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Using cellphone-based Information Systems for quality water monitoring:

A case study of Nkangala District Municipality

Dissertation by

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Prof C de Villiers (HOD)

Declaration

I declare that this mini-dissertation is my own work, that I have referenced all the sources I used and that no part of this work was previously submitted to any tertiary institution.

Tshimangadzo Gloria Raphulu

Abbreviations

BDS: Blue Drop System

DWA: Department of Water Affairs

DWQF: Drinking Water Quality Framework

EWQMS: Electronic Water Quality Management System

GPS: Global Positioning System

HR: Human Resources

ICT: Information and Communication Technology

IS: Information System

IT: Information Technology

MIS: Mobile Information System

NWA: National Water Act

WHO: World Health Organization

WSA: Water Service Authorities

Abstract

South Africa is a water-scarce nation, which must ensure that its water sources are protected (Bartram, 1996). It is true that the UN Environmental Programme positioned the country's water quality 47th out of 122 nations it observed, but that was 15 years ago (Conero, et al., 1998). Despite numerous claims that South Africa has some of the best potable water in the world, this is not true (Gail, 2004)

Rural municipalities in South Africa are not reporting water quality monitoring data effectively and are not complying with the regulation requirements to ensure overall management of the water quality monitoring process (Rivett, et al., 2014), which makes this process ineffective and inefficient. This is due to the fact that the national monitoring system – the Blue Drop System – that has been designed and implemented to monitor water quality compliance in the country, is not user-friendly or practical and compatible with under-resourced or rural municipalities in South Africa (Rivett et al., 2014).

Government conducted a case study, aimed at investigating and evaluating why rural areas are inefficient and ineffective when participating in national water quality monitoring. The researcher conducted collection of data through the Interviews. Interviews involved the researcher, water supply testers, the water service manager and employees of Nkangala District Municipality in Mpumalanga.

The research found that a mobile-based information system has increased interaction and communication between different levels in the municipality. It also enables managers to remain informed and confident about the quality of water service delivery. The study found that the implementation of the information system has led to transparency in job performance, which will lead to the municipal management taking action. Overall, the findings of the research show that the implementation of a mobile-based information system in Nkangala District Municipality has led to effective and efficient monitoring of water quality.

The study proposed that the mobile information system could use a wireless internet connection to share information between municipality stakeholders in real time.

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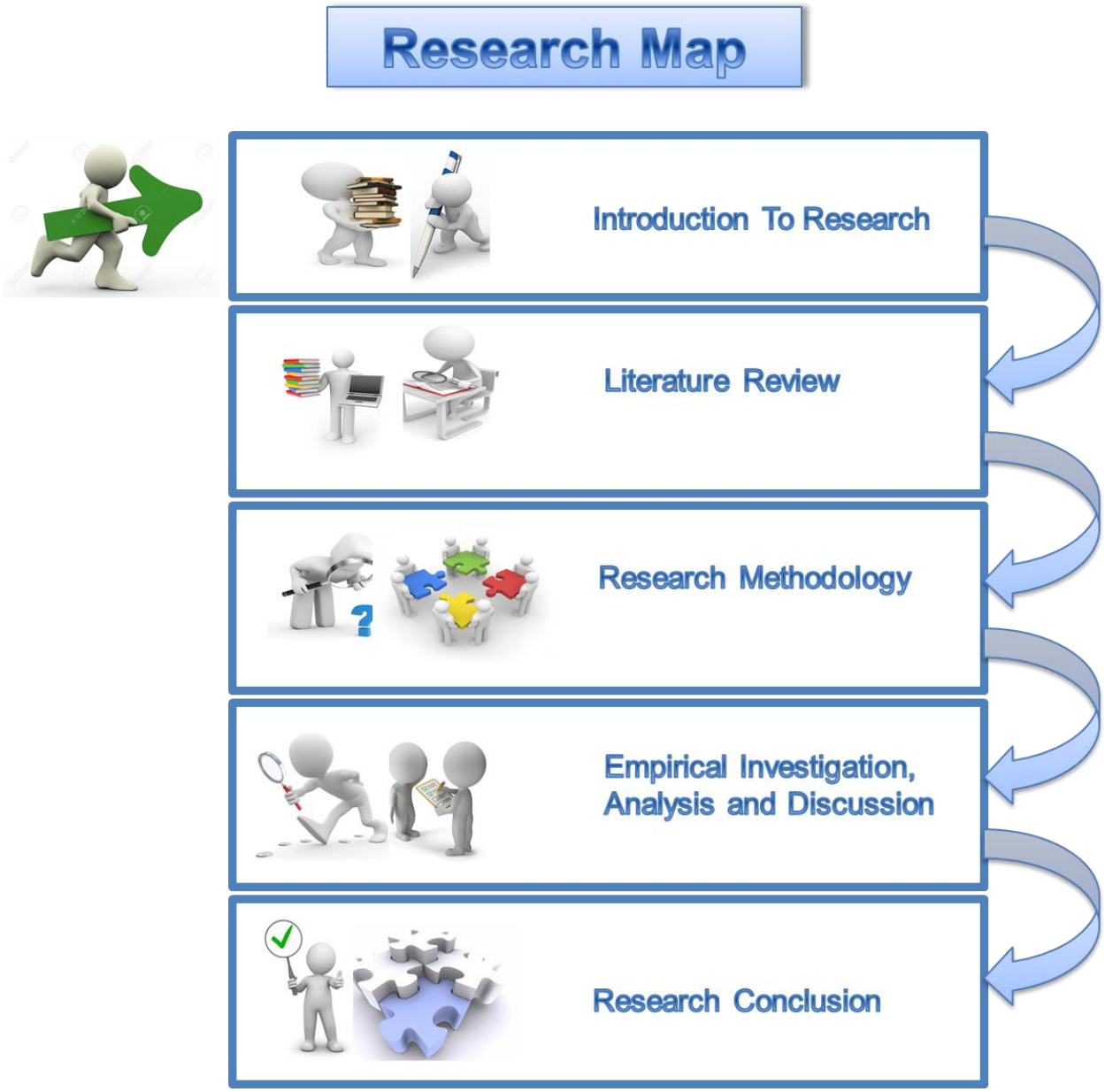
1. Introduction to Research



1.1 Introduction

A safe supply of drinking water is vital for human health and wellbeing. More than 21 million people in South Africa have the right to an improved water source between 1994 and 2012 (Rivett, et al., 2014). The government is trying to fulfil its objective of making sure that every South African has uninterrupted access to quality water (DWA, 2015). In 2004, a local government, Geneva (2004) conducted survey about the quality water in different municipalities to determine the level at which municipalities monitor the quality of water. It was discovered that more than 50% of the water services authorities (municipalities authorised to govern the water service function) were not monitoring the quality of water supplied to people for consumption (Anon., 2015). In response to the survey, the government introduced an electronic Water Quality Management System (EWQMS) to improve the monitoring of water quality and to allow the department access to information, which improved regulation efficiency. By 2007, all the relevant municipalities were undertaking water quality monitoring by using the EWQMS (DWA, 2007). However, the government discovered limitations with regard to the EWQMS. The EWQMS approach promotes action in response to a situation rather than controlling it. In other words, the EWQMS approach focuses on the output results of the monitored water and decision-makers rely on these results to make decisions. This implies that the results of testing water indicate the results about water contamination after many people have already used it. This kind of approach poses a health risk to people. The water quality failures in Delmas in 2005 and 2007 confirm this limitation (Davies, 2007).

1.2 Problem Background

The government prepared a Drinking Water Quality Framework for South Africa, which grounded in a preventative risk management approach (DWAF, 2005). The government has defined a set of compulsory norms and standards to ensure that basic minimum standards are met for quality water (DWAF, 2005). Those norms and standards act as guidelines and regulations that the national government of South Africa has employed and with which all water services authorities must comply in order to deliver safe and quality water to all South Africans. It is the government's duty to monitor these water service institutions.

In 2008 the framework was updated to cover the concept of incentive-based regulation (DWA, 2007). The concept is defined using two programmes, of which one is the Blue Drop certificate

programme. According to the Department of Water Affairs (DWA) (2007), the main objectives of the Blue Drop certificate programme are:

- To introduce incentive-based regulations for water quality;
- To introduce key requirements for efficient and effective management of water quality;
- To initiate transparency in the water quality management of water services institutions; and
- To provide information to the public on water quality per service provider to avoid generalisation.

Water service authorities need to submit information regularly to the Blue Drop System regarding water quality and its management. Since 2009, the AfriForum Blue Drop report has reported that urban municipalities have consistently been improving their water quality management, whereas rural and under-resourced municipalities have been falling behind (AfriForum, 2015).

Rivett et al. (2014) state that it is a known fact that rural areas in South Africa are very difficult to manage and to monitor for reasons such as under-resourcing, skills shortages, lack of understanding of the required standards, lack of intervention to address problem areas, inadequate management and lack of finance, assets and fiscal accountability. Muller (2007) notes that this might be exaggerated by management practices controlling limited resources instead of dealing with policy implementation. According to Rivett et al. (2014), rural authorities do not always respond to national legislation and regulatory requirements and water quality monitoring is often only conducted when absolutely necessary or for a particular reason. The ad hoc information obtained then is not useful or has no impact on identifying and preventing microbiological contamination, which makes it difficult to manage overall water supplies and maintain the quality of water (Rivett, et al., 2014). This occurs mostly in rural areas where there is still only a partially reticulated and treated water supply and where many people still rely on individual boreholes for water supply (Rivett, et al., 2014).

The problem, as indicated in the previous paragraph, has been that rural municipalities are not reporting water quality monitoring data effectively and are not complying with regulation requirements to cover the overall management of the water quality monitoring process (Rivett, et al., 2014). That makes their water quality monitoring process ineffective and inefficient. This is due to the fact that the national monitoring system – the Blue Drop System - has been designed and implemented to monitor water quality compliance in the country (DWA, 2007).

The Blue Drop System is not user-friendly or practical and compatible with under-resourced or rural municipalities in South Africa (Rivett et al., 2014). The Blue Drop System is rather designed and implemented for economically rich and urban municipalities that have the resources and capability to implement policies and best practices. Rural municipalities are failing to provide information to the Blue Drop System or the information provided is very limited, because the management of water quality in urban areas is different from the management of water quality in rural areas. Therefore even if the water in the rural area is of good quality, the report from the national Blue Drop System will always regard it as of poor quality because the information provided is inaccurate and insufficient (DWA, 2015). The Blue Drop System to monitor the quality of water is implemented nationally and does not cater for the information that is specifically relevant at local level (Government, 2012). The Blue Drop System for monitoring the quality of water is centralised nationally, which results in important decision-making about water quality, which does not cater for the local level. Therefore, according to Rivett et al. (2014), there is no accountability at local community level to exercise control over resources and society at large. Small and under-resourced municipalities are affected negatively by these systems to the point where monitoring the quality of water has become a government function that has limited impact on decision-making at local level.

1.3 Problem Statement

Rural municipalities are not reporting water quality monitoring data effectively and are not complying with the regulation requirements covering the overall management of the water quality monitoring process (Rivett, et al., 2014). That makes their water quality monitoring process ineffective and inefficient (Rivett, et al., 2014).

1.4 Motivation for Research

Quality water is essential for human beings and their health (Bartram & Ballance, 1996). Frequent monitoring of water helps to detect water contamination before it can harm people and thus to guarantee the safety of people's health (Heeks, 2002). Efficient monitoring of water will enable municipal officials to make the right decisions for the community (Tancott, 2014). Furthermore, in attempting to fulfil its obligation to deliver good quality water to all South Africans, the government implemented the EWQMS to monitor water quality. Through research, the government discovered that this approach or system had some limitations that compromised the health and wellbeing of people (Asmal, 2000). In response to this, the government

introduced the Blue Drop System with the aim to improve the monitoring process for water quality. It turns out that the system does not benefit rural or under-resourced municipal areas. This has led to the implementation of a mobile-based information system designed specifically for rural and under-resourced municipalities (Rivett, et al., 2014). One of the main reasons for using a mobile device to achieve efficiency in rural municipalities' monitoring of water quality is the "high distribution rate" of mobile phones that results in the community being more familiar with mobile technology and being able to adapt to the implemented application more easily (Rivett & Wilson-Jones, 2010). Another reason to use a mobile device to achieve efficiency in rural municipalities' monitoring of water quality is the "ease of network implementations as well as the low equipment, operational and maintenance cost of mobile phones" (Rivett & Wilson-Jones, 2010). It is important to take into consideration the "needs" and "wants" of the community when deciding on suitable mobile technology, as Heeks (2008) mentions that "developers should look at where the poor have already voted with their wallets". Municipal workers who are involved in the implementation of the system conduct this research with the purpose of evaluating the achievability or feasibility of a mobile-based information system in the municipal environment and the acceptance of this information system. The research will also evaluate and explore whether this mobile-based information system has improved the efficiency of water quality monitoring in the Nkangala municipality.

1.5 Research Objectives and Questions

This study evaluates the feasibility of a mobile-based information system that has been implemented in the Nkangala municipality with the main aim of improving water quality monitoring. The main objective of this study is therefore to evaluate whether the implementation of this information system has improved the efficiency of the water quality monitoring process of Nkangala municipality.

The main research objective led to the main research question:

How will a mobile-based information system be used to improve the efficiency of water quality monitoring in Nkangala municipality in Mpumalanga?

In order to achieve the main objective of this study and to answer the main research question, the following sub-questions are defined:

1. *What are the challenges and effects on the Blue Drop System?*

2. *What are the benefits and shortcomings of using a mobile-based information system in the Nkangala municipality for water quality monitoring?*
3. *What recommendation can be made to Nkangala municipality to make the information system more useful?*

1.6 Expected Contributions

- The importance of this study is that it will contribute to understanding of how mobile-based information systems can be useful in monitoring water quality and how these systems can improve the monitoring process in order to safeguard the quality of drinking water to the community.
- The study will contribute to exploring the challenges associated with the current process of water quality monitoring.
- The study will contribute to understanding of the benefits and shortcomings of using a mobile-based information system for monitoring water quality.
- The study will contribute to efficiency through recommendations on how the use of this mobile-based information system be made more useful in this area.

1.7 Overview of Research Approach

This research is interpretive research, as it focuses on gaining insight and understanding into how a mobile-based information system can improve the efficiency of water quality monitoring in rural areas. The researcher will use the qualitative research method. The strategy of this research is a case study involving the Nkangala District Municipality in Mpumalanga. Data will be collected through interviews and observation. The researcher intends to interview water supply testers, the water service manager and employees of the district municipality in Mpumalanga, as well as the project manager coordinating the implementation. The data will be analysed using thematic analysis because according to Sagepub (2001), involvement and interpretation are the key requirements from the researcher and the focus is on identifying and describing the set of data in details.

1.8 Chapter Overview

The aim of the research chapter overview is to present the components that are included in this research study in a format that is understandable by the reader, as well as other researchers. The table below illustrates the research structure for this study.

Table 1: Research Chapter Overview

Chapters	Description
Chapter 1	This chapter entails the introduction to the research, which covers topics such as the background to the problem, problem statement, motivation for research, research objectives and questions, expected contribution, overview of research approach, overview of research chapters and conclusion.
Chapter 2	The chapter involves previous research that have been conducted by different researchers about water quality monitoring, the overview of water quality, the importance of monitoring water for human consumption and methods used to monitor quality water. This chapter is broken down into the following themes: Theme 1 - Context: South African water quality. This theme explains the definition of water quality, as well as the South African guidelines and principles of quality water set by the government. Theme 2 – Water quality monitoring. This theme discusses the process of quality water monitoring, the models that are used to monitor water quality and the issues South Africa faces when monitoring water quality. Theme 3 – Mobile-based/mobile information system. This theme explores the benefits of using a mobile-based

	information system as well as the shortcomings of which the community needs to be aware.
Chapter 3	This chapter discusses the research approach adopted for the research. The topics discussed in this chapter are the research paradigm, research method, research strategy, data collection, data analysis and data design.
Chapter 4	This is an empirical investigation. This chapter involves analysis of all the data collected through interviews with selected candidates in order to provide understanding and establish the relationship between results and defined research questions and objectives.
Chapter 5	This is the concluding chapter, which is aimed at answering the research questions. It also involves assessing the deficiencies that have been identified during analysis of data that have been gathered through interviews and making recommendations on future research.

1.9 Conclusion

The current chapter showed that implementation of the Blue Drop System benefits water quality monitoring for South Africa urban municipalities, not the rural ones. The focus of the study is to evaluate whether the mobile-based information system that the government implemented to improve water quality monitoring for rural municipalities is efficient and effective.

Chapter 1 is summarised in the table below.

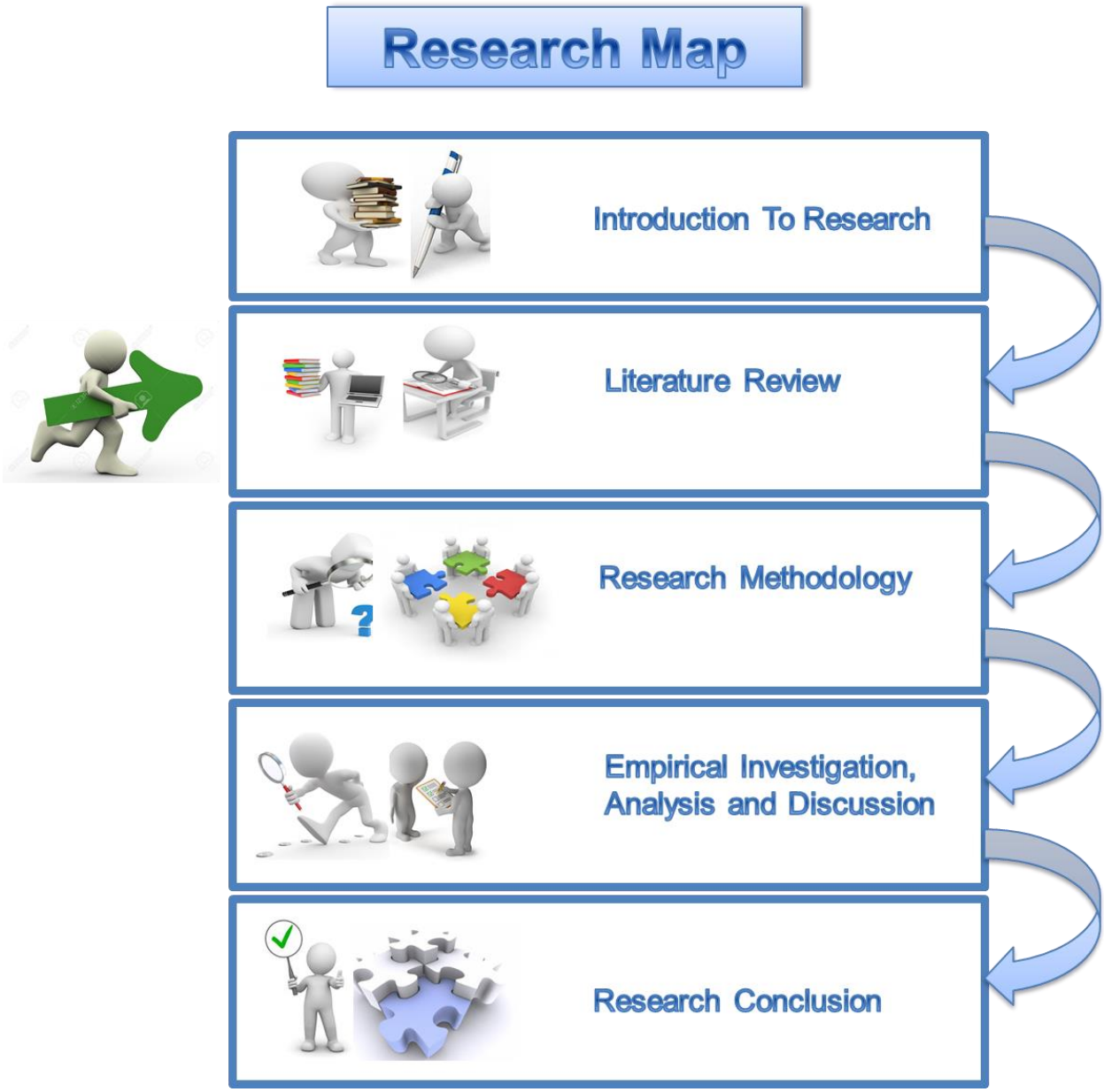
Table 2: Chapter 1 Summary

Chapter 1 Summary	
Research Problem	Water quality monitoring for drinking water in rural areas is ineffective and inefficient. This is because the national system, the Blue Drop System, which has been designed and implemented to monitor the quality of water, is not usable and compatible with under-resourced and rural

	municipalities in South Africa. A mobile-based information system has been implemented to resolve this problem. This research evaluates it and explores whether this mobile-based information system has improved the efficiency of water quality monitoring in the Nkangala municipality.
Research Motivation	The researcher conducted this research with the purpose of evaluating the achievability or feasibility of the mobile-based information system in the municipal environment and the acceptance of this information system by the municipal workers involved in its implementation. The research will also evaluate whether the implementation of this information system has improved the monitoring of water quality in the Nkangala District Municipality in order to ensure that the municipality does not compromise the health and wellbeing of the community.
Research Objectives	The main objective of this study is to evaluate whether the implementation of this information system has improved the efficiency of the water quality monitoring process in Nkangala municipality. This research objective led to the main research question: How will a mobile-based information system be used to improve the efficiency of water quality monitoring in Nkangala municipality in Mpumalanga?
Expected Contribution	The importance of this study is that it will contribute to understanding of how mobile-based information systems can be useful in monitoring water quality and how these systems can improve the monitoring process in order to safeguard the quality of drinking water.

The next chapter of the study provides an overview of the previous academic literature on using a mobile-based information system to achieve water quality monitoring in rural municipalities.

2 Literature Review



2.1 Introduction

This chapter presents the previous research work conducted on the topic of water quality, water quality monitoring and a mobile-based information system. This literature review is divided into three themes, namely Context: South African water quality, water quality monitoring and a mobile-based information system.

2.2 Scope of Literature

The outline of the use of a mobile-based information system for water quality monitoring is described in an in-depth discussion of water quality and mobile information system. An international water quality overview and guidelines, as well as the South African water quality policy, principles and Act of 1998 are discussed under the theme: Context: South African water quality. Processes that are involved in monitoring water quality, models and techniques for monitoring water quality, as well as the issues that are involved when monitoring water quality, are discussed under the theme of water quality monitoring. A description of a mobile information system and the benefits and shortcomings of using mobile information systems are discussed under the theme of a mobile-based information system.

This research study combined South African literature on water quality with international literature in order to determine similarities for this research. The overall scope of this chapter is illustrated in figure1 below, which covers all the topics that will be covered in the literature review.

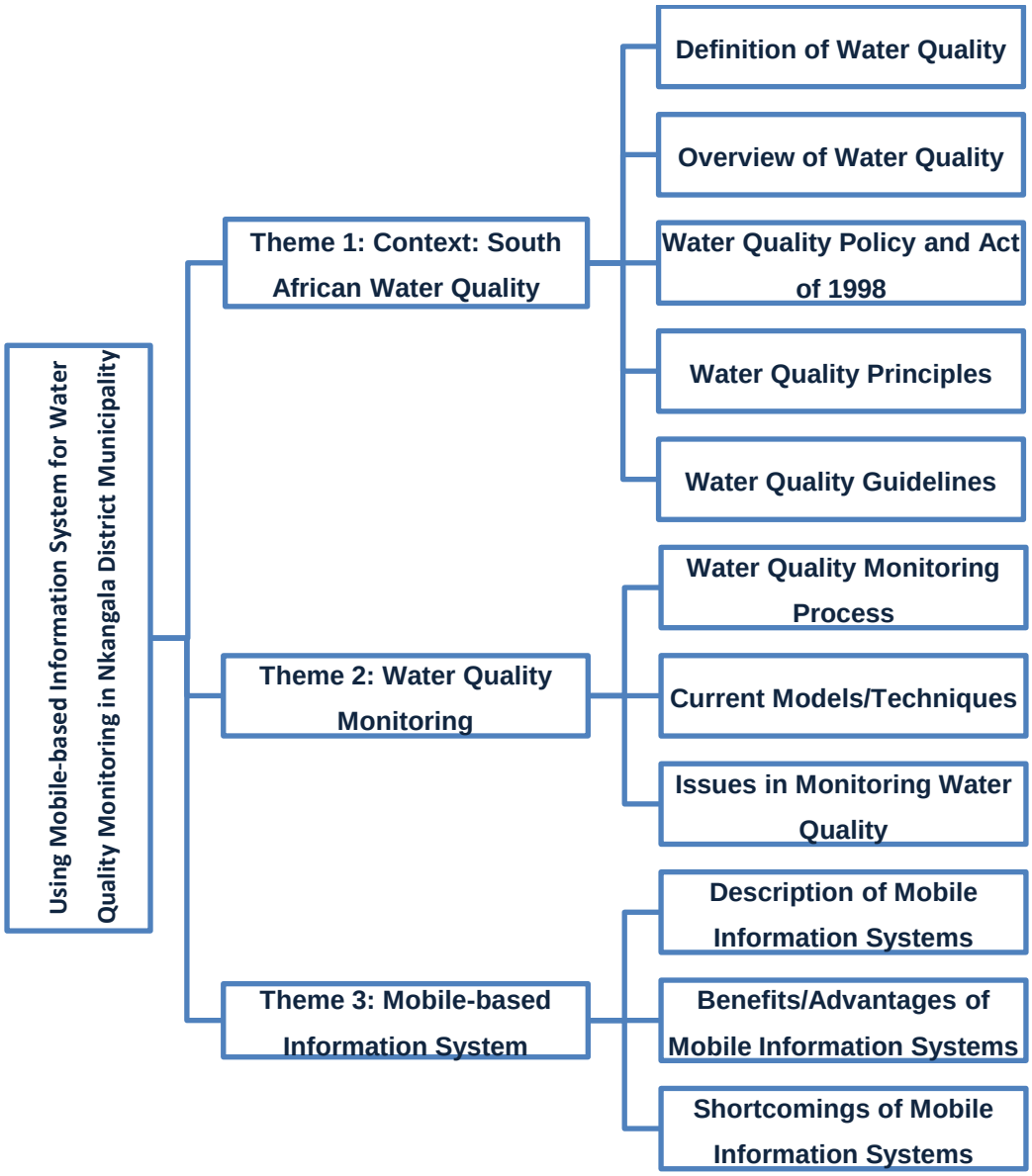


Figure 1: Scope of Literature

2.3 Theme 1: Context: South African Water Quality

2.3.1 Definition of Water Quality

Lack of mutual understanding of water quality terminology that is used to govern the appropriate evaluation and requisite quality of water is currently the main problem in the water quality management field (Fred, 1999). This problem leads to excessive application of regulations on wastewater discharge when there is water that meets the quality standards and criteria. This problem also leads to insufficient control of water quality that is caused by unregulated water quality management although there is good quality water that meets standards and criteria (Fred, 1999). Therefore, when defining water quality, it is important to use words such as "pollutant," "pollution," "water quality," "water chemistry," etc. according to their legal usage and to use them technically correctly in order to avoid incorrect classification of water quality when doing evaluation (Fewtrell & Bartram, 2001). Courts and regulatory boards often issue rulings that require great expenditure of private and public funds to control chemical components that had been called pollutants incorrectly (Fewtrell & Bartram, 2001). Using the following terminology correctly will improve the management of water pollution technically and cost-effectively:

Water pollution: According to the Clean Water Act, pollution can be defined as "damage or weakening of the intended use(s) of water". This means that finding chemical elements in the water or sediments cannot be regarded as pollution, except if the elements are a danger to the intended use of the water (Fred, 1999).

Water quality: Water quality can be defined in a calculable or measurable approach or/and qualitative approach and should be assessed based on the features of the water comparative to the intended use of the water (Lee, 1999). The definition of water quality, according to Twenter and Loftis (2003), "is the measure of quality of water in which the water is fit to do that which it is intended to such as farming, drinking, industrial processing, swimming, fish production etc. There are three parameters that are grouped together into the definition of quality water, which are physical, chemical and biological. Physical factors are such as odour, colour, temperature and turbidity. Chemical factors can be minor and major elements such as pH, Biological Oxygen Demand, and Chemical Oxygen Demand. Biological elements include elements such as Fecal Coli-form and E. coli."

Water quality assessment: Assessment can sometimes be confused with monitoring (Lee, 1999). Water quality assessment is the processes of evaluating the danger of water pollution

that may potentially occur or that is occurring as the result of particular chemical or other elements, whereas water quality monitoring is the process of defining a set of compulsory norms and standards in order to make sure that basic minimum standards are met for quality water (DWAF, 2005). Those norms and standards act as guidelines and regulations to govern the water service function in order to deliver safe and quality water. Unlike water quality monitoring, water quality assessment does not happen frequently but as the need arises (Lee, 1999).

2.3.2 Overview of Water Quality

In South Africa, the problem of polluted water started in the first half of the 19th century when towns and industries were developed and when waste accumulated in built-up areas (DWAF, 2015). Acceptable sewage disposal methods where developed in order to control the water quality. A report by Conero et al. (1998) indicates that 40% of national waterways remain too dirty for drinking, fishing and swimming. Over 290 000 miles of rivers and streams, that were assessed do not meet the national water quality standard, according to EPA's watershed indicators (DWAF, 2015). Only 16% of watershed reported to be of good quality, whereas 36% reported to have moderate water quality problems and 21% of watershed had serious problems with water quality (DWAF, 2015). The quality of the remaining 27% shown as confirmed because of insufficient data that collected. Added to that, one in 14 watersheds in all regions exposed to more risk of water pollution from urban-to-rural runoff (WMO, 2013). The extent and kinds of water impurities shown that they determined by the source of water supply. Water on earth comes from water vapour in the atmosphere; water in the atmosphere is free from any pollution and it remains pure as long as it stays there (WMO, 2013). When water vapour prepares to fall to earth, get exposed to gases, such as nitrogen, oxygen and carbon dioxide, which make it acidic when reaching the earth (sagepub, 2001). After hitting the ground, this water absorbs an additional amount of carbon dioxide from decomposing plant substances, polluting it even further. Two known water interactions occur in groundwater and surface water (Thomas et al., 1999). Groundwater, which is mostly from deep wells, usually has high “concentrations of dissolved minerals”. Its water is normally clear and colourless because of its filtration through sand and rock (Thomas, et al., 1999). Groundwater can also contain different kinds of pollution, such as detergents and industrial waste. If the water is from shallow wells, it may contain an amount of mineral impurities (Lee, 1999). Water from such sources carries a danger of polluted with animal and human wastes. Surface water, which is water that is found

above the earth's surface, contains various impurities, sand, clay and silt, making the appearance of the water cloudy and muddy (Folifac…, 2007). If this water runs through agricultural land, it also picks up chemical and toxic waste that comes from animals (Bartram, 1996), whereas if it runs through swampland, it can absorb an unpleasant taste, odour and plant colour (Bartram, 1996). When there are floods, swamps may release their decomposed plants, colour and bacteria into running streams and rivers (Folifac…, 2007).

2.3.3 Water Quality Policy and Act of 1998

The previous South African Water Act was drafted in 1956 (van Koppena & Schreiner, 2014) .The Act applied the water rules from European countries to South Africa (Asmal, 2000). The water rules were inappropriate because European countries have lots of water, whereas South Africa is dry (Asmal, 2000). The previous Act also did not recognise water as a basic human right and favoured only a small dominant group of people who were privileged, had access to land and had economic power (Moira & Brid, 2009). In addition, the old Water Act "focussed on water use and the development of dams rather than on water protection, conservation and demand management". Government Gazette number 19182, volume 398, issued the new National Water Act (NWA) (No 36 of 1998) in 26 August 1998 in the Republic of South Africa. The Act is the key authorised tool that facilitates the management of water resources in South Africa (Gazette, 1988). The key purpose of the NWA is to ensure that the water resources of South Africa are protected, used, developed, conserved, managed and controlled in a useful and comprehensive way, which makes it possible for the proposals of the National Water Policy to be implemented (Harpe, 1988). Protection, use, development, conservation, management and control of water resources are guided by the principles of sustainability, equity and efficiency, as illustrated in the figure below:

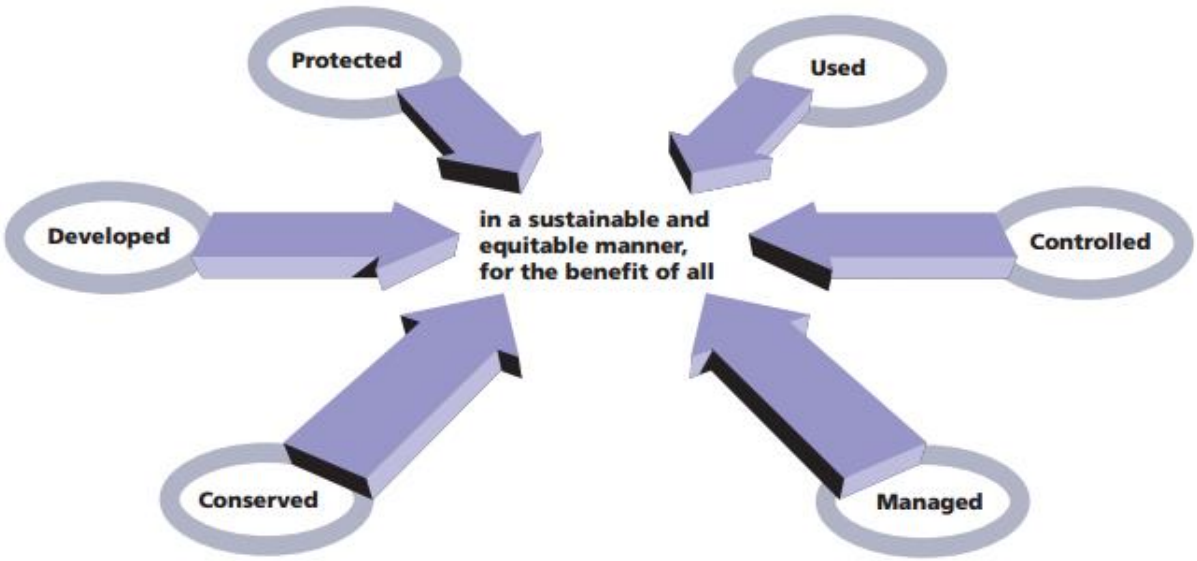


Figure 2: National Water Act

Sustainability in this regards means supporting social and economic development in parallel with making sure that the environment is safe both now and for the future (Robyn, 2001). The environment needs to be protected because it is where water comes from. If there is a good balance between using and protecting water resources, then current and future water needs can be met (Robyn, 2001). Equity refers to a situation where everyone has access to quality water and everyone has the benefit of using water (Kranz et al, 2005). The distribution of water must be fair to all. Efficiency means water should be taken care of and not wasted. Water must be used to the best possible social and economic advantage (Water and Foretry, 2004). These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act.

The other purpose of the NWA is meeting the basic human needs of present and future generations (Asmal, 2000). Water is a natural resource and for that reason, it should belong to everyone and be accessible to everyone who needs it, as recognised by the Water Act (Asmal, 2000). According to the Government Gazette (1988), the Act enforces fair and equal distribution of water. Everyone has the *right* to water as a basic human need, as long as the water is for activities such as drinking, preparing food and personal hygiene (GAZETTE, 1988). The Act

stipulates that water must be provided for basic human needs and for environmental needs before being distributed for other uses (GAZETTE, 1988).

The NWA ensures that water resources are being managed at the lowest level, with the intention of involving people to participate in water resource management because of the importance of water to people (Anon., 1997). Communities and stakeholders also participate in decision-making about water management in order to keep up with international trends in integrated water resource management. The NWA supports water use that is in the public interest and beneficial for the achievement of equitable and sustainable economic and social development (van Koppena & Schreiner, 2014). The NWA "is a fundamental change in how water resources will be managed and accessed" (Bartram, 1996). The Water Supply and Sanitation Policy and the Water Services Act of 1997, which ensure that water and sanitation services are provided to every South African, are the secondary tools implemented to reach the objectives for the Water Policy (Bateman, 2015). The National Water Policy is supported by three key values for water resource management, namely "equity, (environmental) sustainability and efficiency" (DWA, 2007). The Department of Water, Forestry and Sanitation is in charge of developing policy and regulations on water and to ensure that sanitation is provided to all South Africans (GAZETTE, 1988). The provision of sanitation is administered by the Strategic Framework on Water Services as well as the National Service Act of 1997, which states: "All water users who do not receive their water from a service provider, local authority, water board, irrigation board, government water scheme or other bulk supplier, and who use water for irrigation, mining purposes, industrial use, and feedlots or in terms of a general authorisation, have a statutory obligation to register. This includes the use of surface and groundwater" (Government, 2012). Other uses of water that must be registered include "diversion of rivers and streams, discharge of waste or water containing waste, storage, which includes any person or body storing water for any purpose from surface run-off, groundwater or fountain flow in excess of 10 000 m^3 or where the water area at full supply level exceeds one hectare (ha) in total on land owned or occupied by that person or body, and who is not in possession of a permit or permission, local authorities and other bulk suppliers with their own water sources and purification works, controlled activities such as irrigating with waste, power generation with water, atmospheric modification or recharging of aquifers" (Tancott, 2014). The NWA is important because it provides a framework to protect water resources against over-exploitation and to ensure that there is water for social and economic development and water for the future (Folifac…, 2007). It is also important because it recognises that water belongs to the whole nation for the benefit of all people. The NWA is taken directly from the major principles and objectives for acts regulating water use that have been implemented in the new South Africa to

ensure water quality (Harpe, 1988). The discussion below elaborates on the water quality principle.

2.3.4 Water Quality Principles

The principle of water quality ensures that the fundamental environmental processes that control the movement of materials in natural systems is regulated (Anon., 1997). The NWA is based on the principle that the national government is fully accountable for and has power over the management of water resources, together with the equitable allocation and beneficial use of water in the public interest. A person is only entitled to use water if the use is permissible under the Act (Anon., 2000). These principles need to lay the basis for regulating the use of water and to have central significance in the Act (Thomas, et al., 1999). Taking into account the principle of water quality, according to the Department (2004), the various types of entitlements to use water, such as licensed and unlicensed, are clearly defined and dealt with in detail (Government, 2012). South Africa's water and water resources are ruled by the Water Services Act of 1997 and the NWA of 1998 (DWA, 2015). The Acts are complementary and provide a framework for sustainable water resource management while enabling improved and broadened service delivery (UNESCO, 1995). "The NWA is founded on the principle that all water forms part of a unitary, interdependent water cycle, and should thus be governed under consistent rules. It contains comprehensive provisions for the protection, use, development, conservation, management and control of South African water resources (WMO, 2013). The strategic objectives are stipulated in the National Water Resource Strategy" (DWAF 2004). Water resource management has been transformed recently from central management to decentralised management (Anon., 1997). According to Glen (2014) , water management areas have been established, defined largely by hydrological catchment borders, and catchment management agencies will be the main administrative bodies.

The table below presents South African's fundamental principles and objectives for a new water law in the country.

Table 3: Principles and Objectives of Water Law in South Africa

Fundamental Principles and Objectives for a Water Law in South Africa

Principle 1	The water law shall be subject to and consistent with the Constitution in all matters, including the determination of the public interest and the rights and obligations of all parties, public and private, with regard to water. While taking cognisance of existing uses, the water law will actively promote the values enshrined in the Bill of Rights.
Principle 2	All water, wherever it occurs in the water cycle, is a resource common to all, the use of which shall be subject to national control. All water shall have consistent status in law, irrespective of where it occurs.
Principle 3	There shall be no ownership of water but only a right (for environmental and basic human needs) or an authorisation for its use. Any authorisation to use water in terms of the water law shall not be in perpetuity.
Principle 4	The location of the water resource in relation to land shall not in itself confer preferential rights to usage. The riparian principle shall not apply.
Principle 5	In a relatively arid country such as South Africa, it is necessary to recognise the unity of the water cycle and the interdependence of its elements, where evaporation, clouds and rainfall are linked to underground water, rivers, lakes, wetlands and the sea, and where the basic hydrological unit is the catchment.
Principle 6	The variable, uneven and unpredictable distribution of water in the water cycle should be acknowledged.
Principle 7	The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long-term, environmentally sustainable social and economic benefit for society from its use.
Principle 8	The water required to ensure that all people have access to sufficient water shall be reserved.
Principle 9	The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long-term

	sustainability of aquatic and associated ecosystems.
Principle 10	The water required for meeting the basic human needs referred to in Principle 8 and the needs of the environment shall be identified as "the reserve" and shall enjoy priority of use by right. The use of water for all other purposes shall be subject to authorisation.
Principle 11	International water resources, specifically shared river systems, shall be managed in a manner that optimises the benefits for all parties in a spirit of mutual cooperation. Allocations agreed for downstream countries shall be respected.

The DWA is the government department that is responsible for the creation and carrying out of policies governing South Africa's water and forestry sector (sagepub, 2001). The Department makes every effort to ensure that the citizens of South Africa gain access to clean water and safe sanitation, and promotes effective and efficient water resources management to ensure sustainable economic and social development (Anon., 2000). At present it is responsible for water resource management in terms of developing policies, implementing programmes as well as monitoring and regulating South Africa's water resources. The first National Water Research Strategy (NWRS), which was officially introduced in September 2004 in order to satisfy the requirements of the National Water Policy and NWA, No 36 of 1998, has been officially incorporated into water resource management (Water and Foretry, 2004). This strategy provides a framework to protect, use, develop, conserve, manage and control South Africa's water resources.

The table is a continuation of the principles that directly guide water resource management in South Africa.

Table 4: Water resource management principles

Water Resource Management Approaches	
Principle 12	The national government is the custodian of the nation's water resources, as an indivisible national asset. Guided by its duty to promote public trust, the national government has ultimate responsibility for and authority over water resource

	management, the equitable allocation and usage of water and the transfer of water between catchments and international water matters.
Principle 13	As custodian of the nation's water resources, the national government shall ensure that the development, apportionment, management and use of those resources is carried out using the criteria of public interest, sustainability, equity and efficiency of use in a manner which reflects its public trust obligations and the value of water to society while ensuring that basic domestic needs, the requirements of the environment and international obligations are met.
Principle 14	Water resources shall be developed, apportioned and managed in such a manner as to enable all user sectors to gain equitable access to the desired quantity, quality and reliability of water conservation and other measures to manage demand shall be actively promoted as a preferred option to achieve these objectives.
Principle 15	Water quality and quantity are interdependent and shall be managed in an integrated manner, which is consistent with broader environmental management approaches.
Principle 16	Water quality management options shall include the use of economic incentives and penalties to reduce pollution; and the possibility of irretrievable environmental degradation as a result of pollution shall be prevented.
Principle 17	Water resource development and supply activities shall be managed in a manner which is consistent with the broader national approaches to environmental management.
Principle 18	Since many land uses have a significant impact upon the water cycle, the regulation of land use shall, where appropriate, be used as an instrument to manage water resources within the broader integrated framework of land use management.
Principle 19	Any authorisation to use water shall be given in a timely fashion and in a manner which is clear, secure and predictable in respect of the assurance of availability, extent and duration of use. The purpose for which the water may be used shall not arbitrarily be restricted.

Principle 20	The conditions upon which authorisation is granted to use water shall take into consideration the investment made by the user in developing infrastructure to be able to use the water.
Principle 21	The development and management of water resources shall be carried out in a manner which limits to an acceptable minimum the danger to life and property due to natural or manmade disasters.

The table below describes the principles that directly guide water institutions in South Africa.

Table 5: Water Institutions Principles

Water Institutions	
Principle 22	The institutional framework for water management shall as far as possible be simple, pragmatic and understandable. It shall be self-driven and minimise the necessity for state intervention. Administrative decisions shall be subject to appeal.
Principle 23	Responsibility for the development, apportionment and management of available water resources shall, where possible and appropriate, be delegated to a catchment or regional level in such a manner as to enable interested parties to participate.
Principle 24	Beneficiaries of the water management system shall contribute to the cost of its establishment and maintenance on an equitable basis.

The table below lists the principles that directly guide water services in South Africa.

Table 6: Water Services Principles

Water Services	
Principle 25	The right of all citizens to have access to basic water services (the provision of a potable water supply and the removal and disposal of human excreta and waste water) necessary to afford them a healthy environment on an equitable and economically and environmentally sustainable basis shall be supported.
Principle 26	Water services shall be regulated in a manner which is consistent with and supportive of the aims and approaches of the broader local government framework.

Principle 27	While the provision of water services is an activity distinct from the development and management of water resources, water services shall be provided in a manner consistent with the goals of water resource management.
Principle 28	Where water services are provided in a monopoly situation, the interests of the individual consumer and the wider public must be protected and the broad goals of public policy promoted.

Water quality principles have to be applied according to water quality guidelines. The following section explains the guidelines for water quality.

2.3.5 Water Quality Guidelines

Adequate water supply must be available to everyone, as water is crucial to life and survival (Conero, et al., 1998). Providing access to good quality water to all will result in tangible health benefits and it should be made a priority to make water as safe as possible (UNESCO, 1995). Water quality according to international guidelines does not represent the health risk over lifetime consumption of water and these guidelines may not be applicable to some industries and aquatic life (Twenter & Loftis, 2003). These guidelines are there to support the development and implementation of risk management strategies in order to ensure that the supply of good quality water takes into account the elimination of harmful elements (Bartram, 1996). The guidelines describe the minimum requirements for good water quality to protect the health of those using it and develop "numerical guideline values". The guidelines also describe the quality of water that is acceptable for consumption throughout the lifespan (Bartram, 1996). The overall strategy for health protection, including sanitation and other food contamination management, is included in the guidelines. The main purpose of water quality guidelines is to promote an "integrated preventive management framework" to ensure safety and good quality water from catchment to consumer (Bartram, 1996). The guidelines also shape the standards and regulations that must be implemented and enforced to protect public health, although these may vary between countries and regions (WHO, 1997).

The simple and important requirements to ensure that standards for water quality are applied to everyone are based on the framework that has been developed and implemented by the health authorities (Bateman, 2015). This framework ensures that the systematic assessments for managing risk and the methods for controlling the measures are working properly, as well as

making sure that day-to-day management of water quality, including setbacks and failures, is integrated in the overall strategy (Thomas, et al., 1999). Therefore the guidelines for water quality promote or support the framework by covering microbial aspects, disinfection, chemical and radiological aspects and aspects related to acceptability: taste, odour and appearance (Conero, et al., 1998).

The link between the framework and the supporting information for guidelines is presented in figure 3.

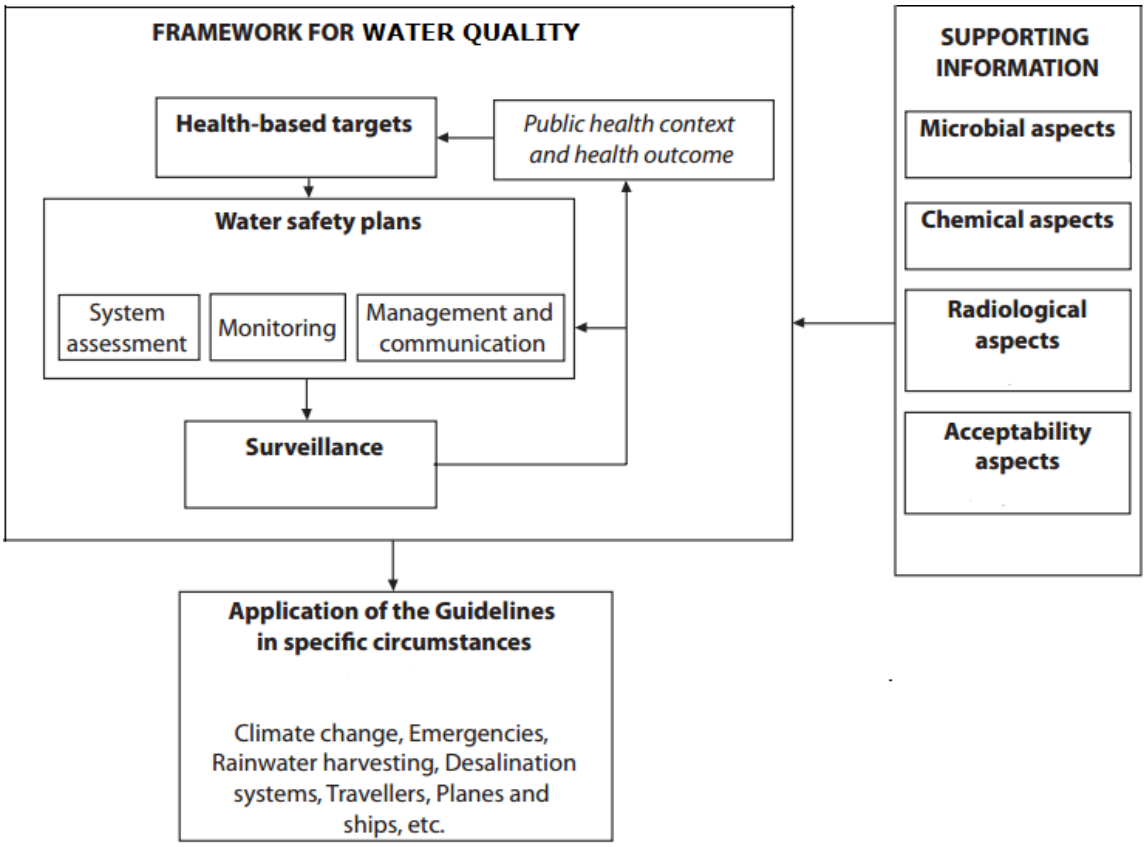


Figure 3: Framework for Quality Water

The framework is founded on an approach and procedure of different integrated systems, which report on the main factors affecting drinking water quality and safety in South Africa (Robyn, 2001). The framework addresses the approach of preventative risk management, which is all-inclusive from catchment to consumer (Fewtrell & Bartram, 2001). This approach ensures that the whole water supply system and events that may compromise drinking water quality, as well as the operational control necessary for optimising drinking water quality and protecting public health, are fully understood. This framework also ensures that the challenges faced by water suppliers are addressed well and the continual improvement approach is well-supported (Geneva, 2004). Water service authorities' alleged lack of resources and capacity to monitor the quality of drinkable water needs to be dealt with immediately (Harpe, 1988). The alleged lack of understanding of governance requirements, accountability and responsibility, for both long- and short-term strategies, as well as the strategy for quality water management, have been noted (Asmal, 2000). A phased approach has been implemented to ensure that failed results for water quality monitoring are identified and addressed in a short time and a long-term regulation

strategy for water quality has been developed and implemented. According to Kader (2000) , this phased approach will ensure that services to the stakeholder are rendered effectively, while reducing the disruption of exciting operational procedures.

2.3.6 Concluding Summary of Theme 1

The aim of discussing the first theme was to determine the context of water quality in South Africa with regard to the definition, policies, Act, principles and guidelines in order to ensure that the researcher and the reader have a common understanding of what the concept means. The findings on the literature on the objective of this theme that was studied are summarised in Table 7 below.

Table 7: Theme 1 Concluding Summary.

Theme 1: Concluding Summary	
Water quality definition	The definition of water quality, according to Twenter and Loftis (2003), "is the measure of quality of water in which the water is fit to do that which it is intended to such as farming, drinking, industrial processing, swimming, fish production."
Principles of water quality	The principles of water quality ensure that the fundamental environmental processes that control the movement of materials in natural systems is regulated (Anon., 1997). These principles need to lay the basis for regulating the use of water as of central significance in the Act.
Guidelines on water quality	The guidelines describe the minimum requirements for good quality water in order to protect the health of those using it and to develop "numerical guideline values". The guidelines also describe the quality of water that is acceptable for consumption throughout

	the lifespan
Implication for Research	
The fact that there is no particular universally accepted definition of water quality means that the research has to depend on descriptions of the concept. This suggests that, as far the current study is concerned, water quality is understood as meeting the stipulated principles and guidelines.	

Definitions of water quality as well as the context of water quality in South Africa are presented and discussed in this theme. To further the study, the water quality monitoring process, techniques and issues are discussed in the next theme.

2.4 Theme 2: Water Quality Monitoring

2.4.1 Water Quality Monitoring Process

A systematic process that has been developed by the council's framework will help in monitoring units that produce and convey the information required to understand, protect, and restore water quality (WMO, 2013). The elements of the framework visually support the interconnection between the six steps and emphasise the need for feedback and evaluation. The features of the framework include the external components that comprise the "3 Cs" – emphasising communication, coordination, and collaboration within monitoring at every step of the process and the significance of comprehensive monitoring of the process framework.

The figure below shows how the external component, the "3 Cs", fits into the quality water monitoring process.

Figure 4: Framework for Water Quality Monitoring

In order to assess water and watersheds accurately, effectively and efficiently, those involved must work collaboratively and make every effort to align methods and achieve data comparability (Gail, 2004). Elements that may hinder collaboration and comparability include great "differences in monitoring design, sampling protocols and analytical methods, data management, and data accessibility" (Meybeck, et al., 1996). This framework is used to direct the activities of the National Water Quality Monitoring Council by "identifying, connecting, and prioritizing" some of the features of the different framework elements (SCIORTINO & RAVIKUMAR, 1999). The framework enables professionals and volunteers working on different components of monitoring programmes to communicate with one another (Anon., 2013). The framework directs the water quality monitoring programmes to ensure that all components are involved, stable, associated, and collectively focused on producing quality information. According to Folifac (2007), the framework "underscores the need for a warehouse of consistent information on water monitoring design methodologies". One of the advantages of the monitoring framework is that it emphasises the response at every step. If the monitoring framework is applied successfully, the outcomes of water quality monitoring can be used to understand, protect, and restore the quality of water (Folifac…, 2007).

The following table illustrates framework steps that are applied when doing water quality monitoring.

Table 8: Water Quality Monitoring Process Framework

Water Quality Monitoring Process	
Step 1 **Develop monitoring objectives**	The main aim of the first step of the monitoring process is to outline the objectives in terms of information that the specific water resource management needs. During this step, one needs to ask and answer questions such as what the purpose of the monitoring effort is, who will use the data and how the data is to be used.
Step 2 **Design monitoring programme**	To meet the objective of water quality monitoring, a monitoring design needs to be developed; the following factors must be taken into consideration when designing the monitoring programme: • The environmental setting. This is the physical environmental conditions where the monitoring would occur. • Location of sampling sites. • Frequency of sample collection. This describes how often the sampling will take place, whether weekly, monthly or yearly. • The constituents to be measured. The most common chemical **constituents** are calcium, phosphates, nitrates, sodium, potassium and chloride. • The methods to be used in the field and the laboratory.
Step 3 **Collect field and laboratory data**	At this stage, measurements taken in the field and the laboratory interprets the water's properties into quantitative data that provide information about the water quality. At this stage of the process, it is vital to document the process precisely and completely.
Step 4 **Compile and manage data**	Data need to be usable and accessible. It is essential that the data in a management system include sufficient

	descriptive information about the data (i.e. “metadata”) so that it can be shared and compared among managers and the public.
Step 5 **Assess and interpret data**	At this point, data start to become information that will address the monitoring objectives. Ideally, the data interpretation methods should have been identified prior to sampling so that the data are collected in direct support of the analysis methodology.
Step 6 **Convey findings and evaluate programme**	The interpretation of data resulting from information is distributed, by various means, to be used by all stakeholders, including water quality managers, policy-makers and the public. Information may be conveyed in various forms, depending on the needs and preferences of the audience.

2.4.2 Current Techniques for Monitoring Water Quality

As concerns about water quality associated with the increasing human population growth and industry pressures continue to increase along the coastline and in national areas, effective water quality monitoring has become crucial for water resource management programmes (Caraco, 1996). Water resources in the world can currently not be assessed sufficiently and preserved effectively. Remedial programmes and properly evaluated programme success are impossible without accurate, thorough and long-term data acquisition (van Koppena & Schreiner, 2014). For many years now, most water services management bodies have depended on expensive, time- and labour-intensive on-site sampling and data collection, and transport to land-based or shipboard laboratories for water quality monitoring (Caraco, 1996). Monitoring the quality of water is carried out using water quality monitoring devices such as MultiParameter Meters, and Sondes, CTDs, pocket testers, ColoriMeters, samplers and online process monitors that enable monitoring large areas in a short period of time (WMO, 2013). The benefits of using such technologies are fast outcome that can be sent immediately, constant and programmed monitoring, short-term management, monitoring of decontamination processes, early warning systems and applications, as well as a reduction in errors associated with sample preparation, transport and storage (Conero, et al., 1998). New technologies for

monitoring water quality are becoming available that yield accurate and precise results for detecting pollutants in water or biological conditions or physiochemical properties (Harpe, 1988).

Quality water monitoring has emerged over the years. The section below illustrates the remote/laboratory-based monitoring approach, as well as the online real-time monitoring approach.

2.4.2.1 Laboratory-based monitoring

Laboratory-based monitoring needs mostly manpower to work in a large data collection environment (Meybeck, et al., 1996). Laboratory-based monitoring of water quality requires large numbers of samples to be collected for testing and making results available takes long (Kakihara & Sorensen, 2001). One of the advantages of traditional laboratory-based monitoring is that it is cost-effective in terms of equipment, as there is no need for big machines. The equipment is portable and easy to use (Fred, 1999). Unfortunately the overall cost of collecting data is high in laboratory-based monitoring, since it prolongs the data collection process, potentially maximises human errors and time delays and significantly decreases the quantity and quality of data on temporal and spatial scales (Conero, et al., 1998).

2.4.2.2 Online real-time monitoring

Clean water is the most natural and yet the most precious natural resource needed by mankind (Bartram, 1996). About 2 billion people around the world lack access to safe drinking water, which is causing 35% of the deaths in developing countries (Bartram, 1996). Forecast models predict that the demand for water among mankind will double in 20 years to come, yet quality water assurance is underestimated and constitutes a global health threat. Some of the implemented frameworks, such as the European Water Framework Directive, have exposed the need to look for new systems and methods that will monitor the biological and chemical pollutants of water in real time (Conero, et al., 1998). Design engineers have developed sensors and other instruments that monitor water in remote areas in real time, allowing water quality scientists to obtain, process and transfer an array of data while still in the field, or remotely from off-site laboratories using “sensor technologies, mobile computing, and wireless communications.” Real-time water quality monitoring is crucial for national and international health and safety, as it can largely lessen the level of damage and also the cost to remedy the problem (Tancott, 2014). Online real-time monitoring provides real-time ‘‘alert notifications’’ of possible poisonous contaminant spill events, ensuring that personnel and instrument resources

are more effectively directed to high-risk areas (Tancott, 2014). Different items of technological equipment are used to measure contaminants of water. Gail (2004) mentions technology such as new enzyme/substrate methods that combine high-sensitivity fluorescence detection instruments, including a dual wavelength fluorimeter, to assess both enzymatic hydrolysis and the loss of substrate simultaneously; quantitative polymerase chain reaction technology, which relies on particular nucleic acid classifications and antibody-antigen binding properties, which include evanescent wave fibre-optic biosensors; and the rapid bacteria detection system, which is based on laser flow-through technology and capturing of the antigen by antibodies on magnetic beads (Bartram, 1996). In aquatic environments, such as humid substances, optical absorption measurements are used to measure a range of analytics; this is called spectrophotometry. Nutrients and other components in the wastewater can be measure directly using ultraviolet (UV) light absorption (Gail, 2004). The advantages of using UV absorption are its simple construction, no analytic consumption, less sensitivity to fouling and good stability (Bartram, 1996).

2.4.3 Issues in Monitoring Water Quality

Water quality monitoring issues are basically specific to site, but actions locally and regional activities can greatly profit from connections at the international level, such as exchanging practices between sites and regions; exchanging data and information on global scientific and internet developments and situating water quality data within a broader geo-spatial context for analysis and assessment (WMO, 2013). Many policy- and decision-makers at local, national and regional levels are concerned about investing sufficiently in data collection systems. Administrations worldwide are becoming progressively more concerned about developing national data and information systems, as well as making sure that these are interoperable. This refers to the ability of a database or system to exchange information and to use information that has been exchanged. Web services are often used to achieve the objective of data and information exchange (WMO, 2013). Unfortunately, long-term monitoring records are rare because of the lack of resources available to sustain them, but they are extremely valuable when available. The other issue is that the success of the database depends on the important role that participating countries play in regional and global water-information systems, to ensure the widest coverage possible and consequently the ability to share data and information (WMO, 2013).

2.4.4 Concluding Summary of Theme 2

The current theme was discussed with the aim to determine the water quality monitoring process, techniques and issues in order to ensure that the researcher and the reader have a common understanding of what the concept means. The findings on the literature on the objective of this theme that was studied are summarised in Table 9 below.

Table 9: Theme 2 Concluding Summary

Theme 2: Concluding Summary	
Monitoring process	The elements of the framework visually support the interconnection between the six steps and emphasise the need for feedback and evaluation. The features of the framework include the external components that comprise the "3 Cs" – emphasising communication, coordination, and collaboration within monitoring at every step of the process and the significance of a comprehensive monitoring process framework.
Techniques	Monitoring the quality of water is carried out using water quality monitoring devices such as MultiParameter meters and sondes, CTDs, pocket testers, ColoriMeters, samplers and online process monitors that enable the monitoring of large areas in a short time (WMO, 2013). There are two water quality monitoring techniques, namely the remote/laboratory-based monitoring approach and the online real-time monitoring approach.
Constraints	Lack of available resources to sustain

	database records. The success of the database depends on the important role that participating countries play in regional and global water-information systems
Implication for Research	
The fact that there is no agreement on how frequently quality water should be monitored means that the research has to rely on univariate medians and distribution of weekly, twice monthly and monthly measurements to get near accurate value results.	

Water quality monitoring processes, techniques and constraints are discussed in this theme. To further the study, the study of a mobile-based information system is discussed in the next theme, where the researcher explores the description of a mobile information system, as well as its benefits and shortcomings.

2.5 Theme 3: Cell Phone-based Mobile Information System

2.5.1 Description of a Mobile Information System

In information communication technology, there are currently different ways of accessing information systems and different ways of making services available across the internet. Personal computers are one of the many ways in which information resources and services are accessed and the associated technology is becoming increasingly mobile (Basole, 2004). The most significant current market and technological development in information technology is mobility, mobile phones being the most relevant example of this. Mobile phones are equipped with GPRS, which allows interaction between sent and received information across mobile networks, enabling the internet service to become independent (Kakihara & Sorensen, 2001). Because of the way in which people use these information resources, new mobile infrastructure is needed to provide a higher broadband and connection network that is available everywhere. A mobile information system enables access to the system from anywhere, at any time and in different ways. Mobile phones are adaptive end user devices that can be used as mobile terminals (Basole, 2004). Therefore, mobile information systems can be described as

information systems that use end user terminals that are easily movable, compatible with wireless connection and can operate in any location to access information resources and services. The user can use different devices and channels, interacting in different contexts at different times to access the services of the information system (Kakihara & Sorensen, 2001).

2.5.2 Benefits/Advantages of Mobile Information System

Mobile information systems can benefit organisations in a way that enhances productivity, increases the flexibility of processes and procedures, improves customer service and provides accurate information for decision-making, which results in good strategy, decreased operational costs and enhanced processes (Lau, 2006; Lee, 2003; Lovell, 1995)

Another benefit of using mobile information systems that is beyond the organisational approach, according to Malladi and Agrawal (2002), is the portability of the mobile device. The main exclusive and distinctive characteristic of a mobile information system is that it enables users physically to have moving computing and communications products and services wherever they go. Normal personal computers limit users to the location of the device and the network plug-in. Localisation is also one of the benefits of a mobile information system, according to Malladi and Agrawal (2002). Localisation refers to the ability to detect geographically where the mobile device or the user is. Just like portability, localisation is one of the exclusive and distinctive characteristics of a mobile information system. Localisation is most useful when the user wants specific information about the location (Malladi & Agrawal, 2002). A mobile information system moreover enables users to access the network in any place and at any time, and to remain in touch and able to be reached, when they use always connected portable devices (Junglas & Watson, 2003). People by nature want to make their day-to-day activities as efficient as possible (Junglas & Watson, 2003). Using mobile information systems enables one to use work time more efficiently (Kalakota & Robinson, 2002). Users who spend more time away from their workplaces are able to access information and services from anywhere, resulting in increasing the overall productivity level (Kalakota & Robinson, 2002). Mobile information systems change the way people carry out their tasks and interact with one another. In addition, mobile information systems assist organisations to use one device to perform multiple tasks, which lowers the overall cost of equipment (Anckar & D'Incau, 2002). In principle, when mobile information systems are applied in the right, well-designed area and used by the right users, it leads to a more “agile, adaptive, real-time, and cost-efficient” organisation (Gribbins, et al., 2003). Mobile information systems contribute to task effectiveness. Tasks that are time-bound and location-sensitive are the key elements requiring mobilisation. When the right information is

delivered to the right place, at the right time and to the point-of-thought, effectiveness of tasks and decisions is achieved. This is because users use one single device to carry out different tasks and can interact with one another via data and voice (Tarasewich, et al., 2002)

2.5.3 Shortcomings of Mobile Information System

Though the use of mobile information systems is beneficial, there are also problems associated with such systems. For example, mobile information systems are narrow-banded, the device is small and easily lost, the screens are small and users and devices are diverse. The overall quality of such systems is threatened by these problems (Kalakota & Robinson, 2002), including the quality characteristic of usability, which is one of the main characteristics supporting the multi-dimensional concept of the quality of information systems.

Other constraints associated with the implementation and use of mobile information systems, as discussed by Basole (2004), are listed below.

Table 10: Constraints when Using Mobile Information Systems

Constraints when Using Mobile Information Systems	
1) Assessing enterprise mobile readiness	It is difficult to assess the readiness of the organisation to implement and use mobile information systems. The level of readiness is based on the organisational objective indicators. A readiness assessment will enable the organisation to determine whether it is prepared and has the potential to implement and use mobile information systems.
2) Identifying mobile business processes	It is argued that not all organisations will benefit from using a mobile information system, since the identification of suitable functional and process areas is critical in order to realise the full value of using mobile information systems. In order to identify business processes, an identification framework needs to be developed, which assesses the value of a mobile information system qualitatively and quantitatively.

3) Understanding the mobile information system user base	In view of the results of the framework that has been developed to identify the business processes, it may become evident that some users in the organisation are not required to use a mobile information system. It is therefore important to identify the type of users and their responsibility in the adoption and implementation phases of the system to ensure that services are used efficiently and effectively.
4) Determining adoption and implementation strategies	All the above-mentioned constraints or problems should be regarded as part of the overall adoption and implementation strategy for a mobile information system. Investigating these problems or shortcomings separately does not sufficiently define the complex environment in which adoption and implementation strategies must be formulated.

2.5.4 Concluding Summary of Theme 3

A mobile-based information system was discussed in the current theme, where the researcher explored the description of a mobile information system, the benefits of such a system and its shortcomings, to ensure that the researcher and the reader have a common understanding of what the concept means. The findings on the literature on the objective of this theme are summarised in Table 11 below.

Table 11: Theme 3 Concluding Summary

Theme 3: Concluding Summary	
Description of mobile information system	Mobile information systems can be described as information systems that use end user terminals that are easily movable and compatible with wireless connection, as well as operating in any location to access information resources and services
Benefits of mobile information system	1) Portability

	2) Localisation 3) Ubiquity 4) Efficiency 5) Effectiveness 6) Convenience
Shortcomings of mobile information system	1) Assessing enterprise mobile readiness 2) Identifying mobile business processes 3) Understanding the mobile information system user base 4) Determining adoption and implementation strategies
Implication for Research	
This theme described the use of a mobile information system and gave a description of it as outlined by researchers in various academic publications. This implies that the knowledge of mobile information systems gained from this theme will be of benefit in the process of monitoring water quality in the Nkangala District Municipality.	

2.6 Conclusion

The literature study enabled the researcher to provide supporting evidence when conducting research in order to develop an informed opinion. The literature study was broken down into themes discussing the key topics of the main research questions. This study evaluates the use of a mobile-based information system to improve water quality monitoring in Nkangala District Municipality in Mpumalanga. This chapter was broken down into different themes that, collaboratively, support the main research objective. The summary of the chapter is presented in Table 12 below.

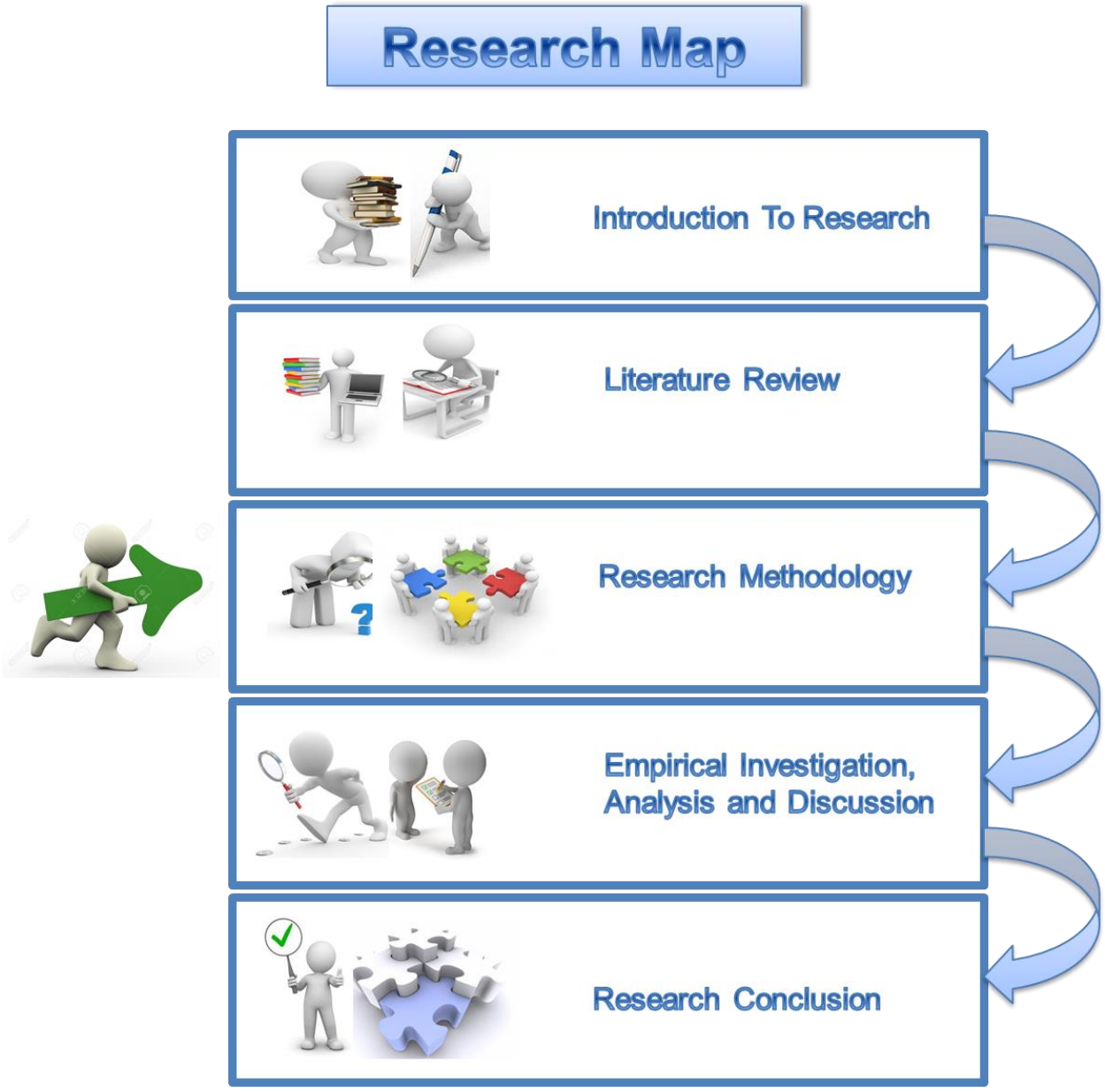
Table 12: Chapter 2 Summary

Chapter 2 Summary	
Theme 1 - Context of South African water quality	The first theme is the context of South African water quality combined with international facts. Water quality is governed by rules and

	regulations nationwide. One cannot conclude that water is of good quality by only looking at it. For water to be classified as being of good quality, it has to satisfy certain requirements. In South Africa, the quality of water supplied to people is governed by the NWA of 1998. There are policies and principles that need to be taken into consideration when classifying water into quality categories. There are also framework guidelines that need to be followed.
Theme 2 - Monitoring of water quality	Theme 2 covered monitoring of water quality. The monitoring process for water quality that can be applied as the framework was discussed. Issues that need to be taken into consideration when carrying out the monitoring process were discussed as well.
Theme 3 - Mobile-based information system	Theme 3 covered the mobile-based information system. This study investigates the use of a mobile-based information system. The definition of mobile information systems explains mobile technology as one of the end user devices that can be used as mobile terminals. The evidence shows that using mobile information systems has benefits as well as shortcomings.

The three themes discussed in this chapter were considered sufficient to direct the researcher in answering the main question of the research. The next chapter discusses the research method and the research design that were followed to evaluate the feasibility of a mobile-based information system that has been implemented in the Nkangala municipality with the aim of improving water quality monitoring.

3 Research Methodology



3.1 Introduction

Research design, according to Yin (1994), is defined as “logic that links the data to be collected to the initial questions of a study.” It is fundamental to analytical understanding and the framework of the study that has to be conducted and enables researchers to provide evidence on the investigation that is directed at answering the research problem (Yin, 1994). According to Oates (2006), research methodology is defined as the grouping of techniques and approaches that researchers can implement to answer the research questions. This chapter is aimed at discussing the research approach that was used to carry out this research study and the research paradigm that was used to investigate the research problem and objectives that have been discussed in Chapter 1. It will also outline the methodology that was used to collect and analyse data and discuss ethical considerations when collecting data from different sources.

The research design components that are to be discussed in the next sections are the research paradigm, research approach, research strategy and research methodology.

3.2 Research Paradigm

This research is interpretive research in which, according to Kaplan and Maxwell (1994), it is assumed that reality is built through understanding and meaning that have been developed informally and though experience. The interpretive research approach also accepts that humans cannot detach themselves from what they know and who they are and that the knowledge they have about the world is a significant part of how they understand themselves, others and the world. The interpretive paradigm speculates that investigators' beliefs are natural in all stages of the research process and that the truth can be transferred though exchange of words. This research study is interpretive research, as it is aimed at investigating and evaluating subjective understanding of why rural areas are inefficient and ineffective when participating in national water quality monitoring. Findings and knowledge claims will be generated as the research study continues. Interpretive research, according to Walsham (1995), can be conducted using an in-depth case study with numerous visits to the site field. As Gubruim and Holstein (2003) said, interpretive approaches seriously depend on naturalistic/realistic methods such as interviews, observations and analysis of existing texts; this research study relies strongly on these methods, which will ensure a sufficient channel of communication between the researcher and employees of Nkangala municipality in order to

build and construct a meaningful reality context. The role of the researcher in an interpretive case study has been referred to as a challenging task by Walsham (1995), as it involves creating context or versions of events out of people's interpretation of things and to make these understandable and readable. The interpretive research paradigm has been selected for this research study and when conducting interviews, the researcher will adopt the role of an outside observer in order to obtain subjective data.

3.3 Research approach

The difference between inductive and deductive research is vital, as it enables qualitative research to be better understood and identified by the researcher. The key difference between the inductive and deductive research approaches is that inductive approach aims at creating a new theory from data collected in a study and deductive approach is aimed at testing a theory. Using the deductive approach, the researcher starts with theory on a general level of focus, analyses the data and then tests its implications for the specific level of focus. Though there are no rules for this, inductive approaches are generally allied to qualitative research, whereas deductive approaches are normally allied to quantitative research. For this particular research study, only the use of a mobile-based information system was defined. The data that were collected through interviews were used to evaluate whether the implementation of the mobile-based information system improved the efficiency and effectiveness of water quality monitoring in the rural area of Nkangala District Municipality.

The approach that has been selected to achieve the objective of this study is the qualitative research method. Qualitative research involves details of elements that are not numeric and makes use of data sources such as observation, documentation, interviews and questionnaires to convey social phenomena. The qualitative research method can be used in study researches such as case study research, action research and ethnography, according to Myers (1997). Qualitative research, according to Myers (1997), is aimed at assisting researchers to understand the relationship between people and the social and cutural environments in the world in which they live. Therefore, qualitative research methods will help in understanding the processes and the use of a cellphone-based information system in the Nkangala Disctrict Muicipality in Mpumalanga. One of the ways in which qualitative research generates data sources is through reactions and the impression of the researcher of a particular observation.

This happens when the researcher is on site to observe and analyse real life events that will enable him/her to frame his/her opinion of the situation (Myers, 1997). It is argued that the qualitative method gives the participants the ability to understand the context of the phenomenon without any possibility of losing the context through quantifying the data. This research approach also refers to the situation in which data is collected in an unstructured way and deals with phenomena that cannot be quantified in a mathematical way, such as meanings, beliefs, attributes and symbols.

3.4 Research Strategy

This research study will be conducted as a case study to investigate and explore the objectives of the study. Compared to other qualitative sources of data, a case study enables the researcher to understand the problem being studied. A case study also helps to explain and explore in detail the nature and complexity of the process of investigating the research problem. Yin (2003) defined a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident and relies on multiple sources of evidence”. He further explained that case studies are appropriate for involving multiple sources of data. In this particular research into the use of a mobile-based information system in a rural area of Nkangala municipality, it will assist in gathering large amounts of data to be analysed. Since case studies centre on a particular “thing” that has to be explored (Oates 2006), the researcher believes that using this strategy will produce in-depth information about the use of a mobile-based information system in Nkangala municipality and whether it has improved the efficiency of water quality monitoring. Oates (2006) states that the main purpose of a case study is to gain rich and better understanding of the processes and complexity of a specific case. In this study it will contribute to rich understanding of the mobile-based information system, how rural municipalities will benefit from it, and how it will improve the monitoring process of water quality. Case studies are helpful when answering questions such as “how” and “why” (Andrade, 2009). The objective of this study is to explore “how” and “why” the mobile-based information system will improve the efficiency and effectiveness of water quality monitoring in rural municipalities. Oates (2006) identified three types of case studies, namely explanatory, exploratory and descriptive. An exploratory case study will be used to carry out the investigation in order to answer the research questions. It is also important to keep in mind the limitations of case studies discussed by Meredith (1998), namely that they are normally conducted in a single

institution or organisation and that they require direct observation of the context of the case, which implies commitment to cost and time.

The case study for this particular research was conducted in Nkangala District Municipality in Mpumalanga. The data collected were analysed and the results were used to convey an opinion.

3.5 Data Collection

The data collection methods that have been selected to collect data for this study are interviews and observation. The following section explained the interviews as data collection in full.

3.5.1 Interviews

Interviews are common data collection methods that involve a dialog between two or more people with the aim of asking questions and getting answers from members. In an interview, one party has a particular objective which is to get information from the other party. As interviews don't just happened, they are normally planned in advance by the interviewer where formal agreement between the interviewee and interviewer is drawn with the outlined purpose of the interview. The conversation is not a free-flowing type as the researcher, who is the interviewer normally guides the conversation. Interviewee's response is usually treated as "on the record" which gives the researcher right to use these responses later in the study unless the interviewee mention that some responses are confidential, that's when they are recorded as "off the record" and the researcher cannot use those responses in the study. The researcher chooses interviews as the form of data collection when they want to obtain rich and detailed information, investigate privilege information or sensible issues that participant would not want to take part with the researcher they do not know. They are usually used independently in a qualitative research or can be joined with other data collection methods.

For this research study, the interviews were selected to be one of the data collections that were used as this is a qualitative case study. Interviews were conducted between the researcher, water supply testers, water service manager and employees of Nkangala district municipality in Mpumalanga. For this research purposes, consent form was prepared and distributed to all participants. Consent form is attached in Appendix A. All participants had agreed and signed the consent form that was used as the formal agreement between participants. Interview Participants in this study were given an opportunity to decide whether they want recorded interview or written

interview. The researcher had preferred to conduct a recorded interview as it gives an assurance that each information is recorded and available for analysis in a later stage. Taking notes manually may result in missing crucial information and make it difficult to obtain direct quotes to use in the research Walsham(2006). In this study, semi-structured interviews were used as the type of interviews. As semi-structured interview according to Oates (2006), allow the researcher to have prepared questions to ask the interviewee with an option to can ask other unprepared questions concerning the issues that the interviewee may bring up. It also allows the researcher to bring up other matters that may be applicable to the study. On this study, the researcher used both forms of interviews, which includes the individual face-to-face interview and face-to-face group interview.

The following process of interviews that is identified by (Jane, et al., 2014) were followed in this study:

Step 1: Thematising – contains the creating of the purpose of the study and explain the problem to be investigated before conducting the interviews. As discussed in chapter one of this research, the main objective of this study is to evaluate the use of mobile-based information system in a rural areas in order to improve the efficiency of monitoring water quality

Step 2: Designing – this step involves planning the entire research study. The participants identified as the water supply testers, water service manager and employees of Nkangala district municipality. Interview question created in order to get the detailed information from the participants about the use mobile-based information system. Appendix C – Interview questions is attached. The interviews are scheduled to be conducted twice a month for a period of 7 months with the participants in different slots.

Step 3: Interviewing – this is the processes of conducting the interview with the participants according to the interview guide. The interview guide is attached in Appendix C.

Step 4: Transcribing – this steps involves interpreting the materials from the interviews and analyse it to be a written text. Materials can be recordings or scripts text.

Step 5: Analysing – Qualitative method for analysis has be decided to be the methodology to be used in this study as discussed in the research methodology in this chapter.

Step 6: Verifying – this step is where the researcher ascent the validation and reliability of the interview findings. The researcher will use the interview results as the consistency guide to determine if the results are reliable.

Step 7: Reporting – this is the step to complete the interview process; where the researcher communicates the findings of the study to relevant stakeholder based on the scientific criteria.

The second data collection method that was used in this study is discussed in the following paragraph.

3.5.2 Observation

This study also made use of observation as the data collection method. (Oates, 2006) describe observation as to watch or "pay attention to" something or process. Observation is another way of researcher to see if what people say they do when they are questioned is the same as what they actually do. Often observation is when one "look", but it can also involve smelling, tasting, hearing and touching. There are two methods of observation that the researcher can use when observing participants, overt and covert. In overt observation, the researcher inform the participant before the study what he is planning to do, which is to observe them for a particular reason, and obtain permission from the participants to undergo the observation process. While covert observation, the researcher do not inform participant what he is planning to do or what he is doing; participants are totally unaware the whole time that they are being observed.

In this study, observation was used as the method of collecting data to watch and pay attention to the process of monitoring water quality using the mobile-based information system. The researcher wanted to see what employees on the municipality actually do when they monitor water quality, how they monitor and where and when do they monitor. This study made use of overt form of observation as the employees, testers and service manager will be notified about the aim of the observation and also get permission from the participants.

Observation can be a systematic observation or participant observation. Systematic observation is the kind of observation where the researcher works with the pre-defined system to observe the participants. The results which are generated by systematic observation are quantitative data as it normally involves counting and timing. You can only obtain the results of "what" happened questions, but not the "why" questions. Challenges with systematic observation are that it can only be covert observation and its difficulty in providing feedback. Participant observation on the other hand is the type of observation where the researcher is involved and participant in the culture and context which is being observed. Researcher's role as the participant involves collecting and storing data as well as analyzing the collected data. It enables researchers to obtain rich and detailed information and gain understanding about the

behaviors which therefore use qualitative data as the method of collecting data. Participant observation can be overt or covert type of observation and obtain results of what and why questions. Some of the challenges with participants' observation are that it is time consuming and the observer has to be always there when things those are to be observed happen.

For this particular research, the kind of observation that were used is participant observation where the researcher will be involved in obtaining the information about the use of mobile-base information system when monitoring the water quality of Nkangala municipality.

3.5.3 Summarizing Data Collection

Table 13: Summary of data collection

What?	Interviews - Semi structured interviews were conducted with the participants in order to collect data from Nkangala district municipality. Participant observation was also used as data collection method.
How?	Conducting interview sessions with the participants asking them pre-prepared questions as well as doing participant observation were used.
Where	The interviews were conducted at the workplace of the participant which is Nkangala district municipality situated at Mpumalanga province in South Africa. Observations for the participants were also done at Nkangala district municipality situated at Mpumalanga province in South Africa.
Who?	10 participants were interviewed : 4 water supply Testers 1 water service manager 5 Employee Administrators
When?	Interviews with the participants were scheduled as follows: Day 1 from 10:00 to 13:00 pm with Administrators Day 2 from 10:00 am to 11:30 with water service manager Day 3 from 9:00 am to 16:00 with Testers Day 4 from 9:00 am to 16:00 with Testers

	.
Why?	The interviews were conducted with the aim of understanding the use of mobile-based information system from the viewpoint of those who have worked with it when monitoring the water quality. Observation was conducted with the aim to observe the process of monitoring the water quality using this particular information system.

3.6 Data Analysis

This particular study uses thematic analysis as the method for analysing data. Braun and Clarke (2006) have described thematic analysis as the process in which the researcher identifies themes and patterns in qualitative data. The main skills used in thematic analysis are beneficial not only in the analysis of data, but also in other kinds of analysis (Braun & Clarke 2006). Data analysis is a flexible process, as it is not linked to a certain epistemology or theory, which makes it a method instead of a methodology. It is difficult to find a clear and straightforward guideline to use thematic analysis, as it can be conducted using several different techniques. This is regarded as an advantage and a challenge at the same time. The following step-by-step guidelines suggested by Braun and Clarke (2006) will be followed in this study when analysing data using thematic analysis:

Table 14: Data Analysis Guidelines

Step 1	*Becoming familiar with the data* The researcher is advised to do lots of reading and re-reading of collected data, as suggested by Braun and Clarke (2006) in order to be more familiar with the collected information from the interview and observation.
Step 2	*Coding* At this level, the researcher breaks down the large sections of data into small units of meaning according to the defined research questions. This study will use theoretical thematic analysis instead of inductive analysis, as the researcher is

	focusing on analysing data with specific research questions in mind. The researcher will use open coding in to create the codes in the coding process instead of using pre-set codes.
Step 3	*Searching for themes* At this level, the researcher looks for patterns in the information collected that are vital and related to the topic of the research or research questions. Unlike codes, themes are meaningful and "bigger" and are related to research questions and topic.
Step 4	*Reviewing themes* This level involves reviewing, modifying and developing the primary themes that were recognised in the previous stage, as well as ensuring if this theme makes sense.
Step 5	*Defining themes* At this level the researcher describes the meaning and principle of each theme. The researcher will also identify how subthemes (if there are any) relate to and interact with main themes.
Step 6	*Writing up* This stage refers to the research report of a research study.

As mentioned earlier, there are many guidelines for conducting thematic analysis. However, for this study, Braun and Clark's (2006) guidelines were selected because they are clear, systematic and well-formulated.

3.7 Ethics

Every participant in this study was treated in accordance with the ethical guidelines of the University of Pretoria's Code of Ethics for Research. Though no risks were identified related to participating in this study, the following ethical considerations had to be followed:

- Participants signed a consent form agreeing to take part in this study
- The results of interviews and observations were used only for the purpose of this study. Information marked as off the record by the participants was not considered for the study and was not included in this study.
- Participants' personal information was not mentioned in this study to protect their privacy.

3.8 Conclusion

The core aim of this chapter was to determine and understand the research methodology that was applied when conducting this research study. The research method gave the researcher guidance on using the collected data to carry out the investigation with the aim of answering the research questions. This chapter covers the overall research design, data collection methods, data analysis and ethical considerations.

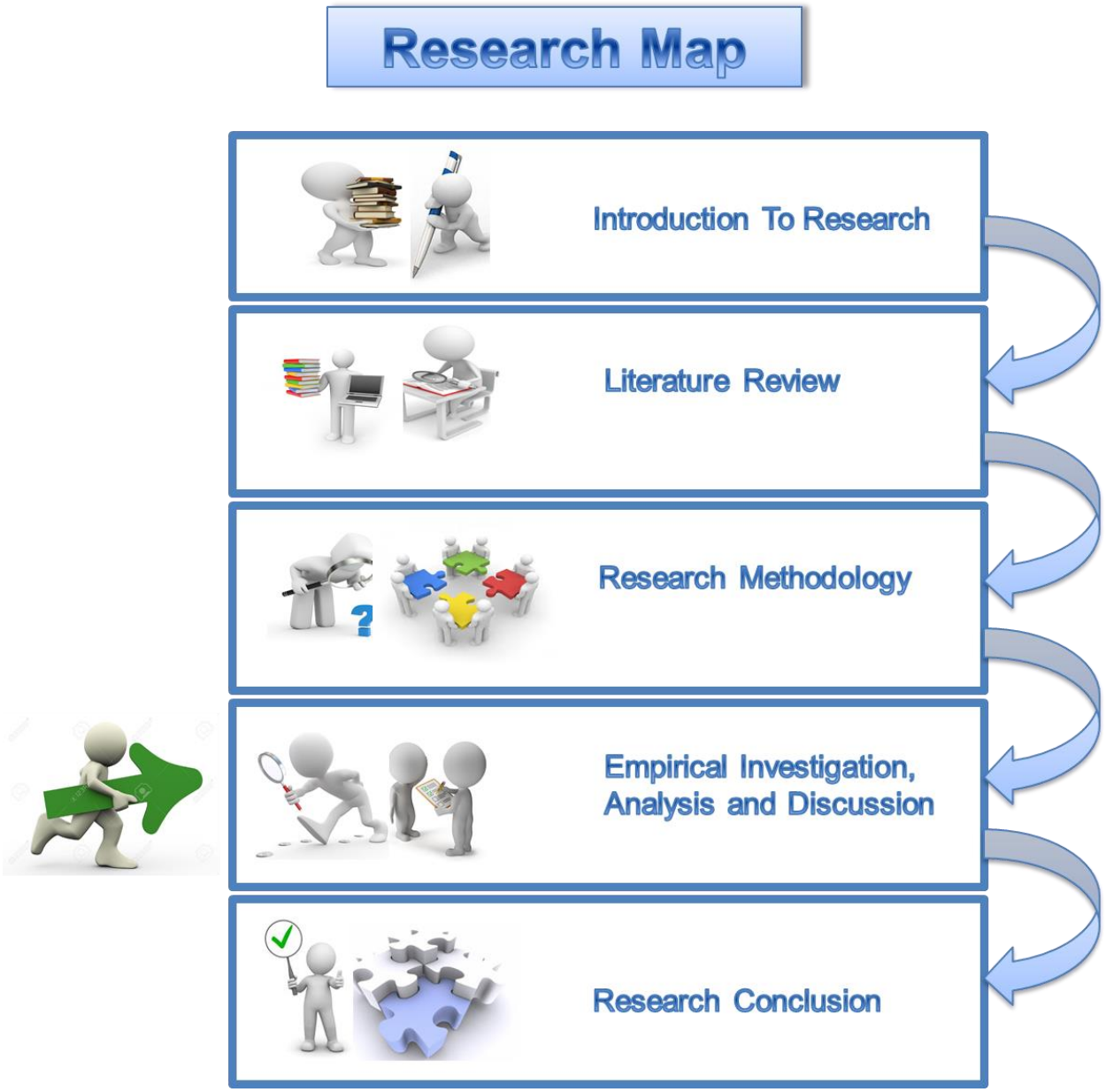
The interpretive paradigm was the selected paradigm for this research study, a case study was the selected research strategy, and the research method required qualitative data. Interviews and observation were the tools selected for data collection and the collected data were analysed using thematic analysis. Below is a table summarising the research methodology discussed in this chapter:

Table 15: Chapter Summary Conclusion

Research Approach Summary	
Research paradigm	Interpretivism
Research strategy	Case study
Research methodology	Qualitative
Data collection	Interviews Observation
Data analysis	Thematic Analysis

The research methodologies discussed in this chapter were considered sufficient to direct the researcher into gathering and analysing data to fulfil the objective of this research. The next chapter discusses the empirical investigation and data analysis of the research.

4. Empirical Investigation, Analysis and Discussion



4.1 Introduction

The purpose of this this study was to evaluate the feasibility of a mobile-based information system that had been implemented in the Nkangala municipality with the main aim of improving water quality monitoring. The main objective of this study was therefore to evaluate whether the implementation of this information system had improved the efficiency of the water quality monitoring process in Nkangala municipality.

This chapter is aimed at gaining new knowledge on the subject of the research. The new knowledge will be gained through empirical investigation, analysis and discussion of the interviews conducted with participants from Nkangala District Municipality, the water supply section as well as the water authority. The data analysis is based on both the researcher's interpretation and analysis of the data collected through the interviews. The interview questions were developed and structured according to the research objectives defined in Chapter 1. The analysis and discussion of the data collected from the interviews is presented according to the defined research objectives of this study.

Baker and Edwards (2012) advise that because of time constraints, academic research should involve a sample size of between five and 20 participants. For the current study, ten people were interviewed: three administration employees from the municipality, four water supply testers, one water service employee, one water service manager and one municipality manager. eight of the ten participants were interviewed physically (face-to-face) by the researcher, while the other two participants chose to complete the interview questions in their own time and space. Three of the four face-to-face interviews were recorded, while the other participant asked not to be recorded. The interviews were specific to employees in managerial positions as well as at operational level, who have been involved and working with the mobile-based information system since its implementation. The purpose of targeting managerial and operational employees who had been involved in implementing the system is that such employees would relate better to the research problem. The targeted sample can relate better to the research problem because, as managerial employees, they have subordinates (knowledge carriers) working under them. Operational employees were targeted to ensure that the participants' experience in working on the mobile-based information system translates to and enriches the findings of the research. All the interviewees who were interviewed worked for the Nkangala District Municipality. This municipality was selected to be the centre of the case study because it was one of the four municipalities where the mobile-based information system to monitor quality

water was implemented. In order to generate meaningful data for this research, semi-structured questions were used in the face-to-face interviews. Baker and Edwards (2012) mentions that the semi-structured interview approach allows data to be easily analysed and compared.

As discussed in chapter 3, the other method of collecting data for this study id through observation.The kind of observation that were used in this study is participant observation where the researcher was involved in obtaining the information about the use of mobile-base information system when monitoring the water quality of Nkangala municipality. Observations for the participants were also done at Nkangala district municipality situated at Mpumalanga province in South Africa. 10 participants were observed : 4 water supply Testers, 1 water service manager ,5 Employee Administrators.

4.2 Demographic Analysis

The interviews and observatios were conducted with employees from the Nkangala District Municipality's water supply section as well as the water authority. The researcher used different employees from different sections in order to ascertain different views on the results of the implemented mobile-based information system. The demographic analysis table below describes the roles of each participant/employee who was interviewed and observed and it is obvious from the table that there is variance in the experience and project involvement of the employees. This variance has enabled the researcher to obtain much data/information that has provided understanding and insight into the investigation intended to evaluate the mobile-based information system.

To protect the privacy of participants, personal information on them, such as name, age and identity numbers will not be displayed. The researcher will only display the employee's roles, number of years of working at the municipality and number of years of working with the information system.

4.2.1 Gender

A combination of males and females participated as interviewees in the study. Figure 5 below shows the gender distribution of the participants.

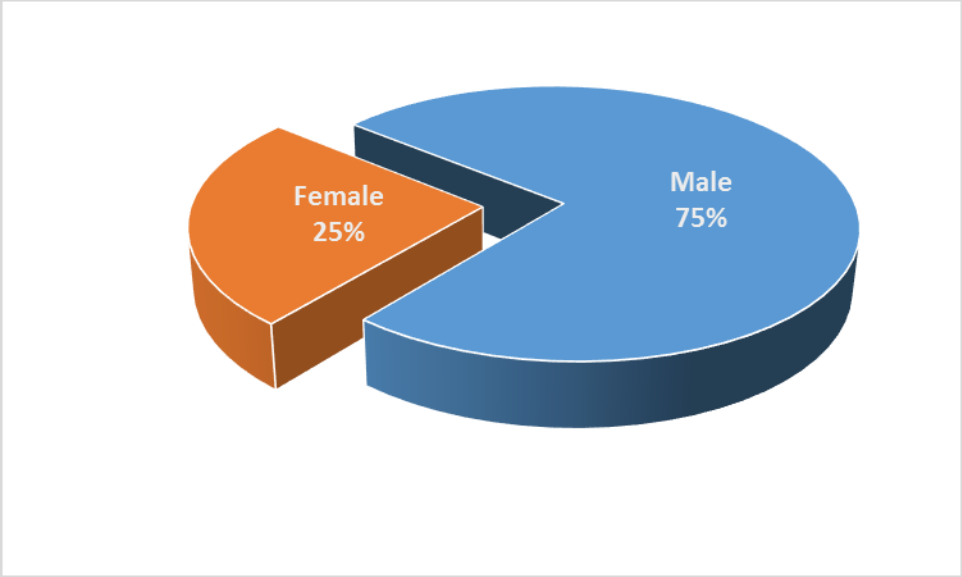


Figure 5: Gender Distribution of Participants

As Figure 5 above illustrates, the majority of the participants (75%) were male; 25% of the participants were female. These findings relate with the general situation in South Africa, where there are more males than females at government workplaces (Kumar, 2015). Since the 1994 elections, the constitution and laws in South Africa have prohibited discrimination in the workplace and demanded that employment equity be enforced, including lack of gender discrimination. However, for many females this change is progressing slowly. “The gender diversity issue has been on the South African agenda for many years but we’re clearly not making any headway” (Davis, 2015). The percentage of women in senior management roles in the government has decreased, dropping from 26% in 2015, and it has even dropped to below the average of 26% achieved between 2004 and 2015 (Davis, 2015). According to Sharon (2015), only one in five females had a formal job, compared to one in three males. In some cases, it goes as far as women earning less that male colleagues doing the same job. This is not only a South African problem; globally, there has been little progress regarding gender equality. Globally, women who occupy senior management roles have increased only by 3% in the past five years. At this rate, it will be 2060 before gender parity is achieved.

4.2.2 Ethnicity

The participants in the research were of varying ethnic origin: of the ten participants, seven were African, and three were white. The Indian and coloured communities were not represented in this study. These findings suggest that African ethnicity dominates in the Nkangala District Municipality.

4.2.3 Age Group

For this particular study, participants were requested to specify their age according to the age groups specified by the researcher. All the participants in the interview were between 25 and 56 years old. The finding shows that no participant younger than 25 years participated in the interview and that there is age diversity at Nkangala municipality. Age diversity is described by Sravani (2015) as the ability of the organisation to accept people from different age groups within the organisational environment and merge these age groups into a single working environment. Having different age groups helps the organisation to have good decision-making skills as well as problem-solving skills. Another advantage of age diversity is that it introduces various opinions and solutions; older people will offer more experienced solutions and the younger generation will be more vibrant and energetic. The disadvantage of age diversity is "the lack of mutual interests, lack of communication, and egoistic approach". The way of approaching a job differs between the younger and the older generation; for the younger generation, their job is related to career goals and for the older generation, it is related to their livelihood. This leads to conflict and tension that result in ego-related issues.

4.2.4 Job Roles

The demographic information analysis highlights the number of years that the employee has worked at the Nkangala District Municipality and the number of years involved in the project, working with a mobile-based information system to improve water quality monitoring. This information is recorded as part of the interview process in order to ensure that the research results have been collected from the employees who have experience of working with this

particular information system. It can therefore be concluded that the data collected are adequate to enable the researcher to make a recommendation on using a particular information system to improve water quality monitoring in Nkangala District Municipality.

Table 16: Participant Demographic Analysis

Employee	Number of years of working	Number of years involved in projects	Current role
Participant 1	16 years	5 years	Water service manager
Participant 2	10 years	5 years	Water supply tester
Participant 3	5 years	5 years	Water supply tester
Participant 4	8 years	5 years	Water service employee
Participant 5	10 years	5 years	Municipal manager
Participant 6	8 years	5 years	Employee administrator
Participant 7	15 years	5 years	Water supply tester
Participant 8	11 years	5 years	Water supply tester
Participant 9	5 years	5 years	Employee administrator
Participant 10	5 years	5 years	Employee administrator

As Table 16 above demonstrates, participants who were interviewed and observed have working experience of between five and 16 years at Nkangala District Municipality. Regardless of their working experience, participants have two to five years' experience of working on the mobile-based information system project. As indicated in Chapter 1 of this study, the mobile-based information system was implemented five years previously at Nkangala municipality. Therefore, out of ten employees, seven people have been working on the system from the time of its implementation. Three employees who have been working for Nkangala municipality for five years have therefore been hired specifically to work on the mobile information system while the other seven participants had been working for the municipality before the mobile information

system was implemented. The conclusion is that all the participants have knowledge and experience of the mobile information system, since they have played a role from the start of the project.

4.2.5 Summary of Findings

Table 17 below provides a summary of the analysis of the demographical information of the participants.

Table 17: Participant Demographic Analysis

Summary of Findings
This section focused on providing an analysis of the participants in the interviews in terms of their demographic characteristics. The analysis revealed that 10 employees participated in the interview; 75% were male and 25% female. With regard to ethnicity, out of the 10, seven were African and three were white. With regard to age, all participants were between 25 and 56 years old. In terms of job roles, two participants had management roles and eight operational roles. Participants' working experience at the municipality ranged between six and 16 years. All participants had been working with the mobile information system since its implementation. The same participants were also observed for the purpose of collecting data.

4.3 Exploring Challenges and Effects of Blue Drop System

Monitoring water quality for human use is very important for the wellbeing of people in communities. The Blue Drop System was implemented nationally by the government of South Africa with the aim of enforcing the standard and regulations for drinking water quality provided to citizens. While investigating the use of this system in Nkangala District Municipality, the researcher found that the reported information for monitoring water quality was inadequate (Rivett & Wilson-Jones, 2010). No case study research that focused on the challenges and effects of the Blue Drop System had been undertaken. The research objective of this study was defined with the aim to conduct a case study in the Nkangala District Municipality to investigate

its quality water monitoring using an information system. The findings in relation to this research objective are represented by the analysis of the interview questions below.

4.3.1 Challenges and Effects of Blue Drop System

This section aims at answering the research question: What are the challenges and effects of using the Blue Drop System for water quality monitoring? The purpose of this question is to enable employees to describe the wider challenges and effects that they experience when using the Blue Drop System at the municipality. This question is asked in order to gain more understanding of what led the municipality to take a decision to implement the mobile-based information system. Analysing the responses from the employees yields clear understanding of their experiences and the challenges they face when using the Blue Drop System.

The table below illustrates the responses received during interviews with the employees of Nkangala District Municipality about the challenges they face when using the Blue Drop System to monitor quality water. The table consists of the raw data, the thematic analysis of the participants' responses to the question and the interpretation of the raw data.

Table 18 : Challenges of Blue Drop System

Raw Data	Theme	Interpretation
Water service manager*: "… power and decision-making about the process of monitoring quality water is being done in a municipal level whereas the Blue Drop System that was implemented for monitoring water quality was done nationally."* *"Therefore local needs are not catered in the system which, always, resulted in our data not*	Decentralisation of management authority.	Local governments often lack the capacity and resources to take over responsibilities in a decentralisation process. Frequently, ceding of power is inadequate. In the process of decentralisation, transparency is often omitted, which results in disadvantaged municipalities receiving poor service delivery, sometimes escalating to no service at all. These

compatible with the system and we always get the lower score of quality water." *There is no accountability and responsibility of anything related to quality water as all the decision making is done at the lower level.* **Water service manager continues**: *"Difficult powers and functions about monitoring water quality were delegated to us as local authorities during the decentralization process, but we do not have the capabilities of managing them".*		municipalities carry on working on service delivery backlogs. The utmost vital reason for this is that complex authority and roles were devolved to local authorities during the decentralization process, but those local authorities did not have the ability to manage them. Municipal systems and processes are sometimes complex to handle.
"Blue Drop is a centralised system that accepts collective data. How we gather and send data to the system will not be the same as the next municipality, therefore there is no individual data per municipality that specifically related to a municipality individually as a result the system accepts collective data and produce results according to that." *"Even if our water is of quality, the Blue Drop System will produce a fail quality because the information that sent to the system is not*	Centralisation of government system	Access to the Blue Drop System for disadvantaged municipalities is limited and it is maintained in a single location. The collective data that are collected by municipalities are not individualised to local municipalities, but rather generalised and nationalised. This leads to serious decreases in the general efficiency of the system.

personalised to the municipality."		
"The technology requirements that we need to perform the monitoring, such as hardware and connectivity, did not exist for our municipality due to shortage of funds." *"If these technologies did exit, they are likely not maintainable due to limited human, technical and financial resources."* *"In addition to other challenges, shortage of skilled resources is really dragging the speed of which the system can perform or work."*	Lack of qualified human resources, technical resources and financial resources.	The quality of the staff that supports the information system for the organisation is important. The project manager should have technical as well as business knowledge, and the ability to communicate with senior management. The project manager must also have the financial and technological background in order to understand the resources that are needed for the system. Support staff must be cultured enough to relate with top management and be able to master the technologies required for the system. The choice of hardware and software has a major bearing on the acceptance of a system. Training human resources is challenging when implementing information system such as these. If successful training is given to the current human resources, the system would be of more value to the users and the information system would give more value according to its objective.

"It seems as if we could not understand the standard and regulations that were required in order to acquire the green light certificate for quality water". Water service manager	Lack of national standard and understanding of regulations	The challenge is in the area of education and training. The employees of Nkangala municipality have to participate in training development in order to gain understanding of the national standard and regulations for water quality monitoring.

Table 18 above shows that despite mixed replies to the question, employees in general are not satisfied with the service or processes of the Blue Drop System. The raw data reveals that the main challenge of the Blue Drop System is decentralisation , where power and decision-making are entrusted to the local municipal level. Though decentralisation is good for organisations in certain contexts, there are certain difficulties in its application to all cases and in all circumstances. One of the limitations of decentralisation at local municipalities are that utilisation of services requires exceptionally talented people and it is difficult to appoint such people because of weak financial resources. Decentralisation increases the cost of operation, as various departments have to be established and specialists need to be employed in each department. The table above also reveals that the collective data collected by municipalities are not individualised to local municipalities but rather generalised and nationalised. This conclusion is aligned with the study done by (Rivett, et al., 2014), who mentions that centralisation of government systems disregards local differences and overlooks local needs. Centralisation of government systems has led to a serious decrease in the general efficiency of the Blue Drop System.

Furthermore, lack of human, technical and financial resources is also a challenge in the Blue Drop System. This is exacerbated by under-investment in people, particularly where technical, management and leadership skills are required, and assumptions about shortcuts to acquiring specialist skills rather than obtaining the required education and work experience (DCoG, 2009). Between 2006 and 2009, municipal employment in the financial administration and technical sectors declined because of, among others, skills shortages (National Treasury, 2011). The high level of staff mobility has also led to dependency on the services of consultants. The real need

is to stabilise the senior management teams of municipalities in order to improve service delivery outcomes.

Participants also revealed that failure to understand the standard and regulations of water quality forms part of the challenges they face with the Blue Drop System. The challenge is escalating at Nkangala municipality, which is unable to provide employees with education and training to understand national standards and regulations for water quality monitoring.

The researcher's observation revealed, "Because the Blue Drop System was implemented nationally, the information collected nationally has a very low priority to the rural municipalities such as Nkangala." Rural municipality given less priority when it comes to water quality monitoring process. The government at national level has given rural municipalities' low priority when it comes to water quality monitoring processes. The roles of government as a consumer, regulator, policy maker and strategy developer of IT would have to be selective, giving priority to those areas/municipalities where government intention can have a maximum impact without distorting other government forces.

The researcher also observed that "The Blue Drop System economically affluent municipalities who have the ability and means to implement policy and best practices. Small and under-resourced municipalities, on the other hand, could be negatively impacted by these systems to the extent that water quality monitoring has turned into an administrative function that has limited impact on decision-making at local level." Manager Compatibility of technology. The employees raised the challenge of incompatibility of technology. The researcher also observed and found that prior to purchasing a technology, it is important to understand the capability and compatibility of the existing to avoid wasting money on technology that is not compatible with existing technology.

4.3.2 Summary of findings

Table 19 below provides a summary of findings on the analysis of the challenges and effects of the Blue Drop System.

Table 19: Summary of Challenges and Effects of Blue Drop System

Summary of Findings
This section focused on analysing the challenges and effects that Nkangala district municipality employees experienced when using the Blue Drop System for monitoring water quality. The findings revealed that decentralisation is the main challenge that caused Nkangala municipality to be ineffective and inefficient when using the Blue Drop System. The findings of the study also revealed that another challenge Nkangala municipality employees encountered was limited access to the Blue Drop System, because this is a disadvantaged municipality that lacks human, technical and financial resources. The study also revealed that the municipality is not compatible with the Blue Drop System, as the Blue Drop System was rather designed and implemented for the economically rich and urban municipalities that have the resources and capability to implement policies and best practices.

The secondary objective of the research was to analyse the challenges and effects of the Blue Drop System. The next objective aims to explore the benefits and shortcomings of the mobile-based information system

4.4 Description of Water Monitoring System – Nkangala Municipality

The Water Monitoring System (WMR) application developed by the iCOMMS team at the civil engineering department at the University of Cape Town in South Africa, under the leadership of Associate Professor Ulrike (Anon., n.d.).

The system carry out residual chlorine water testing, and to carry out hydrogen sulphide tests, which check for microbiological contamination in water destined for household use. It was anything but difficult to utilize and required small preparing to implement the WMS application at the Nkangala Municipality at Mpumalanga. "The live report back system gives immediate indication of non-compliance at sample points that can be immediately followed up," he said, adding that it was also being used to monitor the performance of Nkangala district Municipality staff. (Hartwell, 2012).

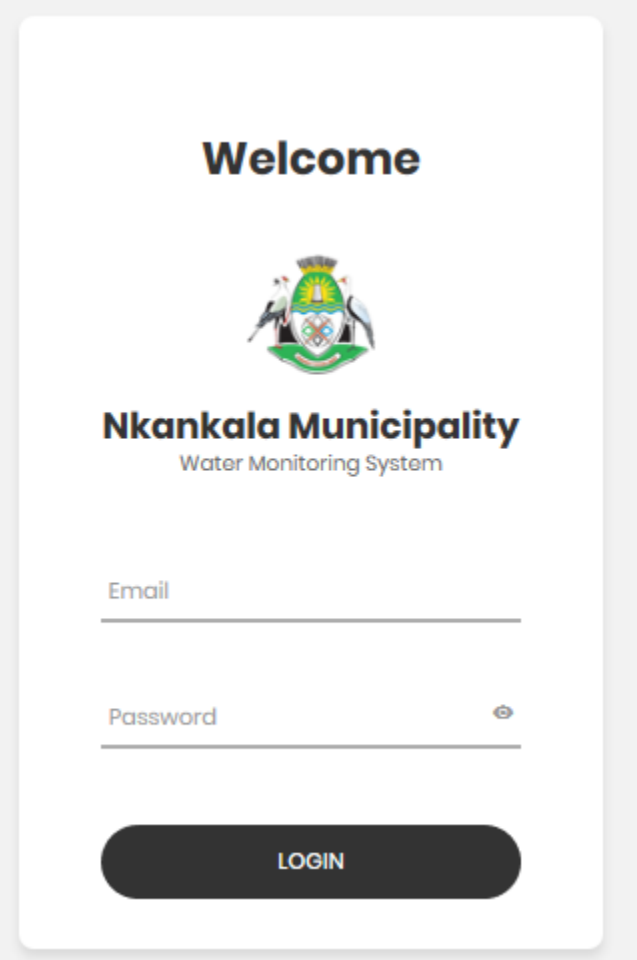


Figure 6 Nkangala Municipality Water Monitoring System-Login

The mobile app starts with the login page as shown in Figure0000. The login page uniquely identify the user/employee who is currently monitoring the quality of water. The employee must put in the email address and the password that is link with the municipality user active directory. The employee cannot use the app for water monitoring data collection without a successful login.

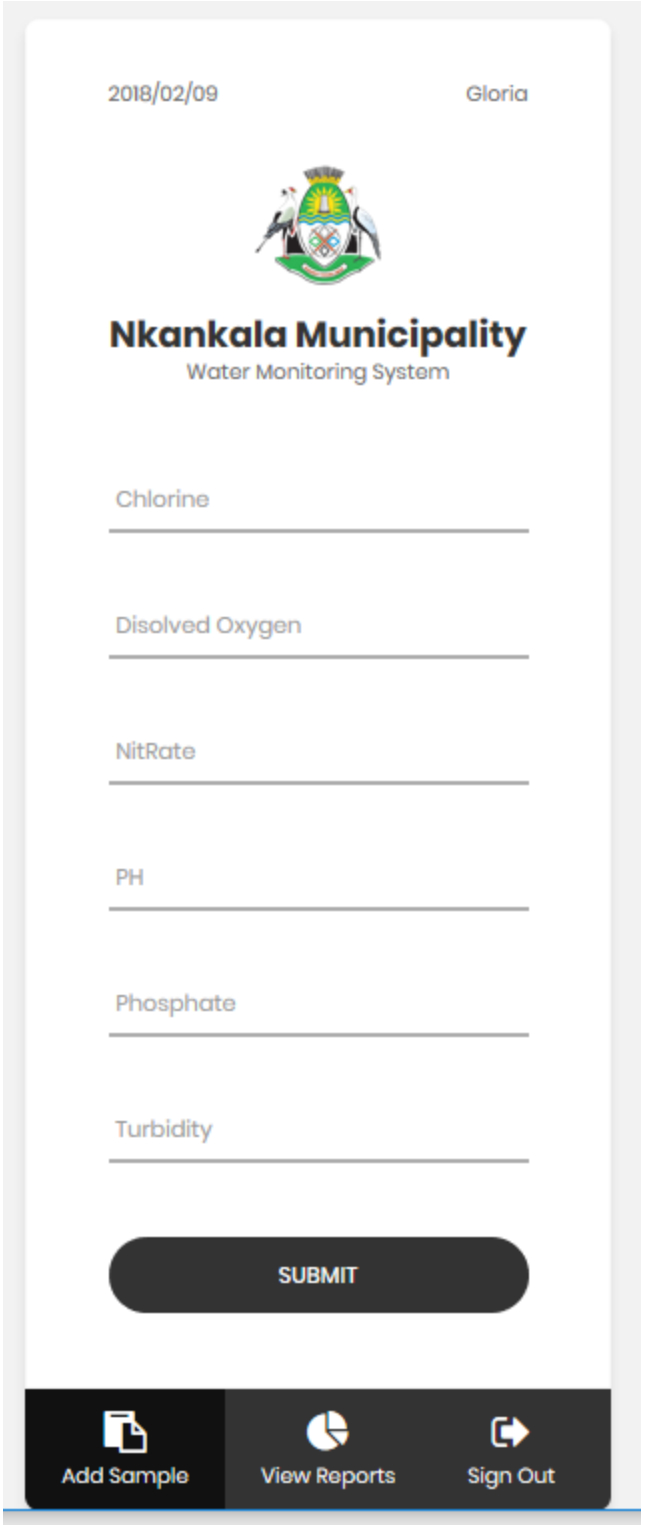


Figure 7 Nkangala Municipality Water Monitoring System

The water monitoring system at the Nkangala municipality is a web application as illustrated in Figure 000. The municipality divides the system into three parts: data monitoring nodes, database station and remote monitoring centre for the water area detected as the testing area. A great number of data monitoring nodes, distributed in water area detected as the testing, constitute a monitoring network in which each node can only collect parameters such as pH, amount of dissolved oxygen, electrical conductivity rate and temperature. The system is also capable of operating linearization and temperature compensation; data packaging; collected parameter memorizing and routing to a database station. The data from the monitoring nodes transferred to a remote monitoring centre by the base station via a GPRS network. The monitoring centre analyses and processes the water quality parameters, gives an alarm for emergencies like water contamination, in addition any sudden changes in water quality, and provides support for decision-making in prevention and remediation of water contamination. The end-user can also realize an all-weather detection on the target water area. The whole water environment monitoring system presents useful characteristics as large network capacity, flexible disposition, low power consumption, low cost, and minor influence on the natural environment. The system uses certain hardware in the field to perform water-monitoring testing. Hardware such as Colorimeters, to gauge the grouping of a water test's parts utilizing light going through the example, which has been responded to give a shaded animal types. Turbidity meters, to decide the lucidity (or darkness) of an example utilizing a light source to see particulates drifting in the example. PH meters, to quantify the pH of drinking water, surface/groundwater and wastewater to guarantee quality and consistence of administrative prerequisites; Dissolved oxygen meters, to decide oxygen accessibility as a basic piece of water contamination control and observing and Conductivity meters, to give a quick, simple approach to decide the aggregate sum of particles in arrangement. (Anon., 2015)

Subsequent to performing water quality tests, the data collector authority begins the WQR application on his telephone and chooses a form, reacting to different inquiries, for example, noticing area and turbidity perusing, free chlorine, electrical conductivity and pH readings as show in figure 0000. Tested Information from testing results from the water tester, collected, arranged and limited to characterized questions and data types. Information collected and checked against conceivable info esteems, and mandatory inquiries received and replied keeping in mind the end goal to continue to the following step.

At the receiving end, an incoming message manager performs basic verification and data integrity checking before storing the incoming data in the database and sending a confirmation

SMS to the tester. In case of a result outside of acceptable operational parameters, an SMS alert received by both the operator and his/her manager.

Another important aspect of the WMS is reporting. Data collected in the field can be save or submitted to the database at real-time. This enables rapid reporting on the water monitoring data as well as compare the current and previous data for decision-making. This removes one of the key biases against non-lab information gathering because collating and reporting.

There is no one single approach to field testing, but having the right gear can make data collection, reporting and analysis just as easy to accomplish outside of the office as it is in the lab. As water systems face-increasing pressure to improve quality while reducing costs, having a full complement of monitoring system could very well be the best way to achieve both decision-making and water quality for community.

4.5 Benefits and shortcomings of mobile-based information system

When the challenges and effect of using the Blue Drop System were assessed, a decision to use an alternative solution was proposed. The suggestion was to implement a mobile-based information system with the aim to monitor the quality of water effectively. Mobile information systems can benefit organisations by enhancing productivity, increasing flexible processes and procedures, improving customer service and providing accurate information for decision-making, which results in good strategy, decreases operational costs and enhances processes (Lau, 2006; Lee, 2003; Lovell, 1995). However, the use of a mobile-based information system for water quality monitoring in rural areas in South Africa has not been explored.

4.5.1 Benefits of Using Mobile-based Information System in the Nkangala Municipality

The aim of this section is to answer the research question: What are the benefits and shortcomings of using a mobile-based information system in the Nkangala municipality for water quality monitoring? The purpose of this question was to ascertain employees' wider view on the benefits that the municipality gains when using a mobile-based information system, as well as the shortcomings of this information system. This question was asked in order to gain more

understanding, to enable the researcher to evaluate the effectiveness and efficiency of the system.

The table below illustrates the responses elicited during interviews with employees of Nkangala District Municipality with regard to the benefits and shortcomings of using a mobile-based information system to monitor the quality of water. The table reflects the raw data, the thematic analysis of the participants' responses to the question and the interpretation of the raw data.

Table 20: Benefits of Using a Mobile-based Information System at Nkangala Municipality

Raw Data	Theme	Interpretation
It caters for local needs. *"The design of the mobile information system is made in such a way that it caters for local data and information needs."* *"The standard and regulations for quality water is catered based on the needs for a particular municipality."* *"It is designed in a way that it respond directly to the local needs."*	Provides solution for local needs	A mobile-based information system provides a unique identity to the Nkangala District Municipality, as it is tailored to suit it or cater for its unique data and information needs. The system enables the municipality to get accurate results for its water quality monitoring, as it provides the base for accurate data to be collected and captured.
"The mobile-based information system is experienced as easy-to-use/user-friendly, due to replicating already existing workflows". *"It is easy to use in such ways that even a person that don't have professional knowledge of*	System is user-friendly.	The functionality of the mobile-based system provides quite a number of benefits such as reduce redundancy, high availability and centralisation of security, as well as a reasonable lead time for water quality monitoring data collection. The system is user-friendly and straightforward; if an employee operating

computer literacy can adopt and be able to use it."		the information system leaves, it is easy to train the next employee to take over. In cases where new employees have to work on the system, the user-friendliness of the system will result in limited delays caused by the functional complexity of the system.
Increase in regular communication and an increase in awareness of the water quality at the various field sites. Managers also reported that the amount of travel to remote sites was reduced since they were able to assess sites from the office/	Increased management communication and awareness	
"Increase in awareness and appreciation for the need to collect information for monitoring purposes." *"We, as managers, felt that our confidence in water quality had increased and the system was experienced as providing relevant information for decision-making."* *"We, as managers, felt that we had a better understanding of the movements of the borehole operators and their needs."* *"In some of the sites, the*	Provides informed reporting	The information system enables the flow of data/information between the Nkangala municipality and the Blue Drop System for meeting the water quality standards and regulations prescribed by the national government. When data are collected and captured with accuracy, this enables the decision-making process to be flexible and accurate; therefore management can manage with better understanding of the challenges in the local areas.

system became an HR management tool and the tool had increased our workload due to being more aware of the challenges in one of the outlying villages."		
"The system was designed in such a way that it allows tracking of progress or communication of the latest statistics. For example, the Blue Drop System communicates to the public the status of water quality in each municipality of South Africa; however, it does not communicate who is responsible and who the various government structures at local level are that should be held accountable." *"Using the mobile-based information system, problems faced at water supply sites were identified sooner and the experience of accountability increased, not only for the government employees but also for the communities involved."*	Improvement of employees' accountability	The pressure here lies in thinking of accountability in terms of improved management and administrative efficiency and accountability, in terms of improving the accountability of government service providers to the public. If accountability is remotely managed, systems have to be introduced that allow each stakeholder to receive relevant information.

The replies of the participants suggest that using a mobile-based information system has benefited Nkangala District Municipality. Table 18 illustrates that the use of the information system caters for local data and information needs, as it enables immediate response to local

needs. The mobile-based system is easy to use/user-friendly, since it replicates already existing workflows. In the interview, site managers reported that the amount of travel to remote sites was reduced. The table above also demonstrates that the use of the information system has benefited the municipality in that reporting of water quality standards has increased, accountability has improved and the administrative processes of the municipality have been systemised.

Through observation, the researcher observed that “the use of the information system requires no paper work administration, as everything is done on the mobile system then uploaded to the national database.”

“It does not require any other installed equipment to be able to operate.” Process systemised The issue with the Nkangala District Municipality is that the employee used to go to the field to collect data by writing the values on a piece of paper in a notebook. Later these values were entered in a worksheet. Subsequently, the values were manually entered into the database system that was sent to the national Blue Drop System. This process was slow and prone to human error. The use of a mobile-based information system reduces the entire process; monitoring is a real-time process that gives managers and other stakeholders’ immediate access to the information for decision-making. The observation by the researcher also found that any devices that need installation and use electronics could break down and may require extensive maintenance, but the use of a mobile information system is a unique hybrid solution that combines the advantages of manual operations with the advantages of automation.

4.5.2 Shortcomings of Mobile-based Information System

Even though there are benefits that accompany the implementation of the mobile-based information system at the municipality, one should not overlook the shortcomings of the system. The purpose of outlining the shortcomings of a mobile-based information system at the municipality is to be able to deal with such shortcomings so that they do not overpower the benefits, as well as to find a possible way of dealing with them. After the interviews conducted with the employees, they identified the following shortcomings of the mobile-based information system:

- Displaying lengthy sample point names on the narrow screen is not ideal. The screen for the mobile device is so narrow that it is difficult to read and capture the information.
- Users were able to delete the application from the phone's storage; this happened regularly despite warnings against it. The water quality tester explained how the application was regularly deleted from the phone devices: "*Our assumption is that this happens because when you are browsing Nokia applications and you press the Menu key, the first option in the menu is Deleting, and this coupled with non-English speakers' results in it being pressed more than it should."*
- Users would fill up the phone with music and video downloads, sometimes to such an extent that the water quality monitoring application could not be reinstalled without removing some of these applications filling up the phone storage. The water quality testers justified this by saying that "*when they are at the field, they entertain themselves with music when conducting the sample*."
- Application reinstallation presented problems; when there are new versions of the application, these new versions can be sent via SMS or downloaded using the phone's web browser. The manager said: "B*oth options are complicated and unfamiliar actions to technicians who have just been taught the basics of the phone. And also the airtime to download is expensive for the technician to use the phone's web browser.*"
- Using the airtime on the phone device to do the day-to-day administration on the phone proved to be challenging; as the municipal manager said: *"The use of airtime is an administrative challenge in all of the settings. … A field technician is provided with airtime to submit data, however, sometimes this airtime is used up by calls, downloads, and so on. It is important to discuss this aspect of a mobile implementation with the relevant stakeholders at the beginning of the project.*"

4.5.3 Summary of Findings

Table 21 below provides a summary of findings on exploring the benefits and shortcomings of a mobile-based information system

Table 21: Summary of the Challenges and Effects of Blue Drop System

Summary of Findings

This section focused on exploring the benefits and shortcomings of a mobile-based information system. This resulted in accurate results for water quality monitoring, as it provided the base for accurate data to be collected and captured.

The findings of the study revealed that the mobile information system was tailored to suit or cater for its unique data and information needs.

The findings of the study also revealed that using the mobile-based information system has reduced data redundancy and offered high availability and centralisation of security, as well as a reasonable lead time for water quality monitoring data collection.

The findings of the study further revealed that the use of a mobile-based information system enables the monitoring process to happen in real-time, giving immediate access to the information to managers and other stake-holder for decision-making. It also enables the decision-making process to be flexible and accurate; therefore management can manage with better understanding of the challenges in local areas.

The secondary objective of the research focused on exploring the benefits and shortcomings of a mobile-based information system. The next objective aims to explore recommendations to make a mobile-based information system more useful.

4.6 Recommendations to Make a Mobile-based Information System more Useful

The first study objective was to explore the challenges and effects of the current water quality monitoring system, namely the Blue Drop System. The second objective was aimed at determining the benefits and shortcomings of using a mobile-based information system in the Nkangala municipality for water quality monitoring. This research objective was also to formulate recommendations to make the information system at Nkangala municipality more useful.

4.6.1 Recommendations to Nkangala Municipality to Make the Mobile-based Information System more Useful

The last interview question of the research required the participants to recommend ways in which the implemented mobile-based information system can be used in order to be more useful at the Nkangala District Municipality. This was an open-ended question to allow the participants to express their insights and suggestions openly. After analysis, the responses of the participants to the question were grouped thematically in Table 22 below. Raw abstractions of the participants' responses, as well as the researcher's interpretations of the thematic analysis, are also presented in Table 22.

Table 22: Recommendations on Making the Mobile-based Information System more Useful

Raw Data	Theme	Interpretation
"Training employees must be focused on the national's standard and regulations regarding what quality in our country" – **Participant 5**. *"Employees' training must be formalised and made mandatory"* – **Participant 5**. *"Management must make sure that their subordinates are trained and skill is transferred in the organisation"* – **Participant 1** *"Offer a variety of skills development programmes to employees"* – **Participant 8.** *"Allow flexibility on some of the HR*	Improve human resources programmes.	Older people possess more knowledge than younger people do. Transferring the knowledge of older employees to younger ones ensures sustainability in the company, since younger employees are more likely to be in the organisation for longer periods than the older ones. Transferring learning ensures that the information from claiming encountered representatives gets passed with respect to should more youthful generations and stays to use inside the organisation. Managing workers to satisfy their own and expert objectives is pivotal for the fulfilment of objectives in the organisation. Human resources programmes (such as career development programmes) that promote the growth of employees are essential to

policies in order to allow employees to grow" – **Participant 7** *"Training and development of employees is essential"* – **Participant 7**. *"Succession planning should be implemented in every division"* – **Participant 8.** *"Have and balance age differences in key positions so that proper knowledge transfer can take place"* – **Participant 8.** *"Incentivise knowledge transfer or knowledge contribution in the company"* – **Participant 9.** *"Improve incentive schemes for critical resources"* – **Participant 6**.		retain knowledge in the organisation. Such programmes assure the representatives that they are esteemed by the organisation and that the organisation has productive arrangements for them. This inspires the employees to stay in the organisation, together with their insight. Developing in relatively younger employees the competency to occupy senior leadership roles in the future is not only essential and cost-saving to the company, but also essential for the personal growth of the employee. Such career development programmes assure employees that they have a future in the organisation. In turn, the employees are more likely to remain in the organisation. The longer employees remain with the organisation, the longer their insight remains of use inside the organisation. It is imperative for an organisation to have programmes that inspire employees and make them feel esteemed by the organisation. The establishment or change of motivating plans for employees' information commitments will encourage representatives to share learning more frequently. The more representatives share information, the more learning is spread and retained throughout the organisation.
"Teamwork should be encouraged across the board" – Participant 8.	Encourage teamwork.	It is a favourable position for each foundation to have a group that has a

"Improve teamwork" – **Participant 3.**		regular vision. Working in groups not only allows work to be finished considerably faster and more effectively, but also promotes the sharing of information. Through cooperation in a group, each individual gets the opportunity to learn and build up individual and expert vocations.
"Reporting system that is rooted on the mobile-based information system is necessary for field worker to communicate with municipality managers and other stakeholder in real-time to ease the period for decision-making."	Embedded Reporting system	External tools such as the iComms reporting system can be used in conjunction with a mobile information system to communicate water quality to an organisation's stakeholders with ease.
"it will be a good functionality to have if the system can capture the physical location for the field worker automatically and store the coordinates" – **Participant 5**	Use of global positioning system GPS functionality	Frequently versatile mobile location concentrates on only one area as setting, for example, for location-aware services. Rather than creating application-particular arrangements, one ought to configure general models, components and stages to bolster the improvement and operation of mobile GPS functionality. In a general solution, all parts of an online data framework may be a GPS mobile setting. There are different possible ways of determining a user's position on a mobile information system, such as manually entered by the user, GPS , Wi-Fi signal strength, cell phone tower triangulation, radio frequency identification, Bluetooth and other tags. Of all the possible ways, GPS is the preferred way to use in this

		specific information system, according to Klasnja and Pratt (2012).
"Water quality failures are rectified within 24 hours of being reported. Although nothing is limiting the municipalities on implementing remedial action, they are currently not formally recorded as well as the actions taken. Nor are they reporting these failures to the communities within the required 24 hours"	Rapid communication to community	Real-time water quality information indicates the in-stream water-quality estimations made accessible on the system continuously. Water-quality estimations are recorded in real-time interims as little as five minutes to hourly and are frequently referred to as persistent. This real-time stream of information is made accessible on the system. Real-time water quality data are made conceivable in view of enhancements in sensor and information recording innovation, since the first in-stream sensors were produced specifically to quantify or process centralisation of many water-quality constituents. If this functionality can be added to the mobile-based system, the community will be able to be informed of any failure or success of the quality monitoring and action can be taken before any harm is caused to community members.
"We have not been showing videos and pictures of the site in the information system, but we realise that this functionality will be of importance to have." *"The field worker can take picture and videos when monitoring water in order to have physical visibility*	Use of photographs and videos	Add geographical metadata to different types of media photographs and videos. Metadata can be added manually or automatically.

of the contaminated water" – **Participant 4** *"it will reduce the workload of water quality data collection, allowing simultaneously of data capturing with photos and videos instead of using external devices to take pictures, which are sometimes limited in times of memory space, batteries and etc.?* – **Participant 7**		
"Workflow functionality will benefit the organisation to track the record or status of the monitoring process" - **Participant 7**	Workflow functionality	Workflow is an application range that fits integration of mobile system functions exceptionally well. The primary task of workflow process functionality in the mobile-based information system will be to enact case-driven business processes in the municipalities. The workflow administration situation has turned out to be perfect focus mobile system integration. Field workers can now access the central municipal database. With the integration environment adjusting to the gadget being used at once they are allowed to bring the gadget with them that best suits their requirements on a particular work day.
"Nkangala district has many municipalities; this information system should be able to share	Integration of system functionalities	Mobile phones offer the promise of linking data from one entity to another. Information and technical subsystems

information with other municipalities within the Nkangala district." *"one municipality should be able to share action taken with other municipalities."* *"Integrating between different devices that runs different system functionalities for the same sample collected. For example, we use three devices to test the same sample in order to get three different results, it will be ideal if this mobile information system can have those three functionality embedded/integrated on one system."*	as well as with other local municipalities in the district	are integrated on system and organisation-information levels to perform tasks in the interest of the region. As a rule, information integration is determined by the necessity of operating a huge quantity of data in a true (or close to true) time scale (Vasily et al., 2009). Be that as it may, often, information transitory change is required as data integrated in this layout is much more agreeable for further handling than just blended data that is kept in various sources with various speed and get to level.

Table 22 above illustrates that for water quality monitoring to be effective and efficient, employees ought to be engaged in training programmes that focus on national regulations and standards. Furthermore, employees should be encouraged to improve teamwork, which will assist in skills transfer and information/skills sharing. Table 22 also illustrates that interview participants reflect that there are other functionalities that can be useful for the mobile-based information system at the Nkangala District Municipality that are not currently being used, for example functionalities such as an embedded reporting system that is necessary for field workers to communicate with municipal managers and other stakeholders in real-time to decrease the period of decision-making, using GPS functionality to determine the exact location of the field where water samples are being taken, real-time rapid communication with the community to be informed of any failure or success of the quality of monitoring and action that can be taken before any harm is caused to community members, using photographs and videos, as well as the integration of other system functionalities with other local municipalities in the district.

4.6.2 Summary of Findings

Table 23 below provides a summary of findings and recommendations to the Nkangala municipality to make the mobile-based information system more useful.

Table 23: Summary of Recommendations on the Mobile-based Information System

Summary of Findings
This section focused on recommendations to Nkangala municipality to make the mobile-based information system more useful. The study has found that there are other functionalities that can be recommended for the mobile-based information system at the Nkangala District Municipality that are not currently being used. These include an embedded reporting system that is necessary for field workers to communicate with municipal managers and other stakeholders in real-time to shorten the period of decision-making. The finding revealed that the mobile information system can make use of the GPS functionality to determine the exact location in the field where water samples are being taken, which can be useful in the future. The findings also show that the mobile information system can enable real-time rapid communication with the community on any failure or success of the quality monitoring and action can be taken before harm is caused to community members The findings show that a mobile-based information system can enable the use of photographs and videos, as well as the integration of other system functionalities with other local municipalities in the district.

The secondary objective of the research focused on recommendations to Nkangala municipality on making the mobile-based information system more useful. The next section aims to explore the concluding findings of this study.

4.7 Conclusion

Monitoring the quality of water from water sources for South African citizens is very important to ensure that citizens are drinking safe and potable water. The government introduced the Blue Drop System with the aim to improve the monitoring process for water quality. However, it has turned out that the system does not benefit rural or under-resourced municipal areas. As the results of many reports have shown, the Blue Drop System in rural municipalities is not meeting the national standards for water quality. In exploring the challenges of using the Blue Drop System in the Nkangala District Municipality, the study found that those challenges outweighed the objectives that the municipality wanted to achieve through monitoring water quality, therefore it was necessary for a mobile information system to be implemented in order to increase the effectiveness and efficiency of water quality monitoring. The study has shown that the Blue Drop System is a hindrance rather than yielding adequate results in terms of water quality in the municipality. Therefore it can be concluded that the Blue Drop System, which is implemented nationally, cannot be an effective and efficient tool or system to use in rural municipalities such as Nkangala for monitoring water quality.

With regard to the technology itself, the expectation of the municipality in using a mobile information system is that the management of the municipality believes that a continual stream of information will improve water quality monitoring and reporting, as well as highlight staff performance. The study has found that the management perceives the mobile tool as useful and easy to use. The application that was installed was found to be user-friendly and easy to navigate. The management also expressed gratitude for the usefulness of having real-time data on a 24-hour basis. Because staff members were familiar with information and communication technology, management did not have a problem with adopting the android technology that the mobile devices were using.

Prior to the implementation of a mobile-based information system, there was no communication between levels within the municipality on water quality monitoring. Before the implementation of the mobile-based information system, contamination of a water source only became known through ad hoc compliance monitoring or if the municipality was told, by the local clinic, of a diarrhoeal outbreak. Research has found that the new information system reporting results have increased interaction and communication between different levels within the municipality. The

system also enables the manager always to be informed and inspires confidence in the quality of water service delivery.

Incidents that are recorded over time as reports can now be mapped and used to make more informed decisions. The study has found that the implementation of the information system has shown that transparency in respect of job performance will lead to management taking action. This has resulted in management and operators communicating more on reported failures and spending more time fixing the failures. Implementing this system has helped the municipality to be aware of untreated water resources and to initiate monitoring of borehole schemes in the district. The community has also become involved and its members are now aware that they are drinking water of quality that is being monitored. The municipal manager is convinced that the community sees this as another service delivery achievement and is more positive about the water quality.

The data produced by the system have affected the use of resources as well as the requirements of the municipality. The study has found that the current management feels that there are enough records and proof of data that can be used as motivation to request additional staff and equipment and a higher water budget from the council. The management believes that if more data can be captured though a mobile-based information system, the tool will be more useful.

If the municipality is to be able to adopt the technology, important considerations are not only the availability and reliability of the service, but also how people perceive the project. In this research, the researcher has found that all people, especially middle management, involved in the project must accept it and commit to the project, not only the management that makes the decisions in the municipality. In fact, the involvement and support of middle management were more important in this project than the involvement of the water sector managers, as the duty of the middle management was to “follow up on failures, question data gaps and monitor the operator’s performance” (Conero, et al., 1998).

The study also found that the implementation of the mobile-based information system for the municipality made the manager perceive the system as an “eye-opener” in terms of employees. The manager stated that previously they would just appoint anyone to do the job, but currently he believes that it is important to employ people who are literate, can be trained and understand the importance of supplying quality and safe water.

The findings suggest that for water quality monitoring to be more effective and efficient, employees ought to be engaged in training programmes that focus on national regulations and standards. Furthermore, employees should be encouraged to improve teamwork, which will assist in skills transfer and information/skills sharing. The study also revealed other functionalities that can be recommended for the mobile-based information system at the Nkangala District Municipality that are not currently being used. These are functionalities such as an embedded reporting system that is necessary for fieldworkers to communicate with municipal managers and other stakeholders in real-time to reduce the period of decision-making; the use of GPS functionality to determine the exact location of the field where water samples are being taken. real-time rapid communication with the community to be informed of any failure or success of the quality monitoring and action that can be taken before any harm is caused to community members, the use of photographs and videos, as well as the integration of other system functionalities with other local municipalities in the district.

This chapter outlined the research objectives and questions that the researcher formulated at the beginning of the research to carry out the case study on evaluating the mobile-based information system implemented to improve the efficiency and effectiveness of water quality monitoring in the Nkangala District Municipality. Table 20 below gives a summary of relevant understanding, insight and interesting points, as well as the implication of the study findings in support of the main research questions.

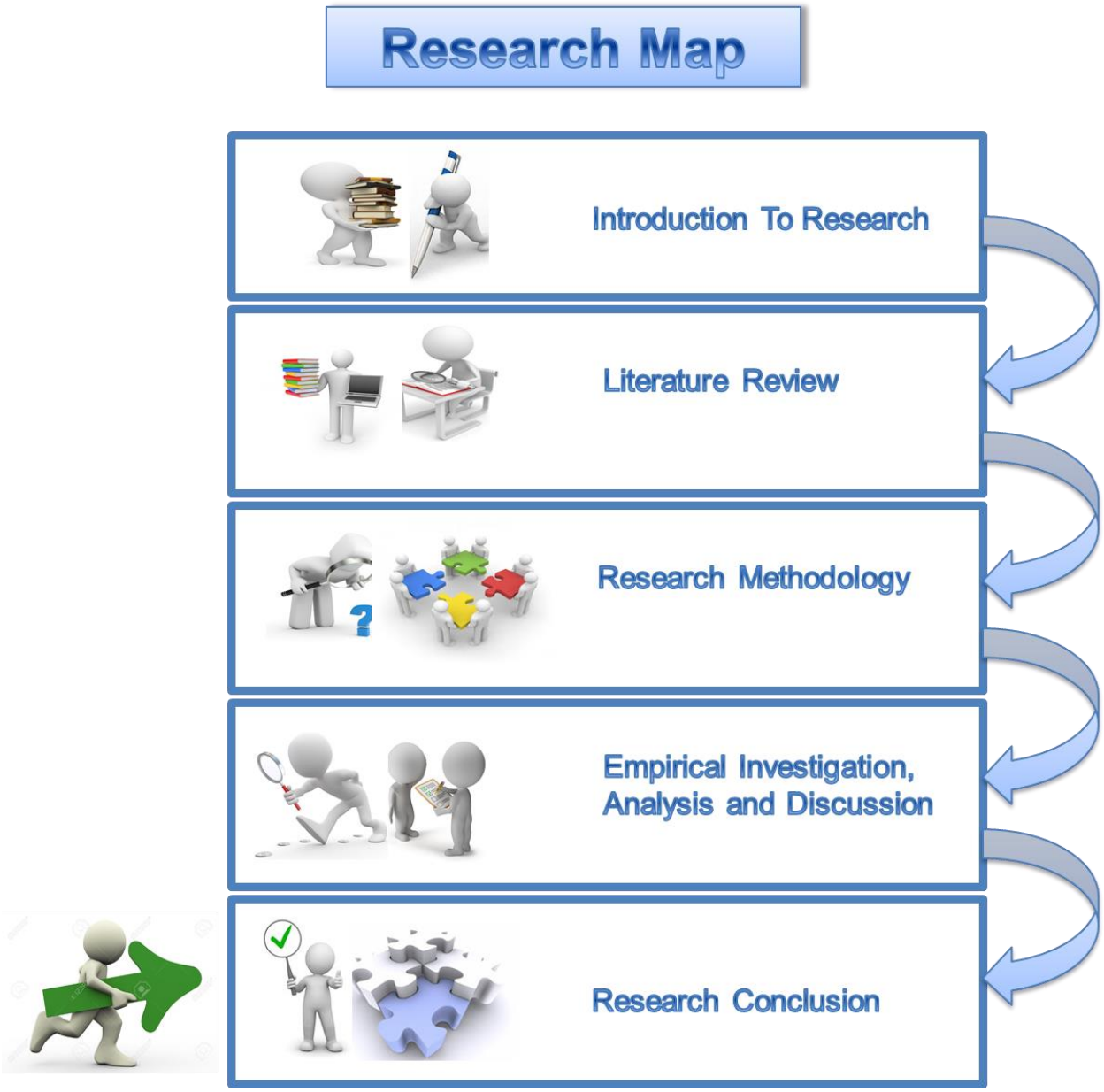
Table 24: Summary of Findings on Research Objective

Summary of Findings on Research Objectives	
Insights	In order to evaluate the feasibility of the mobile-based information system that has been implemented at the Nkangala municipality to improve water quality monitoring, a detailed discussion of challenges that rural municipalities, such as Nkangala District Municipality, encountered when using the Blue Drop System to monitor the quality of water is provided in section 4.3 of this research. Understanding the challenges of the Blue Drop System to monitor water quality led to the implementation of mobile-based information when it was found

	that the challenges of the system outweighed the benefits and defeated the main purpose or objective. In-depth understanding was sought of the benefits and shortcomings of the mobile-based information system at Nkangala municipality through interviews with the management and the employees. The mobile information system can be used for many other purposes at the municipality as well, for which it is not currently being used; recommendations on these are outlined in section 4.5 of this research paper.
Discoveries	The interview with the employees revealed that good results and benefits can be obtained by using the mobile information system to monitor the quality of water. Even though it has shortcomings, they do not outweigh the benefits of the system. The key factor is that the mobile tool is useful, easy to use and the application that was installed was found to be user-friendly and easy to navigate. The new mobile information system's reporting results have increased interaction and communication between different levels in the municipality. Through the use of the system, enough records and proof of data have been obtained that can be used as motivation to request additional staff and equipment and a larger water budget from the council.
Implications	The mobile information system has the potential of easy navigation and by using a wireless internet connection it can be used to share information. This functionality could be very useful to increase communication between the municipal management and the community regarding water quality. Unfortunately this functionality has not yet been explored fully and covered in this research. However, it is hoped that further studies that cover this functionality will follow shortly.

The key objective of the current chapter was to gain new knowledge through analysis of the findings of the data collected during the research interviews. The data analysis and illustration of the findings were focused on the defined secondary objectives of the research. The next chapter presents the conclusion of the research.

5. Research Conclusion



5.1 Introduction

The previous chapter presented a discussion and analysis of the empirical investigation. The current chapter connects the findings of the empirical investigation with the findings in the academic literature in order to draw conclusions on the overall research. This chapter also presents the contribution of the current study to the Nkangala District Municipality. Furthermore, this section of the research outlines recommendations on possible future research.

The main objective of this study is to evaluate whether the implementation of this information system has improved the efficiency of the water quality monitoring process in Nkangala municipality. The researcher found no research in the academic literature into the evaluation of the information system that was implemented at the Nkangala District Municipality. A case study was chosen to gain insight and create rich understanding of the failure of the Blue Drop System at rural municipalities, as well the benefit of implementing a mobile-based information system in these municipalities. Interviews were used as the instrument for collecting data from the participants.

The current research aims to make a contribution to the academic literature through answering the main research question.

5.2 Addressing the research questions

As Outlined in Chapter 1, the main research objective led to the main research question, which was defined as:

- *How will a mobile-based information system be used to improve the efficiency of water quality monitoring at Nkangala municipality in Mpumalanga?*

In order to achieve the main objective of this study and to answer the main research question, the following sub-questions were defined:

- *What are the challenges and effects on the Blue Drop System?*

- *What are the benefits and shortcomings of using a mobile-based information system in the Nkangala municipality for water quality monitoring?*

- *What recommendation can be made to the Nkangala municipality to make the information system more useful?*

The above research sub-questions were designed in such a way that answering them led to the answering of the main research question. The following sections present answers to the secondary research questions according to the literature findings and the findings of the empirical investigation.

5.2.1 Research sub-question 1: *What are the challenges and effects on the Blue Drop System to monitor quality water?*

A few studies have been performed on the Blue Drop System that was implemented by the national government of South Africa. The main purpose of this sub-question was to determine the challenges that the Blue Drop System has experienced, resulting in this system not being effective and efficient for use in rural municipalities to monitor water quality.

The Blue Drop System has been designed and implemented nationally to monitor compliance with water quality regulations in the country. The literature study revealed that water quality in South Africa is guided and ruled by the Water Quality Policy and Act. The key purpose of the NWA is to provide the assurance that the water resources of South Africa are protected, used, developed, conserved, managed and controlled in a useful and comprehensive way, which makes it possible for the proposal of the National Water Policy to be implemented. The Blue Drop System uses the Blue Drop certificate programme to encourage water supply authorities to supply quality water to the community. The main objectives of the Blue Drop certificate programme are to introduce incentive-based regulations on water quality, to introduce key requirements for efficient and effective management of water quality, to initiate transparency on the management of water quality by water services institutions and to provide information to the public on water quality per service provider to avoid generalisation.

The empirical investigation revealed that the Blue Drop System for water quality monitoring presents challenges that are experienced by this particular municipality. The analysis of the empirical investigation reveals that the main challenge of the Blue Drop System is decentralisation, where power and decision-making rest on the municipal level. This is due to the fact that complex authority and roles were devolved to local authorities and those local authorities did not have the capabilities to deal with the sometimes complex municipal systems and processes. The analysis of empirical information also revealed that lack of human, technical and financial resources was a challenge in municipalities to use the Blue Drop System efficiently, as was failure to understand the standards and regulations of water quality.

The empirical investigation and academic literature revealed equivalent findings that the Blue Drop System was indeed found to be a hindrance in determining adequate results on water quality in the municipality. It was found that it was not always true that the water in the rural municipality was not of good quality, but that the process of measuring the quality of the water was ineffective and not compatible with the national Blue Drop System process.

The link between the findings of the academic literature and the findings of the empirical investigation rationally answered the relevant sub-question of the research.

5.2.2 **Research sub-question 2:** *What are the benefits and shortcomings of using a mobile-based information system in the Nkangala municipality for water quality monitoring?*

The most significant current market and technological development in information technology is mobility, mobile phones being the most relevant example of this. The main purpose of this sub-question was to determine and explore the benefits and shortcomings of using a mobile-based information system in the Nkangala District Municipality for water quality monitoring.

The academic literature related to the study revealed that a mobile information system makes it possible to access the system from anywhere, at any time and in different ways. Mobile phones are adaptive end user devices that can be used as mobile terminals (Basole, 2004). Therefore, mobile information systems can be described as the information system that uses end user terminals that are easily movable, compatible with wireless connection and able to operate in any location; to access information resources and services. Furthermore, academic literature on the study also showed that using mobile information systems can benefit the organisation as

they enable one to use work time more efficiently (Kalakota & Robinson, 2002). Users who spend more time away from their desks are able to access information and services from anywhere, resulting in an increased overall productivity level. Other benefits of the mobile information system found in the academic literature are ubiquity, as it enables users to access the network at any place and at any time, and to be in touch, able to be reached at all times wherever they are, using always connected portable devices.

The empirical investigation of the study has revealed that the benefits of using a mobile-based information system are that the information system caters for local data and information needs by responding directly to the local needs. The functionality of the mobile-based system is easy-to-use/user-friendly, since it replicates already existing workflows. The use of the information system has benefited the municipality such that reporting of water quality standards has increased, accountability has improved and the administrative processes of the municipality have been systemised.

The academic literature and the empirical investigation revealed corresponding findings that implementation of a mobile-based information system has led to transparency in job performance, which will lead to management taking action. This resulted in the municipal management and field operators communicating more on reported failures and spending more time on correcting failures. Furthermore, implementing this system has helped the municipality become aware of untreated water resources and to initiate monitoring of borehole schemes in the district. Because of the implementation of the information system, there is better communication between the community and the municipality, so that members of the community are now aware that they are drinking good quality water that is being monitored.

The connection between the findings of the academic literature and the findings of the empirical investigation rationally answered the relevant sub-question of the research.

5.2.3 Research sub-question 3: *What recommendation can be made to Nkangala municipality to make the information system more useful?*

Section 4.4 of this study explores the benefits and shortcomings of using a mobile-based information system in Nkangala District Municipality. The aim of the current study is not only to evaluate the use of the mobile-based information system in Nkangala District Municipality. Its

purpose is also to identify or determine an effective way or recommendations on ways in which the mobile-based information system can be useful at Nkangala District Municipality.

The researcher found no research in the academic literature indicating how the mobile information system can be made more useful to the Nkangala District Municipality. This meant that the empirical study findings were crucial in determining recommendations on making the mobile information system more useful to the municipality.

Analysis of the empirical investigation revealed the most effective way in which the mobile-based information system can be useful at the Nkangala District Municipality. The findings of the empirical investigation revealed training, improving human resources programmes and encouraging teamwork as the most effective means of effectively monitoring water quality through the implemented information system. Human resources programmes (such as career development programmes) that promote the development of employees are essential in the retention of knowledge in the organisation. Such programmes assure the representatives that they are esteemed by the organisation and that the organisation has productive arrangements for them. This inspires the employees to stay in the organisation, together with their insight. This also means that working in groups not only allows work to be finished considerably faster and all the more effectively; it also promotes the sharing of information. Analysis of the empirical investigation also revealed recommendations on improving the usefulness of the implemented information system for Nkangala District Municipality. The findings of the empirical investigation revealed that there are other functionalities that can be useful for the mobile-based information system at the Nkangala district municipality that are not currently being used. These are functionalities such as an embedded reporting system that is necessary for fieldworkers to communicate with municipal managers and other stakeholders in real-time to decrease the period of decision-making, the use of GPS functionality to determine the exact location of the field where water samples are being taken, real-time rapid communication with the community to be informed of any failure or success of the quality monitoring and action that can be taken before any harm is caused to community members, the use of photographs and videos, as well as the integration of other system functionalities with other local municipalities in the district.

Since no research was found on proposals for Nkangala District Municipality in the academic literature, the findings of the empirical investigation were conclusive in answering the relevant research sub-question. The findings of the empirical investigation satisfactorily answered the third sub-question of the study.

Answering all three research sub-questions implies that the main research question was answered. This implies that the current study effectively inspected the research topic and thus made some contributions to the academic literature. The next section covers the contributions of the current study to Nkangala District Municipality.

5.3 Summary of contribution

The present study made discoveries that can be used by municipalities in real-life situations. The current study made a practical contribution to the Nkangala District Municipality by evaluating the use of the implemented mobile-based information system as well as determining the recommendations that can make the mobile-based information system more useful to the municipality. This study also presented a framework for water quality monitoring to the Nkangala District Municipality. The framework was used to direct the activities of the National Water Quality Monitoring Council by “identifying, connecting, and prioritizing” some of the features of the different framework elements (Davies, 2007). The framework enables professionals and volunteers working on different components of monitoring programmes to communicate with one another. The framework directs the water quality monitoring programmes to make sure that all components are involved, stable, associated and collectively focused on producing quality information. The framework “underscores the need for a warehouse of consistent information on water monitoring design methodologies” (Davies, 2007), One of the advantages of the monitoring framework is that it emphasises the response at every step. If the monitoring framework is applied successfully, it will help to reassure people that the outcomes of water quality monitoring can be used to understand, protect and restore the quality of water. This water quality monitoring framework analysis can be used by Nkangala District Municipality as well as other rural municipalities to participate effectively in the monitoring of water quality. The water quality monitoring framework analysis can also be used by Nkangala District Municipality to sustain/obtain a competitive edge within South Africa’s national water quality programme. Furthermore, the water quality monitoring framework analysis can be used by any other rural municipalities that are also affected by the inefficiency of the Blue Drop System. The other useful contribution made by the current research was the proposal of functionalities that can be embedded in the mobile-based information system, which can increase the effectiveness and efficiency of water quality monitoring.

Limited studies are available in the academic literature on a mobile information system designed specifically for the rural municipalities in South Africa to monitor water quality. Studies have been done on water quality monitoring in general. The present study made a theoretical contribution to research on water quality monitoring in municipalities in South Africa. The present research also made a theoretical contribution to the academic literature by adding more knowledge to the limited research that currently exists on the subject of a mobile-based information system for rural municipalities.

5.4 Future Research

Since this research only focuses on one municipality, Nkangala District Municipality, future research can focus on multiple municipalities of the country. This would allow for consolidation of the research findings and consider a more extensive appraisal of the study research problem.

The Blue Drop System poses challenges that hinder rural municipalities from participating effectively in quality water monitoring. The researcher found limited academic literature in this regard. An opening exists for a deeper investigation and study on the Blue Drop System for water quality monitoring.

The use of a mobile-based information system for water quality monitoring has only been evaluated at one district municipality out of six municipalities where this information system was implemented. Future research can be done to evaluate the use of a mobile-based information system to improve water quality monitoring at other district municipalities in the country.

5.5 Concluding Remarks

Quality water is important for better health, easing poverty and community development. It is thus important that water quality monitoring be taken seriously in South Africa. Enough research has been reported in the academic literature on water quality monitoring in general and the use of a mobile information system to solve difficulties such as the efficiency and effectiveness of monitoring the quality of water. The current study investigated this and found that the South

African government does have strategies in place to ensure good quality water is being offered to its citizens; however, the strategies are not suitable to cater for both urban and rural people.

The current chapter focused on answering the main research question by answering the research sub-questions. This chapter managed to answer all sub-questions of the current research that were presented and discussed in this study. The theoretical and practical contributions of the present research were assessed and the overall contribution was explained through the use of Gregor's (2002) classification theory. Future research gaps have also been identified to guide other researchers with an interest in this research topic. The overall investigation succeeded in evaluating the mobile-based information system implemented for quality water monitoring in the Nkangala District Municipality.

"Water Is Life, clean quality water means Health." – Audrey Hepburn

Appendix A – Consent Form

1 Title of research project: **Evaluating a cell phone-based information system implemented to improve water quality monitoring for rural municipalities: Nkangala District Municipality case study**

2 I …… hereby voluntarily grant my permission for participation in the project as explained to me by

……**Tshimangadzo Gloria Raphulu.....**

3 Upon signature of this form, you will be provided with a copy.

Signed: _____ Date: _____

Witness: _____ Date: _____

Researcher: _____ Date: _____

Appendix B – Invitation letter to Participate in Research

Department of Informatics
IT Building, Level 5
University of Pretoria
Cnr Lynnwood Road & Roper Street
Hatfield
Pretoria, 0083
South Africa

1 June 2015

Dear Sir/Madam,

RE: Use of Mobile-based Information System for Water Quality Monitoring

I am a student at the University of Pretoria in the Informatics Department, I am presently piloting research for the purposes of my dissertation, which focus on the use of mobile-based information system implemented to improve the efficiency of water quality monitoring for the Nkangala district municipality.

The main objective of this study is to evaluate if the implementation of this information system has improve the efficiency of water quality monitoring process of Nkangala municipality.

You are hereby requested to participate in the study as the respondent. Your participation will be in the form of an interview that will not consume more than 2 hours of your time.

The information that you will provide is guaranteed to be used only for the purpose of the study and your responses are confidential.

Your contribution will be highly valued. Contact me for any queries on 072302902 or makoyat@gmail.com.

Yours sincerely,

Tshimangadzo Gloria Raphulu
University of Pretoria
0723022902

Appendix C – Interview Guide (Research Questions)

Evaluating a cell phone-based information system implemented to improve water quality monitoring for rural municipalities: Nkangala District Municipality case study

Section 1: Demographic Information of Interviewees

Date of Interview	
Time of Interview	
Venue	
Total Duration of Interview (Hours)	

Interviewee to please supply the following details:

Current position/role in organisation		
Number of years in municipality		
Number of years involved in water quality monitoring projects		
Role(s) in the projects		
Gender	Female	
	Male	
Ethnicity	African	
	White	
	Indian	
	Coloured	
	Other	
Age Group	18-25	
	26-35	

	36-45		
	46-55		
	56-65		
	Above 66		
Highest level of formal qualification	Postgraduate		
	Degree/diploma		
	Degree/diploma		
	National certificate		
	Matric		
	None		

Section 2: Experiences of Respondents

1. How was the previous process of monitoring water quality conducted?
2. What is the current process of monitoring water?
3. What are the challenges you faced when monitoring water before the information system was implemented in your municipality?
4. Did the challenges end with the implementation of the mobile-based information system?
5. In your own opinion, would you say the use of the mobile-based information system improves the monitoring of the water quality?
6. What are the good things you can say about the mobile-based information system?
7. What are the shortcomings you face when using a mobile-based information system?
8. What would you like to see improve in the information system?

9. Rate the following application and business factors according to your supposed ranking. Use the numbers 1-10 to depict the priority.

Application Factors	Priority
Availability	
Performance	
Security	
Scalability	
Integration	
Network and Connection	

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