UNIVERSITY OF NAIROBI.

SCHOOL OF COMPUTING AND INFORMATICS

ROLE OF INFORMATION COMMUNICATION TECHNOLOGIES IN WATER MANAGEMENT

By

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Submitted in partial fulfillment of the requirements for the Degree of Masters of Science Information Technology Management of the University of Nairobi.

DECLARATION

I declare that this project report is my original work except where references are cited. To the best of my knowledge, this has not been submitted for any award in any University

Signature   Date

This project has been submitted in partial fulfilment of the requirement of the Master of Science Degree in Information Technology Management of the University of Nairobi with my approval as the University Supervisor

Dr. Elisha Abade   Date

Signature

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ABSTRACT

Kenya has low levels of water access whereas the demand for water services continues to rise largely as a result of the increasing population. Nairobi which is the capital city of Kenya, only 50 per cent of the population has direct access to piped water. The rest obtain water from kiosks, vendors and illegal connections. Of the existing customers, about 40 per cent receive water on the 24-hour basis. The low access levels have increased pressure to manage the country's water resources more efficiently and ensure that water services are availed equitably among the diverse uses. The purpose of this study was to establish the role ICTs can play in managing the water resources and services efficiently. The study adopted descriptive census design. The response rate for the target population was 83% which is statistically significant to analyze the data. Data collected was analyzed using both descriptive and inferential statistics. The study established that Billing System, Meter Reading System, Financial Management system, Procurement system and the Dam Monitoring System were the main ICT applications used in water management. Further the study established that limited staff skills, limited resources (finance), lack of customized applications, lack of detailed top level management support and appreciation of the role of ICT by other departments were main challenges facing the implementation of ICT applications in the company. The study identified; quality management, water supply chain monitoring, mapping of water supply stations using GIS and customer management to be the priority functions in water management where ICT applications are required most.

***Keywords**: GIS, SCADA, water resource management, mobile applications, water sensors, smart pipes, smart meters*

LIST OF ABBREVIATIONS

AI: Artificial Intelligence

AWSB: Athi Water Services Board

BIM: Building Information Modelling

CCE: Climate Change Education

ESD: Education for Sustainable Development

EU: European Union

GHG: Green House Gases

GIS: Geographical Information System

ICT4D: ICT for development

ICTs: Information and Communication Technologies

ICTWCC: Innovative Application of ICT in Addressing Water-Related Impacts of Climate Change

IDRC: International Development Research Centre

ISO: International Standards Organization

ITU: International Telecommunication Union

KMD: Kenya Meteorological Department

LOs: Learning Objectives

NCWSC: Nairobi City Water and Sewerage Company

NGO: Non-Governmental Organizations

OECD: Organisation for Economic Co-operation and Development

PRSPs: Poverty Reduction Strategy Papers

SL: sustainable livelihoods

SPSS: Statistical Package for Social Sciences

UNEP: United Nations Environment Programme

WISDOM: Water Analytics and Intelligent Sensing for Demand Optimised Management

CHAPTER ONE
INTRODUCTION

1.1 Background

Kenya, which is considered as a water scarce country below 64,710 cubic meter of water per capita compared to the international benchmark of 1,000 cubic metres per capita, faces serious challenges with regard to protection of water resources, water supply and sanitation services. Despite the resources that have been provided so far, existing water sources and facilities have continued to deteriorate whereas the demand for water services continues to rise largely as a result of the increasing population. The pressure to manage the country's water resources more efficiently and ensure that water services are availed equitably among the diverse uses is bound to increases as the country gears itself towards meeting the Vision 2030 goals.

ICTs have a potential to contribute towards improvements in water resource management techniques; strengthen the voice of the most vulnerable within water governance processes; create greater accountability; provide access to locally relevant information needed to reduce risk and vulnerability; and improve networking and knowledge sharing to disseminate good practices and foster multi-stakeholder partnerships, among others (Finlay and Adera, 2012).

Research has shown that ICTs have the potential to improve water use efficiency as evidenced by GeSi & EC. Europa (n.d).. However, it is impossible to realise the full potential of ICTs in improving water use efficiency due the current fundamental problem with the design and priortisation of the existing ICT Infrastructure and applications. If this design problem is rectified, it is believed that ICT can play an immeasurable role in mitigating, adapting to and monitoring climate change. Further supporting evidence is given by Young (2007) that ICTs are to reduce climate change in other industrial and domestic sectors through de-materialising and de-carbonising the economy.

Russell (2008) quoting climate experts asserts that, Africa is steadily warming, climate is changing and that there will be further changes in rainfall and temperatures. Africa is warmer by 0.5 degrees Celsius than it was a century ago. Climate experts say Africa is particularly vulnerable to climate change because of various factors such as widespread poverty, the unsustainable use of natural resources, over-dependence on rain-fed agriculture and weak institutional support structures.” On global trends in climate change, Russell (2008) indicates that “the global surface temperatures have warmed by up to 0.8 degrees Celsius and climate change statistics indicate that globally the sea level has risen by 10-25cm in the last 100 years. This evidence is more than enough to convince anyone that climate is changing and will continue to change if no measures are taken. This in return will continue putting pressure on the limited water resources available.

Importance of ICTs to combat climate change is futher underscored by the UN Secretary General Ban Ki-moon, Horrocks et al (2010) pg 1: *“We all know that information and communications technologies (ICTs) have revolutionized our world...ICTs are also very vital to confronting the problems we face as a planet: the threat of climate change...Indeed ICTs are part of the solution. Already these technologies are being used to cut emissions and help countries adapt to the effects of climate change...Governments and industries that embrace a strategy of green growth will be environmental champions and economic leaders in the twenty-first century.”*

1.2 Problem Statement and purpose of the project

The world is experiencing negative impacts of climatic change some of which include global warming, floods, droughts, heat waves, unpredictable seasons etc. These effects are impacting on both developing and developed countries, with developing countries being the hardest hit. With the advancement of technology worldwide, it has become necessary for stakeholders to find clear structures in which technology can be used to adapt to the effects of climate change.

One sector that has been impacted by the effects of climate is the water sector. For instance, of the three million residents of Nairobi, only 50 per cent have direct access to piped water. The rest obtain water from kiosks, vendors and illegal connections. Of the existing customers, about 40 per cent receive water on the 24-hour basis (NCWSC, 2015). The Millennium Development Goals (MDGs) identifies water and sanitation services as key factors in lifting people out of poverty. Against this background, ways and means in which water access can be improved has been devised, it is in this front that ICTs can play a greater role in water access (Mbugua, 2006).

While the impact of climate change and climate variability on water resources is well documented (IPCC, 2001; IPCC, 2007; UN-Water 2010; Finlays and Adera, 2012), there has been a disconnect between ICT applications implementation at the local communities and the water service providers. This has continued to jeopardise adaptation efforts in water systems and the achievement of development outcomes. In broader development contexts, well structured

ICT applications implementation and priortisation can offer complementary support to integrated approaches to adaptation, including use in monitoring, early warning and other measures to ensure water security for the vulnerable.

1.3 Objectives

1. Establish ICT applications used in management of water resources and the functions they perform.
2. Evaluate the platforms that host the ICT applications used to improce water use efficiency.
3. Identify the challenges faced in the implementation of ICT in the management of water resources
4. Develop a guideline to the use of ICT in water management in Kenya

1.4 Research Questions

1. What are the ICT applications that are being used by water companies to manage water resources?
2. What are the functions of the ICT applications that are being used by the water companies to improve water-use efficiency at the local level?
3. What are the platforms that host the ICT applications that are used to improve water use efficiency?
4. What are the challenges faced in implementing ICT application in water resource management?
5. What guideline can be adopted on the use of ICT in water management in Kenya?

1.5 Research Outcomes and their significance to key audience

This study reviewed the level of application of ICTs in water management as well as explore how ICT applications can help to improve water-use efficiency at local levels. The data obtained from the study was then used to establish a guideline on the use of ICT in Water Management in Kenya.

The value of the study is seen in as two-fold. It has a conceptual depth that enables it to be used for analysis of initiatives at the intersection of climate change adaptation, water resources and ICTs. In addition, it has a practical value for project managers, enabling them to understand concrete decision factors and actions in implementing their projects.

ICT tools have the potential to strengthen the capacity of developing countries to withstand, recover from and adapt to the water-related challenges posed by climate change (e.g. changes in water supply and demand, availability, management and governance), given the presence of key precursors and inputs, the uptake of digital capital, and the impact of ICT enabled interventions.

1.6 Definitions of Important Terms

Water efficiency: is reducing water wastage by measuring the amount of water required for a particular purpose and the amount of water used or delivered.

Climate Change: is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events).

Information Communication Technologies (ICTs): term that stresses the role of unified communications and the integration of telecommunications (telephone lines and wireless signals), computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information

Mitigating climate change**:** actions to limit the magnitude and/or rate of long-term climate change. Climate change mitigation generally involves reductions in human (anthropogenic) emissions of greenhouse gases (GHGs).

Climate change Adaptation: This is to anticipate the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise.

Monitoring climate change: Climate monitoring is the process of observing and understanding the atmosphere, oceans and other components of the Earth System.

Water resource management: is the activity of planning, developing, distributing and managing the optimum use of water resources.

CHAPTER TWO

LITERATURE REVIEW

2.1 Climate change and variability status

According to the United Nations Framework Convention on Climate Change (UNFCCC) (2007), many areas in Africa have climates that are among the most variable in the world on seasonal and decadal time scales. Frequencies of floods and droughts are increasing, with many episodes reported in the same area within months of each other.

Reports indicate that one third of African people already live in drought-prone areas and many more are exposed to drought each year (UNEP, 2010; Lobell et al., 2008). Across Kenya, the effects of climate change are wreaking havoc" (MEMR 2009). The prolonged droughts of the past decade have threatened food security and societal stability, especially in vulnerable pastoral areas (GoK 2007; UNDP 2007).

A number of factors contribute to and compound the impacts of current climate variability in Africa. The IPCC (2007) projects that these factors will have negative effects on the continent's ability to cope with climate change. These factors include poverty, illiteracy and lack of skills, weak institutions, limited infrastructure, lack of technology and information, low levels of literacy and health care, poor access to resources, low management capabilities and armed conflicts (UNFCCC, 2007).

Water is a critical element in ensuring livelihoods, since more than 40% of Africans live in arid, semi-arid and dry sub-humid areas and about 60% live in rural areas and depend on farming for their livelihoods (UNEP, 2010). In terms of dryness, Africa is second only to Australia. The continent's water resources are unevenly distributed, with central Africa holding nearly half of the total inland water reserves (UNEP, 2006).

Significant changes in runoff fluctuations are predicted for Africa (IPCC, 2007). Many climate models project constrained hydrological cycles for many regions and a decrease in annual mean rainfall. Over the past decade observed trends have reflected extended and more frequent droughts as well as an increase in frequency of floods (UNEP, 2007). The mean annual runoff in the main river basins could decline by as much as 32% by 2050 (IPCC, 2007). Climate change is expected to exacerbate the current stress on water resources from population growth, development and land-use change, including agricultural expansion.

In Kenya the changes in precipitation and temperature already are affecting runoff and water available for different uses, including domestic and agricultural demand. Projected trend of increasing temperatures and less reliable rainfall increases the likelihood of floods and droughts (Few et al. 2006; WBGU 2007). In arid and semi arid lands (ASALs), which make up 80% of Kenya's land area, droughts are a common phenomenon (GoK 2007).

The projected decreases in runoff by 25% (IPCC, 2007) in many parts of the continent will be largely due to decreases in rainfall and higher rates of evapotranspiration. These events are projected to occur more often, resulting in a higher total amount of rainfall and an increase of rainfall variability (Christensen et al. 2007; McSweeney et al. 2008). More regions are bound to be drought stricken, adversely impacting on multiple sectors such as agriculture, water supply, energy production and health. Irrigation demands on the continent are also expected to escalate (UNEP, 2006).

Naanyu (2013) concludes that, ensuring food security amidst a changing climate is at the top of developing countries agendas. But most importantly is a matter of survival for the millions of farmers, fishers, herders and foresters whose livelihoods are highly vulnerable to the occurrence of extreme events, changing temperatures and unpredictable seasonality, among other stressors.

2.2 ICT and Water Use Efficiency

Water is a critical natural resource today. Projections made by the 2030 Water Resources Group show that world demand for water will exceed accessible supplies significantly, threatening to impede global economic growth and result in large-scale food insecurity. Water efficiency is reduction of water wastage by measuring the amount of water required for a particular purpose and the amount of water used or delivered. ICT has emerged as a strong way to understand water security challenges. They are increasingly being adopted as key decision support mechanisms for adapting to water use effects in the developing world. The proper use of ICT applied to water use efficiency allows gathering data to know in real time about supply, demand and use of water among its users (Ancarani, 2005).

As the Kenyan economy grows, water scarcity threatens to present a major bottleneck to the country's ambitions for growth and prosperity. Water scarcity may impede growth, create food shortages and increase reliance on external supplies, exacerbate regional conflicts and lead to other fundamental problems for society. Since Kenya's economy is agriculture- based, the efficiency of agricultural water-use in the country should be significantly enhanced coupled with an increase in the perceived value of water among consumers and other stakeholders. Upgrading the country's archaic irrigation infrastructure and adopting modern micro-irrigation technologies such as drip-irrigation and water-sprinkler systems is recommended. Farmers must be encouraged to adopt scientific cropping techniques to maximize agricultural yields and enhance water-use efficiency of their produce. ICT-enabled solutions provide scalability, one-to-one localized connections with stakeholders, automation of several key operations and strategic insight into status reports. Therefore, a combination of digital and field measures to effectively increase water-use efficiency across the country could be used (Henten, Samarajiva & Melody, 2003).

ICT applications enable WSPs to supply enough water to bulk users individually by changing water distribution path with electronic control of water valves thereby preventing excess water production and suppress facility investment. We regard the water network as a communication network and operate water infrastructure by remote and electronic control of pumps and valves. It enables efficient operation of water infrastructure which prevents water loss by suppressing burst of deteriorated pipes and supplies necessary and sufficient amount water to users. With the adoption of ICT, optimal operation plan of water infrastructure can be made from predictions using big data technology (Downs, 2001). This will enable the WSPs to provide the exact amount of water for a particular purpose thereby reducing water wastage.

In particular the mobile phones are continuing to shape development in ways that were not anticipated a few years ago, including in the water sector (Heimbuch, 2009; Houghton, 2009). Examples include the Android application of Field Level Operations Watch (FLOW) for data gathering, analysis and reporting. However, crucial barriers prevail in Africa constraining the wider deployment of ICT-based solutions to water use efficiency problems. The barriers vary from country to country and even within countries (e.g. between urban and rural areas and also between different ecosystems) (Finlay & Adera, 2012). Moreover, over the last few years a new wave of ICT development has impacted on the continent in the form of modernised infrastructures like broadband fibre optic cables and data centres, added value services and IT innovations. With these developments, prices are falling while demand for equipment, expenditure on ICTs and local content are burgeoning. ICT expenditure was expected to grow by 10% across Africa in 2011, reaching a total of USD 25 billion (IDC, 2011).

Emerging experiences from vulnerable communities point to the increasing use of community radio, mobile phones, the internet and other ICTs in water use efficiency responses. They also indicate the value of an e- resilience approach, since this moves beyond shallow surface effects to understanding the way in which ICTs can – but often fail to – have a deeper and systemic effect that will help communities and nations sustain resources management (Ospina and Heeks, 2010a).

2.3 ICTs and Climate change

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2.4 Information communication technology and water resource management

Existing literature points to an increasing role of ICTs in climate change-related water systems management. In Africa, such literature stems from global perspectives and theoretical underpinnings with less stemming from field experiences. A lot therefore remains to be studied, implemented, done, documented and analysed, particularly with regard to the role of ICTs in enhancing water security in marginal ecosystems and among vulnerable communities. The ITU-T Technology Watch Report (ITU, 2011) provides an overview of how ICTs can be a strategic enabler for smart water management policies and surveys upcoming standards that will act as a catalyst for successful implementation of smart water management initiatives. The African global environmental change research agenda and science plan (Odada et al., 2008) enumerates exciting questions to be researched further to unravel these, more so when integrated with ICT functionality.

Scoping studies have been done looking at the application of ICT to solve climate-induced water management challenges in prediction, mitigation, monitoring, and now increasingly, adaptation and national or institutional strategy formulation (Heeks and Ospina, 2009; Houghton, 2009; Maumbe and Okello, 2010; Schuol et al., 2009; SEI, 2009). Ospina and Heeks (2010b) as well as Kalas and Finlay (2009) specifically point out that ICTs need to be innovatively incorporated in mitigation, monitoring, adaptation and strategy of water management systems. The overview model by Ospina and Heeks identifies current gaps and emerging topics that further analysis should focus on. These are arguably relevant for Kenya where there are ongoing shifts in priorities and perspectives and close linkages between ICTs, climate change and vulnerability of water systems and communities. Institutions, governments and communities are increasingly acknowledging the challenges of ICTs within climate change as it relates to other sectors including water. There is a growing need to foster knowledge sharing and collaboration.

Finlay and Adera (2012) further indicate that the rationale for considering ICT tools, platforms and protocols is to facilitate the collection, storage, analysis, distribution and utilization of data via interaction and feedback among various water actors. Such ICT tools may range from simple mobile telephony to the more advanced robust field sensors, telemetric data transmission and satellite-driven remote sensing of hydrological conditions. The scale and complexity depend on geographical coverage and volume of digital data to be moved. Such tools will allow water users and system managers to understand current water systems conditions and make informed forecasts.

New technology platforms are required to sustainably manage urban water resources, that call for intelligent sensing and appropriate data management for optimisation. A good example is the FP7 WISDOM project (Zarli et al, 2014) which aims to achieve a step change in water (and energy) savings via the integration of innovative Information and Communication Technologies

(ICT) frameworks to optimize water distribution networks and to enable change in consumer behaviour through innovative demand management and adaptive pricing schemes. The WISDOM approach couples sensor monitoring and communication systems with semantic modelling (using ontologies, to serve as intelligent linkages throughout the entire framework) and control capabilities to provide for near real-time management of urban water resources. The WISDOM framework will be modelled and simulated with initial testing at an experimental facility in France and in water facilities in Cardiff (UK) and La Spezia (Italy). These demonstrators will evaluate the integrated concept providing insight for wider adoption.

2.5 Athi Water Services Board

Athi Water is one of the eight Water Boards under the Ministry of Environment, Water and Natural Resources created to bring about efficiency, economy and sustainability in the provision of water and sewerage services in Kenya. Athi Water is created under Section 51 of the Water Act 2002 serving a population of over 4.5million (AWSB, n.d).

The board is mandate to planning, developing, rehabilitating and expanding water and sanitation services infrastructure. The Board also ensures efficient and sustainable provision of quality and affordable Water and Sewerage services in its area of jurisdiction which covers Nairobi county, Kiambu county and Gatanga District in Murang'a county.

The board works hand in hand with Water Service Providers who handle operations and maintenance of developed water and sanitation infrastructure. The AWSB has appointed the Nairobi Water & Sewerage Company (NWSC) as the Water Services Provider (WSP) in the City.

The 11 other WSPs appointed to work within the Board's jurisdiction area include the Kiambu Water & Sewerage Co. Ltd; Gatundu South Water & Sanitation Co Ltd; Karimenu Community Water & Sanitation Co Ltd; Gatanga Community Water Project; Limuru Water & Sewerage Co Ltd; Kikuyu Water Co Ltd; Ruiru-Juja Water & Sewerage co Ltd; Thika Water & sewerage Co. Ltd; the privately-run Runda Water & Sewerage Co Ltd and Githunguri Water & Sanitation Co Ltd (Njoroge, 2006). The figure 1 below shows the institutional set-up under Water Act 2002.

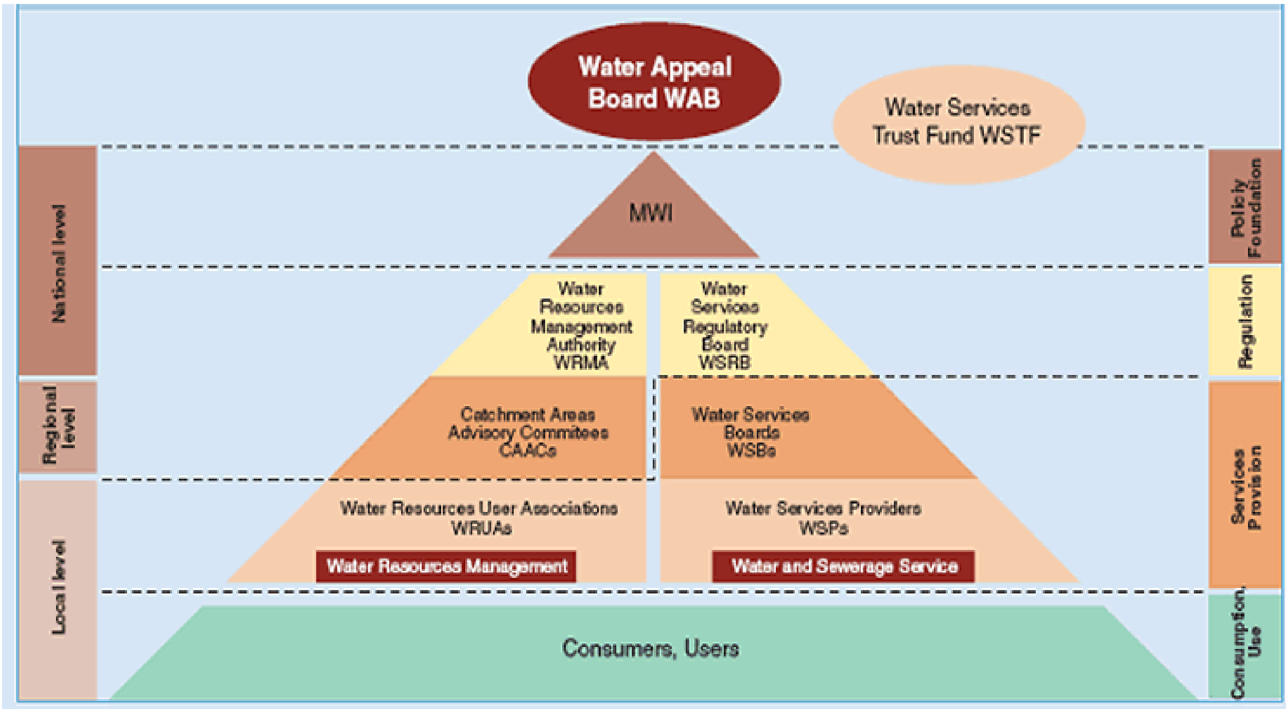

Figure 1 Institutional setup under Water Act

Source: AWSB, n.d

2.6 Nairobi City Water and Sewerage Company

Nairobi City Water and Sewerage Company (NCWSC) was incorporated in December 2003 under the Companies Act cap 486. It is a wholly owned subsidiary of Nairobi City County. It has its headquarters in Kenya, Nairobi City Kampala Road, Industrial Area and has its area of jurisdiction divided into six administrative regions, namely, Northern, Eastern, North Eastern, Central, Southern and Western which are further devolved into 25 zones.

The mandate of the Company is to provide clean water and sewerage services to the residents of Nairobi County, in a financially sustainable manner and within the Government regulations. The City has an estimated population of 3.8 million and projected to grow to 4.5 million by 2019. The 2002 Water Act brought about reforms in the Water Sector that were aimed at facilitating access to clean water and sewerage services to all Kenyans. The reforms saw the creation of regional Water Boards which were tasked with the responsibility of overseeing the operations of water and sewerage/sanitation utilities in their respective areas of jurisdiction, besides major asset development.

Within this structure, NCWSC was under Athi Water Services Board (AWSB). The Water Act 2002 is under review with the draft Bill providing for establishment of Water Works

Development Boards in place of the Water Service Boards. To enhance the Nairobi Water Company's efficiency, the senior management team of the Company has been recruited competitively from the job market.

Both Directors and senior management staff are bound by code of ethics that assures suppliers of due diligence in keeping with the Company's goal of strengthening its corporate governance. Since the Company is run on commercial principles, staff and management are integrated into a competitive and productive environment that is customer-focused and results-oriented. The Company is also ISO 9001 certified to ensure the consumers on the quality management systems adopted within the Company.

The Nairobi Water Company is committed to ensuring that all stakeholders receive water regularly and efficiently and that the water reaching the customers is of highest quality. The Company aspires to be a role model among other water companies established across Africa (NCWSC, 2015).

2.7 Review of related conceptual frameworks

2.7.1 ICT, livelihoods, and multi-dimensional poverty

The objective of the research in the East African countries was to estimate the change in poverty status that results from a change in ICTs usage, taking into account factors such as socio-economic and demographic characteristics and the policy framework that might also influence changes in poverty status. To achieve this, the research made use of the sustainable livelihoods (SL) framework, which brings together a multi-dimensional approach to poverty with the assets and activities used by households in order to obtain the resources that they need. This has been adopted by a number of development agencies and offers a coherent and widely understood approach.

Further, a systems-based approach to ICT has been adopted which recognizes that communication and the information that results are shaped not just by technical factors, but also by the economic and social context, which may enhance or retard the effectiveness of such information, and the complete range of communication, media, and information flows in a community. We make use of three components: technical, economic, and social. The technical sub-system comprises end-user technologies, networks, and access infrastructure, and the applications for use. The economic subsystem comprises economic institutions (including markets, enterprises, and consumers), cost structures, and regulatory frameworks. Finally, the social sub-system comprises social actors (communities, enterprises, households, and individuals), political processes, social interactions and networks, and the content of what is being delivered. Within the technical sub-system, we focus on broadcasting, including radio and television; telephony, including mobile, fixed line, fixed mobile (restricted mobility), and fax; and internet access, including email and web services. Forms of communication resulting from the use of technologies, such as digitally derived print, face-to-face conversation, and so forth are included in this focus, as well as innovations to extend the use of information derived from technologies.

The interactions between the different components of our conceptual framework are brought together with the SL approach. The vulnerability context (household and community exposure to risk and the shocks that result), along with the policy and institutional context (markets, government structures, and community networks) are the major conditioning influences. As a further influence on livelihood activities, outputs, and outcomes, we add what Barrantes (2007) terms 'digital poverty'. Digital poverty is defined as 'the lack of goods and services based on ICTs' (Barrantes, 2007: 30). Digital poverty thus incorporates a demand dimension (the ICT service cannot be afforded), a capability dimension (the skills to use the service are not available), and a supply dimension (the infrastructure to deliver the service is not in place). We propose that the availability of such infrastructure, resources, and skills constitutes a new asset for households that can be termed digital capital.

Recognizing influences on effective demand for ICT has resonance with our research question, thus we include an innovation of Dorward et al. (2003) who note that the nature and extent of demand for outputs from household livelihood strategies will determine the outcomes that follow. The interaction between the different components is summarized in Figure 2. In the upper part of the diagram we show the SL framework as it is conventionally presented, whereby assets are used by households in livelihood strategies to produce livelihood outcomes. These are the five asset categories described by Moser (1998) and others.

Dorward et al. (2003) introduce several other relevant innovations and separate livelihood strategies into activities and outputs. This allows their interaction to be explored in the lower part of the diagram where conditioning influences are shown. The first of the innovations concerns the vulnerability context (household and community exposure to risk and the shocks that result) and the second is the policy and institutional context (markets, government structures, and community networks). From the perspective of the implications for policy, the diagram also shows the four role players conventionally identified by the poverty reduction strategy papers (PRSPs) prepared by many countries, including those included in this research: markets, communities, government, and households. The functioning and performance of an ICT system is thus both a component of, and an influence on, the policy interventions that might be proposed by any PRSP. As a result, the ICT system can enhance (or perhaps limit) household livelihoods, and thereby impact upon social and economic dimensions of vulnerability and poverty and the successful implementation of national PRSPs.

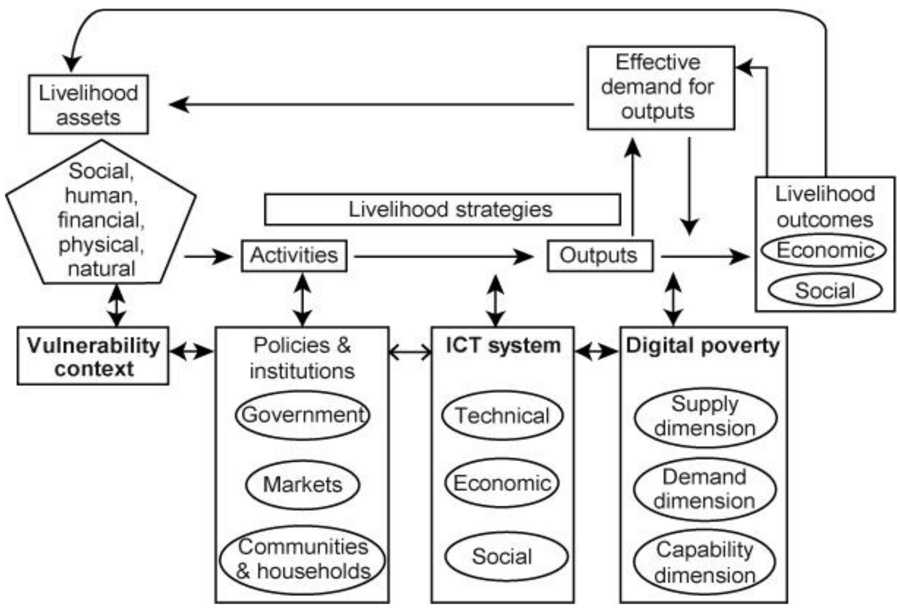

Figure 2 Conceptual framework: ICT, livelihoods, and multi-dimensional poverty

Source: Adera et al, 2014

2.7.2 The WISDOM framework

The WISDOM Framework involves a multi-layered architecture as illustrated in Figure 3. The first layer in the proposed water analytics approach involves understanding the scope and availability of data across and beyond urban water systems, identifying historical as well as (near) real time monitored nodes. The project deals with varying levels of quality (i.e. accuracy and completeness) and devise scope for additional data to be acquired and ways of achieving this to deliver the vision of a dynamic and real-time water system. The second layer involves the scalable physical infrastructure to store all sensed data in a secure and open way. The third layer in the WISDOM framework involves semantic conceptualisation of the complex water system.

The existing water infrastructure is designed and maintained to service our built environment (including domestic, public, leisure, and recreation buildings and facilities). A number of technologies and data format/sharing standards have been used to date to conceptualize and share built and infrastructure artefacts, including BIM (Building Information Modelling), GIS (Geographical Information System), as well as water proprietary data structures. Integrating these standards and their underpinning concepts around common analytical referential and associated mathematical and numerical models is a pre-requisite for addressing the complexity of our urban water systems, and providing a basis for realtime decision making (e.g. exploring 'what-if' scenarios). Moreover, this will enable holistic water system reasoning and analytics in a way that makes possible cross-aspects (economic, energy, etc.) evaluation of changes / perturbations to water city networks (including design, configuration, pricing, management and governance). The resulting water ontological referential can be used as a basis for reasoning on urban water as a dynamic and nonlinear system and unravelling the complex semantic relationships and network interdependencies between key built and infrastructure variables ranging from water, energy to health indicator (linked to water quality).

The fourth layer involves the Artificial Intelligence (AI) components (i.e. optimization module, data fusion and mining module, and rule-based engine) to deliver the decision support environment (layer 6). In this respect, the use of agents (layer 5) provides the required abstraction to access every component of our WISDOM framework. These AI components and underpinning models will enable to explore the implications of interdependencies for the frequency and severity of water system failures (reliability, vulnerability and resilience) and for the capacity of water city infrastructure systems to cope with or respond to environmental stresses and changes (adaptive capacity). The predictive models will be developed with a high degree of plasticity, allowing exploration of the influence of a broad range of socio-technical variables on water (and beyond) system performance – e.g. the impact of different governance styles (demand and supply management, pricing), norms, and regulations. This flexibility is often missing from water city infrastructure analytics, where existing governance practices tend to be hard-wired within or simply excluded from model structures.

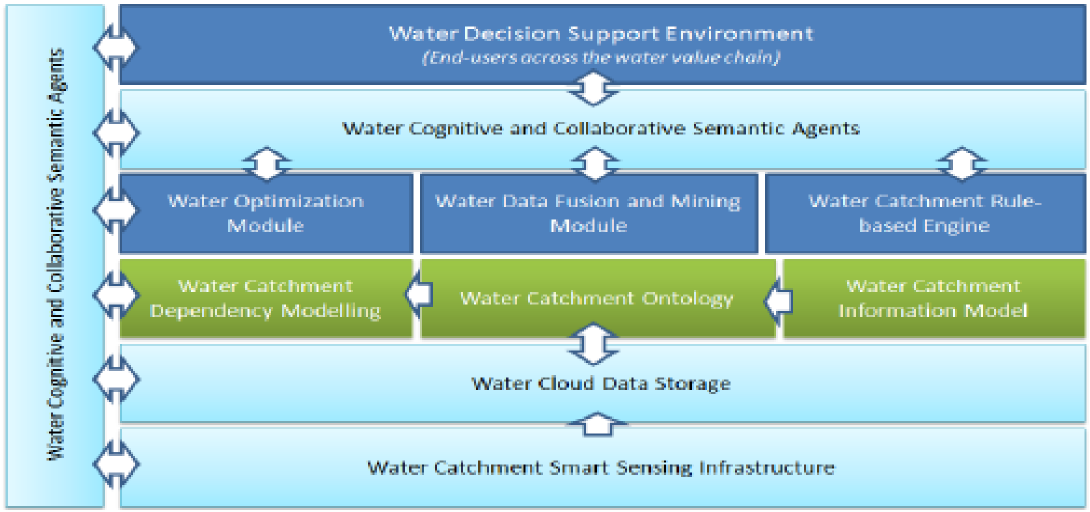

Figure 3 WISDOM multi-layered architecture

Source: Zarli et al, 2014

The upper and sixth layer involves exploiting the semantic, dependency, and predictive models developed in the semantic layer (#3) to deliver managed water urban systems with an actuation capability that factors in decision criticality, implications, water value chain stakeholder and citizen views as well as security, confidentiality, and data sensitivity issues. The WISDOM framework innovative dimension is that the user becomes part of a city system acting both as a sensor (being a component of the sensed artefacts, e.g. through crowd sourcing) and as an actuator with a possibility to inform (through participation and deliberation) or influence water city related decisions.

2.7.3 Linking ICTs and Climate Change Adaptation: A Conceptual Framework for e-esilience and e-adaptation

As summarised in Figure 4, the analysis conducted thus far suggests a chain of linkages that exist, with short- and long-term climate change impacting the six water-related vulnerability dimensions of households, communities, regions, etc. These impacts demand adaptive actions which are shaped by the vulnerabilities, but which in turn reshape those vulnerabilities, ultimately leading to outcomes in terms of broader development goals.

As reflected in Figure 4, both adaptive capacity and adaptive actions are closely linked yet distinctive components of adaptation. This distinction is related to the notion that what a system (household, community, etc.) is free to do – its “capabilities” – should not be automatically equated with what it actually achieves – its "functionings" (Sen, 1999; Heeks and Molla, 2009). Thus, adaptive capacity refers to the system's ability to cope with, adjust to, and take advantage of the opportunities associated with a changing climate (Jones et al., 2010), while adaptive actions are the actual actions taken (Ospina and Heeks, 2010). Adaptive capacity relates to the availability of core livelihood factors such as assets, institutions and structures, knowledge and information, innovation and flexible forward-looking governance, among others (Jones et al., 2010). Adaptive actions are based on the ability of the system to implement and use, in practice, those precursors and inputs towards realised adaptations in one or more of the five fields of water resource adaptation.

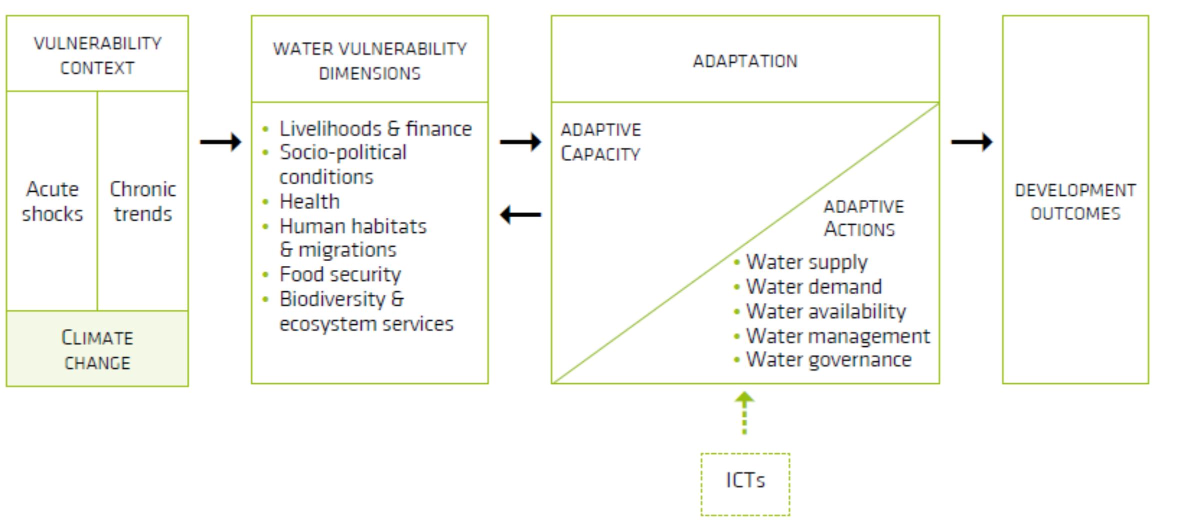

Figure 4 Vulnerability to climate change and water resources adaptation

Source: Finlay and Adera, 2012

Figure 4 (via the dotted box) shows – as described above – the potential for ICTs to contribute to water-related adaptations. But this current model does not offer a conceptual foundation for those seeking to understand how ICTs make this contribution. Nor does it offer specific guidance for project practitioners. Further development of this model is therefore needed. On the one hand, this can help to identify the key factors, enablers and constraints that lie behind ICTs' impact on adaptive capacity.

On the other, it can help to identify the stages that need to be considered in ICT-enabled interventions that seek to achieve such an adaptive impact; for example, in relation to water resources. The proposed conceptualisation can also help practitioners to distinguish between ICT interventions that merely build adaptive capacity, and those that go a step beyond to achieve actual adaptive actions.

2.8 Conceptual model/design/framework.

The model provides independent,dependent and moderating variables that were considered for this research capturing ICT tools, the role they play to improve water use efficiency, factors that will affect the implementation of the applications as well what is the expected result for water efficiency.

The reason why this approach was adapted is because it is beneficial in two-fold. It has a conceptual depth that enables it to be used for comprehensive analysis of initiatives at the intersection of climate change adaptation, water resources and ICTs. But it will also have a practical value for project managers, enabling them to understand concrete decision factors and actions for their projects.

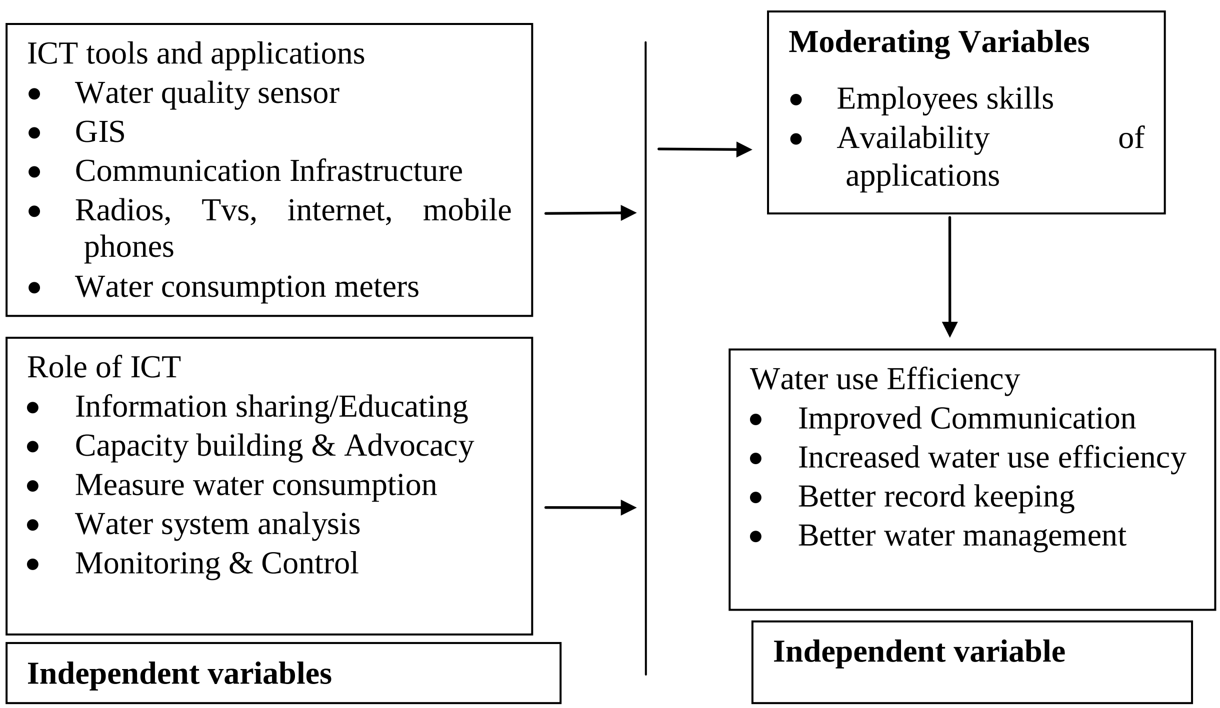

Figure 5 Conceptual framework

CHAPTER THREE

METHODOLOGY

This chapter presents the methodology used to carry out the study. This chapter included the research design, sources of data/information, data collection instruments and procedure, data analysis, presentation and limitations of the methodology used.

3.1 Research Design

This study was conducted through a descriptive census design. The census design was more appropriate as it enabled the researcher to collect data from broader category for comparison purposes. The study settled for this research design in order to better understand the intricate issues involved in the water sector in relation to ICT. This design was considered to be appropriate for this study because they saved time, expenses and the information provided was expected to be of high quality and valid.

3.2 Sources of Data

The descriptive census design was necessary due to the relative small size of the population, it provided an overall picture of the ICT application that are being implemented by the water service providers in Athi Water services board area of operation. The number of water service providers operating within the Athi Water services board area was small and as such sampling is not necessary. AWSB has appointed twelve (12) WSPs within its area of jurisdiction which covers Nairobi, Thika and Kiambu.

3.3 Data Collection Instruments and Procedure

Primary data was collected through structured questionnaires, for secondary data, annual reports and magazines were reviewed. Questionnaires were incorporate both open-ended and closed-ended questions to gather the study’s data. The questionnaire was first pre-tested on appropriateness, structure and relevance to the study. According to Cooper and Schindler (2008), the questionnaire was conveniently used because it was cheaper and quicker to administer, it was above researcher’s effect and variability, and was highly convenient for the respondents as they filled them during free times or when workloads were manageable. The instruments incorporated Likert scales to measure perception, attitude, values and behavior. The questionnaires was self-administered minimizing the measurement error.

3.4 Data Analysis and Presentation

The survey used questionnaires that were issued out to different staff of the organizations who had been identified as key data sources. Quantitative data was reviewed to eliminate huge inconsistencies, summarized and coded for easy classification in order to facilitate tabulation and interpretation descriptive statistics that was used in describing the sample data in such a way as to portray the typical respondent and to reveal the general response pattern. The data generated was analyzed using computer aided software such as Statistical Package for Social Sciences (SPSS) which offers extensive data handling capability and numerous statistical analysis routines that can analyze small to very large data statistics. The data was then represented in the report in form of tables, figures and flow chats for easier understanding.

3.5 Limitations of the methodology used

Surveys collect data at a single point in time, it is difficult to measure changes of indicators unless two or more surveys are done at different points in time. Due to the time limitation for this project such periodic surveys were impractical. However, the study established future trends by analyzing the available information.

Qualitative research, by nature, is much more focused on a small population or case. It is also noted that qualitative research might be influenced negatively by personal opinions more than actual accurate findings, this was mitigated by ensuring that the information obtained is compared and crosschecked sufficiently.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents findings from the analysis of the questionnaires as collected from the field. The study sought to establish ICT applications used in management of water resources, establish the functions of the ICT applications that are used to improve water use efficiency, evaluate the platforms that host the ICT applications used to improce water use efficiency and to identify the challenges faced in the implementation of ICT in the management of water resources. The completed questionnaires were edited, coded and then analyzed using SPSS (v 20).

4.2 Demographic Information

4.2.1 Response Rate

From the findings, a total of 30 respondents filled and returned their questionnaires. This translated to a response rate of 83%. Out of the total 36 respondents, the non-response rate therefore was 17%. According to Mugenda and Mugenda (2003) the statistically significant response rate for analysis should be at least 50%. Table one summarizes the characteristic of the respondents among the 12 WSPs appointed by Athi Water Services Board.

Table 1 Demographic Information

Demographic information	Indicators	Percentage (%)
Gender	Male	80
	Female	20
Respondents Age	19-30 years	20
	31-40 years	40
	41-50 years	30
	Over 50 years	10
Level of Education	Diploma	10
	University Degree	60
	Post graduate	30
Position in company	Manager	30
	Technical Support	70
Years worked in ICT industry	Less than 5 years	10
	5-10 years	30
	10-20 years	50
	Over 20 years	10
Years worked in the water sector	Less than 5 years	10
	5-10 years	60
	10-20 years	20
	Over 20 years	10

4.2.1 Gender of Respondents

The study sought to establish the gender of the respondents. From the responses, majority of the respondents 80% were male while 20% were female. This indicates that both genders were represented in the research study even though there were more males than females.

4.2.2 Age of the Respondents

The study sought to establish the age bracket of the respondents. The study established that majority of the respondents 40% were of age between 31-40 years, 30% were between 41-50 years, 20% were between 19-30 years of age while only 10% of the respondents were over 50 years of age. The finding indicates that all the respondents were mature enough to give valid responses.

4.2.4 Level of Education Attained

The study sought to establish the respondents' level of education. The findings indicated that majority of the respondents, 60% had undergraduate degree, 30% were post graduate, 10% of the respondents had diploma and none 0% of the respondents had college certificate. This means that majority of the respondents had attained undergraduate degree therefore they had vast knowledge on the role of information communication technologies in water resources management and climate change adaptation.

4.2.5 Position in the Company

The respondents were asked to indicate the position they held in the company. From the responses, 70% of the respondents were working in the technical support some as engineers, technician, team leader, IT experts and system admin/analyst while 30% of the respondents were managers. These findings indicate that the respondents were the key people that handle the information technology matters in the organizations and thus are aware of the role of information communication technologies in water resources management and climate change adaptation.

4.2.6 Number of Years worked in the ICT industry

The respondents were asked to indicate the number of years they had worked in the ICT industry. The finding indicates that majority of the respondents 50% had worked in the ICT industry for a period of 10-20 years, 30% of the respondents indicated 5-10 years while 10% said less than 5 years and another 10% indicated over 20 years. This means that all respondents had worked in the ICT industry long enough to be aware of the roles of information communication technologies in water resources management and climate change adaptation.

4.2.7 Number of Years worked in the Water Sector

The study sought to establish the number of years the respondents had worked in the water sector. From the responses, majority of the respondents 60% indicated 5-10 years, 20% said 10-20 years while 10% indicated over 20 years and another 10% said less than 5 years. This means that all respondents had worked in the water sector long enough to be aware of the roles of information communication technologies in water resources management and climate change adaptation.

4.3 ICT Applications Used in Water Management

Finlay and Adera (2012) indicated that the rationale for considering ICT tools, platforms and protocols is to facilitate the collection, storage, analysis, distribution and utilization of data via interaction and feedback among various water actors. Such ICT tools may range from simple mobile telephony to the more advanced robust field sensors, telemetric data transmission and satellite-driven remote sensing of hydrological conditions.

The respondents were asked to indicate ICT applications that are used in water management applied in their organization. The finding was as shown on Table 1

Table 2 ICT applications used in water management

	Mean	Std dev
SMS notifications	3.6234	1.1468
Internet based water bill access	3.5368	0.97581

On whether SMS notifications were used as ICT applications in water management, the respondents agreed with a mean of 3.6234 and a standard deviation of 1.1468 that SMS notification was used in water management. The finding agrees with Houghton (2009) who pointed out that mobile phones are continuing to shape development in ways that were not anticipated a few years ago, including in the water sector. On whether Internet based water bill access, the respondents agreed with a mean of 3.5368 and a standard deviation of 0.97581 that Internet based water bill access was used in water management. The finding concurs with with Heeks and Ospina (2009) who indicated that the application of ICT solves climate-induced water management challenges in prediction, mitigation, monitoring, and now increasingly, adaptation and national or institutional strategy formulation. In addition, the respondents pointed out that Billing System, Meter Reading System (MRS), Financial Management system, Procurement system, Customer complaints Management system (MajiVoice) and Dam Monitoring System were the ICT applications used in water resources management. The finding coincides with The ITU-T Technology Watch Report (2011) which provided an overview of how ICTs can be a strategic enabler for smart water resources management policies and surveys upcoming standards that will act as a catalyst for successful implementation of smart water management initiatives. This finding also corresponds to Kalas and Finlay (2009) who specifically pointed out that ICTs need to be innovatively incorporated in mitigation, monitoring, adaptation and strategy of water management systems.

4.4 Functions of the ICT Applications

Studies have been done looking at the application of ICT to solve climate-induced water management challenges in prediction, mitigation, monitoring, and now increasingly, adaptation and national or institutional strategy formulation (Heeks and Ospina, 2009).

The study sought to establish the functions of the ICT applications. The finding was as shown on Table 3

Table 3 Function of the ICT Applications

	Mean	Std dev
Customer information management	3.74758	1.04879
In Water billing processes	3.86013	0.89256
Communication with customer	3.53561	0.73892
Water quality management	3.48236	1.16125

From the responses, the respondents agreed with a mean of 3.74758 and a standard deviation of 1.04879 that the ICT applications were used in customer information management. The findings agree with Ospina and Heeks (2010a) who reported that emerging experiences from vulnerable communities pointed to the increasing use of community radio, mobile phones, the internet and other ICTs in climate change responses. The respondents further agreed with a mean of 3.86013 and a standard deviation of 0.89256 that ICT applications were used in water billing processes. The finding further concurs with Schuol et al. (2009) who reported that ICT applications also provided directory and authentication services, virtualization services, and infrastructure management and monitoring services.

In addition, the respondents also agreed with a mean of 3.53561 and a standard deviation of 0.73892 that ICT applications were used in communicating with customers. The respondents were agreed to a moderate extent with a mean of 3.48236 and a standard deviation of 1.16125 that ICT applications were used in water quality management. The finding was impartial to Maumbe and Okello (2010) who stated that ICT applications can be used solve climate-induced water management challenges in prediction, mitigation, monitoring, and now increasingly, adaptation and national or institutional strategy formulation. The respondents further highlighted that Laboratory Information Management system (LIMS) for water quality was underway. This concurs with Schuol et al. (2009) who reported that ICT applications also provided directory and authentication services, virtualization services, and infrastructure management and monitoring services.

4.5 Platforms that Host the Applications

The respondents were asked to indicate the platforms that hosted the ICT applications. The finding was as shown of Table 4.

Table 4 Platforms that host ICT applications

	Mean	Standard deviation
Web based	3.92487	1.26854
Mobile phone based	3.74965	1.1487

From the responses, the study established that the respondents agreed with a mean of 3.92487 and a standard deviation of 1.26854 that web based platforms hosted the ICT applications. The respondents further agreed with a mean of 3.74965 and a standard deviation of 1.1487 that mobile phone based platform hosted the ICT applications. The respondents further indicated that basic client/server connection was also a platform that hosted ICT applications. ICT Platforms consist of all components required to deliver a service, as per NIST Cloud Service, the finding coincide with Schuol et al. (2009) that highlighted Messaging, Collaboration, ERP and CRM platforms, Database Management Systems, Operating System and the Servers they run on, as well as key auxiliary systems were platforms for ICT applications.

The respondents were further asked to indicate to what extent the applications were actively used by the current customers' service. The finding was as indicated on Table 5

Table 5 Extent of applications being actively used by current customers' service

	Frequency	%
Always used	24	80.0
Mostly used	6	20.0
Occasionally used	0	0.0
Rarely used	0	0.0
Never used	0	0.0
Total	**30**	**100.0**

From the responses on the extent the applications were actively used by the current customer service, 80% of the respondents indicated always used while 20% indicated the applications were mostly used by the current customers' service. None of the respondents 0% indicated that the applications were occasionally used or rarely used or never used by the current customer service.

In addition the respondents were also asked to indicate the percentage of the customers who actively used applications rolled out by the company. The finding was as indicated on Table 6.

Table 6 Percentage of the customers who actively use the applications rolled out by the company

	Frequency	%
0-25 %	0	0.0
51-75 %	21	70.0
76-100 %	6	20.0
25-50%	3	10.0
Total	**30**	**100.0**

From the responses, the study established that 70% of the respondents indicated that 51-75 % of the customers actively used the applications rolled out by the company, 20% said that 76-100 %, 10% of the respondents highlighted that 25-50% of the customers actively used the applications rolled out by the company while none of the respondents 0% indicated 0-25 %.

The respondents commented further that the rolling-out of e-billing and mobile payment as well as mobile customer complaint management platforms had seen an upsurge in the utilization.

4.6 Challenges faced during Implementation ICT Applications for Companies

The study sought to establish the challenges the respondents faced in implementing ICT application for the company. The finding was as indicated on Table 7.

Table 7 Challenges faced during Implementation ICT Applications

	Mean	std dev
Limited staff skills	3.68247	0.11586
Limited resources (Finance)	3.84369	0.84295
Lack of customized applications	3.77254	1.02487

From the responses, the respondents agreed with a mean of 3.68247 and a standard deviation of 0.11586 that limited staff skills was a challenge they faced during implementation of ICT applications. The respondents indicated limited resources (finance) with a mean of 3.84369 and a standard deviation of 0.84295 as a challenged during implementation of ICT applications. The respondents also agreed with a mean of 3.77254 and a standard deviation of 1.02487 that lack of customized applications was a challenge they faced during implementation of ICT applications.

The findings concur with Heeks (2009) who reported that lack of skilled personnel, infrastructure, finance, poor data systems and lack of compatibility, poor leadership styles, culture and bureaucracy and attitudes were barriers to ICT implementation. the finding further agree with Heeks (2002a) who highlighted that many organizations are not well equipped internally to support and nurture the effective exploitation of ICT to benefit development. They simply do not have the knowledge, expertise, or organizational capacity needed. The use of information technology is often seen as a thorny, problematic issue relating to back office systems. Furthermore, ICT often has a questionable reputation as a result of previous unsuccessful or costly initiatives. The finding further corresponds to Odada et al (2008) who showed that there is significant challenge in adequately planning and financing the use of ICT in development programs.With cyclical funding and pressure to minimize administrative and management costs, it is often difficult for organization to properly plan and resource financial and human investments in ICT as a core capacity for development programs.

The respondents were further asked to indicate of the ICT applications previously mentioned, which ones had improved water-use efficiency the most at the local level. The finding showed that communication customers (MajiVoice), billing applications and water quality management had improved water-use efficiency the most at the local level. The respondents commented further that in the water sector there was total reliance on the customers in terms of revenue and hence continuity of the organization. Systems that made it easier for the customer to get to the organization and sort out their issues provided instant improvement in water-use. Proper billing was efficient as well as assuring quality of the water raises the consumption rates.

In addition, the respondents were asked to suggest on what should be done differently in order for ICT applications to be effectively deployed at the community level in water management. The respondents said that there should be development of more mobile based applications because with the fast growth of mobile technology, more easy-to-use mobile applications for water management would easily reach the vast majority of the community. The finding coincides with Ospina and Heeks (2010a) who highlighted that emerging experiences from vulnerable communities point to the increasing use of community radio, mobile phones, the internet and other ICT tools in climate change responses. They also indicate the value of an e‑ resilience approach, since this moves beyond shallow surface effects to understanding the way in which ICTs can – but often fail to – have a deeper and systemic effect that will help communities and nations sustain resources management.

The study further sought to find out what local climate change impacts (i.e. acute shocks and chronic trends) the respondents were currently facing in their area of jurisdiction. It was established that acute annual droughts were being faced and this was because the main source of water was dams that get the water from rivers which were majorly rain-fed. Deforestation and other vices had led to droughts that saw the continual drop in water levels in the dams and hence inability to meet the growing demands. The finding harmonize with IPCC (2007) who indicated that significant changes in runoff fluctuations are predicted for Africa. The finding further agrees with UNEP (2007) who reported that many climate models project constrained hydrological cycles for many regions and a decrease in annual mean rainfall. Over the past decade observed trends have reflected extended and more frequent droughts as well as an increase in frequency of floods.

In addition, the respondents were asked to indicate existing ICT applications that currently supported stronger integration and interdisciplinary approaches to adaptation to climate variability/change in water resource management by the organization. The respondents indicated that only basic dam monitoring applications supported stronger integration and interdisciplinary approaches to adaptation to climate variability/change in water resource management by the organization. The respondents were also asked to show what ICT tools they needed to have in order to support stronger integration and interdisciplinary approaches to adaptation to climate variability/change in water resource management. The finding showed that GIS applications with remote sensing abilities that can check on climatic changes and provide necessary analytics for decision making since they were predictive.

The respondents were further requested to briefly describe the current implementation process for ICT applications within the company. The respondents reported that requirements analysis was the first process followed by system design/purchase then installation, testing and finally rollout. The respondents were also asked to suggest changes in terms of ICT applications implementation process that would enhance climate change adaptive measures. The respondents suggested that at the requirements analysis stage, the system should be explored to establish if it has the ability to enhance climate change adaptive measures. They suggested further that it should be followed up at the design level and their ability to integrate with the other existing systems considered.

4.7 ICT role in water use efficiency

As shown on table 8 of the 30 respondents who answered the question 90% agreed with the notion that ICT plays a greater role in water use efficiency while 10% disagreed that ICT plays a role in water use efficiency.

Table 8 ICT role in water use efficiency

	Frequency	%
Yes	27	90.0
No	3	10
Total	**30**	**100.0**

4.8 General Information on ICT in water resources management and climate change adaptation

The respondents were asked to indicate to what extent they agreed with the following statements of ICT in water resources management and climate change adaptation. The finding was as shown on Table 9.

Table 9 Statements on ICT in water resources management and climate change adaptation

	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
	%	%	%	%	%
ICT does not play an important role in the water sector	80	20	0.0	0.0	0.0
Climate change effects have critically influenced our organization's ICT policy	0.0	0.0	20	70	10
ICT applications play an important role in shaping the water sector towards responding to climate change	0.0	0.0	10	50	40
It has been easy to integrate the use of ICT in its strategy to combat the effects of climate change	20	70	0.0	10	0.0
It has been easy for our customers to integrate the use of ICT in its strategy to combat the effects of climate change adapt to the increased use of ICT in our operations	10	80	0.0	10	0.0
Our organization has plans to scale up the use of ICT in its operations in the near future	0.0	10	0.0	20	70

The finding indicated that 80% of the respondents strongly disagreed that ICT does not play an important role in the water sector, 20% disagreed while none 0% agreed, strongly agreed or were neutral that ICT does not play an important role in the water sector. This means that majority of the respondents strongly admitted that ICT does play an important role in the water sector. None of the respondents 0% strongly disagreed or disagreed that climate change effects had critically influenced the organization's ICT policy, 20% were not sure while 70% agreed and 10% strongly agreed that climate change effects had critically influenced the organization's ICT policy. This means that majority of the respondents agreed that that climate change effects had critically influenced the organization's ICT policy.

The finding coincides with The ITU-T Technology Watch Report (2011) that showed that there is an increasing role of ICTs in climate change-related water systems management. The report indicated that ICT can be a strategic enabler for smart water management policies and surveys upcoming standards that will act as a catalyst for successful implementation of smart water management initiatives. The finding further agrees with Kalas and Finlay (2009) who specifically pointed out that ICTs should be innovatively incorporated in mitigation, monitoring, adaptation and strategy of water management systems.

On whether ICT applications played an important role in shaping the water sector towards responding to climate change, none of the respondents 0% strongly disagreed or disagreed whereas 10% was not sure, 50% agreed while 40% strongly agreed that ICT applications played an important role in shaping the water sector towards responding to climate change. This indicates that majority of the respondents agreed that that ICT applications played an important role in shaping the water sector towards responding to climate change. . The finding concur with IDC (2011) who reported that ICT development had impacted the continent in the form of modernised infrastructures like broadband fibre optic cables and data centres, added value services and IT innovations. With these developments, prices are falling while demand for equipment, expenditure on ICTs and local content are burgeoning. ICT expenditure was expected to grow by 10% across Africa in 2011, reaching a total of USD 25 billion.

Majority of the respondents disagreed that it had been easy to integrate the use of ICT in its strategy to improve water use efficiency, 20% of the respondents strongly disagreed that it had been easy to integrate the use of ICT in its strategy to combat the effects of climate change whereas 70% disagreed, 10% agreed while none of the respondents 0% strongly agreed or were not sure if it had been easy to integrate the use of ICT in its strategy to combat the effects of climate change.

From the responses on whether it had been easy for our customers to integrate the use of ICT in its strategy to combat the effects of climate change adapt to the increased use of ICT in our operations, 10% strongly disagreed while 80% disagreed. 10% of the respondents agreed while none of the respondents 0% strongly agreed or were neutral that it had been easy for our customers to integrate the use of ICT in its strategy to combat the effects of climate change adapt to the increased use of ICT in our operations.

The finding concur with Zarli et al (2014) who showed that FP7 WISDOM project which aims to achieve a step change in water savings via the integration of innovative Information and Communication Technologies (ICT) frameworks to optimize water distribution networks and to enable change in consumer behaviour through innovative demand management and adaptive pricing schemes. However, there is a growing need to foster knowledge sharing and collaboration.

None of the respondents 0% strongly disagreed that the organization had plans to scale up the use of ICT in its operations in the near future, 10% (1) disagreed while none 0% of the respondents were not sure, 20% agreed while 70% strongly agreed that the organization had plans to scale up the use of ICT in its operations in the near future. The finding agree with Finlay and Adera (2012) who further indicated that the rationale for considering ICT tools, platforms and protocols is to facilitate the collection, storage, analysis, distribution and utilization of data via interaction and feedback among various water actors.

4.9 Correlation Analysis

Pearson correlation was used to measure the degree of association between variables under consideration i.e. independent variables and the dependent variables. Pearson correlation coefficients range from -1 to +1. Negative values indicates negative correlation and positive values indicates positive correlation where Pearson coefficient <0.3 indicates weak correlation, Pearson coefficient >0.3<0.5 indicates moderate correlation and Pearson coefficient>0.5 indicates strong correlation.

Table 10 Correlation Co efficiency

	ICT tools	Role of ICT	Employee skills	Availability of applications
ICT tools	1			
Role of ICT	0.331	1		
Employee skills	0.351	0.651	1	
Availability of applications	0.411	0.491	0.613	1

*. Correlation is significant at the 0.05 level (1-tailed).

The analysis on table 10 shows that the variable role of ICT and employee skills has the strongest positive (Pearson correlation coefficient =.651). In addition, employee skills and availability of applications had a positive and strong correlation of (Pearson correlation coefficient =.613). Role of ICT and availability of applications was noted to have a Pearson correlation coefficient of 0.491. The study thus established a strong linear relationship between the variables but no autocorrelation was established.

4.10 Regression Analysis

Table 11 Coefficient of Determination (R2)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.731(a)	0.534	0.487	.52126

Source: Author 2015

As shown on Table 11, Coefficients, provides the information on each predictor variable. The coefficient of determination explains the extent to which changes in the dependent variable can be explained by the change in the independent variables (ICT tools, role of ICT, employee skills and availability of applications).

The independent variables that were studied explain only 53.4% of water use efficiency as represented by the R^2. Further research should therefore be conducted to investigate the other information and communication technology techniques which explain (46.6%) of water use efficiency.

Table 12 ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F Calculated	Sig.
1	Regression	33.421	4	8.553	4.725	.0015[a]
	Residual	256.682	149	1.703		
	Total	302.324	153			

Source: Author 2015

For Table 12, ANOVA, indicates that the regression model predicts the outcome variable significantly well. This indicates the statistical significance of the regression model that was applied. The significance value is 0.0015. This value is less than 0.05 which means that the model is statistically significant in predicting ICT tools, Role of ICT, employee skills and availability of applications influence water use efficiency. The F critical at 5% level of significance was 2.33. Since F calculated is greater than the F critical (value = 4.725), this shows that the overall model was significant

Table 13 Coefficient of Regression

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.324	.301		4.285	.000
X1	ICT tools	0.134	.154	.183	.776	.386
X2	Role of ICT	0.186	0.0381	0.0326	0.4059	0.0146
X3	Employee skills	0.197	0.0713	0.2225	2.7636	0.0162
X4	Availability of applications	0.278	0.0511	0.0474	0.5749	0.0465

Regression equation obtained from table 4.13:

$$\mathbf{Y= 1.324+ 0.134X_1+0.186X_2+ 0.197X_3+ 0.278X_4}$$

A Coefficient of Regression analysis was conducted so as to determine the relationship between the water use efficiency and the four factors. According to the Coefficient of Regression, a unit increase in ICT tools will lead to a 0.134 increase in the water use efficiency; a unit increase role of ICT will lead to a 0.186 increase in the water use efficiency while a unit increase in employee skills will lead to a 0.197 increase in water use efficiency while a unit increase in availability of applications will lead to a .278 unit increase in water use efficiency.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses achievements, gives conclusions from the study based on the objectives and finally recommendations. The study sought to establish the role of Information communication technologies in water management.

5.2 Achievements

Out of the targeted 36 respondents, 30 filled and returned the questionnaire translating to a response rate of 83% which according to Mugenda and Mugenda (2003) is statistically significant to conduct the study.

5.2.1 ICT Applications used in Water Management and their Functions

One of the objective of the study was to identify ICT applications that are being used in water management. From the data collected it was established that Billing System, Meter Reading System (MRS), Customer complaints Management system (MajiVoice), Financial Management system, Procurement system and Dam Monitoring System were the ICT applications used in water resources management.

On the functions of the ICT applications, the study affirmed that the ICT applications were mainly used in customer information management, water billing processes, communicating with customers, water quality management and the respondents highlighted further that Laboratory Information Management system (LIMS) for water quality management was underway.

5.2.2 Platforms that host the Applications

From the responses, the study established that web based platforms and mobile phone based platform hosted the ICT applications. The respondents further indicated that basic client/server connection was also a platform that hosted ICT applications. ICT Platforms consist of all components required to deliver a service, as per NIST Cloud Service. Database Management Systems, Operating System and the Servers they run on, as well as key auxiliary systems were platforms for ICT applications.

5.2.3 Challenges faced during implementation of ICT applications

The study achieved results for this objective where by it was noted that limited staff skills, limited resources (finance), that lack of customized applications and lack of detailed top level management support and appreciation of the role of ICT by other departments were challenges facing implementing of ICT application. The use of information technology is often seen as a thorny, problematic issue relating to back office systems. Furthermore, ICT often has a questionable reputation as a result of previous unsuccessful or costly initiatives. With cyclical funding and pressure to minimize administrative and management costs, it is often difficult for organization to properly plan and resource financial and human investments in ICT as a core capacity for development programs.

5.2.4 Guideline to use of ICT in Water Management in Kenya

This was the outcome objective for this study. This was achieved with the eventual release of a detailed guideline that has been discussed in appendix 1. The guideline will go a long way to inform policy makers, water sector players and ICT support teams in the sector in improving mangement of the water resources.

5.3 Limitations of the research

The research faced some challenges and limitations, they include: Primary data collection was the main source of obtaining the relevant information. Not all respondents were comfortable to provide information as they were not very certain how the information they provided was to be used. Other respondents found it difficult to take time off their busy schedule to respond to the questionnaires.

Climate change and water resources have a broad scope, due to the limited period for conducting this study, not all aspects were dealt with in this study comprehensively. Focus was mainly on ICT applications that affect water use efficiency. In addition, secondary data and information on the subject have mainly focused on the global scope and therefore on the local scene which is the main focus of this study we faced dearth of information.

5.4 Conclusion

5.3.1 ICT Applications used in Water Management

The study concluded that SMS notifications and Internet based water bill access were used in water management. These tools allow water users and system managers to understand current water systems conditions and make informed forecasts. The study concluded that Billing System, Meter Reading System (MRS), Customer complaints Management system (MajiVoice), Financial Management system, Procurement system and Dam Monitoring System were the ICT applications used in water resources management.

5.4.2 Functions of the ICT applications

The study further concluded that ICT applications were used in customer information management, water billing processes, communicating with customers, water quality management and soon on Laboratory Information Management system (LIMS) for water quality.

5.4.3 Platforms that host the Applications

In addition, the study concluded that web based platforms and mobile phone based platform hosted the ICT applications. It was further concluded that basic client/server connection was also a platform that hosted ICT applications. The study also concluded that the applications were actively used by the current customer service; 51-75 % of the customers actively used the applications rolled out by the company and rolling-out of e-billing and mobile payment as well as mobile customer complaint management platforms had seen an upsurge in the utilization.

5.4.4 Challenges faced during implementation of ICT applications

The study concluded that limited staff skills, limited resources (finance), lack of customized applications, lack of detailed top level management support and appreciation of the role of ICT by other departments were challenges facing the implementation of ICT applications in the company. It was concluded further that communication customers (MajiVoice), billing applications and water quality management had improved water-use efficiency the most at the local level. The study also concluded that the water sector totally relied on the customers in terms of revenue and hence continuity of the organization and that the systems made it easier for the customer to get to the organization and sort out their issues provided instant improvement in water-use.

The study also concluded that acute annual droughts were being faced and deforestation and other vices had led to droughts that saw the continual drop in water levels in the dams, hence inability to meet the growing demands. The study further concluded that basic dam monitoring applications and GIS applications with remote sensing abilities supported stronger integration and interdisciplinary approaches to adaptation to climate variability/change in water resource management.

5.4.5 Information on ICT in water resources management and climate change adaptation

The study concluded that ICT plays an important role in the water sector; climate change effects had critically influenced the organization's ICT policy and ICT applications play an important role in shaping the water sector towards responding to climate change. The study further concluded that it had not been easy to integrate the use of ICT in its strategy to combat the effects of climate change and also it had not been easy for customers to integrate the use of ICT in its strategy to combat the effects of climate change adaption to the increased use of ICT in our operations. They study finally concluded that most of the companies had plans to scale up the use of ICT in its operations in the near future.

5.5 Recommendations

5.5.1 ICT Applications used in Water Management

The study recommends that the organization should increase the use of community radio, mobile phones, the internet and other ICTs in water management responses since they help communities and nations sustain resources management.

5.5.2 ICT Applications used in Water Resources Management

The study also recommends that more mobile based applications be initiated because with the fast growth of mobile technology, more easy-to-use mobile applications for water management would easily reach the vast majority of the community.

5.5.3 Functions of the ICT applications

The study also recommends that Laboratory Information Management system (LIMS) for water quality be completed faster to ensure provision of clean and healthy water. Other key ICT applications that need to be prioritised in order to have improved water use efficiency include.

5.4.3.1 Customer management

Application of ICT in the management of customers can go a long way in improving the general service delivery and customer satisfaction in the water sector. Automation of processes such as customer records, billing, and tracking of user complaints go a long way in improving service provision efficiency. ICT applications developed to facilitate these processes and by extension improving the efficiency in management and use of water resources.

5.4.3.2 Quality Management

Water is a basic need, and as a necessity, its quality must be assured to the end user. Diseases (water borne diseases) easily spread through water. Management of the quality of the water supplied to clients is therefore very vital. The use of Laboratory Information Systems (LIS), and other ICT systems in the monitoring and management of water quality should be enhanced. Water processing and supply stations should embrace the use of the LISs to keep records of the laboratory processes that check for the quality of the water supplied to clients

5.4.3.3 Water supply chain monitoring

The most common water supply chain used is pressurized water pipes. Excess pressure can lead into the bursting of these pipes (majority are made of plastic). Lower pressure in the pipes may also result into water not reaching the clients. Leakages can also occur in the delivery process. ICT applications can be used to monitor this supply chain and give timely feedback to the stations for respective corrective action measures to be taken, in the process improving efficiency.

5.4.3.4 Mapping of water supply stations using GIS

Geographical Information Systems are increasingly being used in monitoring and management of resource allocation. The water sector can also apply GIS technology to map out the water resources available and get a visual representation of the distribution of these resources, and based on this information, decisions can then be made on how best resources can be distributed to serve the population better, hence improving water use efficiency.

5.4.4 Platforms that host the Applications

The study further concluded that more key platforms should be exploited by the organization to ensure proper functioning of ICTs in water resources management and climate change adaptation.

5.4.5 Challenges faced during implementation of ICT applications

The study recommends that the top management and other departments in the organization should support the ICT department in implementation of ICT applications. The study also recommends that at the requirements analysis stage, the system should be explored to establish if it has the ability to improve water use efficiency. It recommends also that the design level should be checked for the ability to integrate with the other existing systems.

5.4.6 Information on ICT in water resources management and climate change adaptation

The study also recommends that more ICT applications be used in the water resources management and climate change adaptation because they play an important role in shaping the water sector towards responding to climate change. The study further recommends that the organization should adopt more applications for stronger integration and interdisciplinary approaches to adaptation to climate variability/change in water resource management.

Objective five of this study has been discussed in detail on appendix 1 where a guideline to use of ICT in Water Management in Kenya has been provided.

5.4.7 Recommendation for further Studies

The study recommends that a similar study be carried out in other regional water authorities in the country to establish the role of ICT in water resources management and water use efficiency. It recommends also that a similar study be carried out in other organizations in the East African region and beyond to determine role of ICT in water resources management and water use efficiency. The study further recommends that a study should be carried out to establish the extent the organization has adopted ICTs in water resources management and climate change adaptation.

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Appendix 1: Guideline to use of ICT in Water Management in Kenya

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Chapter 1: Introduction

1.1 Preamble

Rapid urbanization has become an inevitable fact, cities are facing increasing challenges to secure financially sustainable water and sanitation services for its citizenry. For instance, of the three million residents of Nairobi, only 50 per cent have direct access to piped water. The rest obtain water from kiosks, vendors and illegal connections. Of the existing customers, about 40 per cent receive water on the 24-hour basis (NCWSC, 2015).

Appropriate and effective ICT solutions, need to be undertaken in the water management. ICT has a potential to contribute towards improvements in water resource management techniques; strengthen the voice of the most vulnerable within water governance processes; create greater accountability; provide access to locally relevant information needed to reduce risk and vulnerability; and improve networking and knowledge sharing to disseminate good practices and foster multi-stakeholder partnerships, among others (Finlay and Adera, 2012).

Research has shown that ICTs have the potential to improve water use efficiency GeSi & EC. Europa (n.d).. However, it is impossible to realise the full potential of ICTs in improving water use efficiency due the current fundamental problem with the design and priortisation of the existing ICT Infrastructure and applications. If this design problem is rectified, it is believed that ICT can play an immeasurable role in mitigating, adapting to and monitoring climate change. Further supporting evidence is given by Young (2007) that ICTs are to reduce climate change in other industrial and domestic sectors through de-materialising and de-carbonising the economy.

Russell (2008) asserts that Africa is steadily warming, climate is changing and that there will be further changes in rainfall and temperatures. Africa is warmer by 0.5 degrees Celsius than it was a century ago. On global trends in climate change, Russell (2008) indicates that "the global surface temperatures have warmed by up to 0.8 degrees Celsius and climate change statistics indicate that globally the sea level has risen by 10-25cm in the last 100 years. This evidence is more than enough to convince anyone that climate is changing and will continue to change if no measures are taken. This in return will continue putting pressure on the limited water resources available.

1.2 Purpose

The main purpose of this guideline is to provide framework for selecting, implementing, and managing ICT services in our cities to improve on water resource management. The Guide intends to showcase how data can be collected, analyzed and be of use in decision making for the water sector. This document is meant to translate National ICT Policy 2003, ICT policy master plan 2014 and existing circulars into implementation in the form of guidelines which are easy to follow on the day to day operations for the water sector.

1.3 Scope

This guideline offers both analytical and technical insights into urban water management and the role of ICT, seeking to reach decision-makers, practitioners and experts working in this field. This document addresses different levels under which ICT is applicable in water resource management the major areas:

i) Physical and environmental working areas
ii) ICT resource access control
iii) Data and information security

iv) Network and its services

v) Software deployment and use

vi) Business continuity management

vii) Third party management

viii) Training, awareness and support

ix) Customer data security

x) Monitoring and evaluation

The Guide will be reviewed from time to time and when the need arises in order to address new technological challenges and new business practices.

Chapter 2: ICT Framework

Figure 1 provides an ICT framework that can be adopted by the water sector in order to achieve results for the various application that can improve water access in Kenya:

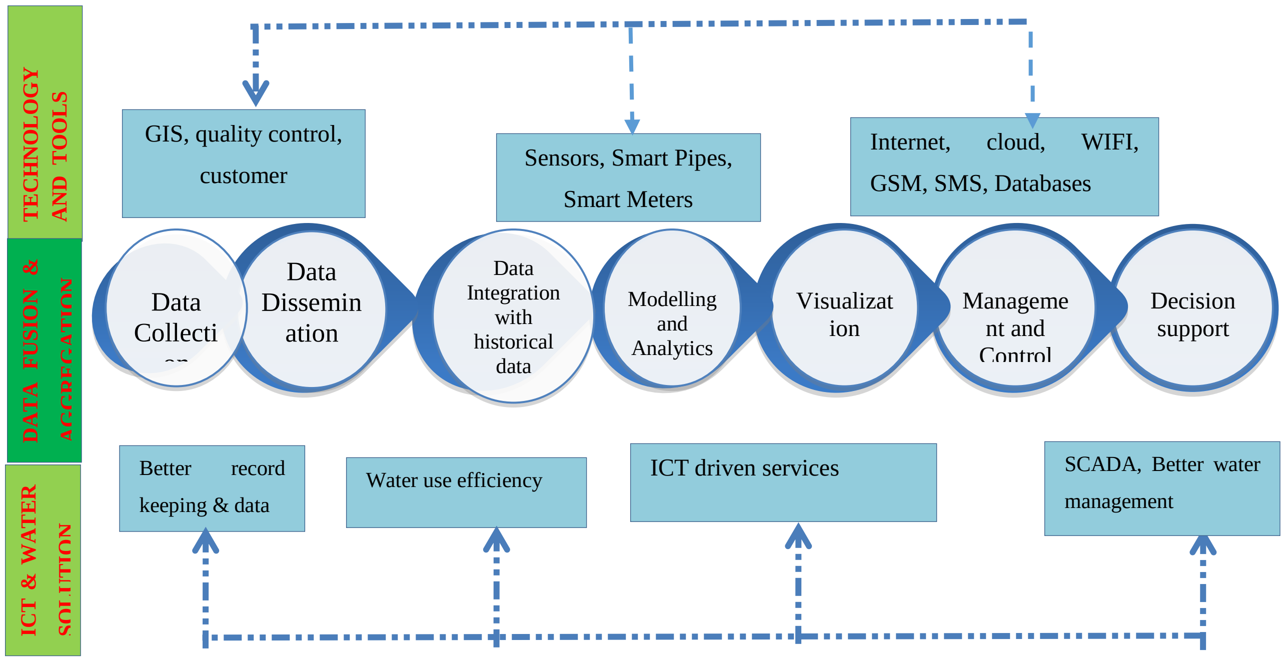

Figure 1 – Schematic Representation of Water Management Technologies and Tools

The three key elements of the framework are discussed in detail below:

2.1 Technologies and Tools

This layer contains the different technologies and tools required in the water sector management systems. Internet, cloud wifi, GSM and SMS are some of the components of technology that facilitate the operation of the different devices that are being deployed for the sector.

This technological devices deployed include sensors, smart pipes, smart meters, other intelligent electric devices (IEDs) used to retrieve state information, alerts, any relevant physical parameter from the water supply infrastructure at all levels – in this structure are also included parameters collected through existing SCADA and passed through to the ICeWater upper layers,

Water management technologies often overlap a series of functionalities that are key for the effective operation of urban water systems. The different technologies available put together with the appropriate ICT services we are able to get systems for quality management, GIS, customer management and the supply chain system management.

2.2 Data Fusion and Aggregation:

This is the level where all data gathered are cleaned, normalized, aggregated and stored in order to be made available to the decision support system (DSS).
When water management systems are deployed in cities, the availability of reliable data to enhance operations can improve decision-making at multiple levels (ITU, 2014). In order for the smart systems to work gathering data is required in order to optimize all aspects of a city's water management system and feed information back to citizens, water operators, and technical services of cities. Different stages of data management can be categorized in the six main areas listed below. It should be noted that the examples provided are not limited to these areas, but may overlap several others, as seen in Figure 1.

1. Data acquisition and integration (e.g. sensor networks, smart pipes, smart metres).
2. Data dissemination (e.g. radio transmitters, wireless fidelity (WiFi), Internet).
3. Modelling and analytics (e.g. geographic information system (GIS), Mike Urban, Aquacycle, assessing and improving sustainability of urban water resources and systems (AISUWRS), and urban groundwater (UGROW).
4. Data processing and storage (e.g. software as a service (SaaS), cloud computing).
5. Management and control (e.g. supervisory control and data acquisition (SCADA), optimization tools).
6. Visualization and decision support (e.g. web-based communication and information systems tools).

7. Restitution of data and information to cities' technical services and to the end users (e.g. Tools for sharing information on water and on services).

2.3 ICT Solutions

This is a level of the framework where we look at the benefits that the use of ICT will have in the water management sector. Within urban environments, the implementation of ICT applications can make significant improvements in water distribution, helping to decrease losses due to non-revenue water, and helping to enhance waste-water and storm water management.

In addition, implementing ICT applications in water management can improve performance, customer control and choice, decreased redundancy, and lower environmental impacts. These improvements increase the efficiency of the water sector, while contributing to its economic sustainability since municipalities and water utilities are better able to recover costs from non-revenue water, including the detection of illegal connections.

Chapter 3 Applications and Information

3.1 Information

When ICT applications are applied to cities water management systems, the availability of reliable data to enhance operations can improve decision-making at multiple levels. Many innovative ICT tools have been developed in support of next-generation urban water infrastructure systems, helping to improve performance, increase efficiency, and reduce costs, decrease redundancy, and lower environmental impacts, among others.

3.2 Applications

The water management sector has different ways in which ICT application can be deployed in different ways, the main ones are; Billing System, Meter Reading System (MRS), Customer complaints Management system, Financial Management system, Procurement system, Laboratory Information Management system (LIMS) and Dam Monitoring System.

The guideline also identified; quality management, water supply chain monitoring, mapping of water supply stations using GIS and customer management to be the priority functions in water management where ICT applications are required most.

Chapter 4 Tools and Technologies

4.1 Tools

The following sub-sections will illustrate possible ICT tools that may mitigate some of the challenges facing the water sector by either providing a means to better measure, control, model, or predict water resources supply and demand.

4.1.1 Sensors

Meters and sensors are currently being intensively applied to regulate different activities of water distribution systems such as hydraulic pressure and flow, water quality, head losses, and water and energy consumptions. The major aim of water utilities is to convey water from one place to another without any losses, saving water and avoiding any damages caused by leaking water.

Detecting and localizing leakages help in effectively and easily managing water loss. Leakages are detected mainly by measuring and controlling hydraulic pressures and water flows inside and within the piping network. Sensors are used as a basic tool for monitoring the pressure and flow of water, which enable advanced management.

4.1.1.1 Pressure Management Sensor

The pressure management sensor is an efficient and cost-effective method to lower real water losses and operational costs in water distribution networks. Different types of pressure sensors applied for the measurement of water in pipes to detect storage water levels and other activities can be used in a supply system.

4.1.1.2 Flow Sensors

Flow sensors help to regulate volume of water flow inside the production and distribution system. Flow sensors usually employ the principles of electromagnetics, which are considered as adequate assessment methods for water flow rates and environmental conditions.

4.1.1.3 Energy Consumption Sensors

Energy or power consumption sensors are mainly applied for the optimal power management of pumps inside the waterworks. Power or energy measurement and monitoring systems often rely on a large amount of information from the electric motors that need to be communicated back and forth to the control and monitoring system. Sensors provide a reasonable use of electrical energy during the production and distribution of the water system.

4.1.2 Supervisory Control and Data Acquisition (SCADA)

Supervisory control and data acquisition (SCADA) technology has evolved over the past 30 years as a method of monitoring and controlling large processes. SCADA includes, but is not limited to, software packages that can be incorporated into a system of hardware and software to improve the safety and efficiency of the operation of these large processes. In general, SCADA systems perform main functions like the acquisition of data through the sensors, the transmission of the acquired data between a number of remote sites, the data presentation through the central host computer and the control of the data at the operator terminal or workstations (ICeWater, 2012).

4.1.3 Water Quality System

Water quality system help to detect and address problems related to the quality of water before affecting consumers. Water quality monitoring inside the distribution or the network system helps in addressing problems and providing related operational management activities. An application of different water quality sensors provides verified information that leads to informed decisions related to the observed water quality change. An advanced water quality sensor measures the water pH, dissolved Oxygen, temperature, turbidity, salinity, and conductivity (Analyticon, 2014).

4.1.4 Water Consumption Meter

Water consumption meters measure and record the amount of water used over time by different methods. The water meters not only measure the consumption, but also improve management and help to detects leakages. The consumption measurement methods can be broadly classified as velocity or volume types. The velocity types of meters measure the flow of water from single or multiple jets that pass through well-designed hydraulic structures. The different kinds of velocity meters compute consumption of water by integrating the discharge rate measured over time. The velocity meters work by using a sensor that is either, mechanical, ultrasonic, electromagnetic, pressure, optical, or fluid oscillation based. Volume types of meters uses a mechanical sensor gauge of designed volume that directly prevent the flow of water to measure the water volume over time (ICeWater, 2012; Kamstrup, 2014).

4.1.5 Communication Infrastructure

The traditional water management system mainly depends on protocols, industrial control systems, and adopted registered structures. Therefore, it is difficult to follow emerging communication trends very quickly. Currently, the water utility networks provide an opportunity to adopt an existing infrastructure into a more flexible IP-based monitoring system: alarm gathering, leakage detection and prevention, demand prediction, energy reduction, water quality monitoring, and billing activities.

SCADA systems, advantageous for being highly distributed, are applied to control geographically distributed resources where centralized data acquisition and control are important to the system operation. The general packet radio services (GPRS) and global system for mobile communication (GSM) are the common wireless technologies applied to cellular networks to be used as water metering infrastructure. This is because they are widely available and supported by many telecom operators and vendors. GPRS is a packet-data tool that allows GSM users to apply wireless data services, e.g., e-mails (4G-Americas, 2014).

4.2 Technologies

Technology play a role in managing companies or industry activities by providing the required information and data for effective management of different project activities. In the water sector, information system and knowledge management are recognized as important attributes for efficient and effective water works.

4.2.1 Geographic Information System (GIS)

GIS is a technology that integrates hardware, software, and data required to capture, manage, analyse, and display all forms of geographically referenced information. GIS allows the user to view, visualize, question, interpret, and understand data in different circumstances that clarify patterns, trends, and relationships in the form of reports, maps, and charts.

GIS system helps in answering questions and solves problems easily by looking at the generated data. The GIS system includes a sequence of maps and applications structured on a common information model, which is designed to work across several disciplines and help water professionals to support daily utilities, in addition to a wide range of operations and workflows (ESRI, 2014).

4.2.2 Enterprise Resource Planning (ERP) Systems

Enterprise resource planning (ERP) systems integrate internal and external management information across an entire organization, embracing finance/accounting, manufacturing, sales and service, customer relationship management, etc. ERP systems are automated through an integrated software application. The purpose of ERP is to facilitate the flow of information between all business functions within the organization and to manage the connections to external stakeholders. The potential of ERP systems in smart water management is tremendous. ERP packages help many companies to reduce operational cost, improve customer service, and increase productivity. (Beor & Mendal, 2000; ERP, 2008)

4.2.3 AQUAkNOW Information System

AquaKnow is an active web-based platform for sharing knowledge related to water issues. It is a collaborative workstation and data management system committed to scientific and technical knowledge for sustainable water resource development. The platform is intended for practitioners and experts of different institutions involved in the water sector as a space for gathering and providing productive tools to manage technical and scientific information. It also enables to share documents, data and information (such as, news and events), ideas, experiences and to find help and work with other members involved in the water sector (AquaKnow, 2014).

4.2.4 EUWI Communication and Information System

The European Union water initiative (EUWI) communication and information system (CIS) is a web-based communication and information system that contains comprehensive information about the water initiative activities. CIS enables efficient communication through internet based tools and services to all the EUWI members ranging from the international organization to non-governmental organizations. The general objective of the EUWI-CIS is to disseminate knowledge and information on water through effective networks and to affirm both transparency toward the public and exchange among its members (Dondeynaz, Mainardi, Carmona, & Leone, 2009).

4.2.5 Hydraulic Models

Hydrological models help water resource professionals, companies, and universities, local, regional, and governmental authorities, meteorological agencies, and other water sectors to effectively manage, predict, and make proper decisions on the available water resource. Hydraulic model based simulation and optimization of water distribution network (WDN) was a trend of research during the last decades. The ICe-Water decision support system component incorporates simulation models with a network of sensors and forecasting models for practical management of the water distribution system. The new simulation and optimization linkage approach developed based on the innovative use of traditional and global simulation and optimization algorithms. Different companies provide models, simulation and optimization products to the water network managers to design, optimization of energy and costs, lowering the water loss, and effective controlling strategies.

The SIWA technology developed by Siemens AG is a computer-based system used to compute the hydraulic behaviour in the water supply and helps to optimize related operations. The SIWA water management technology consists of SIWA OPTIM modules used to optimize water supply operations, and SIWA LEAK control used for leak management that lower the operation costs and brings higher reliability through dynamic simulation and optimization of network and pipeline distribution systems (Siemens, 2012).

Chapter 5 Policies and Governance

5.1 Policies

A revised water policy, the National Policy on Water Resources Management and Development, came into effect in 1999. The new policy, among other things, emphasized increased participation of local actors and the private sector in the development and management of water resources to benefit all Kenyans.

A new Master Plan (Strategic Plan 2005-2009) was also deemed necessary to effectively address issues of water resource development and management for the people of Kenya.58 Additional amendments and revisions targeting the 1974 Water Act resulted in the 2002 Water Act with far reaching goals and objectives.

The present policies are substantial however, they require full implementation in order to realize expected results. There is need harmonise policies and legislations related to energy, roads and ICT, as appropriate with provisions for categorization of ICT services as high energy users benefiting from special tariffs, and recognition of ICT infrastructure as a basic utility so that infrastructure access can receive similar protection and rights as other utilities, especially during road construction and maintenance.

5.2 Governance

Overall the Water and ICT ministries need to work closely and have an aspect of ICT to be incorporated to water management. The ICT State Department shall have the overall mandate of overseeing ICT staff development in the public and private sector. This will be achieved through a working group on ICT Professional Development under the State Department and drawn from representatives of private and public sector organizations involved in professional development of ICT staff that van handle specific departments

Chapter 6 Water Sector Management

Rapid technological advances, especially in water extraction, resources assessment and distribution, are a big challenge as well as an opportunity to the country and the Ministry. Available technologies can be used for better management of water resources including ground waters, harvesting and storage of rain water as well as in the provision of sanitation services such as water reuse technologies. In addition utilisation of alternative energy sources for water supply is an area the country needs to exploit. The lack of modern ICT-based systems is a particular challenge to the Ministry of water whose technical departments continue to rely largely on manual and paper based information systems. Use of modern ICT based systems for operations will help in enhancing the productivity of staff. Linked to this is the need to build capacity in the use of ICT as a management and decision support tool. It is therefore imperative that all departments keep pace with technological advancement in order to leverage technology for better service delivery to the citizens as per its service charter.

Chapter 7: Training and Awareness

In order to deliver the expected levels of service in the water sector training and capacity building need to be enhanced. Service delivery has been compromised due to by low skills virtually in all fields. Major areas of concern that require urgent attention were identified as ICT/computer skills, GIS applications including Mike Basin software, report writing, financial management and public relations for the industry.

The lack of structured internship and graduate training programs by local industry has also reduced the pool of well-trained engineering graduates who are not specialized on specific sectors such as water.

Strengthen and structure ICT professional development in Kenya. This strategy requires development of guidelines for training of ICT graduates by companies with certification. In engineering, this will be developing a graduate engineering training program for at least one year. At the end of the industry training, the ICT graduate trainees will be required to pass some locally developed certification programs for different sectors of ICT.

Chapter 8: Conclusion and Recommendation

8.1 Conclusion

The guideline established that Billing System, Meter Reading System (MRS), Customer complaints Management system, Financial Management system, Procurement system and Dam Monitoring System were the ICT applications that can be deployed in water resources management. These applications can be used for the purpose of customer information management, water billing processes, communicating with customers, water quality management and soon on Laboratory Information Management system (LIMS) for water quality.

The key challenges in implementing this applications include; limited staff skills, limited resources (finance), lack of customized applications, lack of detailed top level management support and appreciation of the role of ICT by other departments were challenges facing the implementation of ICT applications in the company.

In the upcoming years, new ICTs will affect the entire water cycle and the management of the water resource related activities. The overall process of bringing ICT into the water resource sector represents a major task in present and coming years. The integration and implementation of new ICT into the existing implemented water management systems remains one of the most challenging tasks facing technology and water experts. Developing an integrated comprehensive smart water management solution that uses ICT for the measurement, automation, control, monitoring of water supply and demand has a definite positive impact on the entire economy.

8.2 Recommendations

The guideline recommends increased use of community radio, mobile phones, the internet and other ICTs in water management responses since they help communities and nations sustain resources management. Mobile based applications be initiated because with the fast growth of mobile technology, more easy-to-use mobile applications for water management would easily reach the vast majority of the community.

Water is a basic need, and as a necessity, its quality must be assured to the end user. Diseases (water borne diseases) easily spread through water. Management of the quality of the water supplied to clients is therefore very vital. The use of Laboratory Information Systems (LIS), and other ICT systems in the monitoring and management of water quality should be enhanced. Water processing and supply stations should embrace the use of the LISs to keep records of the laboratory processes that check for the quality of the water supplied to clients

The most common water supply chain used is pressurized water pipes. Excess pressure can lead into the bursting of these pipes (majority are made of plastic). Lower pressure in the pipes may also result into water not reaching the clients. Leakages can also occur in the delivery process. ICT applications can be used to monitor this supply chain and give timely feedback to the stations for respective corrective action measures to be taken, in the process improving efficiency.

Geographical Information Systems are increasingly being used in monitoring and management of resource allocation. The water sector can also apply GIS technology to map out the water resources available and get a visual representation of the distribution of these resources, and based on this information, decisions can then be made on how best resources can be distributed to serve the population better, hence improving water use efficiency.

Figure 1 provides a framework indicating the tools and technologies that are involved in the water sector and how they relate with one another to achieve the expected results. This guideline proposes the implementation of the framework in the water sector.

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Appendix 2: Questionnaire

The objective of this study is to determine the Role of Information Communication Technologies in Water Use. The information given will be used purely for academic purposes and will be treated with high degree of confidentiality. Please provide the correct required information.

SECTION A: DEMOGRAPHICS

1. Organization name (Optional) …………………………… …………………
2. Your position in the Organization
   Technical support (engineer, technician, team leader, IT experts, system admin/analyst) [ ]
   Supervisory/ Manager [ ]
   Others (specify) ……………………………………………………. [ ]
3. What is your gender? Male [ ] Female [ ]
4. Your age bracket please?
   19 - 30 Years [ ] 31 - 40 Years [ ]
   41 - 50 Years [ ] Over 50 years [ ]
5. What is your highest level of education?
   College certificate [ ] diploma [ ]
   University degree [ ] Post graduate [ ]
   Others (specify) ………………………………………………….
6. How long have you been working in the ICT Industry?
   Less than 5 Years [ ] 5- 10 Years [ ]
   10- 20 Years [ ] Over 20 yrs [ ]
7. How long have you worked in the water sector?
   Less than 5 Years [ ] 5- 10 Years [ ]
   10- 20 Years [ ] Over 20 yrs [ ]

SECTION B: GENERAL INFORMATION

8. Below are some of the ICT applications used in water management? Kindly indentify the ones applied in your organization.
   Internet based water bill access [ ]
   SMS notifications [ ]
   Other, Please specify
   i. …………………………………………………………………………………………………
   ii. …………………………………………………………………………………………………
   iii. …………………………………………………………………………………………………

9. What ICT applications does your company use in water resources management?
   i. ……………………………………………………………………………………
   ii. ……………………………………………………………………………………
   iii. ……………………………………………………………………………………
   iv. ……………………………………………………………………………………

10. What are some of the functions for the applications named above?
    Customer information management [ ]
    In Water billing processes [ ]
    Communication with customer [ ]
    Water quality management [ ]
    Water treatment [ ]
    Knowledge management [ ]
    Other please specify [ ]
    i. ……………………………………………………………………………………

ii. …………………………………………………………………………………………
iii. …………………………………………………………………………………………
iv. …………………………………………………………………………………………

11. Give a brief description of the functions of the applications listed above.
    Customer information management [ ]
    Water quality management [ ]
    Water treatment [ ]
    Knowledge management [ ]
    Other please specify [ ]
    i. …………………………………………………………………………………………
    ii. …………………………………………………………………………………………
    iii. …………………………………………………………………………………………
    iv. …………………………………………………………………………………………
12. On which platforms are the applications hosted?
    Web based [ ]
    Mobile phone based [ ]
    Other (Please explain) [ ]
    i. ……………………………………………………………………………………………………
    ii. ……………………………………………………………………………………………………
    iii. ……………………………………………………………………………………………………

13. To what extent are the applications actively used by your current customers service?

Always used	Mostly used	Occasionally used	Rarely used	Never used

14. What percentage of the customers actively use the applications rolled out by your company?

0-25 %	25-50%	51-75 %	76-100 %

    Any additional comment
    ……
15. What challenges do you face in implementing ICT applications for your company?
    Limited staff skills [ ]
    Limited resources (Finance) [ ]
    Lack of customized applications [ ]
    Other (please specify) [ ]
    i. …………………………………………………………………………………………
    ii. …………………………………………………………………………………………
    iii. …………………………………………………………………………………………
    iv. …………………………………………………………………………………………

16. Of the ICT applications above which ones could you say have improved water-use efficiency the most at the local level?
    i. ……………………………………………………………………………………………………
    ii. ……………………………………………………………………………………………………
    iii. ……………………………………………………………………………………………………

    Give reasons ………………………………………………………………………………………..
    ………
    ………

17. What do you think can be done differently in order for ICT applications to be effectively deployed at the community level in water management? Please explain
…………………………………………………………………………………………………
Give reasons ……………………………………………………………………………………………..

18. What local climate change impacts (i.e. acute shocks and chronic trends) are you currently facing in your area of jurisdiction?
i. ……………………………………………………………………………………………
ii. …………………………………………………………………………………………………
iii. …………………………………………………………………………………………………

Give reasons ……………………………………………………………………………………………

19. What existing ICT applications currently support stronger integration and interdisciplinary approaches to adaptation to climate variability/change in water resource management in water resources by your organization?
i. ……………………………………………………………………………………………
ii. ……………………………………………………………………………………………
iii. ………………………………………………………………………………………………

20. What ICT tools do you need to have in order to support stronger integration and interdisciplinary approaches to adaptation to climate variability/change in water resource management?
………
Give reasons ……………………………………………………………………………………………

21. Briefly describe the current implementation process for ICT applications within your company
……………………………..……...………………………………………………………………………
……………………………………………………………………………………………………

22. In terms of ICT applications implementation process what changes do you suggest to enhance climate change adaptive measures?
……………………………..……...………………………………………………………………………
Give reasons …………………………………………………………………………………………….

23. Please indicate the level at which you agree with the following statements:

Statements	**Please tick the most appropriate answer**				
	Strongly Agree	Agree	Not sure	Disagree	Strongly disagree
ICT does not play an important role in the water sector					
Climate change effects have critically influenced our organisation’s ICT policy					
ICT applications play an important role in shaping the water sector towards responding to climate change					
It has been easy for our organisation to integrate the use of ICT in its strategy to combat the effects of climate change					
It has been easy for our customers to integrate the use of ICT in its strategy to combat the effects of climate change adapt to the increased use of ICT in our operations					
Our organisation has plans to scale up the use of ICT in its operations in the near future					

Respondents are also invited to comment on any other issues not covered herein that they consider important to the study.

We thank you for completing the questionnaire.