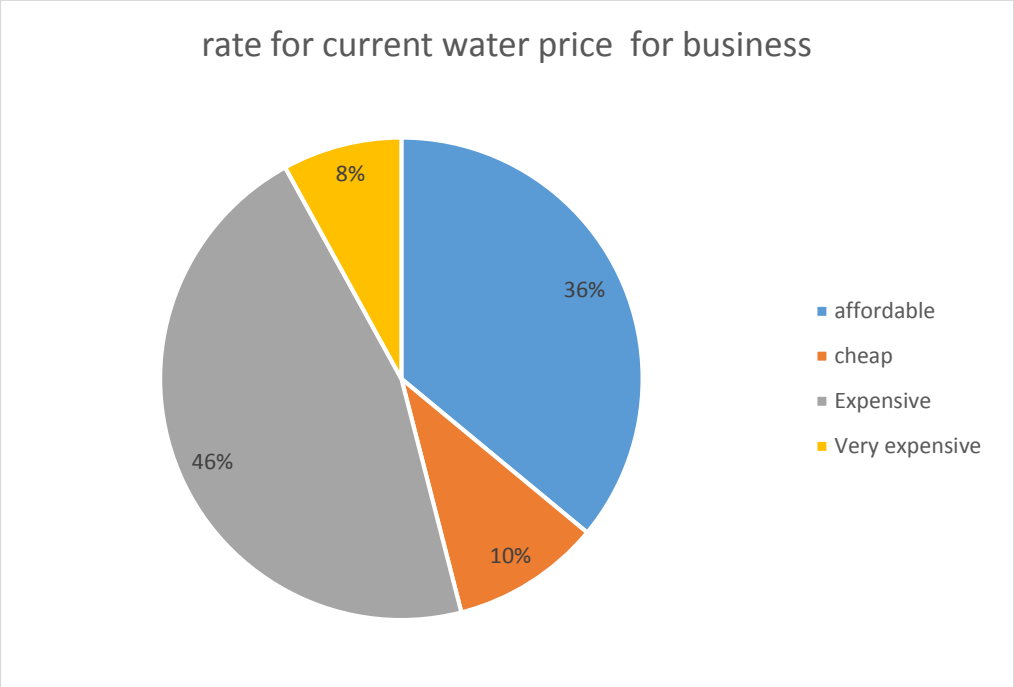


Figure 16 Rate for water price for 100 business respondents

The research found out water kiosks in Athiriver township sell 20 litres jerican at 3 Ksh. for MAVWASCO water and 20 Ksh. for fresh water from Nairobi water and Sewerage Company.

The field study established that MAVWASCO uses inclining block rate to bill their customer's i.e. water prices increases as consumption increases. The water tariff covers; pumping cost, watershed purchase/protection, treatment costs, and distribution system operation, electricity / fuel, and debt services. The company doesn't get any subsidies from the National or Machakos county government to cover some costs hence all the costs are calculated and passed to the customers. A revenue sufficiency pricing scheme is implemented by the utility company. This means that the tariff's primary goal is frequently cost recovery. Revenue from water users should be sufficient to cover the water utility's operating and maintenance costs, repay loans made to replace and expand the capital stock, provide a return on capital at risk, and keep a cash reserve for unforeseen events. According to the findings of the field research in Figures 12 and 14, the water tariff is expensive for both households and businesses.

5.2.4 Non- Revenue water management

Water loss reduction is frequently the least expensive and most effective way of ensuring water supply sufficiency. According to the research, MAVWASCO does not conduct water audits in its distribution network. Water auditing is a periodic exercise that determines the amount of water supplied, consumed,

and lost in the distribution system, providing a utility with data to make effective O&M and investment decisions. Because the water utility lacks a water audit program, it is difficult to reduce non-revenue water because there is no data to show the amount of water lost from the system. It was determined, however, that the utility conducts a full leak detection program every quarter. This enables them to identify where there is leakage and repair it within 24 hours to prevent water losses.

The field study established that all households and business enterprises which have piped water connection have installed a water meter from MAVWASCO. It was also found out that the water utility has a policy for every new connection to be issued with a meter. For the faulty meters, a meter repair program is in place. Metering is used to implement conservation measures such as water pricing and mandatory rationing, which are not possible without meters.

5.2.5 Water Demand Management strategies employed by households and business

Demand management aims to improve efficiency by changing how people and businesses use water. According to the study, the majority of households and businesses use one or two strategies to reduce water usage and waste. To save water, 34% of household respondents said they turn off water taps when not in use, while 20% said they avoid washing clothes daily. 29 percent taught their family members the value of water conservation. (as shown in figure 17 below)

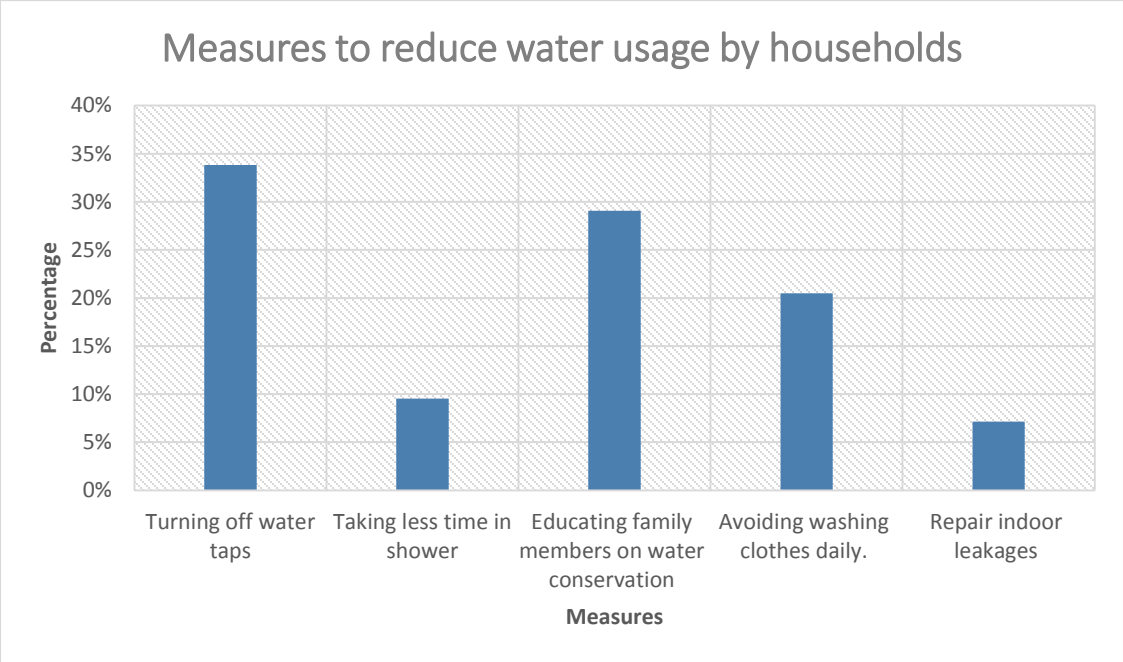


Figure 17 Measures to reduce water usage by 250 household respondent

The field study found that 28% of respondents in the business sector turned off water taps when not in use, while 8% recycled wastewater to reduce water usage. It was also established that some business combined two measures to reduce water usage. 10 % of the respondents combined educating employees on importance of water conservation and metering. 12% of respondents carried out water audits in their premises to ensure they were given correct water bills by MAVWASCO (as shown in figure 18 below).

On the issue of sensitization on water management the study found out 50% of respondents had been sensitized on importance of water conservations (as shown in figure 19 below). This tallied with the information from MAVWASCO whereby they indicated they conduct public education and awareness on water conservation measures.

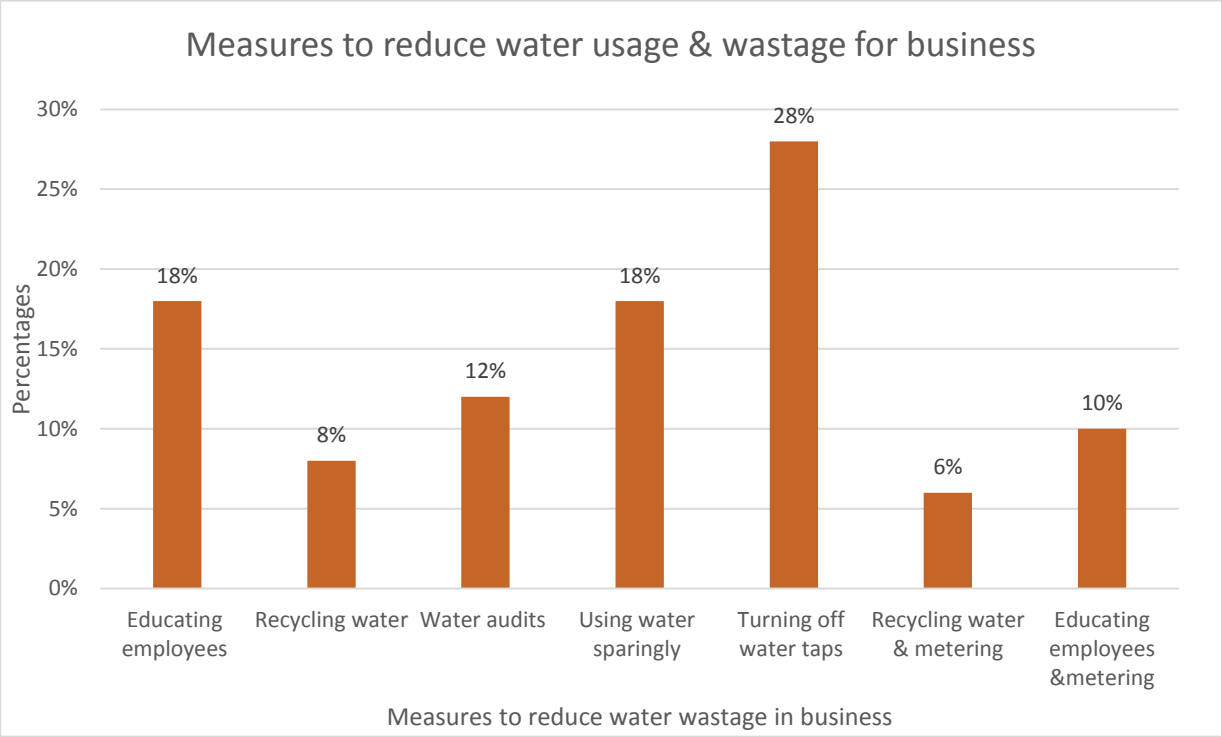


Figure 18 Measures to reduce water usage for 100 business respondents

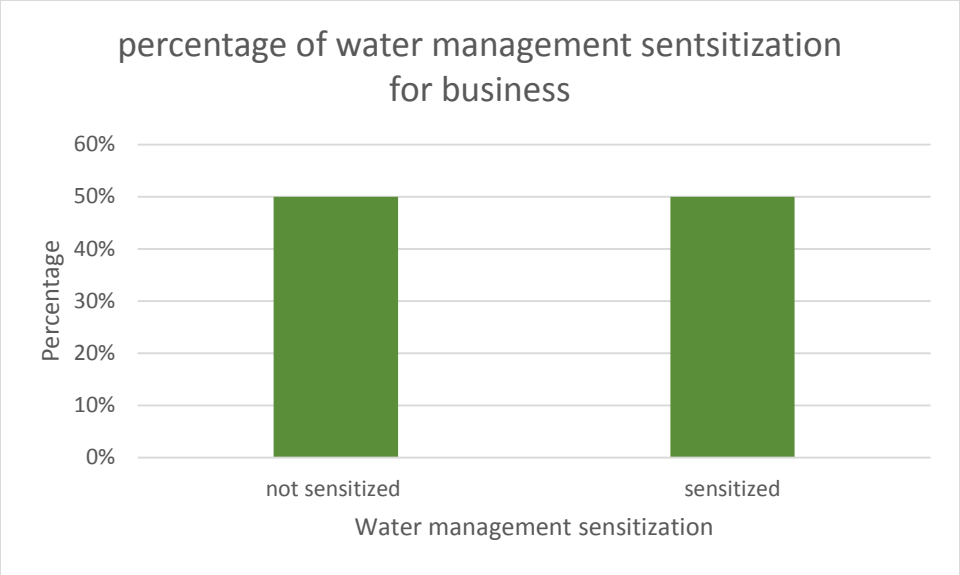


Figure 19 percentage of sensitization to water management.

5.2.6 Water governance

The field study discovered that the country lacks policies for long-term water supply and demand management. Non-revenue water reduction policy is in place, and implementation is being led by the Ministry of Water, Sanitation, and Irrigation. Because there is no policy in place to encourage rainwater harvesting and water reuse, the development of these alternative water sources is hampered. Although a national water master plan has been developed, implementation is difficult due to financial constraints.

5.2.7 Challenges faced by water services providers.

1. **Water scarcity**

The field study revealed that MAVWASCO and water vendors are faced with the challenge of scarce water sources. Water supply in Athiriver Township is affected by prolonged droughts and siltation which affects Kasuitu dam holding capacity.

2. **High water demand**

According to the findings of the field study, water demand in the township exceeds water supply, resulting in water scarcity. Water demand is increasing as a result of population growth and urbanization.

3. **High cost of electricity**

The field study established that MAVWASCO and water vendors use electricity and fuel to pump water from sources to the distribution lines. The high cost of electricity has led to increase operations cost. The

high cost of operation is passed over to water users hence high water tariff. Power disruptions in the area affect water supply due to halting of water pumping.

4. **Illegal water connections**

The filed study established that MAVWASCO is faced with the challenge of illegal connections majorly in informal settlements. This has resulted to high Non-revenue water in the distribution line as the connections are not metered.

5. **Pollution of water sources**

The field study found out that some industries in Athiriver Township are releasing waste water to the nearby rivers without treatment. This has resulted to water pollution both in surface and underground water.

CHAPTER 6

SUMMARRY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.0 Summary of findings.

This section of the thesis is based on the study's findings, which included categorizing and analyzing views sampled and information gathered from stakeholders in Athiriver Township. These key findings will, among other things, revolve primarily around the study's objectives.

1. *To evaluate the existing water and infrastructure management issues in Athi River Township, Mavoko municipality.*

2. To investigate success factors and successful water and infrastructure management case studies around the world.

3. To recommend working water and infrastructure management solutions in Athi river township, Mavoko municipality.

6.1.1 Water and infrastructure management issues in Athiriver

MAVWASCO, the town's utility provider, has limited capacity to supply potable water. MAVWASO is primarily reliant on one water reservoir, two boreholes, five operational pumping stations, seven storage tanks, and one operational treatment plant. According to the research, MAVWASCO has connected 5,000 households in Athiriver town to piped water. This represents 25% of the total number of households in the town. The utility company has built 49 water kiosks throughout town to sell water to residents. The water utility capacity to provide potable water to residents is estimated to be 145,000 M3 per month, with a demand of 570,000 M3 per month.

According to the study, the high rate of non-revenue water 44 percent was caused by deteriorating water infrastructure. To meet daily needs, the population relied on groundwater and alternative water sources such as private water tankers. According to the study, water prices are reasonable. Based on the research, the water utility company does not conduct water audits in their distribution network. According to the study, the majority of residents turned off water taps when they were not in use to reduce water waste. The study area's least used strategy for demand management is the use of water-saving technologies.

6.1.2 Best practices of water and infrastructure management from the case studies

The study proposed seven universal themes for replication in Athiriver and any other township seeking a sustainable water supply.

6.1.2.1 Reuse of treated water

From the secondary data review on the three selected case studies reuse of treated wastewater is one of the best practice which is carried out in Israel and Windhoek, Namibia. In Windhoek water reclamation plants produce water for direct portable reuse. From the three case studies analyzed water reuse is the most used method to provide alternative water sources.

6.1.2.2 Using aquifers as reservoirs

The research found out that arid countries like Israel and Namibia use aquifers as reservoirs. One of the most remarkable innovations of Israel water management is that aquifers have been gradually switched from being overexploited resources to becoming major storage reservoirs. Aquifers are recharged with treated wastewater during low-demand months and capture of occasional flash floods. The city of Windhoek has developed aquifer recharge scheme to act as water bank. The underground storage is not affected by evaporation preventing losses that would have occurred had this water been stored in open reservoirs.

6.1.2.3 Water saving technologies

From the case studies it was established that policy measures to enforce use of water saving technologies were implemented. Some of this measures are; toilet cisterns must be 6/3 liter dual flush units, automatic flushing devices without activation by the user are prohibited, only low flow showers are allowed to be installed. Such devices can reduce overall household consumption by 30%.

6.1.2.4 Non- revenue water reduction strategies

The research revealed that the case studies developed strategies to reduce non-revenue water. Technical measures implemented are mainly with regard to leakage control and proper watering of gardens. In order to reduce water losses both leakage detection and water audits are done on a continuous basis. Additionally, repairs as well as systematic pipe replacement programmes have been implemented and a proper management of water meters is done in all case studies.

6.1.2.5 Public awareness campaigns

The three case studies promote water conservation through the media and the internet, through the distribution of brochures, and the implementation of a range of public awareness activities such as: Educational programs in schools, on radio and television, and in the print media. This increases awareness of water conservation and acceptance of the use of treated water.

6.1.2.6 Institutional reforms

Having few institutions with specific roles in the water sector has enabled the three case studies to have efficient water provision services. Implementing institutional reforms to promote financial sustainability of the water sector as a whole, and separate political decisions from infrastructure planning and operations.

6.1.2.7 Development of master plan

The research found out that the three case studies have prepared a water master plan which guides investments and programmes to be implemented. Implementation of the water master plans has enabled the countries to achieve water sustainability. The master plans are reviewed after some time to suit projected future demand and supply conditions

6.2 Conclusions

This study has generated some useful information that will be used to improve water supply delivery in Athiriver town. Consumer perceptions of water shortages, water cost, and water connection issues will all aid MAVWASCO and Machakos County government officials in addressing these pressing issues confronting Athiriver residents. Because of increased population and urbanization, the demand-supply gap is rapidly increasing from day to day. MAVWASCO will be unable to meet the rapidly increasing water supply needs of the study area unless investments are made to close the demand-supply gap. These are the main findings of the study, and they will revolve primarily around the study's objectives.

To evaluate the existing water and infrastructure management issues in Athi River Township, Mavoko municipality.

Access to reliable and sustainable water supply is a problem faced by Athiriver township residents. To address the water scarcity issues MAVWASCO has to develop alternative water sources. Technical, Non- technical, infrastructure and legal solutions must be combined to achieve sustainable water supply. MAVWASCO should build efficient water system (treatment, distribution and operation), install leakage detection technology and install smart meters. Strategies to educate community on how to enhance water conservation need to be given priority. Construction of wastewater treatment plant will encourage water recycling and reuse hence creating alternative water source. Desilting of the water reservoir at Kasuitu should be a priority activity in order to increase the holding capacity. Long term actions such as construction of dam at Mto Mawe and investing in ground water storage through aquifer recharge will help to develop a sustainable water supply in the township.

MAVWASCO has a high level of non-revenue water due to system losses. This represents lost revenue and a missed opportunity to better serve users at a lower cost.

Current trends indicate that increasing population growth, urbanization, and industrialization are inevitable, making meeting future water demand one of MAVWASCO's biggest challenges. Strategic plans for urban water management which include adequate supply and demand analysis are required. Water sector governance issues are slowing progress toward sustainable water supply.

To investigate success factors and successful water and infrastructure management case studies around the world.

According to the case studies examined in this study, financial sustainability and sustained service delivery go hand in hand. As a result, utilities must have healthy revenue streams and carefully manage their costs. Utilities can use excess capital to implement a variety of revenue-generating measures to cover operation and maintenance costs. Water scarcity necessitates public awareness of the value of water, as well as demand management strategies and a shift toward pricing water at its true cost.

It was determined that simply investing heavily in new water infrastructure is insufficient; this must be done in a financially sustainable manner through appropriate institutional reforms. This includes establishing clear roles for policy development, regulation, planning, and operation of water infrastructure.

For a country or city to be water-sustainable, strong government and political commitment are required. Only through a strong commitment can a country or city invest in the infrastructure and technology required to achieve long-term water supply sustainability.

6.3 Recommendations.

The study's findings indicate that certain measures must be taken by water providers, the government, and consumers to achieve a sustainable water supply in the study area by 2030. The following recommendations will help achieve a sustainable water supply in Athiriver and any other town in the country. These key recommendations will, among other things, revolve primarily around the study's objectives.

6.3.1 Water and infrastructure management issues in Athiriver

To address the problem of limited water sources, alternative sources must be developed and incorporated in the supply system. This will be achieved by:

MAVWASCO's establishment of a water reclamation plant will enable the reuse of treated wastewater in Athiriver Township. Reclaimed water can be used to irrigate sports fields, recreational areas, parks, and farms. Second, reclaimed water can be used on construction sites. The use of reclaimed water allows for the release of scarce fresh water for domestic use, reducing pressure on freshwater supplies. The county government of Machakos and the national government can make reclaimed water more accessible

by developing a national wastewater recycling policy. This will create a legal framework that will allow people to accept recycled water as an alternative source of water.

The county government of Machakos and National government can use aquifer as reservoirs. This can be implemented by developing aquifer recharge project in Mavoko. The aquifer should be recharged with flash floods water or treated wastewater. This will make the aquifers be a major storage reservoirs which is not affected by climate changes like other water sources.

Rainwater harvesting should be promoted by MAVWASCO as an alternative source of potable water. This will help to reduce demand of municipal water during rainy season. The National government should promote use of rainwater by developing a policy on rainwater harvesting in the country. This will provide legal framework to enable people and enterprises to use rainwater as alternative water sources.

Implementation of national water master plan 2030. This master plan has projections of future water demand and supply for the whole country. In the master plan there are proposals to have two dams in Athiriver Township, one at Mto Mawe and expansion of Kasuitu dam. If the investments and programs in national water master plan 2030 concerning Athiriver township are implemented the town will have sustainable supply of water.

To address the challenge of high non- revenue water the following suggestions can be adopted:

To reduce Non- Revenue water from 44% to the set standard by WASREB of below 20% the utility company will need to implement water audit programme and improve leak detection programme from quarterly to monthly basis. Introducing technology for leak detection and control, as well as regular evaluation of the water supply system. To implement water audit programme MAVWASCO needs to install District Metered Areas monitoring (DMA). This will help in zoning the township, each area having one common meter at the distribution line before the water is distributed to end users. DMA will enable the utility company to accurately identify areas where there is leakage and repairs are done promptly.

To reduce water demand in Athiriver the following suggestions can be adopted:

Policy on water saving technologies can be enforced by the Machakos county government and National government. Tax waving on these equipment's will make them affordable to more people. This policy will result to reduction in household water consumption hence reducing demand on fresh water.

Machakos county government, National government and MAVWASCO should promote behaviour change campaign through public awareness campaigns to have education programs in schools, radio and television talk shows. This will increase awareness to water conservation and acceptance of reclaimed water hence adding another water source to already existing ones.

To reduce water price the following suggestions can be adopted

The utility company, County government of Machakos and National government needs to collaborate and develop alternative but sustainable funding modes which will enable price reduction to water users. Some financing mechanisms which can be used include:

Subsidies from County government or National government - one method which can be used to lower the tariff is cross subsidy this will involve subsidizing the poor and surcharge the high-income consumers. As a result, the service will be more equitable and affordable to the poor. The other method would be government subsidies, in which the national and county governments allocate a portion of their budgets to operations and maintenance. Subsidies can also be obtained by lowering the prices of spare parts and chemicals, as well as lowering the taxes imposed by various government agencies in the water sector.

Credit mechanisms- The national government can establish a social and development fund that will provide special funding for social and development purposes at a much lower interest rate than the financial market. Water Sector Trust Fund (WSTF) can be enhanced through increased fund allocation. This will enable water utilities to have access to more capital to invest in water projects.

MAVWASCO can cut operating and maintenance costs by shifting away from reliance on fuel or electricity and toward solar or wind energy. Choosing a technology with low spare parts or high operating costs, as well as reducing reliance on chemicals and systematic leakage control. These actions will aid in cost reduction, resulting in lower water tariffs for water users.

6.4 Areas of future Research

The study suggests the following additional areas of research:

i. The sustainability of aquifer recharge project in the study area.
ii. The effects of air pollution on rainwater quality in the study area.
iii. The effects of using septic tanks as a wastewater management method on groundwater sources.
iv. The advantages of using Public Private Partnership (PPP) as a financing model for urban water projects.

6.5 IMPLEMENTATION MATRIX OF PROPOSED STRATEGIES.

S/NO	ISSUE	STRATEGY	ACTIONS
1.	Water supply	Alternative water sources	• National government through Athi water development agency to construct the proposed dam at Mto Mawe River in Mavoko municipality. • Machakos county government and MAVWASCO to sensitize residents on rain water harvesting on urban rooftops by house owners. • Construction of water storage facilities by individual house owners. • Machakos county government and MAVWASCO to drill more water boreholes. • MAVWASCO to expand Kasuitu water reservoir • Public awareness campaign on rain water harvesting to be done by MAVWASCO • Preparation of rain water harvesting policy by National water Harvesting and Storage Authority.
		Promoting reuse of treated wastewater.	• MAVWASCO to construct wastewater reclamation plant. • Machakos County Government, MAVWASCO, and Mavoko municipal board to carry out public awareness campaign on use of reclaimed water. • National government through the Ministry of water, irrigation and sanitation to develop water reuse policy.

		Developing aquifer recharge programme.	• Water Resource Authority and Machakos county government to carry out research to Identify aquifers to be used as reservoirs • Machakos county government to construct aquifer recharge infrastructure.
2.	Water demand management	Promoting use of water saving technologies.	• National government to implement tax wavers on water saving technologies. • Households to install water saving technologies.
		Reducing Non- revenue water	• MAVWASCO to upgrade water supply infrastructure • MAVWASCO to Install District Metered Area to help in zoning. • MAVWASCO to initiate water audit programme. • MAVWASCO initiate leakage detection programme. • Households to repair any water leakages in their premises.
		Behaviour change campaigns	• National government and Machakos county government to carry out Public awareness campaigns on water conservation • MAVWASCO and Machakos county government to carry out television/radio talk shows to promote water conservation. • National government to implement water conservation education programmes in schools.
3.	Water governance	Financing	• National government to provide Credit to water service providers. • National government and Machakos county government to provide subsidies to private developers investing in water supply. • National and Machakos county government to use public private partnership to develop water resources and infrastructure.

		Policy changes	• National government through the ministry of water irrigation and sanitation to develop water reuse policy. • National water Harvesting and Storage Authority to develop rain water harvesting policy. • Water resource authority to develop aquifer recharge policy. • National assembly to amend water Act 2016 to incorporate the functions of county government in water resource development and management. • Machakos county assembly to enact by laws outlining the functions of water companies and the county department of water. • Machakos county government to prepare water resources management and development action plans. • National government through the ministry of water, irrigation and sanitation to develop water conservation policy.

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ANNEXURES

QUESTIONNAIRES

University of Nairobi

SCHOOL OF BUILT ENVIRONMENT

DEPARTMENT OF ARCHITECTURE AND BUILDING SCIENCE

SUSTAINABLE URBAN WATER MANAGEMENT: The case of Mavoko Municipality

Appendix 1 water users

a) HOUSEHOLD QUESTIONNAIRE

Note: The information obtained through this questionnaire is purely for academic purposes and shall be treated in confidence.

General information

Date of interview……. Questionnaire No……

Time interview started …… Time interview ended ……

Respondent name…….....

Locality (Sub location or area name)……..

Please tick where appropriate and write in available spaces where applicable

Section 1: Demographic data

1) Sex : Male [ ] Female [ ]

2) Age in years: A.18-25 [ ] B. 26-35 [ ] C. 35-45 [ ]
D. 45-55 [ ] E. Above 55 [ ]

3) Marital status: A. Married [ ] B. Separated [ ] C. Widowed [ ]

D. Divorced [ ] E. Single [ ]

4) Household size: A. 1-4 [ ] B. 5- 8 [ ] C. More than 8 people [ ]
5) Level of education of the respondent: A. Primary [ ] B. Secondary [ ]
   C. College [ ] D. University [ ] E. No. formal education [ ]
6) Main Occupation of household head. A. Student [ ] B. Employee (formal) [ ]
   C. Unemployed [ ] D. Retiree [ ] E. Businessman/woman [ ] F. Self-employed [ ]
7) For how long have you been staying in this area? A. Less than 2 years [ ]
   B. 2-5 years [ ] C. 6-9 years [ ] D. More than 10 years [ ]

Section 2: water supply and services

8) What is your main source of domestic water supply? A. Municipal water [ ]
   B. Communal yard tap in the plot [ ] C. Public borehole [ ] D. Private borehole [ ]
   E. Water vendors [ ] F. River/Stream [ ] G. water kiosk [ ] H. Shallow well [ ]
   I. Rain water harvesting [ ] J. other, specify [ ]
9) Do you have a household water connection?
   A. Yes [ ] B. No [ ]
10) If yes in (9) above what is the frequency of supply?
   A. Daily [ ] B. 2 times per week [ ] C. Once per week D. 3 times per week
11) How many litres of water do you use per day?
   A. 1-20 [ ] B. 21-60 [ ] C. 61-100 [ ] D. More than 100 [ ]
12) How often do you experience a water shortage in your household?
   A. On a daily base [ ] B. On a weekly base [ ] C. On a monthly base [ ]
   D. Every three months or more (please specify)
13) Do you have any other alternative source of water supply in case of shortage?
   A. Reserve tanks [ ] B. Wells [ ] C. Water vendors D. No other source
14) What is the distance from the house to the water source?
   A. Less than 20m [ ] B. 21 - 100m [ ] C. 101- 250m [ ] D. 251- 500m [ ]
   E. 501 – 1000m [ ] F. above 1001m [ ]

15) Do you harvest rain water? Yes [ ] No [ ]

a) If yes in (15) where do you store the water?

A. Buckets/Drums [ ] B. Galvanized iron sheet tanks [ ]

C. Masonry/Concrete tanks [ ] D. Plastic water tanks [ ]

E. Other (Specify)……..

b) If No in (15) above what are the reasons for not harvesting rain water

……..

……

……

……

16) What is the status of your domestic water supply in terms of quality?

A. Very good [ ] B. Fairly good [ ] C. Poor [ ] D. Very poor [ ]

17) What measures do you use to reduce water usage and wastage in your household?

A. Turning off water taps when not in use [ ]

B. taking less time in the shower [ ]

C. Educating family members on importance of water conservation [ ]

D. Avoiding washing of clothes unnecessarily [ ]

E. Repair indoor leakages [ ]

F. Not washing dishes under running tap [ ]

18) How much do you spend on domestic water per month?

A. Less than Ksh.500 [ ] B. Ksh.501- 1000 [ ] C. Ksh. 1001- 3000

D. Above Ksh. 3000

19) Rate the current water price per unit:

A. Cheap [ ] B. Affordable [ ] C. Expensive [ ] D. Very expensive [ ]

20) How would you rate the existing water supply services?

A. Excellent [ ] B. Very good [ ] C. Good [ ] D. Bad [ ]

Thank you for your time.

QUESTIONNAIRE TO BUSINESS ENTERPRISES AND INDUSTRIES

Note: The information obtained through this questionnaire is purely for academic purposes and shall be treated in confidence.

General information

Date of interview……. Questionnaire No……

Time interview started …… Time interview ended ……

Respondent name……..... position in the organization ……..

Locality (Sub location or area name)……

Nature of business ……

1. What is the source of water in your business?
   A. Municipal water [ ] B. Communal yard tap in the plot [ ] C. Public borehole [ ] D. Private borehole [ ] E. Water vendors [ ] F. River/Stream [ ] G. water kiosk [ ] H. Shallow well [ ] I. Rain water harvesting [ ] J. other, specify [ ]
2. How many litres of water do you use per day?
   A. 1-100 [ ] B. 101-300 [ ] C. 301-600 [ ] D. 601-1,000 [ ]
   E. 1,001- 5,000 [ ] F. 5,001- 10,000 [ ] G. More than 10,000
3. How often do you experience a water shortage in your business?
   A.On a daily base [ ] B. On a weekly base [ ] C. On a monthly base [ ]
   D. Every three months or more (please specify)
4. Do you have any other source of water supply in case of shortage?
   A. Reserve tanks [ ] B. Wells [ ] C. Water vendors D. No other source
5. Do you harvest rain water? Yes [ ] No [ ]
6. If yes in (5) where do you store the water?
   A. Buckets/Drums [ ] B. Galvanized iron sheet tanks [ ]
   C. Masonry/Concrete tanks [ ] D. Plastic water tanks [ ]
   E. Other (Specify)……..

7. If No in (15) above what are the reasons for not harvesting rain water

   ……..

   …….

   ……

   …….

8. Rate the quality of water supplied in your business

   Very good [ ] B. Fairly good [ ] C. Poor [ ] D. Very poor [ ]

9. What are the problems you encounter in accessing water in your business?

   ……

   ……..

10. Have you ever been sensitized on water management

    Yes [ ] No [ ]

11. What measures do you use to reduce water usage and wastage in your business?

    A. Turning off water taps when not in use [ ]

    B. installing low flow showers [ ]

    C. Educating employees on water conservation [ ]

    D. recycling water [ ]

    E. Repair indoor leakages [ ]

    F. Water audits [ ]

    G. Metering and sub metering

12. How much do you spend on water per month?

    A. Below Ksh.5,000 [ ] B. Ksh. 5,001- 10,000 [ ] C. Ksh. 10,001- 20,000 [ ]

    D. above Ksh. 20,000 [ ]

13. Rate the current water price per unit:

    A.Cheap [ ] B. Affordable [ ] C. Expensive [ ] D. Very expensive [ ]

14. How would you rate the existing water supply services?

    A. Excellent [ ] B. Very good [ ] C. Good [ ] D. Bad [ ]

THANKS FOR YOUR TIME

Appendix 2 water service providers

INTERVIEW SCHEDULE FOR WATER SERVICE PROVIDERS (MAVWASCO)

Note: The information obtained through this questionnaire is purely for academic purposes and shall be treated in confidence.

General information

Date of interview……. Questionnaire No……

Time interview started …… Time interview ended ……

Respondent name……..... position in the organization ……..

Locality (Sub location or area name)……..

1) What kind of water services do you offer in the municipality?

   ……..

   ……

   ……..

2) What is your main source of water that you provide to Mavoko Residents?

   A. Dam [ ] B. Borehole [ ] C. River [ ] D. Others, specify

3) How many boreholes and dams do you manage in Athiriver Township?

   ……..

4) How many households have you connected with water?

   ……..

5) How many water kiosks has the company constructed in Athiriver township

   ……

6) What is the amount of water consumed per day in the municipality?

   …….

7) What is the size of water distribution network in the municipality in Km?

   ……

8) How many pumping stations does the water distribution network has

……..

……..

9) How many water storage tanks does the water distribution network has

10) Do you experience any water shortage from the source?

Yes [ ] No [ ]

11) If yes in (9) above what alternative sources do you have to ensure continuous water supply?.....

12) What do you think causes water shortage? ……..

Water audits and leak detection

13) Do you conduct water audit of distribution your system?

[ ] Yes [ ] No

If yes when was the last water audit performed

…….

14) Do you conduct a full leak detection program for your distribution system?

[ ] Yes [ ] No

If yes how often do you conduct leak detection?

[ ] Annually [ ] Quarterly [ ] Monthly

15) How long does it take to repair a burst pipe in your distribution system?

[ ] 1 hour [ ] 6 hours [ ] 12 hours [ ] 24 hours

16) What strategies have been put into place to reduce water leakage in the supply system?

…….

……..

…….

Metering

17) Is your system 100% metered?

[ ] Yes [ ] No

If no, what is not metered? …….

What steps are you taking to complete metering of your system? .....

……

18) Are all public sector facilities billed for their water use?

[ ] Yes [ ] No

19) Do you bill based on actual meter readings or estimation?

……..

If estimation what steps are you taking to bill based on actual meter readings

……..

20) Do you have a meter repair/replacement program?

[ ] Yes [ ] No

If no, what happens to fault/damaged meters?

…….

Pricing

21) What pricing structure does the company use in setting water tariffs

A. Uniform rate [ ] B Inclining block rate [ ]

C .Declining block rate [ ] D. Excess use rate [ ]

22) Which of the following items are covered by the price of water charged to customers?

[ ] Pumping [ ] watershed purchase/protection

[ ] treatment costs [ ] distribution system operation

[ ] electricity/ fuel [ ] debt service

23) Is the revenue collected sufficient for the running of the company activities?

……

24) What are the other sources of income for the company?

…….

……

……

Public education and awareness

25) Does the company conduct public education and awareness on water conservation measures?

[ ] Yes [ ] No

If yes, which outreach program?

[ ] media adverts (Tv, Radio, Newspaper and social media)

[ ] public awareness campaign in the town

[ ] water conservation workshops for the general public

[ ] water conservation seminars in schools

26) What challenges does MAVWASCO face in accomplishing its mandate?

…….

……

…….

……

27) Has MAVWASCO prepared a master plan for water provision in the municipality?

Yes [ ] No. [ ]

a) If No, what are the challenges in preparing one?

…….

…….

…….

28) Does the company has a policy in place for water recycling and rain water harvesting?

…….

……

…….

INTERVIEW SCHEDULE FOR WATER SERVICE PROVIDERS (WATER VENDORS/ KIOSKS)

Note: The information obtained through this questionnaire is purely for academic purposes and shall be treated in confidence.

General information

Date of interview……. Questionnaire No……

Time interview started …… Time interview ended ……

Respondent name…….....……..

Locality (Sub location or area name)……..

1) How many litres of water do you sell per day?

.....

2) What is the source of the water?

……

3) Is the source reliable?

   ……..

4) What is the price of 20 liter jerican?

   ……

5) How long has this kiosk been operational?

   A. Less than 2 years [ ] B. 2-5 years [ ]

   C. 6-9 years [ ] D. More than 10 years [ ]

6) What challenges do you face while providing water services?

   …….

   ……..

   ……..

   …….

APPENDIX 3 WATER REGULATORY BODIES

INTERVIEW SCHEDULE FOR WATER RESOURCE AUTHORITY

Note: The information obtained through this questionnaire is purely for academic purposes and shall be treated in confidence.

General information

Date of interview……. Questionnaire No……

Time interview started …… Time interview ended ……

Respondent name……..... position in the organization ……..

Locality (Sub location or area name)……

1) What role does the authority play in water resources development and management?

   ……..

   …….

   ……

2) What are the challenges experienced when implementing your mandate

   ……..

   ……..

……..

3) What is the status of underground water within Mavoko municipality?

……..

…….

……..

4) What strategies are in place to protect various water sources in the municipality?

……

……

……..

5) Does the authority have a master plan for water resources development and management?

……..

……

APPENDIX 4 WATER GOVERNANCE

INTERVIEW SCHEDULE FOR WATER OFFICER MACHAKOS COUNTY

Note: The information obtained through this questionnaire is purely for academic purposes and shall be treated in confidence.

General information

Date of interview……. Questionnaire No……

Time interview started …… Time interview ended ……

Respondent name……..... position in the organization ……..

Locality (Sub location or area name)……

1) What is the role of your office in water supply and demand management in Mavoko municipality?

……

……

……

2) What is the estimated urban water demand in the municipality?

…….

3) What is the current water supply in the municipality?

   ……..

4) What initiative have been put in place to improve water supply in the municipality and county

   ……..

   …….

5) How many boreholes have been drilled and operational in the municipality?

   Public……..

   Private……

6) How does the county government regulate and ensure water quality is maintained by various service providers?

   .....

   ……

7) What strategies are in place to control over extraction of ground water in the municipality and county?

   …….

   …….

8) What strategies are in place to protect water sources from pollution?

   ……

   …….

9) Does the county has a policy in place for water recycling and rain water harvesting?

   ……

   ……

   ……..

10) Is the county involved in setting water prices?

    [ ] Yes [ ] No

11) Do you have a County specific plan/policy for the management of water within Machakos County?

    …….

    ……

    …….

12) Does the department provide financial support to water utilities in the county

[ ] Yes [ ] No

If yes how much of financial support

……

……..

…….

13) What challenges are there in ensuring sustainable water supply and demand management?

…….

…….

…….

14) Does the department conduct public education and awareness on water conservation measures?

[ ] yes [ ] No

If yes, which outreach program?

[ ] media adverts (Tv, Radio, Newspaper and social media)

[ ] public awareness campaign in the town

[ ] water conservation workshops for the general public

[ ] water conservation seminars in schools

INTERVIEW SCHEDULE FOR MINISTRY OF WATER NATIONAL GOVERNMENT

1) Does the country has water policy

[ ] yes [ ] No

If yes what are the objectives?

…….

……

2) What percentage of ministry budget goes to water development?

……

……..

3) How is the progress in implementation of water master plan 2030

A.0-30 % B. 30-50 % C. 50-70% D. 70-100%

4) What are the challenges the ministry has faced in implementing the water master plan?

……..

……

……

5) What measures has the ministry initiated to reduce non-revenue water in the country?

……

……..

……

6) Does the ministry has a policy on water meter replacement?

[ ] yes [ ] No

If yes after how long should the meters be replaced?

[ ] 5years [ ] 8 years [ ] 10 years

7) What institutional reforms has the ministry initiated to ensure water utilities are financially sustainable

……..

…….

…….

8) Does the ministry have plans to support water desalination in the country?

.....

…….

9) Does the ministry advocate for reuse of treated waste water to irrigate crops?

.....

……..

10) Does the ministry conduct public awareness campaigns to sensitize the citizens on importance of water conservation?

[ ] Yes [ ] No

If yes, which outreach program?

[ ] media adverts (Tv, Radio, Newspaper and social media)

[ ] public awareness campaign in the town

[ ] water conservation workshops for the general public

[ ] water conservation seminars in schools.