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The use of Water Point Mapping (WPM) as a tool to assess improved water resources in rural communities

by

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A dissertation submitted to the Department of Microbiology in the School of Mathematical and Natural Sciences, University of Venda in fulfillment of the requirements of the Master of Science Degree in Microbiology

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Declaration

I Taonameso Solomon student number 11634561 declare that the dissertation for the award of an MSc in Microbiology degree at the University of Venda, hereby submitted by me has not been submitted previously for a degree at this or any other institution, that it is my own work in design and in execution, and that all reference material contained herein has been duly acknowledged.

28-09-2015

Signature Date

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Abstract

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Background

The sporadic outbreaks of child dysentery in the Vhembe rural areas, where the incidences have been occurring at more than the national average signals that there could be a problem in the provision of safe drinking water. Questions relating to the functionality and sustainability of rural water supply services become eminent. It can be assumed that service delivery has slowed down and where infrastructure exists, not all poor households experience the benefits of this infrastructure.

Objectives: The purpose of this research was to examine the existing water supply status in the Thulamela Local Municipality using the Water Point Mapping (WPM) tool; with a view to determine the extent of deficiency and determine what would be required to meet the MDG of halving the number of people without access to safe drinking water by 2015. The objectives of the study include recording the distribution of Municipal borehole water points in Thulamela Municipality using a global positioning system (GPS) to produce a map that indicated the improved water point coverage and functionality and to determine the microbiological and physico-chemical quality of all functional boreholes. Digital maps were developed to correlate with the demographic, administrative and physical data.

Methods

A GPS was used to get coordinates of all borehole water points. A structured questionnaire was also used for each Improved Community Water Point (ICWP) to record the information relating to location, ownership, age, and functionality, history of maintenance and hardware type of all ICWPs.

Water samples were collected from all functional boreholes for water quality analysis. Total coliforms and *E. coli* were analyzed using the Colilert® Quanti-Trays/2000 (IDEXX, USA). Molecular characterization of *E. coli* strains was carried out using a published multiplex PCR protocol.

As part of analysis, Equity of Distribution (ED), Functionality Rate (FR) and Water Point Coverage (WPC) indicators were presented to quantify the degree to which resources were fairly distributed, the level of access to safe water and investment needed to improve water supply coverage.

Survey results were captured using a database form prepared in Microsoft excel spreadsheet. The GIS ArcView 10.1 software was used to reproduce the information on a map. EXCEL-formatted water point inventories were correlated with spatial information based on South Africa statistics 2011 population census. Based on the official spatial infrastructure information, densities divided into Enumeration Areas (EAs), of which the smallest was the village.

Results: A total of 125 boreholes were mapped of which only 12 were functional (9.6%). Seven of the functional boreholes tested positive for Total coliforms with 4 of these tested positive for diarrheagenic *E. coli*. The results indicated that 58.3% of the water samples were microbiologically good, 16.67% were marginal and 25% were poor according to the South African water Assessment Guidelines. Functionality rate was 12%, 10.35% and 8.57% in wards 15, 18 and 19 respectively. ICWP coverage was 0.29, 0.56 and 0.39 WPs per 1000 inhabitants in wards 15, 18 and 19 respectively.

Conclusion: The WPM tool revealed that drinking water borehole coverage in the assessed rural villages was unacceptably low and periodic monitoring of water quality should be stepped up in South Africa rural areas.

Key words: PCR, Water Point Mapping, Diarrheagenic *E. coli*, Colilert® Quanti-Trays/2000, Functionality Rate, Improved Community Water Point Coverage, Equity of Distribution

LIST OF ABBREVIATIONS (ACRONYMS)

ADEM	Alabama Department of Environmental Management
AMBIO	Journal of the Human Environment
AMCOW	African Ministers' Council on Water
BDCP	Blue-drop Certification Programme
Bfp	Bundle forming pilus
cfu	Coliform forming units
CSIR	Council for Scientific and Industrial Research
DCOG	Department of Cooperative Governance
DEC	Diarrhoeagenic *E. coli*
DWA	Department of Water Affairs
Eae	*E. coli* attaching and effacing
EAs	Enumeration Areas
EPA	US Environmental Protection Agency
ECOSOC	United Nations Economic and Social Council
ED	Equity of Distribution
EAEC	Entero-aggregative *E. coli*
EIEC	Entero-invasive *E. coli*
EHEC	Entero-hemorrhagic *E. coli*
EPEC	Entero-pathogenic *E. coli*
ETEC	Entero-toxigenic *E. coli*
FC	Full Coverage
FR	Functional Rate
GPS	Global Positioning System
HWT	Household water treatment
ICWP	Improved Community Water Point
IDP	Integrated Development Plan
JICA	Japanese International Co-operation Agency
JMP	United Nations Joint Monitoring Programme
lt	Labile enterotoxin
MDG	Millennium Development Goal
MOWI	Ministry of Water and Irrigation
m-PCR	Multiplex polymerase chain reaction
NGO	Non-Governmental Organization
PCR	Polymerase chain reaction

pH	Potential of Hydrogen (acidity or alkalinity)
PRH	Poor and Rural Households
RADWQ	Assessment of Drinking Water Quality
PRS	Poverty Reduction Strategy
RDP	Reconstruction and Development Programme
RIPPLE	Research-Inspired Policy and Practice Learning in Ethiopia
RWSN	Rural Water Supply Network
RWSS	Rural Water Supply and Sanitation
RWSS	Rural Water Supply and Sanitation
SNV	Netherlands Development Organization
SSA	Sub-Saharan Africa
St	Heat-stable enterotoxin
stx1	Shiga toxin 1
stx2	Shiga toxin 2
Stats SA	Statistics South Africa
TAs	Traditional Authorities
TAWASANET	Tanzania Water and Sanitation Network
TDS	total dissolved solids
TLM	Thulamela Local Municipality
UNDESA	United Nations Department of Economic and Social Affairs
UN	United Nations
UNICEF	United Nations Children Education Fund
VDM	Vhembe District Municipality
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WP	Water Point
WPC	Water Point Coverage
WPM	Water Point Mapping
WSA	Water Service Authority
WSP	Water and Sanitation Program

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Chapter 1
Introduction

1.1 General introduction

Inadequate safe drinking water supply and sanitation services is an issue of concern worldwide and recent reports indicated that at least 783 million people in the world live without safe water, while 2.5 billion people lack adequate sanitation (WaterAid UK, 2012). As of 2014, 748 million people worldwide mostly the poor and marginalized still lack access to an improved drinking water source according to the World Health Organization and the United Nations Children's Fund (WHO/UNICEF JMP, 2014). Without safe water or sanitation, people are trapped in a cycle of poverty and diseases (WaterAid UK, 2012). It is the United Nations' (UN) belief that every human must have access to safe adequate drinking water according to the United Nations Economic and Social Council (UN ECOSOC, 2002). Rural Water Supply Network (RWSN) also recognizes the rights and the natural justice of all citizens to enjoy secure water services regardless of location, lifestyle, gender, age, disability, ethnicity or income (RWSN, 2014).

The World Health Organization (WHO, 2004) clearly states that the combination of safe drinking water and hygienic sanitation facilities is a precondition for health and success in the fight against poverty, hunger, child deaths and gender inequality. The precarious water and sanitation situation across the world motivated the UN to come-up with International Millennium Development Goals (MDGs) of which one is on water and sanitation. This follows the Millennium Summit of the United Nations in 2000. The UN included provision of improved water and sanitation in its millennium declaration after realizing that lack of access to safe water and sanitation, as well as poor hygiene practices, sickens and kills thousands of children every day and leads to impoverishment and diminished opportunities for many (WHO, 1997).

Access to safe drinking water and sanitation is a fundamental human right and is essential to life, health and dignity (UN ECOSOC, 2002). On 28 July 2010, the United Nations General Assembly adopted Resolution 64/292 recognizing that safe and clean drinking water and sanitation is a human right essential to the full enjoyment of life and all other human rights (WHO/UNICEF JMP, 2011). The General Assembly voiced deep concern that "almost 900 million people worldwide do not have access to clean water". At the end of the UN set International Drinking Water Supply and Sanitation decade (1981-1990), the WHO and UNICEF) established a Joint Monitoring Programme (JMP) for water supply and sanitation. The JMP's aim is to report globally on the status of water supply and sanitation sector and to support countries in improving their monitoring performance to enable better planning and the management at country level (WHO, 2006). The JMP embraces the principle that monitoring access to drinking water and sanitation is indispensable for promoting the prioritization of the water supply and sanitation needs of the world's vulnerable and marginalized people (WHO, 2006). All UNICEF Water, Sanitation and Hygiene (WASH) programmes are geared towards achieving the Millennium Development Goals (MDG), especially goal number seven (7), target 10, which is to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation (WHO/UNICEF JMP, 2013). The reports given by the JMP are based on statistics regarding access to technologies that are either "improved' or 'unimproved" (WHO/UNICEF JMP, 2013).

1.2 Access to "improved" drinking water sources

According to WHO and UNICEF JMP (2012) an "improved" water source is one, which, because of its design and or quality of construction, adequately protects water from outside contaminants, especially human faecal matter and hence is likely to provide water of better quality and reduce the public health risk. Between 1990 and 2008, the proportion of the world's population with access to improved drinking water sources increased from 77% to 87% (WHO/UNICEF JMP, 2011). This constituted an increase in almost 1.8 billion people worldwide and put the world well on track for meeting the MDG drinking water target of 89%. In 2008 there were still 884 million people that did not use improved drinking water sources and at that current rate it was estimated that 672 million people would not use improved drinking water sources in 2015 (WHO/UNICEF JMP, 2011). According to the WHO/UNICEF JMP (2012), world drinking water coverage is at 89% but Latin America and the Caribbean are at 94%, Southern Asia is at 90% while Sub-Saharan Africa (SSA) has a water coverage rate of only 61%.

The world coverage indicates that the world has already achieved the MDG target on water three years in advance of the 2015 MDG deadline. The world's population that was using improved drinking water sources at the end of 2010 was at 89%, which is equal to 6.1 billion people, thus 1% more than the 88% MDG target (WHO/UNICEF JMP, 2012). Although the world has met the MDG drinking water target, 748 million mostly poor and marginalized people still lack access to an improved drinking water source. Of these, a quarter (173 million) relies on untreated surface water and over 90% live in rural areas (WHO/UNICEFJMP, 2014). The proportion of the population that used improved drinking water sources varies significantly by country and region (WHO/UNICEF JMP, 2014). Large geographic, socio-cultural and economic inequities in access persist and sometimes have increased. It is clear that sub-Saharan Africa is not on track to meet the MDG target with 40% of the total population in 2008 still lacking access to improved water sources as compared to 51% in 1990. Figure 1.1 shows the proportion of the word population that was using an improved water source in 2008. Sub-Saharan Africa faces the greatest challenge in increasing the use of improved drinking water sources.

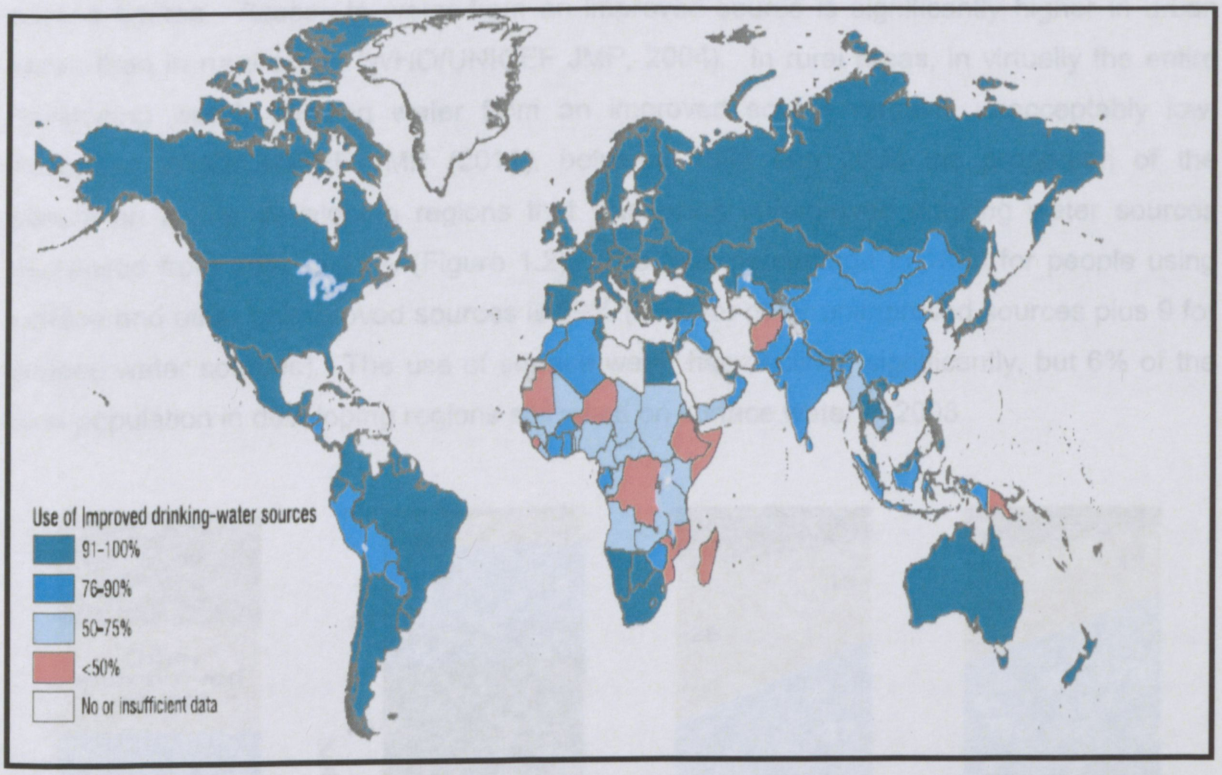


Figure 1.1: World populations using improved water sources in 2008 (WHO/UNICEF JMP, 2011)

Of the estimated 884 million people without access to improved sources of drinking water in 2008, 37% live in Sub-Saharan, 25% in Southern Asia, 17% in Eastern Asia and 9% in South Eastern Asia (WHO/UNICEF JMP, 2011). Between 1990 and 2012, 2.3 billion people gained access to an improved drinking water source raising the global target of 89% in 2012. There were only three countries namely Democratic Republic of Congo (DRC), Mozambique and Papua New Guinea where less than halve the population had access to an improved water source. However, huge disparities continue to exist as seen in the regional and in-country drinking water coverage variability. Africa still has the lowest total water supply coverage of any region in the world (WHO/UNICEF JMP, 2012). The same 2012 report states that currently about 300 million people in Africa do not have access to safe water and 313 million have no access to sanitation. Over 40% of all the people without access to safe drinking water live in Sub-Saharan Africa. Sub-Saharan Africa has its own disparities with Mauritius having water coverage of 99%, South Africa with 91%, Benin 75%, Uganda 72%, Sierra Leone 55%, Mozambique 47%, and amongst the lowest are Ethiopia and Somalia with 44% and 29%, respectively. This data clearly indicate that Sub-Saharan Africa is off track from meeting the MDG on water, with the current pace it cannot reach a 75% target set for the region (WHO/UNICEF JMP, 2012).

Apart from massive disparities among continents and countries, there are also massive disparities within countries, provinces and districts, with most rural areas having the lowest access figures. Access to water from an improved source is significantly higher in urban areas than in rural areas (WHO/UNICEF JMP, 2004). In rural areas, in virtually the entire developing world, drinking water from an improved source remains unacceptably low. According WHO/UNICEF JMP (2011), between 1990 and 2008 the proportion of the population in the developing regions that was using unimproved drinking water sources decreased from 29% to 16% (Figure 1.2). The total percentage in 1990 for people using surface and other unimproved sources is 29% (20% for other unimproved sources plus 9 for surface water sources). The use of surface water has declined significantly, but 6% of the rural population in developing regions still relied on surface water in 2008.

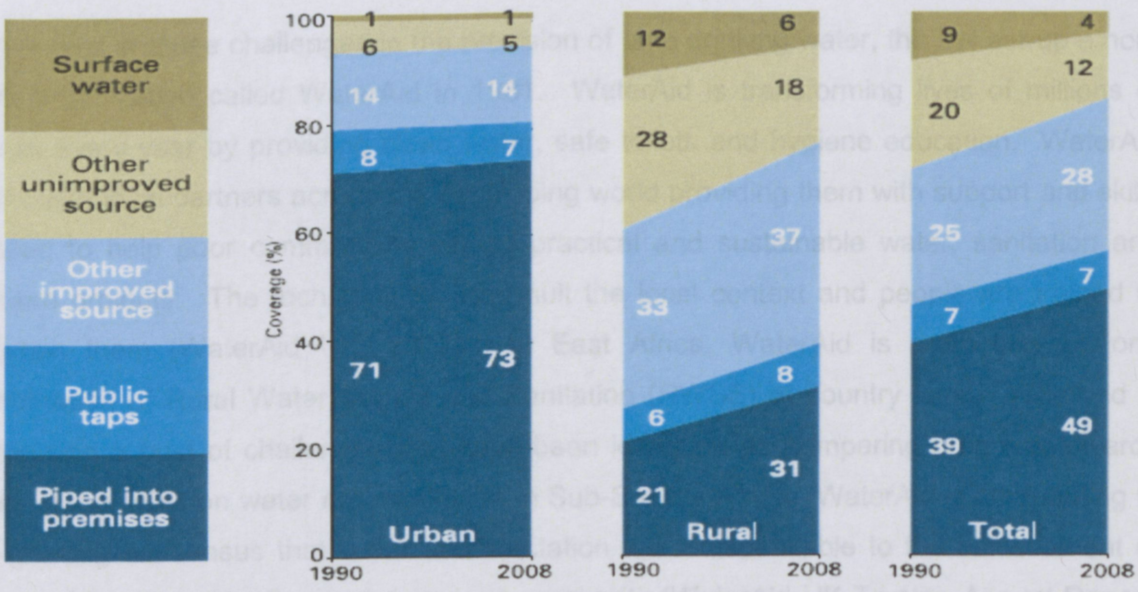


Figure 1.2 Proportion of the population using piped drinking water on premises, public taps, other improved Drinking water sources and unimproved sources or surface water, in developing regions between 1990 and 2008 (WHO/UNICEF JMP, 2011)

As of 2011, 16% of rural population still consumed water from unimproved or surface water sources which was a drop from 58% in 1990 (WHO/UNICEF JMP, 2013). For example, only one in ten in the poorest rural Sierra Leone has access to safe drinking water. In rural South Africa, the proportion of people with improved water supply was 40% in 1990 and 82% in

2009 (WHO, 2010). According to the WHO/UNICEF JMP (2012), 84% of the people without access to safe drinking water live in rural areas. According to WHO and UNICEF JMP (2011), despite the fact that the overwhelming majority (84%) of the global population without access to an improved drinking water source lives in rural areas, more people in urban areas gained access than did in rural areas (949 million compared to 728 million). It was estimated that with this pace it would take considerable time and effort to cover the remaining 726 million without access to an improved drinking water source, and to ensure continued access for those who have. With the exception of Western Europe where there is parity, in almost all countries of the world access to improved drinking water sources is less in relative terms in rural areas than in urban areas (WHO/UNICEF JMP, 2011). Although the gap between rural and urban has narrowed considerably since 1990, there are still significant disparities across many regions and countries. Of particular concern among those people without access to improved drinking water sources are those who rely on surface water sources such as rivers, dams, lakes, ponds and canals and most susceptible to pollution and most likely to have poor water quality (WHO/UNICEF JMP, 2011).

With a host of these challenges in the provision of safe drinking water, the UN set-up a non-profit organization called WaterAid in 1981. WaterAid is transforming lives of millions of people every year by providing clean water, safe toilets and hygiene education. WaterAid works with local partners across the developing world providing them with support and skills needed to help poor communities set up practical and sustainable water, sanitation and hygiene projects. The technologies used suit the local context and people are trained to maintain them (WaterAid UK, 2012). In East Africa, WaterAid is promoting sectoral coordination of Rural Water Supply and Sanitation (RWSS) at country level. WaterAid is addressing a host of challenges that have been identified as hampering progress towards meeting the MDG on water and sanitation in Sub-Sahara Africa. WaterAid is contributing to the growing consensus that water and sanitation are indispensable to the achievement of improved health, education and economic prosperity (WaterAid UK Trustee Annual Report, 2013). It is estimated that 5.6 million people have been reached with safe water between 2009 and 2010 since WaterAid kicked off its global strategy of reaching 25 million people with water and sanitation in the period 2009-2015 (WaterAid UK Trustee Annual Report, 2013). Through local partners, WaterAid reached 1.7 million people with safe water in 2012 and this has transformed lives in some of the poorest communities in the world (WaterAid UK Trustee Annual Report, 2013).

Water supply services in South Africa are generally developed in urban as opposed to rural areas (Dungumaro, 2007). According to Tissington et al. (2008), water services in most of these rural areas are still non-existent or poorly developed (rudimentary) and are being upgraded to basic water supply. The Reconstruction and Development Programme (RDP) of the current government (ANC, 1994) was formulated as a policy framework for development to redress the many inequalities that existed up to 1994, including access to safe water (Majuru, 2010). The framework ensued the White Paper on Water Supply and Sanitation Policy (Republic of South Africa [RSA], 1994) on which are based the benchmarks for basic water supply services prescribed in the Water Service Act (RSA, 2007, Majuru, 2010). Despite the policies and legislation on the supply of water services, many households were still without basic water supply services, partly because they could not afford the services (Muller, 2008, Majuru, 2010).

According to DWA (2001), the Free Basic Water Policy was formulated as a means to make water economically accessible for all. This is calculated as 25 litres per capita per day of free water (Majuru, 2010). According to DWA's 2008/2008 annual report, 88% of South African's total population now receives free basic water which shows a basic or higher water supply service with 79% of the rural areas being supplied in this fashion (Department of Environment Affairs and Tourism, 2008). Majuru (2010), stated that the remainder is divided between areas that have no water supply infrastructure existing and are still to be served, or the 'no service' areas and where rudimentary infrastructure exists but does not meet the requirements of a basic water supply service. The DWA (2009) estimates that 5% of the total South Africa's population still has no water supply services at all and the majority of these are rural people. In most rural areas of the Vhembe District Municipality (VDM), water boreholes are the main water sources in areas where treated water supply schemes do not exist (VDM, 2011). The boreholes can either provide a 'rudimentary service' where a drill-well (borehole) is fitted with a handpump and people have to walk distances to fetch the water (DWA,2000), or provide a 'basic service' where there is technology in the form of small community-level infrastructure, consisting of a small supply system based on on-site sourcing and storage technology (reservoir) with distribution of the potable water in pipes that terminate in communal taps (Majuru, 2010) According to the Infrastructure Development Plan (IDP, 2013) report, many boreholes are non-functional due to theft of pumps and other Electricity parts and vandalism.

1.3 Water Point Mapping

In 2007, WaterAid developed a monitoring tool for water and sanitation called Water Point Mapping (WPM). WPM helps to identify how many improved water points are available in an area (country, provincial, district or ward level) and highlights issues of service coverage, functionality of water points, and helps authorities identify where to channel resources (WaterAid UK, 2012). The inequalities that have been identified as existing in water and sanitation provision can be easily addressed because this tool pinpoints where there is a service and who does not have services. Hence, WPM reveals where needs are greatest and where resources must be channeled to improve levels of equity in the distribution of improved water supplies and sanitation. WPM is a tool that is used to collect data about functionality and status of improved rural water resources.

The presented data sets contain information on geographical position (location); type of water point, its management and who constructed it and when; whether payments are made for water; and whether or not the water point is functional (Jiménez and Pérez-Foguet, 2011). The data is entered into a Geographical Information System (GIS) and then correlated with official demographic, administrative and physical data (population density, administrative boundaries and roads). The information is displayed via digital maps. The strongest feature of these water point maps is that the distribution of water points within the district or municipality can now be clearly visualized and inequities are easily spotted. The WPM is therefore an objective tool that can allow for targeted planning of water scheme improvements (Jiménez and Pérez-Foguet, 2011). The WPM tool reveals where needs are greatest and where resources must be channelled to improve levels of equity in the distribution of improved water supplies. As such, it is a tool in the campaign to achieve the MDG of halving the proportion of people without access to safe water supply by 2015 (Jiménez and Pérez-Foguet, 2011). For the case of Water Point Mapping, the broad political context is defined by the MDGs, the Poverty Reduction strategy (PRS) process, as well as wider processes of sector reform and decentralization for South Africa. The immediate relevant context of mapping is determined by the impact of reform processes at local level, in particular the evolving and existing arrangements with regard to sector planning, resources allocation and monitoring (MacDonald et al, 2009).

MacDonald et al (2009), has identified the following broad challenges as having some impact on the delivery of Water and Sanitation Services:

i) Better planning is needed and this requires realistic data that targets and includes poor people. There is the need for awareness that the current coverage data are far from comprehensive or accurate,
ii) More effective financing and co-ordination of all parties is vital. Policy decision by authorities needs to be guided by evidence on where and how to allocate resources effectively, equitably and efficiently. In reality, decision making is limited by

substantial information gaps and existing evidence does not often enter the political realm because it is pushed aside by other, more powerful agendas. As a result, decision-making is not transparent and often leads to unequal outcomes.

The use of WPM in this study will assist with the monitoring of the distribution and status of Municipal borehole water points in the Thulamela Local Municipality and hence help to inform planning processed and can be a basis for decision making. For example, WPM can be used to support monitoring of seasonal water availability levels, which may become more important if climate variability and population density increases in certain geographical areas in the municipality. It is important to note that WPM is a tool that can introduce greater transparency and efficiency into the allocation of resources. Information is made accessible to policy officials, citizens or pressure groups (MacDonald et al, 2009). This can help stakeholders to point out issues and demand improvements in services and have the potential to improve accountability in service provision. WPM information shows results of investments made so far towards water supply and can therefore help to track performance of investments in the water sector thus highlighting issues beyond narrow-based monitoring such as equity and sustainability of services (MacDonald et al, 2009).

The strength of the Water Point maps that are generated using the data collected using WPM is that they will provide a clear message on who is and who is not served, and particularly in rural areas, it can be used to highlight equity issues and schemes functionality levels below the district level. The national government of South Africa's transfer of the responsibility of water and sanitation services management and resources allocation to local municipalities requires adequate performance monitoring frameworks backed by accurate and reliable data at local level.

1.4 Significance of the study

According to the WHO, South Africa's progress towards the MDG drinking water and sanitation target is on track. Access to an improved water source is at 91% and sanitation is at 76% (WHO/UNICEF JMP, 2010). However, these national figures tend to mask huge inequalities that persist between rural and urban populations. The pace of service delivery in rural areas has slowed down and there are concerns relating to the functionality and sustainability of rural water supply services. There still exist problems concerning financial sustainability of service providers, which leads to a lack of maintenance programmes. The MDG water target is defined in terms of "sustainable" access to safe drinking water, therefore sustainability, and resilience of water sources need to be assessed (WHO/UNICEF JMP, 2011). Non-operating, and intermittent or unreliable supplies place an increased burden on the populations they are designed to serve, lead to household water storage in often unhygienic conditions and as a consequence increase health risks (WHO/UNICEF JMP, 2011). According to the Water and Sanitation Programme (WSP, 2011) there are three main areas of backlog in South Africa's rural water supply and sanitation (RWSS) that are hard to reach and these include:

(i) Water supply in deep rural areas

(ii) Rural sanitation, and

(iii) Sanitation in informal settlements.

The sustainability of improved drinking water services is often compromised by a lack of technical skills, equipment or spare parts for operation and maintenance, and a lack of sustained financing mechanisms for recurrent costs (WHO/UNICEFJMP, 2011). There is evidence that service delivery in these areas has slowed down and where infrastructure exists, not all poor households experience the benefits of this infrastructure owing to a large number of poorly functioning systems in rural areas (WSP, 2011). A big challenge is looming on sustainability of both the new infrastructure (built in favor of extending services) and the old. Many poor and rural households (PRH) still continue to have difficulties with accessing sufficient volumes of potable water because of unavailability of basic services as well as poor maintenance and operation in areas with a service (Rietveldt et al, 2009). The safety of water from improved sources in rural areas is now doubtful because of the lack of maintenance. Most of the people in rural South Africa are still getting their water from outside sources, from where they then transport it into the households. Most of the available water systems in rural areas are not reliable, thus leaving the communities without water for weeks and months. Communities are usually left with no option except to go back to the unprotected water sources, which causes outbreaks of diseases (Rietveldt et al, 2009).

The challenges haunting the South African RWSS services indicate that the WPM tool would be an adequate tool to assess the country's progress towards meeting the MDG on water and sanitation. This tool has never been used before in South Africa for the purpose of addressing problems in the rural water supply service. The purpose of this study is to use the WPM as a tool to assess improved water resources in the Thulamela Local Municipality (TCLM) of the Vhembe District to give an objective insight into levels of improved water point coverage, equity of distribution, and functionality and water point characteristics. The definition of an improved water source should not only be generalized to technology because community taps or hand pumps can become risky if aspects of sanitation are not properly observed. The safety of most rural water sources therefore needs to be assessed if the full benefits of an improved water source are to be enjoyed.

The WPM will also incorporate water quality assessment and will inform authorities in the Thulamela Local Municipality, Vhembe District Municipality, Provincial Government and the National Government on the status of improved water supply in Thulamela Local Municipality so that they can intervene accordingly where there is a need to do so. If information is made accessible to policy officials, citizens or other stakeholders, WPM can help them to point out issues and then steps can be taken to improve the performance of rural water sector and in doing so providing dignity and health for many South Africans in rural communities.

1.5 Outcomes and expected impacts of this study

a) Society

The introduction of WPM in the assessment of water supply coverage in rural communities promotes equity and non-discrimination by assisting the Municipality to take informed decisions on drinking water supplies in rural communities and to rectify any challenges that could be found relating to allocation of water points and water safety. When water is scarce and risky to use, the community will be alerted and intervention measures will be taken by authorities. The action that will be taken by the community will save them from diseases related to water and will assist in reaching the MDG on water and sanitation for South Africa.

b) Economy

The mismanagement of water infrastructure and poor quality fails the government in terms of investment on water supply and compels communities to use unprotected water supplies/sources. Most infrastructures break down because of lack of skills and knowledge on how to use them. The data from the WPM tool could be used to prevent breakdowns of boreholes, fixing the infrastructure and maintaining by water authorities.

1.6 Aims and Objectives

1.6.1 Primary Objective

The main goal of this research is to use WPM as a tool to assess improved water resources in rural communities.

1.6.2 Specific Objectives

- To record and assess distribution of improved water points (Municipal drinking water boreholes) in three wards in the Thulamela Local Municipality (TLM), using a global positioning system (GPS) unit,
- To determine the microbiological and physico-chemical quality of all Functional improved water points,

- To assess the aesthetic parameters that cause rejection of water (notably taste, colour and odour) using published reference tables (Water Assessment Guideline),
- To develop digital maps using collected data from the GPS and correlate it with the demographic, administrative and physical data to show Municipal drinking water borehole coverage and level of service.

Chapter 2

Literature review

2.1 General Background

According to the UN (2010), progress on the MDG number seven (7) target, to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 is currently on track. Yet rural areas in developing countries across the world remain severely disadvantaged, with eight out of ten people having no access to an "improved" water supply (UN, 2010). Only 47% of the rural population of Sub-Saharan Africa has access to an improved water source (UN, 2010). The same report indicates that achieving the MDG goals in Sub-Saharan Africa is still a major challenge as this goal is predicted to be achievable by at least half of the countries in Africa. The WHO/UNICEF JMP (2012) reported that most poor and rural areas do not have access to potable water, are still relying on unprotected sources and travel long distances to get water for domestic chores.

The majority of rural areas make use of groundwater worldwide and that 1 out of 3 pumps installed in rural areas of Africa is not working, which have greatly reduced the supply efficiency volume of water in public (RWSN,2009). The use of boreholes and tubewells has increased in both rural and urban areas. In rural Sub-Saharan Africa, 32% of people who use an improved drinking water source rely on boreholes or tubewells, most of which are equipped with handpumps and in most cases such water points are managed by the communities they serve. Across Sub-Saharan Africa, an average of 36% handpumps is non-operational at any given time and in some countries it is estimated that more than 60% of handpumps are non-functional (RWSN, 2008). The reasons for such low levels of rural water supply sustainability are multifaceted and include demand, lack of affordability or acceptability among communities, limited sustainability of community management structures , inadequate supply chains for equipment and spare parts, insufficient government support, and environmental issues (Harvey, 2008). Increased loss of functioning infrastructure as a result of climate change is inevitable and would set back progress in drinking water supply and indirectly towards other MDG targets (RWSN, 2009). Inadequate operation and maintenance cause frequent failures and contamination.

A more recent compilation of data showed that 30-40% of handpumps in Africa are not working at any given time (RWSN, 2010). In a similar vein, Improve International, a Non Governmental Organization (NGO), maintains a list of links to studies on water system failure with examples from around the world all showing similar rates of failure (Improve International, 2012). According to Butterworth et al (2013), there was 21% non-functional handpumps in the study in Ethiopia. Taking the example of Ghana case (one of three in a report), of all the boreholes with handpump systems visited in 200 villages not only were 11-12% completely non-functional, but 57-58% had broken down in the past six months (Komives et al., 2008, Moriarty et al., 2013). There is therefore a general consensus that non-functioning of rural supplies is a problem (Majuru, 2010).

2.2 Health implications of poor access to safe drinking water

The WHO (2007) reports that diarrhea kills about 1.8 million people per annum, most of them are children, and that about 4 billion cases are reported worldwide of which 88% is attributed from unsafe drinking water. Approximately 93% of disease outbreaks, such as cholera, are reported from Africa, frequently due to poor access of safe water (WHO, 2010). According to the Council for Scientific and Industrial Research (CSIR, 2009) in South Africa, diarrhea is the third biggest killer and cholera outbreaks are one of the most common threats that usually happen in most parts of rural areas. The emergence of communicable disease outbreaks related to water in most parts of South Africa's rural areas, remains a major challenge even though there is a vast improvement of infrastructure dedicated to accessing safe drinking water to these communities. Consequently, some of these outbreaks caught some of the authorities unprepared. There is no universal method that is currently used to detect the risks of an area without acceptable volumes of water rather than the standard set by the government.

i) Microbiological quality of water

This parameter refers to the presence of micro-organisms such as protozoa, bacteria and viruses. Many of these microbes are associated with the transmission of infectious waterborne diseases such as gastro-enteritis and cholera (WHO, 2004). According to Figuera and Borreso (2010), the evaluation of the microbiological quality of drinking water aims to protect consumers from illness due to consumption of water that may contain pathogens such as bacteria, viruses and protozoa, and thus to prevent drinking-water related illness outbreaks. Since it is difficult to detect these pathogens, it is common practice to use microbiological indicators as the indication of recent faecal contamination and the potential risk of infectious diseases from water (WHO, 2004). Faecal and total coliforms are commonly used as indicators to determine the microbiological quality of domestic water supplies. The most important contamination from public health perspective is faecal pathogens namely total coliforms and *E coli* (WHO, 2004). Studies were conducted in Tshitale-Hlanganani the Vhembe district of the Limpopo Province of South Africa using *E. coli* as an indicator for microbiological quality of water which indicated high contamination levels in borehole water (Potgieter et al. 2006). The number of coliforms detected in borehole water indicates that the microbiological quality of the water sources used was poor, unsafe and not acceptable for human consumption. The microbial quality of the water sources exceeded the maximum safety limit for drinking water as stipulated by the water quality guidelines (Obi *et al*. 2002). Gundry et al. (2009) also conducted a similar study in the Vhembe District where water quality tests showed that in "improved" groundwater, *E. coli* counts were less than 10 cfu/100ml in 90% of the cases.

ii) Physical quality of water

This refers to water quality properties that may be determined by physical methods such as conductivity, pH and turbidity and total dissolved salts (TDS) measurements (WHO, 2004). The physical quality mainly affects the aesthetic quality, taste, odour and appearance of water. Electrical conductivity (EC) is a measure of the ease with which water conducts electricity (DWAF, 2004). The EC of water indicates what the dissolved salts (TDS) content of water is. The EC measurement in mS/m can be used to estimate the TDS in mg/l by multiplying the EC by the factor 6.5 (DWAF, 2004). Electrical conductivity/ total dissolved salts affect the taste and freshness of the water and therefore indicate whether the water is fresh or salty. EC values above 370mS/m cause adverse effects on infants as it disturbs the salt and water balance (DWAF, 2004). People with heart diseases, high blood pressure and renal disease are also adversely affected by EC values >370ml/l (DWAF, 2004). The pH refers the degree of acidity or alkalinity of water. The pH is an indicator of whether water is sour (pH<7) or soapy (pH>7) to the taste (DWAF, 2004). The direct effects of extreme pH include irritation of mucous membranes. The indirect effects include corrosion of utensils and water pipes as a result of acidic pH values (DWAF, 2004).

iii) Chemical quality of water

This parameter refers to the nature and concentration of dissolved substances such salts, metals and organic chemicals (WHO, 2004). Many chemicals in water are essential as part of the daily intake required, but at high concentrations they make water unpalatable and cause illnesses.

In studies done by Esrey et al. (1991), Gundry et al. (2004) and Fewtrell et al. (2005), child dysentery and watery diarrhea are noted as resulting from a complex interaction of water quality, household sanitation and hygiene. In a study by Gundry et al. (2009) the incidence of child dysentery in Vhembe District was higher than the national average (224.3 per 1000 compared with the national average of 133.4 per 1000). The district has below average access to "improved" water supplies and sanitation (59% compared to 93% average in the country). Water quality testing showed that, for 'improved" water, sources such as stand pipes (community taps) and "improved" groundwater, *Escherichia coli* (*E. coli*) counts were less than 10 cfu/100ml in 90% of the cases. In unimproved water sources, *E. coli* counts were less than 10cfu/100ml in 26% of cases (Gundry et al, 2009).

New systematic review of literature commissioned by JMP, estimated that 1.8 people globally use a source of drinking water that is faecally contaminated. According to WHO/UNICEF JMP (2014) of these 1.1 billion people drink water that is at least "moderate" risk (>10 cfu/100ml sample). Data from nationally randomized studies suggest that 10% of improved drinking water sources may be "high" risk containing at least 100 cfu per 100ml sample (WHO/UNICEF JMP, 2014). The limit set by the South African national guideline for water quality for Total coliform is 0-5 cfu /100ml (DWAF, 2004). The principal health and development priority for drinking water is universal access to an improved source and preferably to piped water at home. However, with large populations it is not feasible hence community water points will remain in the foreseeable future (RWSN, 2008).

2.3 South Africa's water access levels

Access to clean potable water and basic sanitation is an indicator for human development. According to the UN standards, access to safe drinking water is measured by the proportion of the population with access to an adequate amount of safe drinking water located within a convenient distance from the user's dwelling (WHO/UNICEF JMP, 2008). At is 15th session in September 2010, the UN Human Rights Council, in its Resolution A/HRC/RES/15/9, affirmed that the right to water and sanitation is derived from the right to adequate standard of living and inextricably related to the right to the highest attainable standard of physical and mental health, and the right to life and human dignity. The enjoyment of the right is assessed based on availability, safety (with reference to WHO drinking Water Quality Guidelines), accessibility, acceptability, affordability, participation, non-discrimination and accountability (WHO/UNICEF JMP, 2011). South Africa is one of the few countries in the world that enshrines the basic right to sufficient water in its constitution (WHO/UNICEFJMP, 2010). However, much remains to be done to fulfill that right. The proportion of the population with access to "improved" water sources was 91% in 2010 from 83% in 1990 (WHO/UNICEF JMP, 2010). In 2004, the government promised that all households would have running water within five years (WHO/UNICEF JMP, 2010). Despite substantial progress this goal has not been fully achieved. WHO's JMP (WHO, 2010) reported that women in rural areas spend up to one third of their time fetching water from streams and wells. This water was used for cooking, washing, laundry and bathing children.

Presently, 90% of the population lives in rural areas and do not have access to potable water (VDM, 2011). The National target is to achieve at least a basic level of water and sanitation service for all by 2014 (IDP, 2013). Despite the fact that many households have access to water, upgrading, resource extension, operation and maintenance as well as refurbishment needs are immense. Infrastructure upgrading and refurbishment were identified as the major problem and sighted were the Tshifudi ground water upgrading, Vondo Water Works refurbishment (filters), Malamulele Water Works refurbishment Lagoon/filters, upgrading of bulk pipeline to Mtititi/Halahala/Altein and surrounding villages. However, funding for implementation of these projects was sighted as the major challenge and all are in Thulamela Local Municipality (IDP, 2013).

In the Limpopo Province of South Africa, the Vhembe District Municipality (VDM) is one of the water service authorities and as from the 2012/2013 financial year, the VDM is a water service provider. The Department of Water Affairs is responsible for all dams (IDP, 2013/2014). Vhembe District Municipality has twelve water supply systems which include Makhado (Louis Trichardt), Malamulele, Mutale, Musekwa, Mutshedzi, Tshifire, Musina, Thohoyandou, Elim, Kutama, Tshedza and Nzhelele. (van der Westhuizen, 2012). It is reported that water in the first six above- mentioned water supply schemes is of excellent quality and safe to drink. Water in Musina, Thohoyandou, Elim, Kutama and Tshedza is generally safe to drink but with some recorded microbial failure (van der Westhuizen, 2012). The district purchases raw water from the Department of Water Affairs, then process or clean for reticulation (IDP, 2013). The goal of Vhembe District Municipality Water Service Authority (WSA) is to supply every household with an adequate and reliable water supply and to manage the water supply service in an affordable, equitable and sustainable manner.

In 2008, the Department of Water Affairs (DWA) introduced the "Blue-Drop" incentive-based quality regulatory strategy. Under this strategy, Municipal service providers are certified with a "Blue-drop" if they fulfill certain requirements (WHO/UNICEF JMP, 2010). The standard does not only include compliance with water quality standards, but also the existence of a Water Safety Plan (WSP), process controlling and credibility of sample results and others. This is regarded internationally as unique in the drinking water regulatory domain and has been received quite well by the WHO.

According to the Blue-drop certification Programme (van der Westhuizen, 2012), Nzhelele water did not comply with the expected standards. The overall national blue-drop assessment score improved from 72.9% in 2011 to 87.6% in 2012 (van der Westhuizen, 2012). The Limpopo Province is on fifth position out of the nine provinces with 79.4% having improved from the 2009 54% rate. The Vhembe District Municipality is fourth in the province with 74.85% and in position 67 on the national log (van der Westhuizen, 2012). In 2011, the Vhembe District Municipality scored 45.87% and was rated number 101 nationally. Malamulele, Mutale, Musina, Mutshedzi, Tshifhile and Makhado water supply schemes in the Vhembe District all scored above 70% in the 2012 BDCP (van der Westhuizen, 2012). However, Musekwa, Tshedza and Elim scored 58.37%, 67.97% and 53.79% respectively (van der Westhuizen, 2012). Kutama and Nzhelele water schemes had the lowest scores of 46.40% and 44.08% respectively (van der Westhuizen, 2012).

Observers from the private sector state that a "strong spin element" surrounds the programme and that water quality is actually deteriorating nationally (WHO/UNICEF JMP, 2010). It is noted that in 2009, 23 water supply systems obtained the 'Blue-drop' certification but in 2010, 9 of them lost it, and in 2009 only 38 water systems received the "Blue-drop" certification which is less than 5% out of the 787 systems that were assessed in the country (DWA, 2009).

Stakeholders in the Public Water and Sanitation in South Africa include the national government, represented by DWA, water boards which provide bulk water, but also some retail services and operate some wastewater treatment plants, and Municipalities, which provide most retail services and also own some of the bulk supply infrastructure (DWA, 2009). In South Africa, 231 municipalities are in charge of water distribution and sanitation, either directly or indirectly through municipality owned enterprises or private companies. There are 52 District municipalities and 231 Local municipalities in the country (DWA, 2009). In 1996, the constitution strengthened the autonomy of municipalities and as a result, the responsibility for rural water supply and sanitation has been transferred from national government to municipalities.

The Vhembe District has four local municipalities which include Makhado, Musina, Mutale and Thulamela. Water schemes that are currently in place in Vhembe District Municipality are old and were intended to serve a smaller population (Gaffney, 2009). The low population density in rural areas makes it extremely difficult and costly to improve levels of service delivery. According to Gaffney (2009), the Vhembe District has the lowest access to infrastructure amongst all the Districts in the province. A State of Local Government Assessment found that there is a lack of provision of water, sanitation and better roads in the district (Gaffney, 2009). In terms of the Municipal Turn-Around Strategy, the District identified access to water and sanitation as still a huge priority in the district. Two out of the four Local Municipalities in Vhembe District have been classified as in the category of most vulnerable by the Department of Co-operative Governance (DCOG) in terms of functionality, socio-economic profile and backlog status (Gaffney, 2009). This profile confirms that infrastructure in the Vhembe District should be focused on access to clean water and sanitation.

Numerous potential sources of water have been identified, and it is hoped that this will contribute to a reduction of the backlog in water provision. Access to piped water above the Reconstruction and Development Programme (RDP) level slightly increased from 58% in 1996 to 60% in 2009 (VDM, 2011). According to the same report, there has also been an increase in piped water below RDP level and more than 30% of the households are now getting this service. It is estimated that out of 129 000 households, only 79 590 have access to basic water (VDM, 2011).

The following weirs existed in Thulamela Local Municipality: Malamulele East constructed in 1973, Mphambo constructed in 1995, Musaswau constructed in 1985 and Xikundu constructed in 1937. There is reduction in water storage at Mphambo and Malamulele is small and silting (IDP, 2013/2014). Xikundu or Mhinga weirs are affected by small scale farmers and the effluent of Mhinga ponds is discharged into the river before the weir. The Thulamela Local Municipality is threatened by theft and vandalism of water infrastructure and illegal connections of water. Between 2001 and 2010, the population of Thulamela Local Municipality increased tremendously with an estimated growth of 21 990 (Stats SA, 2007). This growth resulted in an increase in demand for services. According to Statistics South Africa (Stats SA, 2010) the water service backlog is at 36 375 households and this has led to a host of challenges amongst which is inadequate water supply, lack of consistent flow from water taps and lack of adequate infrastructure. The sanitation backlog is at 39 995 households according to the same report and there are no sewer systems in rural areas. Households use pit toilets that lack ventilation and there is high risk of health hazards owing to an absence of proper sanitation, which may lead to underground water contamination. Most of the water infrastructure is ageing and there is lack of preventive and routine maintenance which culminates in quite a number of challenges in as far as meeting the MDG on water and sanitation is concerned.

In rural areas, many households change water sources seasonally. Common communal water sources cited by Gundry et al (2009) include:

i) standpipes (where water has been piped from a source remote from the village);
ii) improved groundwater (protected wells and boreholes);
iii) unimproved groundwater (well and spring); and
iv) surface waters (rivers, canals, stream and dams)

The Millennium Development Goals have set us on a common course to push back poverty, inequality, hunger and illness. The world has pledged to reduce by half the proportion of people living without sustainable access to safe drinking water and basic sanitation by the year 2015. Although great strides have been made in meeting this goal, the safety of many water supplies remains unknown and uncertain (WHO/UNICEF JMP, 2012). Another challenge to meet the MDG goal 7 on water and sanitation is the rapid pace of urbanization which requires a major effort by authorities to keep-up the current coverage level in areas with the service, and in addition to this there is a huge backlog of rural people not served with basic safe potable water and basic sanitation, which calls for an intensive mobilization of resources to reduce the vast gap between urban and rural population (WHO/UNICEF JMP, 2011). Rural areas still lag far behind urban areas on drinking water coverage from improved sources (WHO/UNICEF JMP, 2006). Within rural areas, remote difficult-to-reach areas, such as those far from roads may have markedly lower access to improved water compared with populations that are easier to reach (WHO/UNICEF JMP, 2014).

More intensive, effective and concerted action by all stakeholders is needed if the MDG on drinking water and sanitation target is to be met in South Africa. Even when improved drinking water sources are accessible, huge efforts are still needed to improve access to the services. A household connection drawing water from a public distribution system will stimulate greater use of water for hygiene purposes and even yield the greatest health benefits (WHO/UNICEF JMP, 2006). RWSN is advocating for universal access to safe drinking water by 2030 as part of its strategy for 2015-2017. Its vision is to promote sustainable and reliable rural water supplies which can be effectively managed to provide sufficient, affordable and safe water within a reasonable distance of the home (RWSN, 2014). The Joint Monitoring Programme (JMP) managed by WHO and UNICEF is a UN mechanism for monitoring MDG 7 target 10. The JMP aims to inform policy-makers and the civil society on trends and progress in water supply and sanitation through dissemination of annual reports. The NGO WaterAid has been working with various countries in Africa with similar situations to that of South Africa. Its aim is to ensure provision of sustainable water and sanitation services in rural areas. WaterAid introduced the WPM tool which is used to determine water and sanitation coverage and then highlight the issues of equity and functionality of water and sanitation systems in an area in order to enhance service delivery (WaterAid Tanzania, 2009).

2.4 Water Point Mapping (WPM)

In 2004, a WPM was carried out in Tanzania to support planning for equitable and sustainable water supply service provision at local government level (Welle, 2005). Many water pumps which were built across the country were broken down and no longer functional. Instead of building new water points, WaterAid and other Non-governmental Organizations (NGOs) focused on repairing the existing ones. With the use of the WPM tool, 55 of the 132 districts in the country were mapped and it was found that 43% of the water points were no longer working and that 25% of the water schemes had become non-functional within two years of construction, as noted in a report by a Netherlands Development Organization (SNV, 2012). The evidence from this WPM was used by WaterAid to feed into discussions at national sector review meetings, especially during the 2008 and 2009 equity reports about Tanzania Water and Sanitation Network (TAWASANET) to which WaterAid managed to provide very substantial inputs (Welle, 2005). By 2008, WaterAid had managed to have rural WPM accepted as a useful monitoring tool with other NGOs and development partners and most importantly with the Ministry of Water and Irrigation (MOWI).

The mapping of Improved Community Water Points (ICWP) in Malawi started in 2002 in the Salima District. There was an inherent problem of lack of information related to the distribution of water points in this District. There was also an apparent duplication of work which prompted WaterAid to carry out a survey in the district as part of their support to the District Coordination Team (DCT). After the intervention by WaterAid's WPM tool, the DCT reported that before water point maps became available in the district, Councilors, and local Chiefs used to quarrel between themselves about the allocation of water points (Welle, 2005). WPM has reportedly had an impact on the allocation of water points (WPs) within and between districts in Malawi. It was very difficult for the DCT to have an impact on decisions concerning the distribution of water points due to a lack of information (Welle, 2005). Welle (2005) indicated that the DCT had printed maps to support their recommendations for the allocation of future investments and as a result their voice gained importance and counter arguments from politicians have faded away slowly. On a positive note, the planning process in Salima became more transparent and Councilors have now started to actively support the mapping projects.

In one case, the Government of Malawi in 2003/4 had to withdraw a project proposal that was given to the Japanese International Cooperation Agency (JICA) by the Ministry of Water Development requesting a large scale rural water supply project in Mzimba District (Welle, 2005). The withdrawal was based on the mapping results showing that this district was comparatively well covered on a national comparison. As a result, the JICA rejected the Ministry's proposal and requested that another proposal be submitted focusing on Lilongwe West, where ICWP mapping had shown an overall coverage rate as low as 4% (Welle, 2005). In Salima and Dowa Districts, District Assemblies reported that they changed financial allocations for water projects from equal allocation to all Traditional Authorities (TAs) to a specific targeting of underserviced areas basing on WPM information. Overall, the use of the WP maps significantly improved district-level cooperation on WP allocation between different stakeholders (Welle, 2005). The DCT also targeted the identified non-functional WPs and was able to rehabilitate most of those facilities. It is clear from these examples that the WPM tool gives the green light to projects relating to rural water supply. According to Welle (2005), Huong Le, a senior SNV WASH advisor indicated that "water point mapping has a potential as an effective monitoring and management tool for planning and decision making. It can really help us persuade the government to focus more on maintenance and training instead of only investing in new infrastructure" (Welle, 2005). Most countries fail to sustain WASH commitments, with 80% of the countries reportedly falling significantly behind the trend required to meet their defined national access targets for drinking water and sanitation.

South Africa has a mix of developed and under developed regions, and about 3.5 million people are without access to water supply, and an additional 5.4 million people have some access that still has to be brought up to minimum standard requirements (Mutamba, 2014). Notably, most of the water supply backlogs are also in rural areas (Mutamba, 2014). Based on the Water Service Authority (WSA), the South African government established regulations defining the "basic water service supply standard" as: "minimum quantity of potable water of 25 litres per person per day or 6 kilolitres of water per household per month, at a minimum flow rate of not less than 10 l/minute within 200 metres of a household, and with effectiveness such that no consumer is without water supply for more than seven full days in any year" (DWA, 2012). In 1994, only 59% of South Africans had access to basic safe and clean drinking water, with the larger proportion of the backlog (3.9 million households) living in the poor rural former homeland areas (DWA, 2012). However, access to an improved water source was 88% in 2008 and 94% in 2012 (DWA, 2012).

The remaining backlog of 6% translates to 700 000 households and is equivalent to about 3.5 million people, who, unfortunately, are mostly rural households (DWA, 2012). It is important to note that South Africa's milestone of reducing massive backlogs of people without access to safe drinking water is being achieved in environments full of huge and, often, insurmountable challenges and more particularly so in rural settings. Some of the challenges encountered include: general water scarcity; continued deterioration of source water quality; complex stakeholder requirements; limited funding resources; as well as poor, and, at times non-existent, operation and maintenance. All these challenges lead to a general lack of access to water. At village level, a lack of access to water results in poor agricultural production; food insecurity and poor livelihoods; village 'water wars' characterized by service delivery protests; and conflicts among community members over competing priorities for water (Narayan, 1993).

Despite the numerous challenges and severe implications associated with lack of access to water in rural communities, there are a number of workable options to improve rural water supplies. The Water Point Mapping tool can be helpful in this scenario to solve these inherent problems in South Africa's rural water supply. WPM can highlight issues of service coverage, functionality of water points, maintenance and operational issues, and can help authorities identify where to channel resources (WaterAid UK, 2012). The inequalities that have been identified as existing in water provision can be easily addressed because this tool pinpoints where there is a service and who does not have services. Hence, WPM reveals where needs are greatest and where resources must be channeled to improve levels of equity in the distribution of improved water supplies in the South African rural communities.

2.5 Summary of literature review

According to the UN (2010), progress on the MDG number seven (7) target, to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 is currently on track. Yet rural areas in developing countries across the world remain severely disadvantaged, with eight out of ten people having no access to an "improved" water supply (UN, 2010). Most poor and rural areas do not have access to potable water, are still relying on unprotected sources and travel long distances to get water for domestic chores (WHO/UNICEF JMP, 2012). Across Sub-Saharan Africa, an average of 36% handpumps is non-operational at any given time and in some countries it is estimated that more than 60% of handpumps are non-functional (RWSN, 2008). Inadequate operation and maintenance cause frequent failures and contamination. The emergence of communicable disease outbreaks related to water in most parts of South Africa's rural areas, remains a major challenge even though there is a vast improvement of infrastructure dedicated to accessing safe drinking water to these communities. Presently, 90% of the population lives in rural areas and do not have access to potable water (VDM, 2011). However, WaterAid introduced the WPM tool which is used to determine water and sanitation coverage and then highlight the issues of, equity in allocation and functionality of water points and sanitation systems in an area in order to enhance service delivery

(WaterAid Tanzania, 2009). The Water Point Mapping tool can be helpful in this scenario to solve these inherent problems in South Africa's rural water supply systems. WPM can highlight issues of service coverage, functionality of water points, maintenance and operational issues, and can help authorities identify where to channel resources (WaterAid UK, 2012). This study uses WPM in rural communities of South Africa to see if it can highlight issues of access to safe borehole water because boreholes are one of the main sources of safe drinking water in most of South Africa's rural communities (VDM, 2011), equity of distribution of boreholes, rural water supply systems functionality and the quality of the water that people are being served with from these boreholes.

Chapter 3
Methodology

3.1 The study area

The study was conducted in the Limpopo Province of South Africa and focused specifically on wards 15, 18 and 19 in the Thulamela Local Municipality in the Vhembe District Municipality. Thulamela Local Municipality (TLM) is a category B municipality (a municipality that serves as the third, and most local, tier of local government), and is one of the four municipalities comprising the Vhembe District Municipality (Figure 3.1).

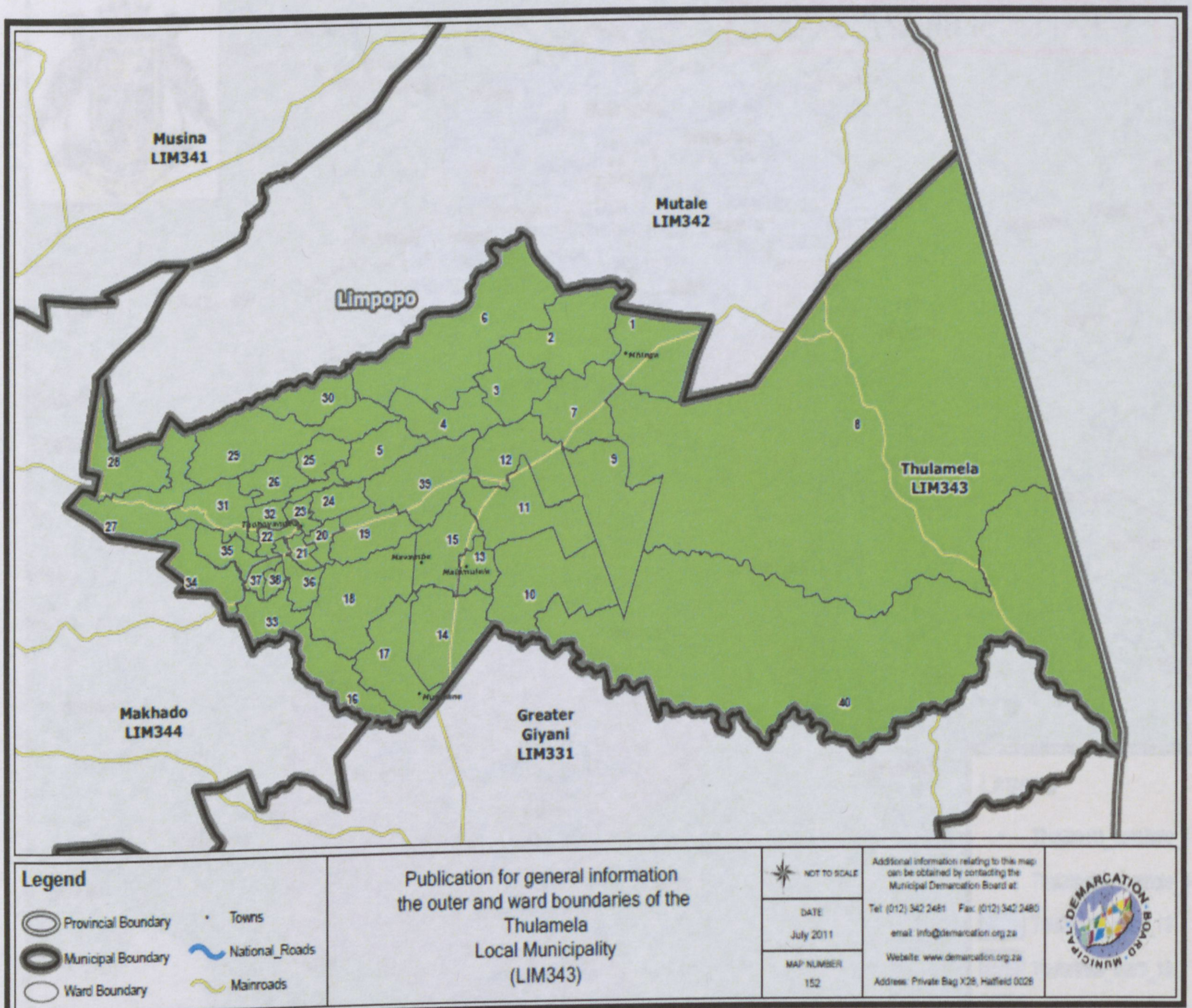


Figure 3.1: The outer and ward boundaries of the Thulamela Local Municipality

The Kruger National Park and Greater Giyani Municipality from Mopane district form the boundary in the east while sharing border with Mutale Local Municipality in the north-east and Makhado Local Municipality in the south and south-west. It is the largest local municipality in the Limpopo Province, with a population of 618 462 people and a population density of 110 people per square kilometer with 40 wards (StatSA, 2012). Thulamela Local Municipality covers vast tracks of land which are mainly tribal, and Thohoyandou is its political, administrative and commercial centre. The Municipality's main resources are in agriculture, agricultural processing, tourism and mining. It extends over 5 835km^2 according to the Integrated Development Plan (IDP, 2013) (Figure 3.1). Wards 18 and 19 are situated in the south-western parts of the TLM (Figure 3.2). The three wards cover a total surface area of 75.48 square kilometers with a total of 21 villages that have 48 448 inhabitants.

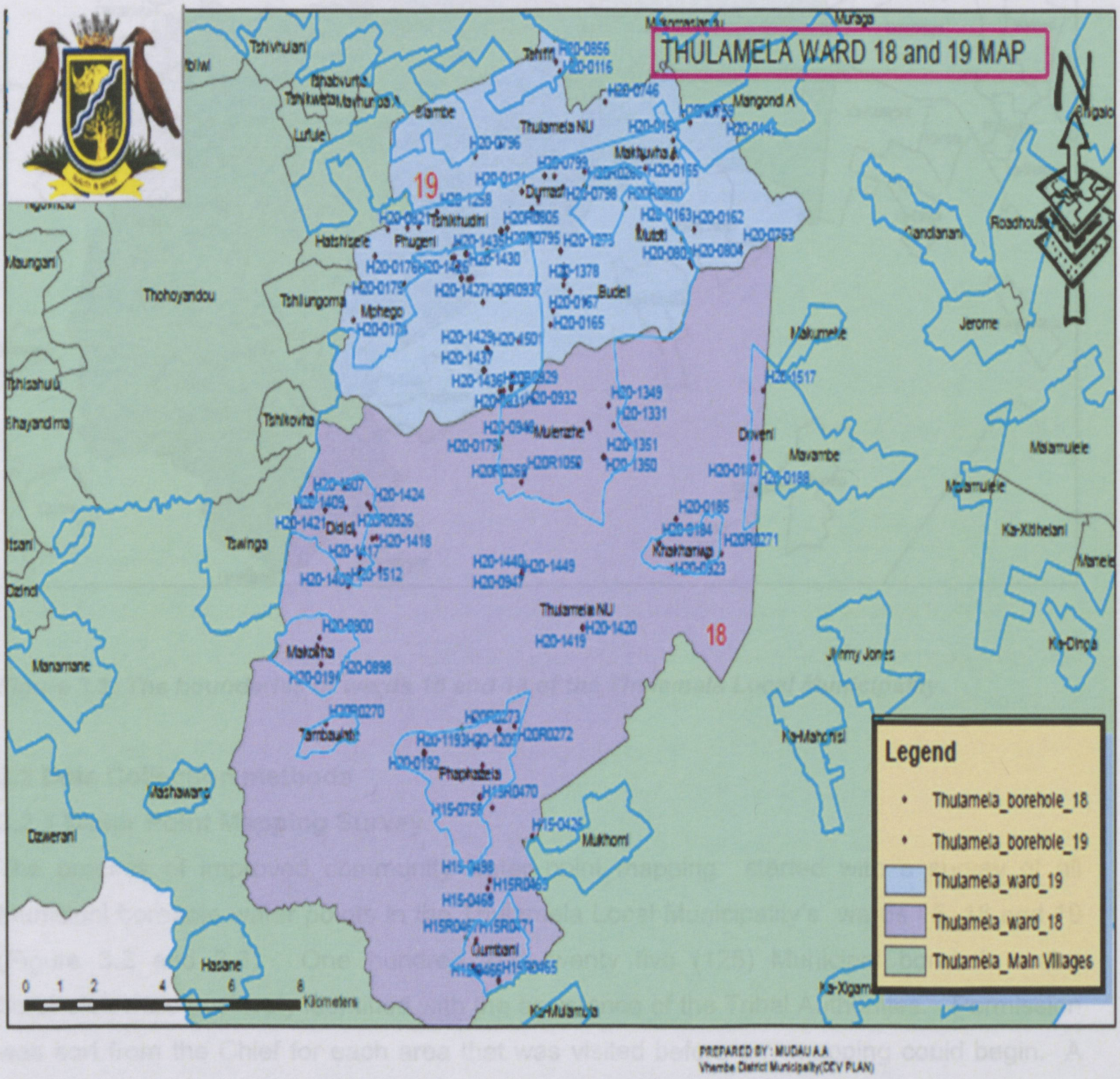


Figure 3.2: The boundaries of wards 18 and 19 of the Thulamela Local Municipality.

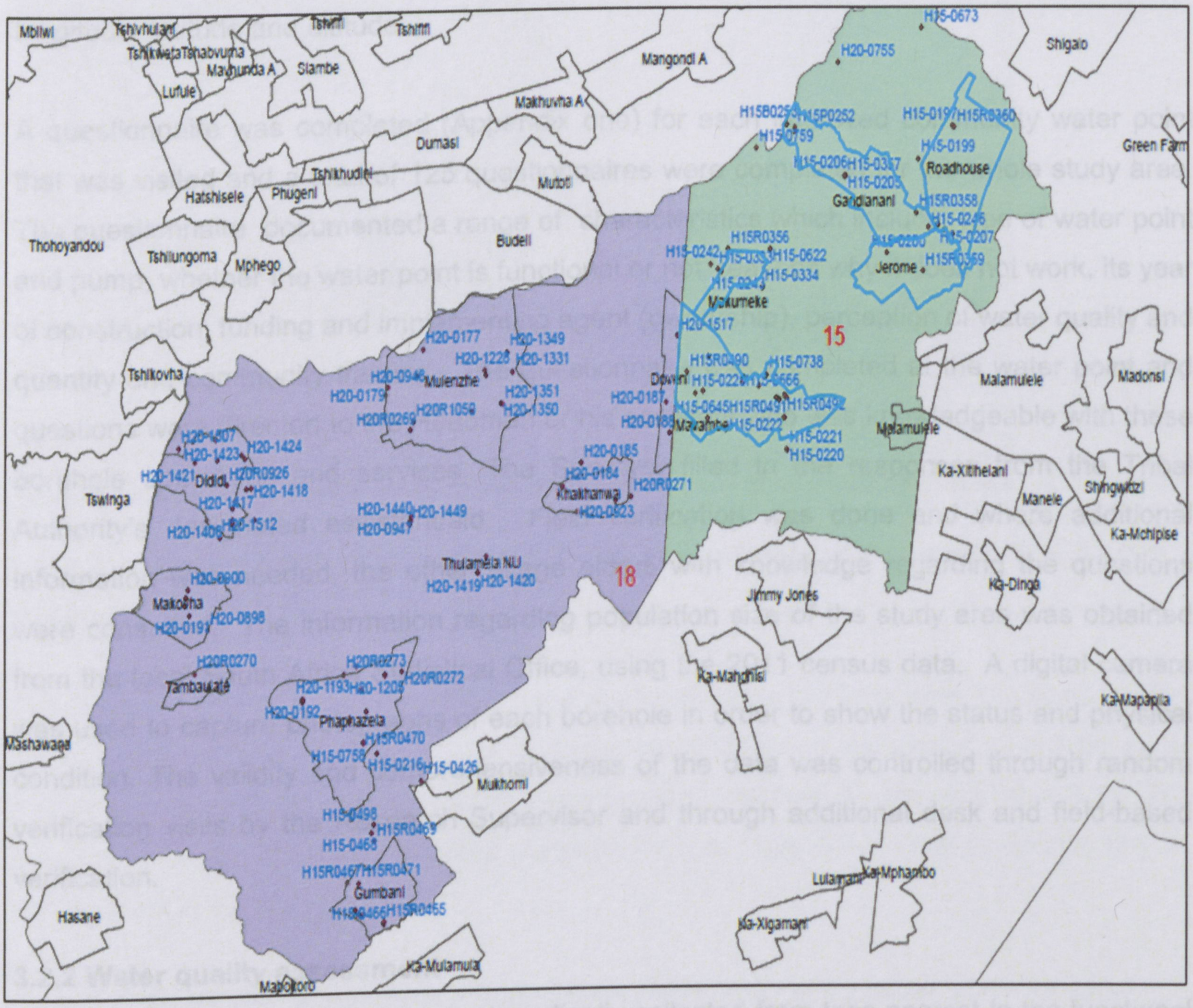


Figure 3.3: The boundaries of wards 15 and 18 of the Thulamela Local Municipality.

3.2 Data Collection methods

3.2.1 Water Point Mapping Survey

The process of improved community water point mapping started with a survey of all Municipal borehole water points in the Thulamela Local Municipality's wards 15, 18 and 19 (Figure 3.2 and 3.3). One hundred and twenty five (125) Municipal borehole water boreholes were positively identified with the assistance of the Tribal Authorities. Permission was sort from the Chief for each area that was visited before any mapping could begin. A meeting was initiated with the respective Local Tribal Authorities (the Headmen). All water points were identified and water borehole's status was highlighted during this seating. The Surveyor was given an assistant(s) who was knowledgeable with the boreholes and to help locate the boreholes. All the identified Municipal water boreholes were marked using a GPS.

The borehole coordinates were manually recorded on a hard copy and a soft copy was kept in the GPS unit waiting for decoding. The position of each water borehole was given in longitude, latitude and altitude.

A questionnaire was completed (Appendix one) for each improved community water point that was visited and a total of 125 questionnaires were completed for the whole study area. The questionnaire documented a range of characteristics which include, type of water point and pump, whether the water point is functional or not, reasons why it does not work, its year of construction; funding and implementing agent (ownership), perception of water quality and quantity and community training. The questionnaire was completed at the water point and questions were directed to the Headman or his assistant who was knowledgeable with these borehole operations and services. The Surveyor filled in the responses from the Tribal Authority's designated assistant/aid. Field verification was done and where additional information was needed, the other village elders with knowledge regarding the questions were consulted. The information regarding population size of the study area was obtained from the local South Africa Statistical Office, using the 2011 census data. A digital camera was used to capture photographs of each borehole in order to show the status and physical condition. The validity and comprehensiveness of the data was controlled through random verification visits by the Research Supervisor and through additional desk and field-based verification.

3.2.2 Water quality assessment

In this study water samples were systematically collected from taps nearest to the functional borehole (Figure 3.4). Water samples were collected using 500ml sterile sampling bottles. The samples were stored in cooler boxes at 4°C before being taken to the laboratory for analysis at the University of Venda. General attitude and perception of residents regarding water quality was captured by a questionnaire that was filled for each borehole. Samples were analyzed for Total coliforms and *E. coli* using the Colilert® Quanti-Trays®/2000 according to the manufacturer's instructions (IDEXX, USA). The trays were incubated at 37°C for 18 to 24 hours. The yellow wells were identified as positive for Total coliforms and all yellow and fluorescing wells were identified as positive for *E. coli*. The counted wells were converted into the most probable number (MPN) of Total coliforms and *E. coli* present in each of the samples, using tables and formulae provided by the manufacturer.

Figure 3.4: Water samples being collected from the tap nearest to the borehole (ID H20-0155) in Makhuvha A in ward 19

The bacterial counts in the MPN table were analyzed using the Department of Water Affairs (DWA), Assessment Guideline. The Assessment Guidelines categorize domestic water supply according to their health risk by considering faecal coliform counts (Table 3.1). The limit set by the South African national guideline for water quality for Total coliform is 0-5 cfu /100ml (WHO, 2004).

Table 3.1: Faecal coliform bacteria grouped according to their risk categories (WHO, 2004).

Faecal coliform range (cfu/100ml)	Effects
0 (Target water quality range)	No detectable chance of infection
0-1	Insignificant chance of infection
1-10	Clinical infections unlikely in healthy adults, but may occur in some sensitive groups
10-100	Clinical infections common, even with once-off consumption
>100	Serious health effects common in all users

The DWA Assessment Guidelines also use colour coded classification system for domestic to make easier to understand the water quality status as numbers tend to confuse. Table 3.2 below illustrates this colour coded classification system. The colours blue, green and yellow represent the faecal coliform range 0-10 cfu /100ml which according to the

Assessment Guideline, the water is safe to drink by all healthy adults. The colours red and purple include poor and dangerous water quality respectively. This corresponds to 10-100 and >100 cfu/100ml (Table 3.2). The same Assessment Guideline was used to analyze physico-chemical parameters of the water samples.

Table 3.2: Colour coded classification system for domestic water quality (DWAF, 2004).

Colour	Classification	Meaning
Blue	(Class 0)	**Ideal water quality**-suitable for lifetime use.
Green	(Class I)	**Good water quality**- suitable for use, rare instances of negative effects.
Yellow	(Class II)	**Marginal water quality**-conditionally acceptable. Negative effects may occur in some sensitive groups.
Red	(Class II)	**Poor water quality**-unsuitable for use without treatment. Chronic effects may occur.
Purple	(Class III)	**Dangerous water quality**- totally unsuitable for use. Acute effects may occur.

Negative effects can be:

Health effects: illnesses

Aesthetic: Changes in water colour, taste or odour, staining of laundry and household fixtures

Economic effects: Increased soap consuming and scaling and corrosion of household pipes

For the molecular identification of *E. coli* pathogenic strains, a total of 2 ml of sample was removed from up to ten positive *E. coli* wells of the Colilert® Quanti-Trays®/2000 with sterile 1ml Neomedic disposable syringes with mounted needle (Kendon Medical Suppliers) and aliquoted into 2ml sterile eppendorf tubes. The tubes were centrifuged for 5 min at 13,000 × g to pellet the cells and the supernatant discarded. DNA was extracted from the collected bacterial cells using an adapted version of the guanidium thiocyanate/silica method reported by Boom *et al.*, (1990) using homemade spin columns prepared as reported by Borodina *et al.*, (2003). The changes to the DNA extraction method included the addition of 250µl 100% ethanol to the lysis buffer to enhance the binding of DNA to the celite. The celite containing the bound DNA was loaded into spin columns before doing the washing steps. DNA was eluted from the celite with 100µl Qiagen elution buffer (Southern Cross Biotechnology). The extracted DNA was used as template in all PCR reactions (Omar *et al.*, 2010).

All m-PCR reactions were performed in a Biorad Mycycler™ Thermal cycler in a total volume of 20µl. A multiplex PCR kit (Qiagen) was used for the m-PCR protocol. Each reaction consisted of 1X Qiagen® PCR multiplex mix (containing HotstartTaq® DNA polymerase, multiplex PCR buffer and dNTP mix); 2µl of the primer mixture (0.1µM of *mdh* and *lt* primers (Forward (F) and reverse (R), 0.2µM of *ial* and *eagg* primers (F and R), 0.3µM of *eaeA* and *stx2*primers (F and R), 0.5µm of *stx1* and *st* primers (F and R), 4µl of sample DNA and 4µl PCR grade water. The reactions were subjected to an initial activation step at 95^{0}C for 15 min, followed by 35 cycles consisting of denaturing at 94^{0}C for 45s, annealing at 55^{0}C for 45s, extension at 68^{0}C for 2 min and final elongation at 72^{0}C for 5 min (Omar *et al*.; 2010). DNA was analyzed using a 2.5% (w/v) agarose gel in TAE buffer (40mmol^{-1} Tris acetate; 2mmol^{-1} EDTA, pH 8.3) with 0.5µgml^{-1} ethidium bromide.Electrophoresis was conducted for 1-2 h in electric field strength of 8Vcm^{-1} gel and the DNA visualized with UV light (Gene Genius Bio Imaging system, Vacutec®). The relative sizes of the DNA fragments was estimated by comparing their electrophoretic mobility with that of the standards run with the samples on each gel, either a 1kB or 100bp markers (Fermentas®) (Omar *et al*.; 2010).

For physico-chemical quality analysis, an HM digital meter, COM-100 was used to measure pH, electrical conductivity (EC), total dissolved salts (TDS) and temperature. The DWA Assessment Guideline was used to assess the domestic health risk of the water using the reference tables for EC, TDS and pH. The water was classified as ideal, good, marginal, poor or completely unacceptable based on the reference tables. Water with EC values <70mS/m which is equivalent to TDS <450mg/l is classified as Ideal. This water has no effects to health and the water tastes fresh (DWAF, 2004). Water classified as Good has EC value between 70 and 150mS/m and TDS between 450 and 1000mg/l. The water has no significant effects on sensitive groups and the water tastes good (DWAF, 2004). Water classified as Marginal has EC between 150 and 370 mS/m and TDS between 1000 and 2400 mg/l. The water has a slight possibility of salty overload in sensitive groups and has a distinctly salty taste. EC between 370 and 520 mS/m and TDS between 2400 and 3400 mg/l have possible health risk to all individuals and is classified as Poor, the water extremely salty and causes impaired soap lather (DWAF, 2004). Water classified as completely unacceptable has EC >520mS/m and TDS >3400mg/l. The water has increasing risk of dehydration, tastes extremely salty and bitter causing impaired soap lathering and is corrosive. Water with pH values 5-6, 6-9 and 9-9.5 is classified as Ideal. The water has no effects to health. Water classified as Good has pH values in the range 4.5-5 and 9-9.5. The water may cause mild irritation of the mucous membranes and is slightly soapy (DWAF, 2004). Water that is classified as marginal has pH values in the range 4-4.5 (sour taste) and 10-10.5 (soapy taste). The water causes irritation of mucous membranes (DWAF, 2004). Poor water has pH between 10.5 and 11, pH in the range 3-3.5 and 3.5-4. The pH range

10.5-11 causes severe irritation of mucous membranes and is extremely soapy. The pH between 3 and 3.5 burns skin, causes severe irritation of mucous membranes and has an extremely sour taste. The pH between 3.5 and 4 causes severe irritation of mucous membranes with a very sour taste. Completely unacceptable water has pH>11 and <3. The pH >11 is an alkali and therefore burns with an extremely soapy taste. The pH that is below is extremely acidic and burns skin and eyes.

3.2.3 Statistical Analysis of Data

Once the data collection process was completed, survey results were captured in a database to form an inventory. The GIS Arc 10.1 was employed to reproduce the information on a map. Sets of EXCEL-formatted water point inventories were correlated with spatial information based on South Africa statistics 2011 population census provided by the National Statistics Office. Based on the official spatial infrastructure information, densities were broken down into Enumeration Areas (EAs), the smallest administrative unit, comprising of the village. In addition to the distribution of water points, other crucial information was also displayed on the map. The other information included major road networks, rivers and lakes, hydrological information or natural reserves. Water points were distinguished on the map by their ID numbers.

Data from the questionnaire survey was presented and entered into Microsoft Excel 2007. SPSS was used for descriptive analysis; to determine if the frequency of boreholes allocation. Data from the questionnaire relating to functionality, maintenance installation, water committees and funding were quantitatively and qualitatively assessed and captured in data tables. The data was entered into Microsoft Excel spread sheets to generate graphs that show various aspects of the water points like Functionality Rate, WP coverage, Equity of distribution and level of investment. The most influential analysis was the correlation between the availability of water points and the population density in an Enumeration Area, which highlights inequity in distribution at the lowest administrative level. This allowed for a comparison between clusters of villages as opposed to official statistics masking differences in distribution below the district level. In addition, the wealth of the data set provides the basis for additional types of analysis. It is, for example possible to investigate the level of investments in a specific area over a period of time, to analyze whether investments have been channeled to the appropriate technology (for example, based on the depth of the aquifer) or to conduct queries regarding reasons for differences in life spans of water point functionality.

<u>Calculations for specific answers were done as follows:</u>

i) *Functionality rate (FR)*

FR is the percentage of water points that are functioning. It was found by expressing the number of functioning water points over the total number of water points multiplied by 100% (Stoupy and Sudgen, 2003b).

iii) Water point coverage (WPC)/density

WPC was found by expressing the number of water points over the population multiplied by 1000 (Stoupy and Sudgen, 2003b).

Full coverage (FC): A calculation of full coverage was done in comparison to the South African National Water Policy. For example in Tanzania, full coverage equates to 1 water point per 250 people. This equates to water point coverage of 4 water points per 1000 people. This full coverage is only applicable to Tanzania, Malawi, Kenya, Uganda and Ethiopia whose governments and local water ministries set full coverage to 4 water points per 1000 inhabitants (Stoupy and Sudgen, 2003b). South Africa does not have a set number of water points per a particular number of inhabitants to represent full coverage and hence access levels described here were weighted against international set targets for full coverage.

iv) Equity in distribution (ED)

ED captures the difference in water point coverage between areas (Stoupy and Sudgen, 2003b). It is an expression of the average deviation from the mean water point coverage of the areas being considered. The greater the average deviation from the mini water point coverage, the greater the inequity in distribution of water points. Zero represents perfect equity, meaning that all areas have the same level of service (Stoupy and Sudgen, 2003b).

Chapter 4

Results and discussion

4.1 The study area

Permission was sort from the Chief (Figure 4.1) for each area that was visited before any mapping could begin. A meeting was initiated with the respective Local Tribal Authorities (the Headmen). All water points were identified and water borehole's status was highlighted during this seating. The Surveyor was given an assistant(s) or aid(s) who was knowledgeable with the water boreholes to help locate the boreholes (Figure 4.2).

Figure 4.1: The panel of traditional authorities for Phaphazela under Mukhomi Tribal Authority assisting in identifying all boreholes under their jurisdiction.

There was coordination among all community members who had knowledge regarding the number, functionality and other relevant information regarding the boreholes under the community's jurisdiction. Although prior to the survey, the Municipality's inventory showed a total of two hundred and four (204) boreholes, only one hundred and twenty five (125) water boreholes were actually identified in the three wards. Figure 4.3 shows all the boreholes that were mapped in the three study wards of the area. The borehole IDs were positively identified with the help of the respective Tribal Authorities. It was later discovered that some boreholes on the Municipality's inventory have never existed and that some reservoirs were actually indicated as boreholes on the inventory. The Water Points shown on the maps of the study area reflect the real situation of Municipal borehole water distribution in the three wards.

Figure 4.2: An aid for Musanda HaMutoti (Village Head) in a blue work suit calling to verify borehole locations in the Mutoti village from other village elders.

Specifically Figure 4.4 shows distribution of borehole water points in ward 15; Figure 4.5 shows the distribution and detailed view of ward 18's identified borehole water points; and Figure 4.6 shows a detailed view of ward 19's distribution of identified borehole Water Points. Identification and verification of all 125 water points was done in the field and desk verification was done after every survey to minimize errors. All the borehole information is summarized in Appendix two. In brief: only 12 of the boreholes had information regarding borehole depth. The arithmetic mean depth of the boreholes was 74.31m. The arithmetic mean water level of all the boreholes that had information on depth was 10.95m. Approximately 67 of the boreholes (53.6%) had information regarding power type or source of power. Out of these, 35.82% (24 boreholes) were electrically powered, 10.45% (7 boreholes) were diesel powered, 52.24% (35 boreholes) were hand powered and 0.02% (1 borehole) was wind powered. With regards to installation type, out of the 125 boreholes identified, 44 (35.20%) were mono pumps or progressive cavity pumps while 25 (20%) were Afridev and India mark 2 handpumps and 56 (44.8) had no pumps or hardware. The common hardware problems that were identified included broken pumps, damaged sources, stolen pumps, broken pipes and source drying out (Photos are shown in Appendix three). All boreholes were owned and managed by the Vhembe District Municipality (VDM). There were no Community Committees for water except in the Makhuvha A village area. No payments for water were made in all communities and no public meeting about expenditure on water and maintenance were held.

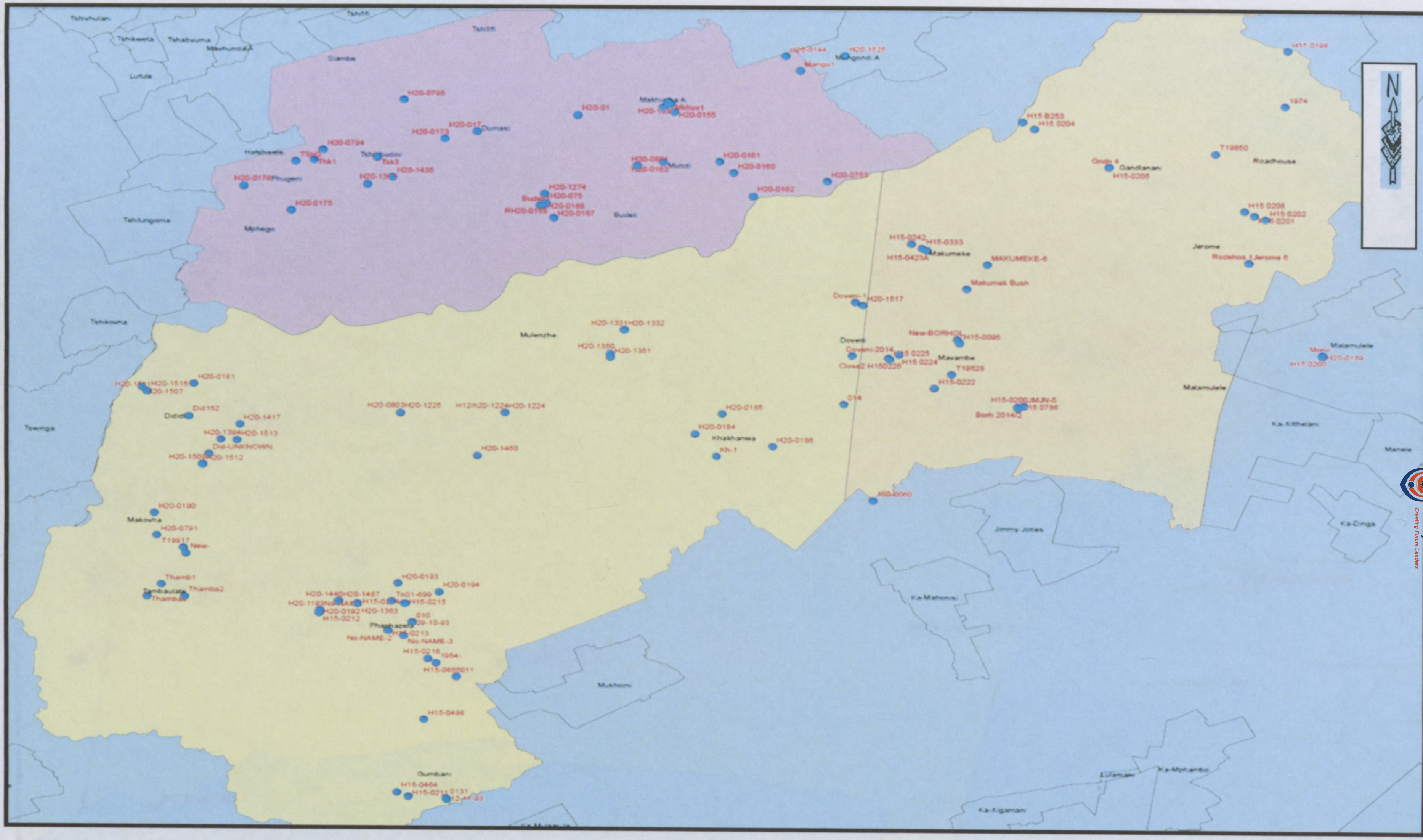


Figure 4.3: All mapped boreholes in ward 15, 18 and 19 of the Thulamela Local Municipality using the GPS coordinates (Appendix two)

Figure 4.4: A detailed view of ward 15 in peach colour showing all the boreholes that were identified together with their ID numbers.

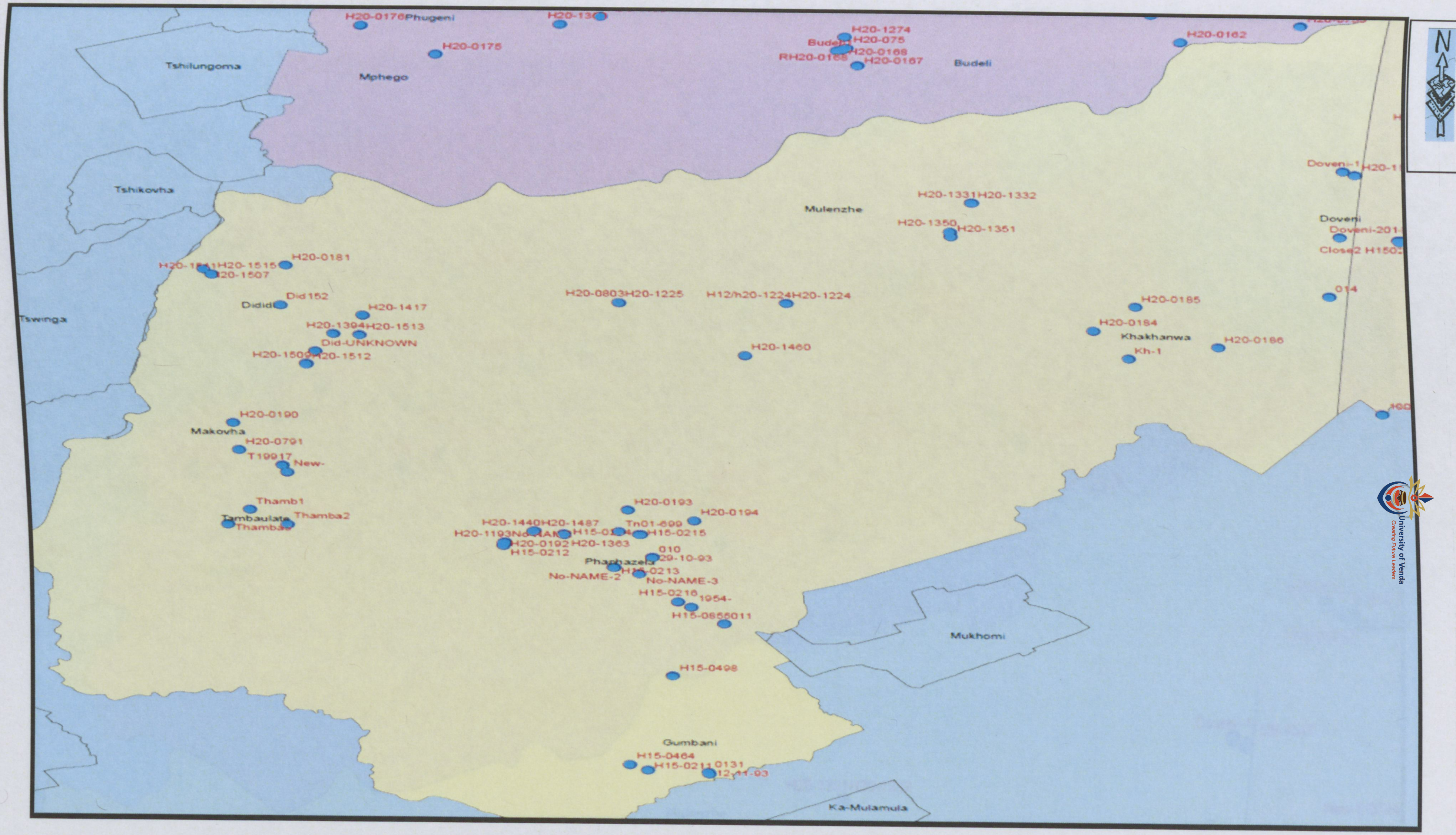


Figure 4.5: A detailed view of ward 18 in cream colour showing the entire boreholes that were identified together with their ID numbers.

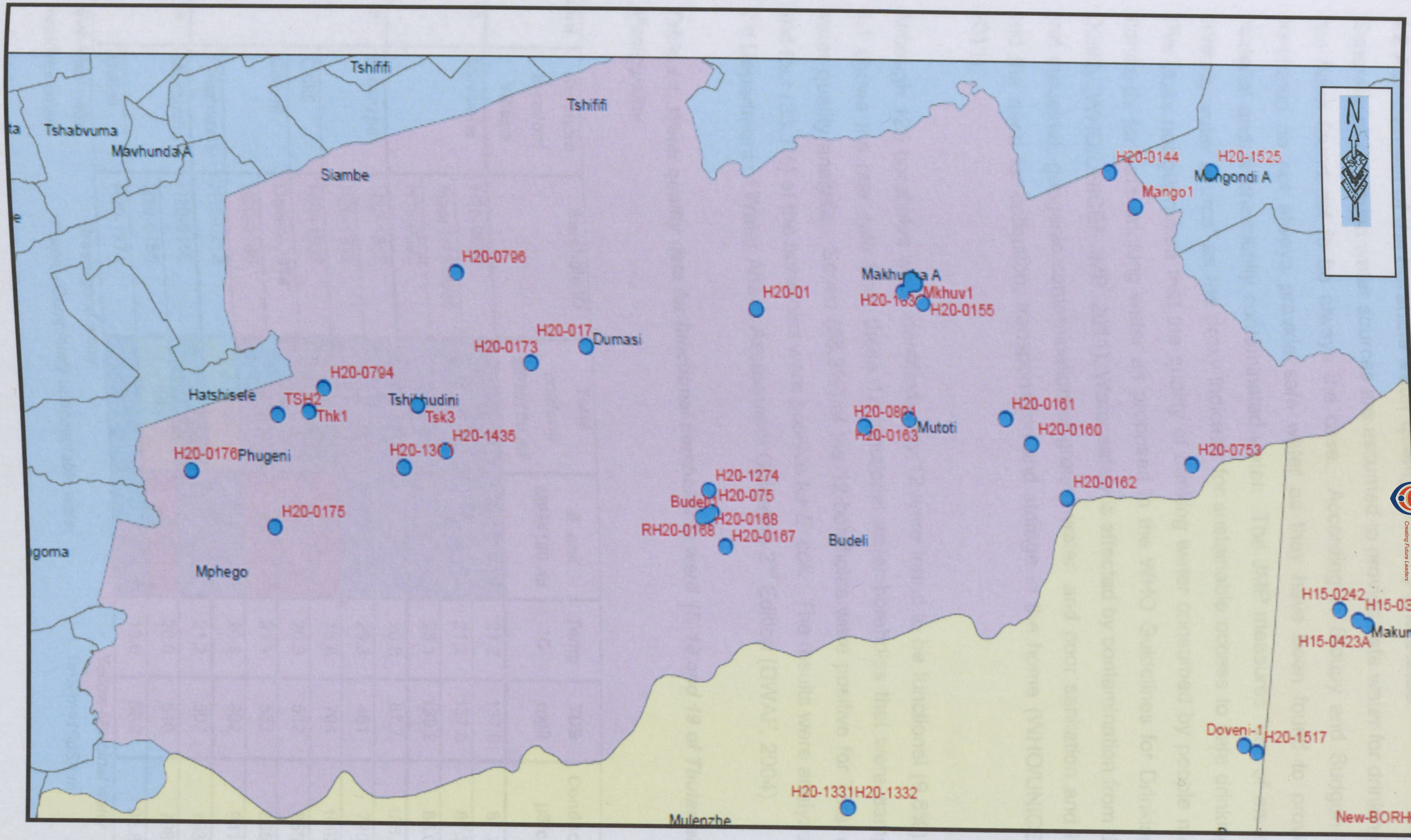


Figure 4.6: A detailed view of ward 19 in purple colour showing the entire boreholes that were identified together with their ID numbers.

4.2 Assessment of the borehole water quality, quantity and status

Generally all improved water sources are assumed to provide safe water for drinking but this has been found not to be always the case. According to Stoupy and Sudgen (2003b), boreholes do not always provide safe water as they have been found to provide both bacterial and or chemically contaminated water. The JMP measures "use of an improved drinking water source" as the proxy indicator for sustainable access to safe drinking water. This does not guarantee that the quality of drinking water consumed by people meets the standards for safe drinking water as proposed in the WHO Guidelines for Drinking Water Quality (WHO/UNICEF JMP, 2011). Water safety is affected by contamination from domestic and industrial, geogenic contamination of ground water, and poor sanitation and hygiene, and the need for collection, transportation and storage in the home (WHO/UNICEF JMP, 2011).

Although 125 boreholes were identified, only 12 were found to be functional (9.6%). Table 4.1 shows the raw data from these 12 functional water boreholes that were sampled for water quality analysis. Seven (58.3%) of the 12 boreholes were positive for Total coliform and four (33.3%) of the boreholes were positive for *E. coli*. The results were analyzed using the Department of Water Affairs Assessment Guideline 2nd Edition (DWAF, 2004).

Table 4.1: Water quality data for functional boreholes in ward 15, 18 and 19 of Thulamela Local Municipality

Ward	Borehole location/ Village	Borehole ID	*Total coliform MPN/100 ml*	*E. coli* MPN/100 ml	Temp °C	TDS mg/l	Conductivity µS/cm	pH
15	Mavambe	H15-0095	<1	<1	21.2	137.0	87.2	8.76
		Near H15-0095	<1	<1	21.2	137.0	87.2	8.76
		H15-0222	<1	<1	23.1	139.2	86.0	8.65
18	Mulenzhe	H20-1350	<1	<1	20.8	87.7	136.4	7.64
		H20-1332	>2419.6	<1	20.3	461	720	7.64
	Dididi	H20-1507	5.2	2.0	15.8	704	1092	8.09
	Doveni	Doveni 2014	>2419.6	1.0	20.3	552	865	7.89
		H20-0186	>2419.6	2.0	21.1	552	865	7.85
	Phaphazela	H15-0212	21.6	<1	20.3	602	941	7.92
19	Makhuvha A	H20-0158	9.7	<1	21.2	507	793	8.89
		H20-0155	14.8	6.3	20.0	510	798	8.03
	Budeli	H20-1274	<1	<1	19.6	59.2	92.8	8.70

Blue-Ideal water *Green-good water* *Yellow-Marginal water*

Red-Poor water *Purple- Completely unacceptable water* *1mS/m=10µS/cm*

Analysis of physico-chemical parameters indicated that 5 out of the 12 functional water boreholes (42%) were classified as "Ideal" and 7 (58.33%) were classified as "Good" for EC and TDS (450 mg/l – 2400 mg/l). The TDS range was between 59.2 and 704mg/l. The EC was also in the acceptable range of the DWA guideline with a range between 8.6 and 109.2 which is classified as "Good" (EC: 70-150mS/m), DWAF (2004). The pH range for all water samples was between 7.64 and 8.89 which are classified as "Ideal" by DWAF (2004) Assessment Guidelines.

Table 4.2 shows a summary of the analysis. Water quality of the 12 boreholes is ranked from good, marginal, poor to unacceptable for human use. Physico-chemical parameters were ranked as soft, hard, clear, and milky and quantity as insufficient. All the analyzed data in Table 4.2 were fed into an excel spreadsheet to produce Figure 4.7 results which shows that 7 of the functional boreholes assessed (58.33%) were microbiologically good and provided enough water. Two boreholes (16.67%) were Microbiologically marginal meaning that even though they were positive for total coliform they do not cause any health effects if used for drinking. They also pumped enough water for the communities. Three boreholes (25%) were Microbiologically unacceptable and may have health effects if used for drinking; but pumped enough water all the time.

The parameter relating to water quantity, taste, odour and general perception about water quality were obtained from the questionnaire survey. Regarding taste of the water, 9 boreholes (75%) provided soft water which was microbiologically good. Three boreholes (25%) provided hard water. All the 12 functional boreholes pumped enough water all the time. All the water provided by the functional boreholes was clear (Figure 4.7).

Only 4 of the 7 boreholes tested positive for *E. coli* counts. Table 4.3 shows the diarrhoeagenic *E. coli* strains that were identified from the boreholes water. Three *E. coli* strains were identified from 4 borehole water samples. The three recognized strains are amongst the six diarrhoeagenic E. *coli* that cause public health problems in development countries and present etiological agent of diarrhoea (Nataro and Kaper, 1998). The results indicated that 50% (2) of the samples that tested positive for *E. coli* harbored genes for:

i) Shiga-like toxins (*stx1* only, sample H20-0158),
ii) Enterotoxins: Heat-Stable and Heat- Labile toxins (*st* and *lt* respectively) and
iii) Enterocyte effacing factor also known as intimin (*eae* only, as *bfp* was not present) as was reported by Jerse et al, (1990).

Table 4.2: Analysis of water quality, quantity and status for functional boreholes in ward 15, 18 and 19 of the Thulamela Local Municipality showing the number of boreholes in each water quality category

Ward	Village	Microbiological Quality				General water status from survey					
		Good	Marginal	Poor	Unacceptable	Soft	Hard	Enough	Insufficient	Clear	Milky
15	Mavambe	3	0	0	0	3	0	3	0	3	0
18	Mulenzhe	1	0	0	1	2	0	2	0	2	0
	Dididi	1	0	0	0	0	1	1	0	1	0
	Doveni	0	0	0	2	2	0	2	0	2	0
	Phaphazela	0	1	0	0	0	1	1	0	1	0
19	Makhuvha	1	1	0	0	2	0	2	0	2	0
	Budeli	1	0	0	0	0	1	1	0	1	0
Total		**7**	**2**	**0**	**3**	**9**	**3**	**12**	**0**	**12**	**0**

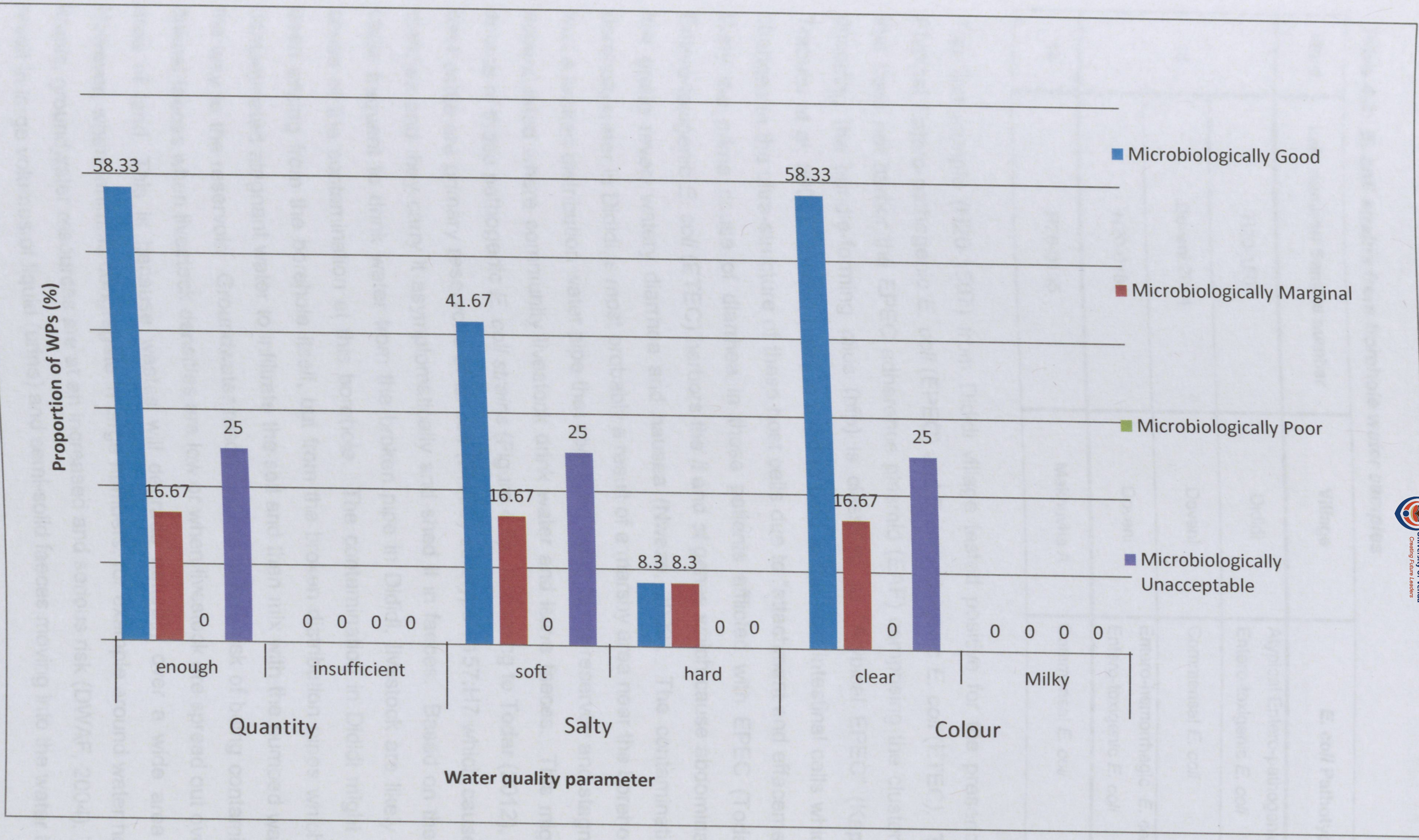


Figure 4.7: Water Microbiological quality, quantity and physico-chemical quality of 12 functional Municipal boreholes

Table 4.3: E. coli strains from borehole water samples

Ward	Lab number/ Sample number	Village	*E. coli* Pathotype
18	H20-1507	Dididi	Atypical Entero-pathogenic *E. coli*, Entero-toxigenic *E. coli*
	Doveni 2014	Doveni	Commensal *E. coli*
	H20-0186	Doveni	Entero-hemorrhagic *E. coli* Entero-toxigenic *E. coli*
19	H20-0155	Makhuvha A	Commensal *E. coli*

The first sample (H20-1507) from Dididi village tested positive for the presence of both Atypical Entero-pathogenic *E. coli* (EPEC) and Entero-toxigenic *E. coli* (ETEC). The EPEC that does not harbor the EPEC adherence plasmid (EAF) comprising the cluster of genes encoding the bundle-forming pilus (bfp) is classified as "Atypical EPEC" (Kaper, 1996, Trabulsi et al. 2002). Intimin (eae) is used to bind to the host intestinal cells which causes changes in the ultra-structure of these host cells due to "attachment and effacement" and is likely the prime cause of diarrhea in those patients afflicted with EPEC (Todar, 2012). Entero-toxigenic *E. coli* (ETEC) harbors the *lt* and *st* genes which cause abdominal cramps, low grade fever, watery diarrhea and nausea (Nweze, 2009). The contamination of the borehole water in Dididi is most probably a result of a marshy area near the borehole. There was a broken distribution water pipe that conveyed water to the reservoir and stagnant water accumulated where community livestock drink water and leave faeces. This might be the source of these pathogenic *E. coli strains* (Figure 4.8). According to Todar (2012), dairy and beef cattle are primary reservoirs of *E. coli* (EHEC) serotype 0157:H7 which causes bloody diarrhea and they carry it asymptomatically and shed it in faeces. Based on the fact that cattle frequent to drink water from the broken pipe in Dididi, livestock are likely the main cause of the contamination at this borehole. The contamination in Dididi might not have been arising from the borehole itself, but from the broken distribution pipes which allowed contaminated stagnant water to infiltrate the soil and then mix with the pumped water along the way to the reservoir. Groundwater resources are at less risk of being contaminated by animal faeces when livestock densities are low or when livestock are spread out over a wide area of land. This is because wastes will degrade naturally over a wide area of land. However, where animals congregate in large numbers, for example around water holes or in kraals, groundwater resources are at an increased and serious risk (DWAF, 2004). This may result in large volumes of liquid (urine) and semi-solid faeces moving into the water table and in this case for Dididi the surface contaminated water flows into the distribution pipes when hydraulic pressure from the pump is low.

Figure 4.8: Broken water pipe from borehole Id H20-1507 in Dididi where water accumulates and possibly is the source of contamination.

The second sample (H20-0186) from Doveni was positive for Entero-haemorrhagic *E. coli* (EHEC) or Shiga toxin-producing *E. coli (STEC)* and ETEC. EHEC harbors the *stx1* gene and is found in humans, cattle and goats where it causes bloody diarrhea. Entero-pathogenic *E. coli* and Entero-toxigenic *E. coli* cause diarrhea in humans. Entero-toxigenic *E. coli* (ETEC) is the leading bacterial cause of diarrhea in the developing world as well as the common cause of traveler's diarrhea (Nguyen et al, 2006). Each year, ETEC causes more than 200 million cases of diarrhea and 380 000 deaths monthly in children in developing countries (Nguyen et al, 2006).

The other 2 samples (50%) harbored genes for the non-pathogenic strain of *E. coli* namely the Commensal *E. coli.* However, the presence of these strains still raises some challenge to the water service providers to probe into the causes of this contamination. The presence of these bacteria is a very good indicator of faecal contamination since *E. coli* bacteria are among the normal bacterial floral of human gut (Nataro and Kaper, 1998).

The water point status for boreholes H20-0155 in Makhuvha A (Figure 3.4 and Appendix three photo 0255) and H20-0186 in Doveni (Appendix three photo 0147) is similar to that observed in Dididi where stagnant water accumulated around the borehole enabling underground contamination through seepage. Contaminated stagnant water that is located next to or upslope of boreholes, wells and springs (Figure 3.4 and Appendix three photo 0255) has the potential to contaminate the water source (WHO, 2004). The penetration of surface water carrying animal waste or sewage to groundwater abstraction wells may lead to gastrointestinal illnesses as faecal material may contain various pathogenic microbes (Schijven et al. 2010). The most common causative agents in waterborne gastrointestinal illness outbreaks in developed countries have recently been norovirus, *Campylobacter, Cryptosporidium, Giardia* and pathogenic *E. coli* (Hrudey and Hrudey, 2007). To a lesser extent, rotavirus, *Shigella, hepatitis A, Salmonella* and Toxoplasma are known to cause waterborne outbreaks. Many of the waterborne outbreaks have been associated with small water supplies (Hrudey and Hrudey, 2004). Small community water supplies are recognized internationally as an issue critical to public health (WHO, 1997). The operation and management of small water supplies may be inadequate due to the limited resources and lack of awareness of factors affecting water quality. In Dididi, the community leaders claimed that they raised the problem of the broken distribution pipe with the Vhembe District Municipality about a year ago at the time of sampling, till then there have never been any maintenance done. The principal public health concern is the use of vulnerable groundwater aquifers without water purification or disinfection measures for drinking purposes. At vulnerable drinking water supplies, the deficiencies in multi-barrier approach increase the risk of drinking water contamination (Cool et al, 2010; Joerin et al, 2010).

Abandoned wells are directly linked to aquifers and can channel harmful materials such as sewage, pesticides, fertilizer, toxic chemicals, and bacteria from the land surface into aquifers as they provide a good preferential flow pathway to these contaminants (WHO, 2004). A preferential flow pathway is a short cut that a contaminant can take from the surface to the groundwater, or to an abstraction point (WHO, 2004). This means that the contaminants take much less time to reach the groundwater or abstraction point, than they would if the contaminants were to travel through undisturbed soils, sub soils and underlying bedrock (WHO, 2004). Illegal dumping of waste material in these open main holes is a source of contamination of the aquifers. During the survey, many open abandoned boreholes were identified (Appendix three for photographs). Abandoned wells are not difficult to seal properly, but many remain open. Because of their large number and wide distribution, abandoned wells pose a significant threat to local ground water supplies (ADEM, 2001) (Figure 4.9). Boreholes penetrating shallow aquifers which have not been properly sealed could also become conduits for surface pollutants to enter the subsurface (ADEM, 2001). When a well is no longer useful, it should not simply be left as an open hole. Any open well is a threat to the environment (ADEM, 2001)

An open abandoned borehole main hole located some few metres away from a newly drilled water borehole in Mavambe borehole number H15-0095 (enclosed in the metal structure seen in the background) can provide a preferential flow pathway to the aquifer.

Figure 4.9: An open abandoned borehole in Mavambe which can act as a source of underground water contamination.

Comparing the results of this study with a similar study conducted assessing the quality of groundwater in the South African rural communities of the Mpumalanga province, the results indicated that 78% of the boreholes assessed (81%) did not comply with the limits set by the national guidelines in terms of faecal (0 cfu/100ml) and Total coliforms (0-5 cfu/100ml), respectively (Mpenyana-Monyatsi *et al.* 2012). A similar study was conducted in the Tshitale-Hlanganani the Vhembe district of the Limpopo Province of South Africa. The results showed that during the rainy season, 20% of the borehole water samples were classified as poor (>100 cfu/100ml) for Total coliforms and 15% classified as poor (>10 cfu/100ml) for faecal colifoms (Potgieter et al. 2006). The number of coliforms detected in borehole water indicates that the microbiological quality of the water sources used was poor, unsafe and not acceptable for human consumption. The microbial quality of the water sources exceeded the maximum safety limit for drinking water as stipulated by the water quality guidelines (Obi *et al.* 2002). This is in agreement with findings by similar studies that were done in Vhembe rural areas by Gundry et al. (2009) where water quality tests showed that in "improved" groundwater, *E. coli* counts were less than 10 cfu/100ml in 90% of the cases. A new systematic review of literature commissioned by JMP, estimated that 1.8 people globally use a source of drinking water that is faecally contaminated. According to WHO/UNICEF JMP (2014) of these 1.1 billion people drink water that is at least "moderate" risk (>10 cfu/100ml sample). Data from nationally randomized studies suggest that

10% of improved drinking water sources may be [illegible] risk containing at least 100 cfu per 100ml sample (WHO/UNICEF JMP, 2014).

The results point out that even though water boreholes are an improved source of drinking water and by using this proxy are duly expected to provide safe drinking water, in most cases they are found to provide water of poor microbiological quality. Water resources can be contaminated both directly and indirectly by the disposal of excreta in a rural environment (DWAF, 2004). Pathogenic bacteria, viruses and other substances from excreta in pit latrines can move through the sub-surface soils and contaminate groundwater. Groundwater in areas with high rainfall and shallow water tables is more vulnerable to contamination from pit latrines (WHO, 2004). Groundwater vulnerability is also high in fractured rock and other high permeability environments, such as sandy or gravelly soils. This may account for the contamination of borehole water in Doveni village, especially the Khakan'wa borehole which is down slope the closest households and the soil is gravely (Appendix three photo 0147). The risk of groundwater being contaminated by pit latrines is increased where: the base of the pit occurs near the water table or the pit latrine is located too close to a water source. The separation distance then does not give enough time for the geological sub-surface material to remove potential contaminants before they reach the water table or the water source (WHO, 2004). The other cause may be that the bottom part of the pit is unlined. Impermeable linings act as a barrier to contamination, helping to prevent contaminants finding a short cut from the lower part of the pit to the water table (WHO, 2004). When there is high loading as a result of more people who use a pit latrine for example in a school environment, then the greater the number of infective pathogens that will be produced, resulting in a higher risk of groundwater contamination. Based on the findings of this study, regular monitoring of borehole water is essential for diarrhoeagenic *E. coli* to prevent potential public health problems.

4.3 Functionality Rate (FR) assessment

Functionality Rate refers the percentage of water points that are functioning and is determined by expressing the number of functioning water points over the total number of water points multiplied by 100%. Table 4.4 shows Functionality Rate in ward 15. Three out of the five villages in ward 15 did not have even a single borehole that is functional. Mavambe and Makumeke FR is too low implying that there is a large number of none functioning WPs. The arithmetic FR for the whole ward 15 is 7.85%.

Table 4.4: Borehole Functionality in Ward 15 in the Thulamela Local Municipality

Village name	Total WPs	Functional WPs		Non-Functional WPs	
Mavambe	13	3	23.08%	10	76.92%
Makumeke	6	1	16.67%	5	83.33%
Gandlanani	4	0	0%	4	100%
Jerome	5	0	0%	5	100%
Roadhouse	4	0	0%	4	100%
Total	***32***	***4***	***12.5%***	***28***	***87.5%***

In ward 18, the trend of large number of none functioning WPs still evident as shown in Table 4.5. Out of the 9 villages in ward 18, five have at least a borehole that is functional. However, the arithmetic FR mean in ward 18 is 9.48% which is extremely low.

Table 4.5: Borehole Functionality in Ward 18 in the Thulamela Local Municipality

Village name	Total WPs	Functional WPs		Non-Functional WPs	
Mulenzhe	8	2	**25%**	6	**75%**
Khakhanwa	3	0	0%	3	100%
Doveni	5	1	20%	4	80%
Thulamela NU(Thovowani)	4	0	0%	4	100%
Thambaulate	3	0	0%	3	100%
Dididi	11	1	9.09%	10	90.91%
Makhovha	4	0	0%	4	100%
Phaphazela	16	1	6.25%	15	93.75
Gumbani	4	1	25%	3	75%
Total	**58**	**6**	**10.35%**	**52**	**89.65%**

WPs – Water Points

Table 4.6 shows the FR data for ward 19 which also shows similar trend in borehole functionality as in ward 18. Five villages out the seven in ward 19 did not have any functioning borehole as is shown by 100% non-functional boreholes. The two villages which had functional water boreholes still continue to have very low functional rates for example

16.67% and 33.33% respectively. There were boreholes that were drilled but they were never without hardware or equipment. Two of the drilled boreholes in Dididi were abandoned due to insufficient water but the rest of the boreholes were awaiting hardware and this contributed to the low Functionality Rate. There were no clear reasons to community as to why the boreholes could not be fitted with equipment. The Functional Rate arithmetic mean for ward 19 was 7.14%.

Table 4.6: Borehole Functionality in Ward 19 in the Thulamela Local Municipality

Village name	Total WPs	Functional WPs		Non-Functional WPs	
Mutoti	6	0	0%	6	100%
Mangondi A	5	0	0%	5	100%
Mahkuvha A	6	2	33.33%	4	66.67%
Budeli	6	1	16.67%	5	83.33%
Dumasi	4	0	0%	4	100%
Tshikhudini/Phugeni	6	0	0%	6	100%
Mphego	2	0	0%	2	100%
Total	**35**	**3**	**8.57%**	**32**	**91.43%**

WPs – Water Points

The water point FR mean in the three wards was shown to be 8.16% which indicated that there were a large number of non-functioning WPs in the three wards. The level of functionality is the same and from these results indicates that most of the boreholes that were installed in these three wards are non-functional and the sustainability and management of water boreholes needs immediate attention. The low borehole Functionality Rate that was observed in the three study wards can be attributed to lack of funding to maintain the boreholes. Lack of funding is contributed by non-payment for the water service. It was captured during the questionnaire survey that people do not pay for the water and as a result there is not enough financial backing to support maintenance and repairs. Another factor that was noted as contributing to high non-functionality was vandalism of the boreholes. Vandalism that was noted included removal of parts like electrical components or the hardware itself especially on the hand pumps. Evidence on this is captured in the research pictures in Appendix three. At most boreholes it was discovered that parts were stolen especially the diesel engines and this contributed to non-functionality.

The questionnaire survey also indicated a problem relating to community training. There were no Water Committees in any of the study villages except for Makhuvha A village where this specific committee was not trained on how to operate and maintain the water boreholes. Without training, the users lack the expertise to operate and sustain their water infrastructure and this contributes to high non-functionality rate.

Out of the twelve boreholes that were functional, only one was a hand pump (borehole number H20-0158 Appendix two). It was also noted during the questionnaire survey that all boreholes are owned by the Vhembe District Municipality (VDM) and not by the individual Water Schemes. Given the size of the Vhembe District Municipality, it becomes an insurmountable task for the Municipality to effectively monitor and maintain all the water boreholes under its jurisdiction and this may also possibly contribute for the high non-functionality rate that was identified.

The results for Functionality Rate were represented in form of a map where the differences at Ward, Tribal Authority and village settings are highlighted. The enumeration levels are clearly highlighted by their demarcation lines. Figure 4.10 was developed from the FR assessment of all the villages in the three wards. The GIS Arc View 10.1 was used to reproduce the map. It is clear that almost all the villages lie in the density category of less than 1 functional borehole per 1000 people. From the map it should be noted that all the villages with the red colour have ICWP densities of less than 1 and indicate challenges of water shortage.

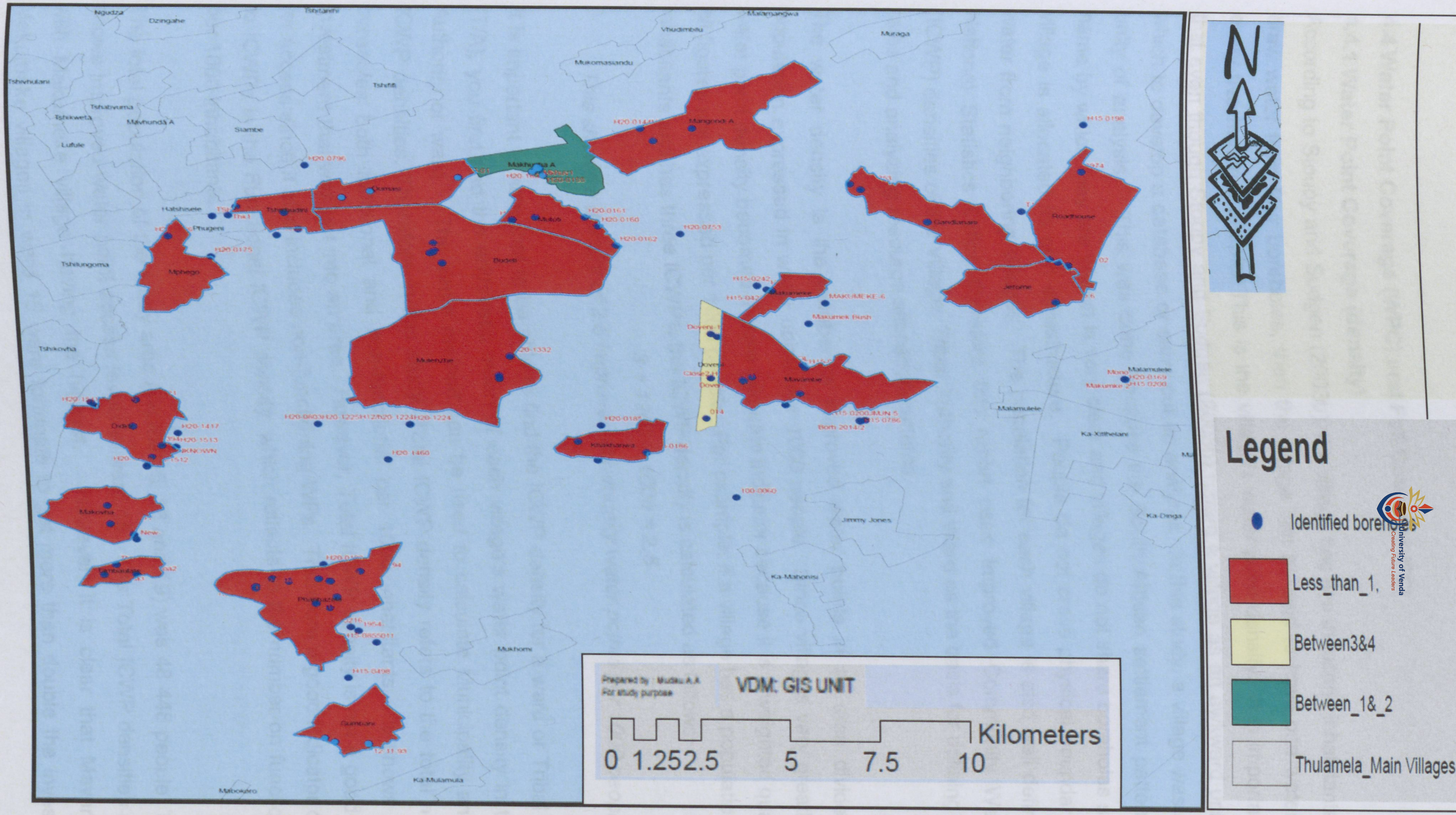


Figure 4.10: The Functional ICWP density (functional ICWPs per 1000 people).

4.4 Water Point Coverage (WPC) and Full Coverage (FC)

4.4.1 Water Point Coverage (density)

According to Stoupy and Sudgen (2003b), if a village has two thousand inhabitants and they draw water from four boreholes, then the village can be said to have one water point for every five hundred people. This is the village's water point density. It is important to note that even though Stoupy and Sudgen (2003b) regard a village as an awkward unity around which to develop a database or carry out an analysis. In this study, a village was used as a unity of analysis. This was done because the South African settlement pattern and the name by which they are known is very clear and villages do not share boreholes since each village is allocated its own infrastructure. People do not cross physical boundaries to get water from neighboring villages. The population for each village is also well defined in the National Statistics Office therefore this report uses Improved Community Water Point (ICWP) densities of the Village, Tribal Authority and Ward as the basis for defining coverage rates and analyzing resource allocation patterns.

The water density is the number of improved water points in an area divided by the population expressed in water points per 1000 people. Since villages vary greatly in size, water point density becomes a more accurate indicator because it is a weighted quantity and all figures are expressed per 1000 people. For example, if a village has a population of 1200 inhabitants and has three ICWPs, the ICWP density is calculated as follows:

$$3 \div 1200 \times 1000 = 2.5$$

This shows a density of 2.5 improved community water points per 1000 people.

It is important to note that to be able to find the ICWP density for a ward or Tribal Authority (T/A), you first find the arithmetic mean of each village's water point density in the Tribal Authority or ward. The same method can be used to calculate Municipality and District ICWP densities. Therefore in this study, Total ICWP density refers to the total number of boreholes both functional and non-functional per 1000 inhabitants. It shows the total investment that was put into an area. However, Total ICWP density is not a good indicator for access since it also includes non-functioning WPs. Therefore a good indicator of access to ICWPs is the Functional ICWP density, which reflects to the number on functional WPs per 1000 inhabitants.

The total population of the study area (Wards 15, 18 and 19) was 48 448 people. Table 4.7 shows improved water point access levels in ward 15. The Total ICWP densities are high, with Makumeke village having the highest. However, it is clear that Mavambe and Makumeke villages in ward 15 were fortunate to get more than double the investment in water boreholes than the other three villages. Unfortunately, a large number of non-functioning boreholes in both the Mavambe and Makumeke villages have caused the actual access to safe water to fall below 1 WP per 1000 people as is shown by the low Functional ICWP densities for these two villages. There is a very big difference between the arithmetic mean of the village WP densities as is shown by the means 2.21 and 0.29 respectively. However, when one considers functional ICWP coverage (densities), it is clear that all the five villages are at the same level of poor access to borehole water. Table 4.7 may not give a clear trend of the results; therefore Figure 4.11 makes a clear visual representation of the data in Table 4.7.

Table 4.8 shows water point densities in ward 18 villages. In ward 18 the results also show a high level of inequity in investment levels between the enumeration areas that were surveyed. The results indicated that three villages had a Total ICWP density >4 boreholes per 1000 inhabitants. The other 6 villages have a Total ICWP density less than 4 boreholes per 1000 people. That's the level of investment in water boreholes is highest in Doveni and Thambaulate where density is greater than 10 boreholes per 1000 people. However the whole effort of investment has been rendered fruitless as the Functional ICWP density has been reduced to <2 boreholes per 1000 people in all the villages except in Doveni where Functional ICWP density is 3.15 boreholes per 1000 people. In ward 18, the mean Total ICWP density is 5.20 and the mean Functional ICWP density is 0.56. There is also a big difference between these two densities. The large number of non-functioning WPs suggests that there is a very big problem in the sustainability of water boreholes.

Table 4.9 shows the WP situation in ward 19. Analysis of results for ward 19 also shows the same trend in access to borehole water among the villages. Makhuvha A and Mutoti villages had >4 Total ICWP density per 1000 inhabitants. A total of 4 out of the 7 villages in ward 19 have a Total ICWP density less than 2 WPs per 1000 people. The problem of borehole sustainability is still evident in this ward as the Functional ICWP densities are extremely low with 5 out of the 7 villages having no Functional ICWP density. None of the boreholes installed in Mutoti village is functional, but this village received the highest investment with a Total ICWP of 6.64 boreholes per 1000 people. Only Budeli and Makhova A village have at least a functional borehole. It was noted during the survey that Makhuvha A is the only village out of 21 villages surveyed that had a Water Committee and community members make some contributions for the payment of a security guard who guards the existing functional boreholes. Consequently this village had the highest Functional ICWP density of 1.91 followed by Budeli with a Functional ICWP density of 0.42.

Table 4.7: Water Point Status in Ward 15 in the Thulamela Local Municipality

Tribal authority (TA)	Village	Rural population	No. of boreholes	Total ICWP density (WP/1000)	FR (%)	Functional ICWP density	Equity in Total WPs	Equity in Functional WPS
Mavambe	Mavambe	4133	13	3.15	23.08	0.73		
	Makumeke	1429	6	4.20	16.67	0.70		
	Gandlanani	3445	4	1.16	0	0		
	Jerome	3413	5	1.47	0	0		
	Roadhouse	3710	4	1.08	0	0		
		16130 (total)	**32 (total)**	**2,21 (arithmetic mean)**	**12.50**	**0.29 (arithmetic mean)**	**1.17**	**0.32**

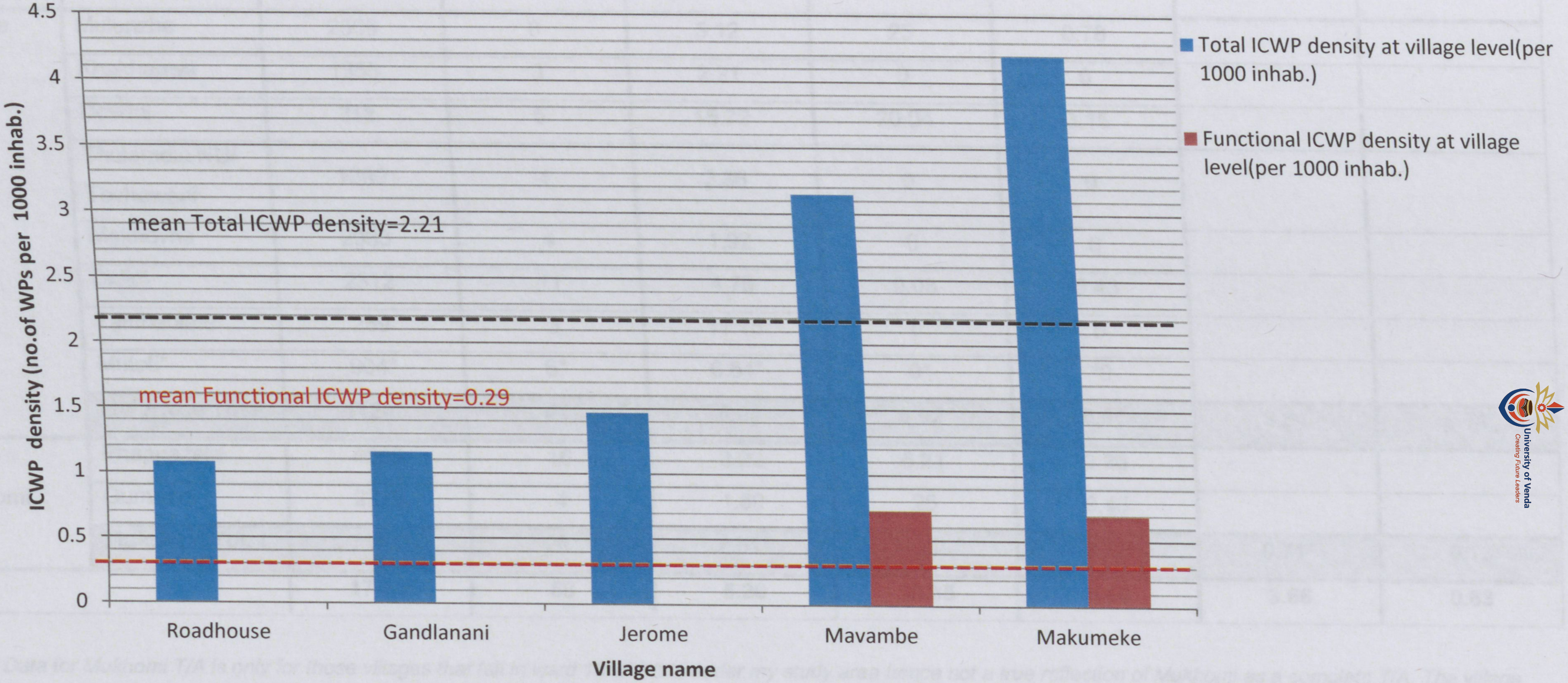


Figure 4.11 ICWP densities at village level per 1000 people in ward 15.

Table 4.8: Water Point Status in Ward 18 in the Thulamela Local Municipality

Tribal authority (TA)	Village	Rural population	No. of boreholes	Total ICWP density (WP/1000)	FR (%)	Functional ICWP density	Equity in Total WPs	Equity in Functional WPS
Mulenzhe	Mulenzhe	2566	8	3.12	25	0.78		
	Khakhanwa	1355	3	2.21	0	0		
	Doveni	318	5	15.72	20.04	3.15		
	Thulamela NU/ Tovhowani	1399	4	2.86	0	0		
	Makhovha	2083	4	1.92	0	0		
	Dididi	2312	11	4.76	9.03	0.43		
	Tambaulate	269	3	11.15	0	0		
	Mutoti*	904*	6*	6.64*	0*	*0		
	Mulenzhe Total	**11206**	**44**	**6.05**	**9.92**	**0.55**	**3.84**	**0.71**
Mukhomi	Phaphazela	4965	16	3.22	6.21	0.20		
	Gumbani	2229	4	1.80	25	0.45		
	Mukhomi Total	**7194***	**20***	**2.51***	**10**	**0.33**	**0.71***	**0.13**
Total		**17496**	**58**	**5.20**	**10.35**	**0.56**	**3.66**	**0.63**

Note. Data for Mukhomi T/A is only for those villages that fall in ward 18 which is under my study area hence not a true reflection of Mukhomi as a complete T/A. The village Mutoti is in ward 19 but falls under Mulenzhe T/A which falls under ward 18.*

Table 4.9: Water Point Status in Ward 19 of the Thulamela Local Municipality

Tribal authority (TA)	Village	Rural population	No. of boreholes	Total ICWP density (WP/1000)	FR (%)	Functional ICWP density	Equity in Total WPs	Equity in Functional WPS
Mphaphuli	Mangondi A	2373	5	0.42	0	0		
	Makhuvha A	1050	6	5.71	33.33	1.91		
	Budeli	2362	6	2.54	16.67	0.42		
	Dumasi	2154	4	1.86	0	0		
	Tshikidini	2976	6	2.02	0	0		
	Mphego	3003	2	0.67	0	0		
	Mphaphuli	***13918**	**29***	**2.20***	**10.35**	**0.39***	**1.28***	**0.52***
Mulenzhe	Mutoti	904	6	6.64	0	0		
Total		**14822**	**35**	**2.83**	**8.57**	**0.39**	**1.90**	**0.50**

*Note *Data for Mphaphuli T/A is only for those villages that fall in ward 19 which is under my study area hence not a true reflection of Mphaphuli as a whole T/A and hence the data is asterisked.*

Figure 4.12 shows the Total ICWP density which relates to total investment in water boreholes received per village in ward 15, 18 and 19. Analysis of results at Tribal Authority level is very important in assisting future investment and allocation of water infrastructure. Tribal Authorities are very influential in decision making and budgets that relate to infrastructure development. Traditional leaders who are more influential in decision making are more likely to have better investment in their areas than those who are not prominent. In this case allocation of water points is not informed and is biased. Figure 4.13 shows levels of investment per Tribal Authority across the study area.

The Tribal Authority of Mulenzhe has received better investment in WPs with a Total ICWP density of 6.05 boreholes per 1000 person followed by the part of Mukhomi Tribal Authority that lies in ward 18 (Phaphazela and Gumbani villages) with a Total ICWP density of 2.51. By considering the ICWP density Mukhomi, Mphaphuli and Mavambe villages were almost at the level of investment with densities around 2 WPs per 1000 people. However, when considering WPs that are functional, all Tribal Authorities are almost at the same level of access with Functional ICWP densities less than 1 ICWP per 1000 people. The mean Functional ICWP was found to be 0.39 ICWPs per 1000 people. When the Total ICWP density and Functional ICWPs are compared, there is a very big difference between the two means showing that most people do not enjoy the health benefits of an improved water point as a result of a large number of non-functional WPs in these areas.

A large number of WPs that were drilled lacked equipment as a result of lack of repair or vandalism. A certain proportion of the WPs were damaged and hence abandoned. It was noted with great concern that a certain proportion of the non-functional boreholes were drilled and never fitted with the pumping equipment/hardware. One borehole (ID number 1974 and photo ID 0088/0089) was drilled in 1974 and has never been fitted with a pump ever since. It may not be that the Government does not have capital to fit this borehole, but that this borehole might not be on the municipality inventory and hence its existence may be unknown. Some old residents who witnessed the drilling of this borehole claim that it has a lot of water. Table 4.10 shows all the boreholes that were drilled and never fitted with equipment.

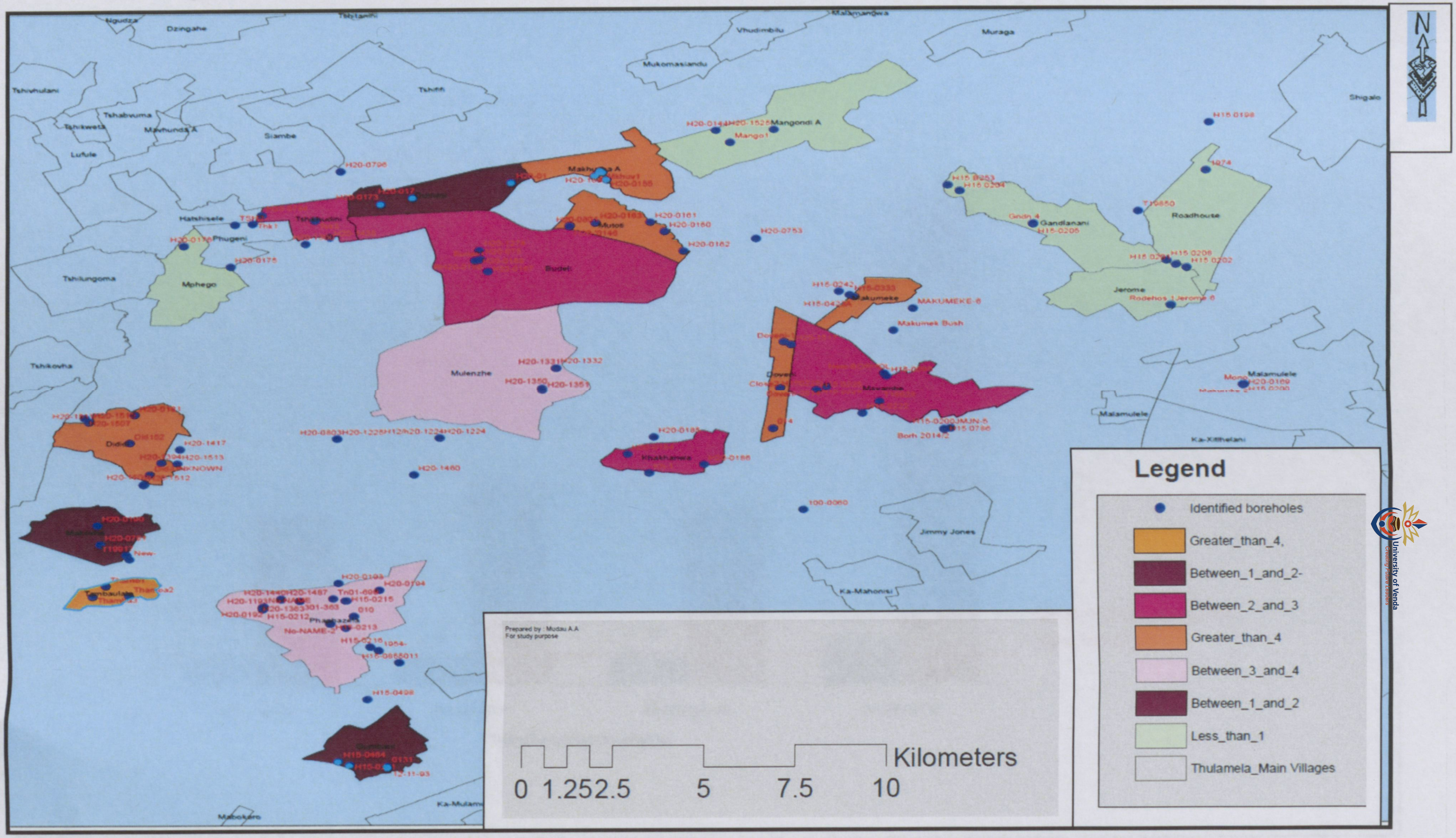


Figure 4.12: The Total ICWP density which also gives an insight into the level of investment received by the area.

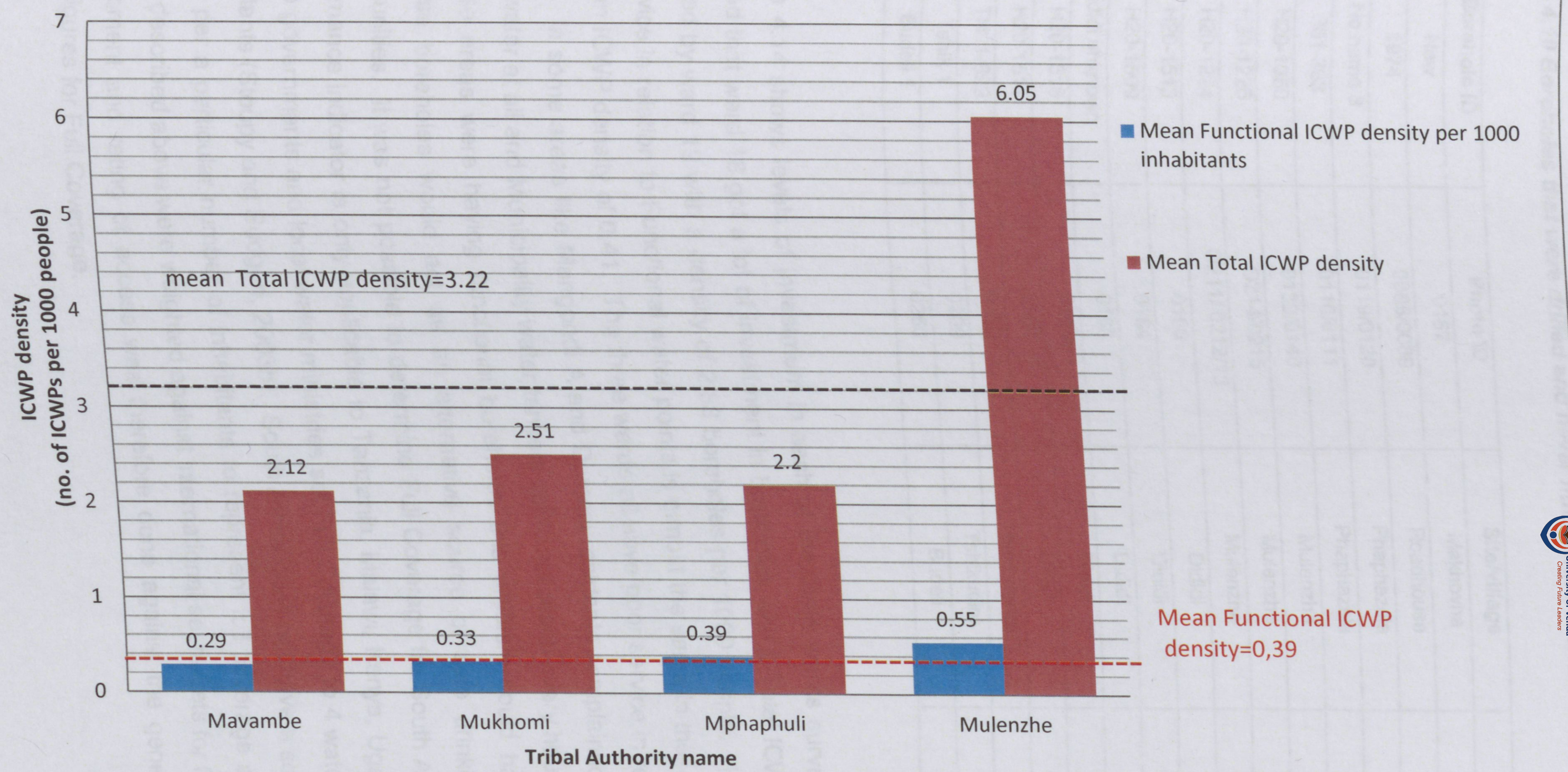


Figure 4.13: ICWP density per Tribal Authority (no. of ICWPs per 1000 people).

Table 4.10 Boreholes that were drilled and never fitted with hardware in ward 15, 18 and 19

Borehole ID	Photo ID	Site/village	Year drilled
New	0167	Makhovha	2014
1974	0088/0089	Roadhouse	1974
No name 3	0119/0120	Phaphazela	unknown
301-363	0110/0111	Phaphazela	20-11-2012
H20-1350	0139/0140	Mulenzhe	unknown
H20-1225	O214/0215	Mulenzhe	unknown
H20-1224	O211/ 0212/13	Mulenzhe	Unknown
H20-1513	0166	Dididi	unknown
H20-1509	0164	Dididi	unknown
Dididi unknown	0163	Dididi	unknown
H20-1515	0153	Dididi	unknown
H20-1511	0154	Dididi	unknown
TN01-699	0199	Thovhowani	2013
Tshik 1	0269	Tshikudini	unknown
Budeli 1	0260	Budeli	2014

Figure 4.14 shows levels of investment in each of the three wards surveyed. The results showed that ward 18 got a lot of investment in boreholes with a Total ICWP density of 5.20 followed by ward 19 with a density of 2.83 boreholes per 1000 people. However, the level of service in relation to Functional water points is almost the same in these three wards with a mean ICWP density of 0.41. The three wards all have poor service in relation to borehole water. In some areas like Mangondi A and Dumasi residents complained that they did not have water at all and Municipality water tankers could not reach every household with water. If these areas were having functional boreholes this problem could have been averted because boreholes would act as an alternative source of safe drinking water for the communities. It was not possible to determine Full Coverage for South Africa because this performance indicator is only applicable to Tanzania, Malawi, Kenya, Uganda and Ethiopia whose governments and local water ministries set Full Coverage to 4 water points per 1000 inhabitants (Stoupy and Sudgen, 2003b). South Africa does not have a set number of water points per a particular number of inhabitants to represent full coverage and hence access levels described above were weighted against international set targets for full coverage. The assessment and rating of access was therefore done against the general internationally used figures for Full Coverage.

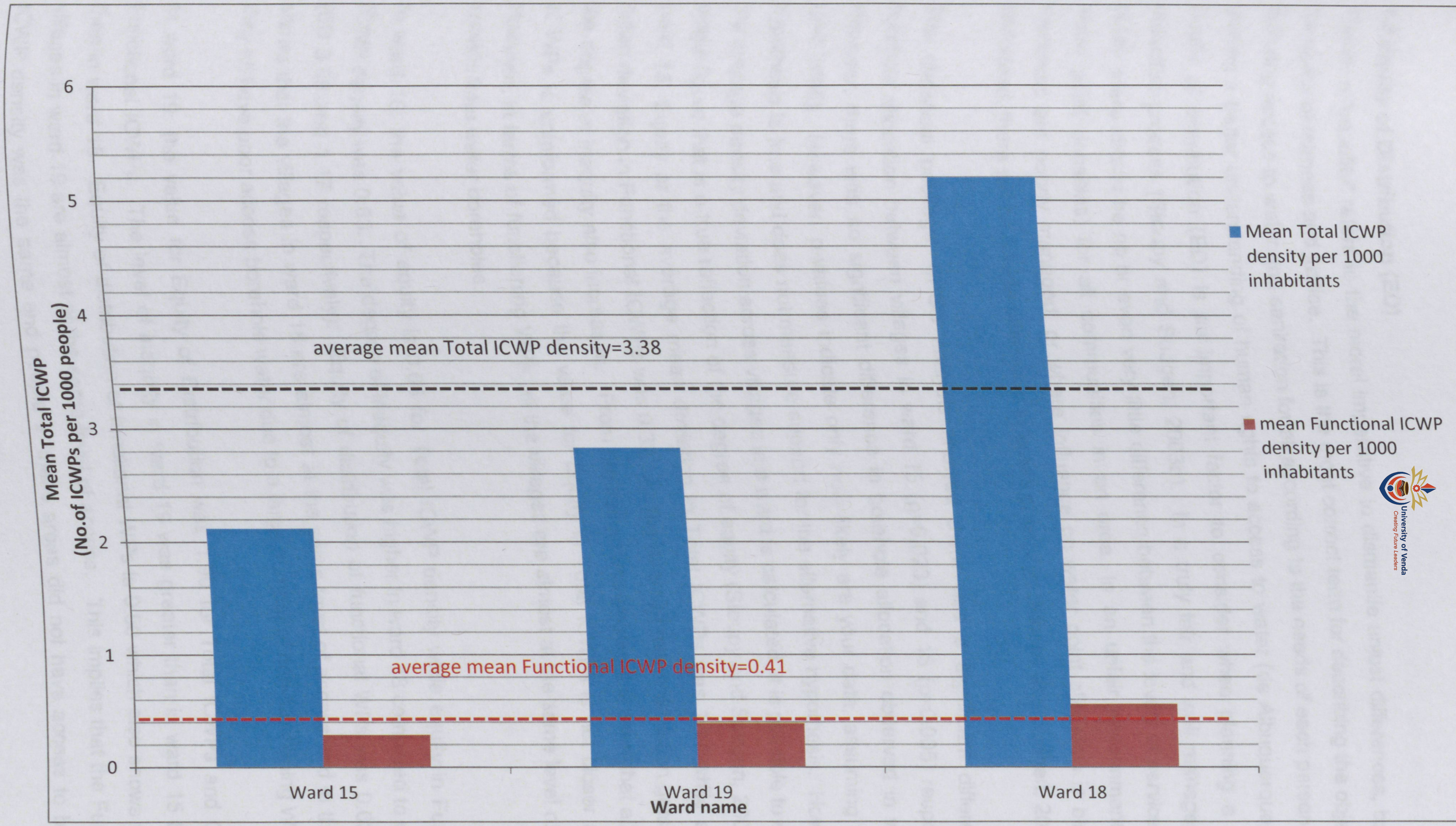


Figure 4.14: Ward MeanTotal ICWP density (number of ICWPs per 1000 inhabitants).

4.5 Equity of Distribution (ED)

The term "equality" refers to the moral imperative to dismantle unjust differences, based on principles of fairness and justice. This is the most correct term for describing the objective of ensuring access to water and sanitation for all according to the needs of each person and for gaining a better understanding of human rights to access to water (de Albuquerque, 2011). Equity of distribution (ED) is an important factor to consider when planning a poverty reduction process (Stoupy and Sudgen, 2003b). In a truly fair and well managed water sector there should be no or even very little difference between the levels of service (or the water point densities) for all communities in an area. In an unfair environment where resources are poorly managed, or where influence on water point allocation is biased or uniformed, there will be a wide difference in levels of service (Stoupy and Sudgen, 2003b).

The statistical package, SPSS analysis showed there was a significant difference in borehole allocation between villages in ward 15 ($p=0.023$) and 18 ($p=0.005$) respectively. However, there was no significant difference in borehole allocation observed in ward 19 ($p=0.7695$). However, p-values indicate only how likely are your data, assuming the null hypothesis is true and does not measure support for the alternative hypothesis. However, if the average density deviation across villages in a ward is calculated, it is possible to obtain a single figure that is a true reflection of the degree of equity (Stoupy and Sudgen, 2003a). In ward 15, Equity or the average mean deviation in Total ICWPs was 1.17 while average mean deviation in Functional ICWPs was 0,32. As the average mean deviation gets bigger, the degree of inequity also increases. From the two values above, it is clear that allocation of WPs is uninformed because the value for Equity in Total ICWPs is not closer to zero. However, in terms of functioning WPs, all the villages are almost at the same level of lack of service from water boreholes.

In ward 18, the value of equity is 3.66 for Total ICWP density while equity in Functional ICWP density was 0.63. The degree of inequity was higher in ward 18 compared to ward 15 (ED 3.66 and 1.17 respectively). Equity of distribution of functional WPs was 0.63 which shows that the villages in ward 18 are almost at the same level of access and in this case they all have poor access borehole water due to a large number of non-functioning WPs.

In ward 19, the value for Equity of Distribution was 1.90 for Total ICWPs and 0.50 for Functional ICWPs. The level of inequity in ward 19 was greater than in ward 15 but less than in ward 18. Equity of distribution of functional WPs is 0.50 which also shows that the villages in ward 19 are almost at the same level of access. This implies that the Functional ICWP density was the same and people in these areas did not have access to borehole water. The situation was aggravated by areas that did not have treated rural water schemes like the Malamulele, Xikhundu/Mhinga , Vondo and Nandoni dam water works (just to mention a few) or those areas that had interrupted flow of the water from the rural water supply schemes since they were left with no other option of safe drinking water.

4.5.1 Evaluation of ED using Ward and Traditional Authorities density profiles

The differences in equity can be visualized by developing a profile of the whole study area and then confirmed by viewing the variation in water point densities on a map (Stoupy and Sudgen, 2003b). Traditional Authority and Ward profiles can provide important information on the,

i) Level of investment within an area
ii) Equity at which the investment was made
iii) Sustainability of the investment

To draw these profiles the survey collected data on number of WPs and functionality. The following performance profiles were used:

i) Density of all water points: This represents the number of Improved Community Water Points (all boreholes installed working and not working) per 1000 people
ii) Density of functional water points: This represents the total number of water points that were working at the time of the survey (Stoupy and Sudgen, 2003b).

The performance profile shows the Total ICWP density and the Functional ICWP density in different colours. The area covered by the profile or size of the overall profile gives an insight into WP density. The greater the area covered, the greater the number of water points in an area, and the better the population is served. The whole study area has a higher density of installed boreholes and a very low density of functional boreholes as is revealed on the study area performance profile in Figure 4.15.

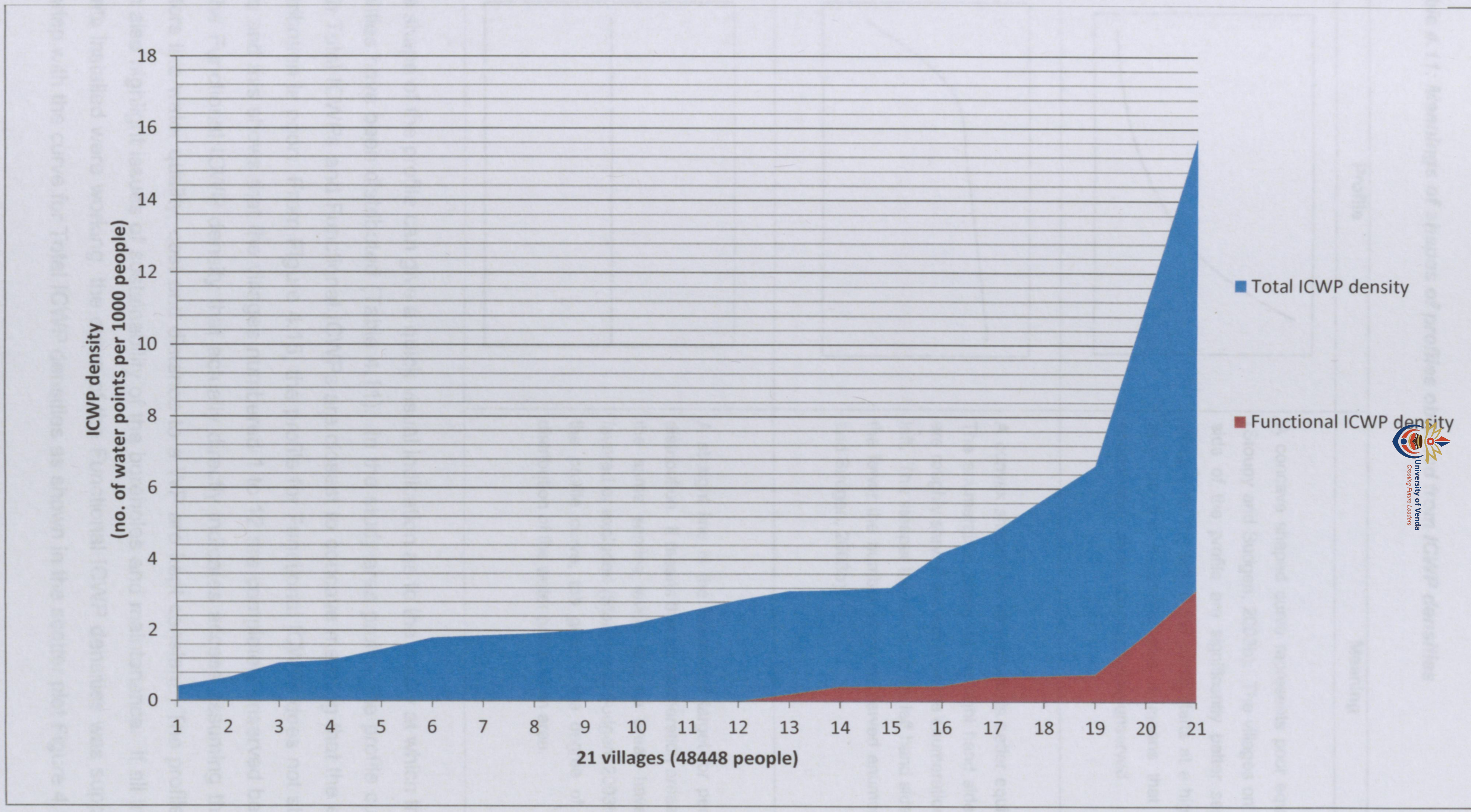
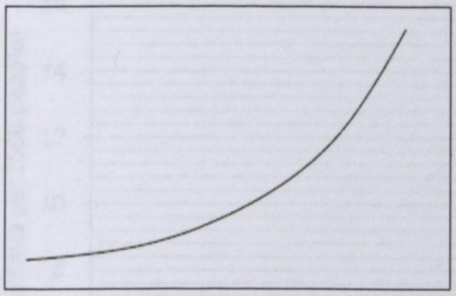
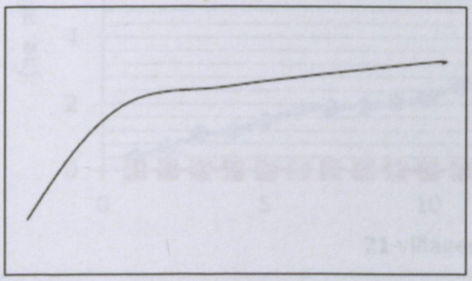
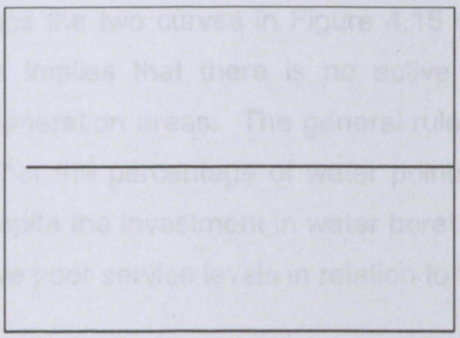


Figure 4.15: ICWP densities at village level for ward 15, 18 and 19.

Table 4.11: Meanings of shapes of profiles obtained from ICWP densities

Profile	Meaning
	A concave shaped curve represents poor equity distribution (Stoupy and Sudgen, 2003b). The villages on the right hand side of the profile are significantly better served than the villages on the left. If the curve starts at a higher level than zero on the horizontal axis it means that some of the enumeration areas are completely unserved
	A convex shaped curve represents better equity distribution. The enumeration areas on the right hand side of the profile are roughly served the same as the enumeration areas on the left. The steeper the curve on the left hand side of the profile, the fewer the number of poorly served enumeration (Stoupy and Sudgen, 2003b).
	A straight line is the theoretical target for perfect equity of distribution. It means that all enumeration areas are served at the same service levels and no areas have either been favored or excluded (Stoupy and Sudgen, 2003b). The flatter the profile curve, the greater the degree of equity in the distribution of the water points in an area.

The shape of the profile can give a quick visual indication as to the equity at which the water facilities have been distributed (Table 4.11). In the study area profile, the profile curves for both Total ICWPs and Functional ICWPs are closest to concave meaning that the equity of distribution is poor. From Figure 4.15, the profile for Functional ICWPs does not start from zero and this shows that the villages numbered 1 to 12 are completely unserved because it is the Functional ICWP density that actually directly indicates access assuming that other factors like water quality, cost and distance to a WP are kept constant. The profile curves can also highlight issues of sustainability of the boreholes and maintenance. If all the water points installed were working, the curve of the Functional ICWP densities was supposed to overlap with the curve for Total ICWP densities as shown in the scatter plot Figure 4.16.

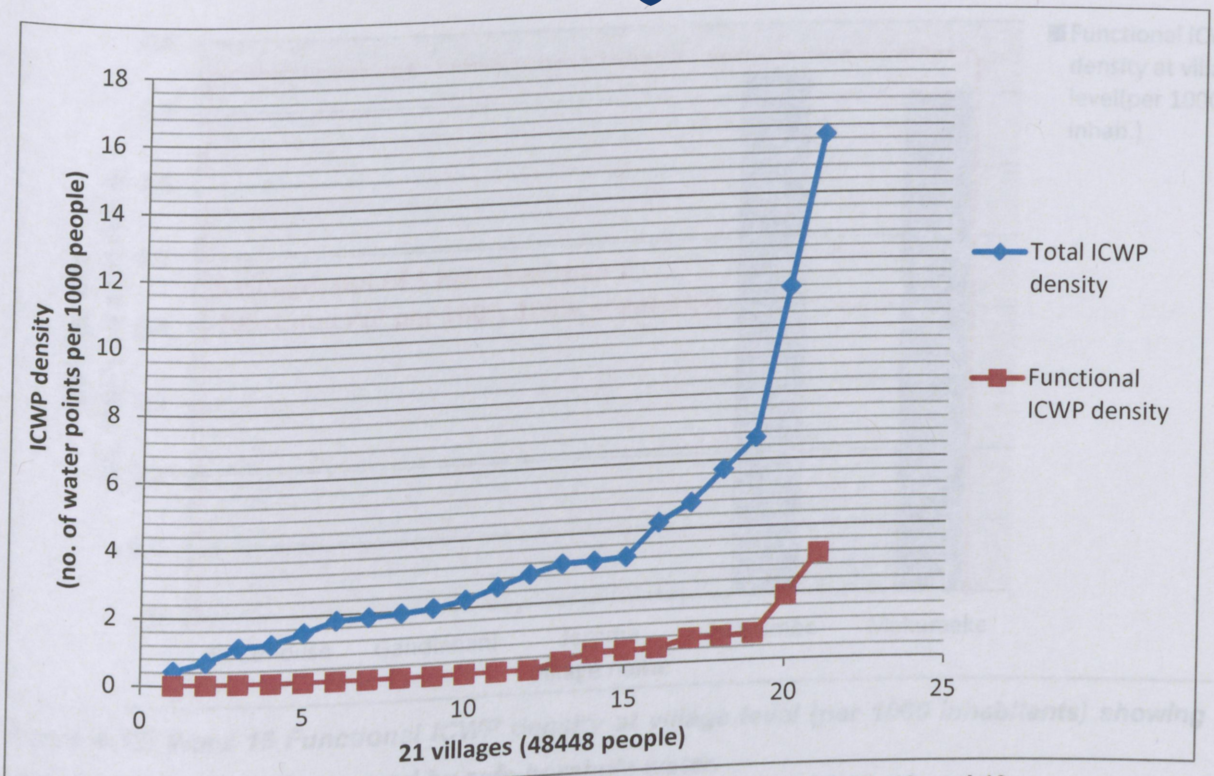


Figure 4.16: Scatter plot for ICWP densities at village level in ward 15, 18 and 19.

Since the two curves in Figure 4.15 do not overlap and are not even closer to each other, this implies that there is no active maintenance of the installed water points in these enumeration areas. The general rule is that the closer the two lines are to each other, the higher the percentage of water points in an area is working (Stoupy and Sudgen, 2003b). Despite the investment in water boreholes in the surveyed areas, the communities presently have poor service levels in relation to borehole water.

4.6.2 Assessing equity using the percentages of the population served by safe borehole water

Equity of distribution can also be assessed by considering the percentage of a population living in enumeration areas served with ranges of water point densities. Figure 4.17 shows the percentage of the population living in areas with different WP densities in ward 15. As can be seen in Figure 4.17, all the inhabitants in ward 15 live in areas with zero density or densities less than 1 borehole per 1000 people. In the absence of rural piped water scheme (the Nandoni Dam Water Scheme, the Malamulele Water Scheme and other rural schemes in these areas) this situation portrayed is very serious because the population would live without access to any safe source of drinking like the situation that was observed in Roadhouse and Gandlanani villages in this ward where people were left with no any other source of safe drinking water.

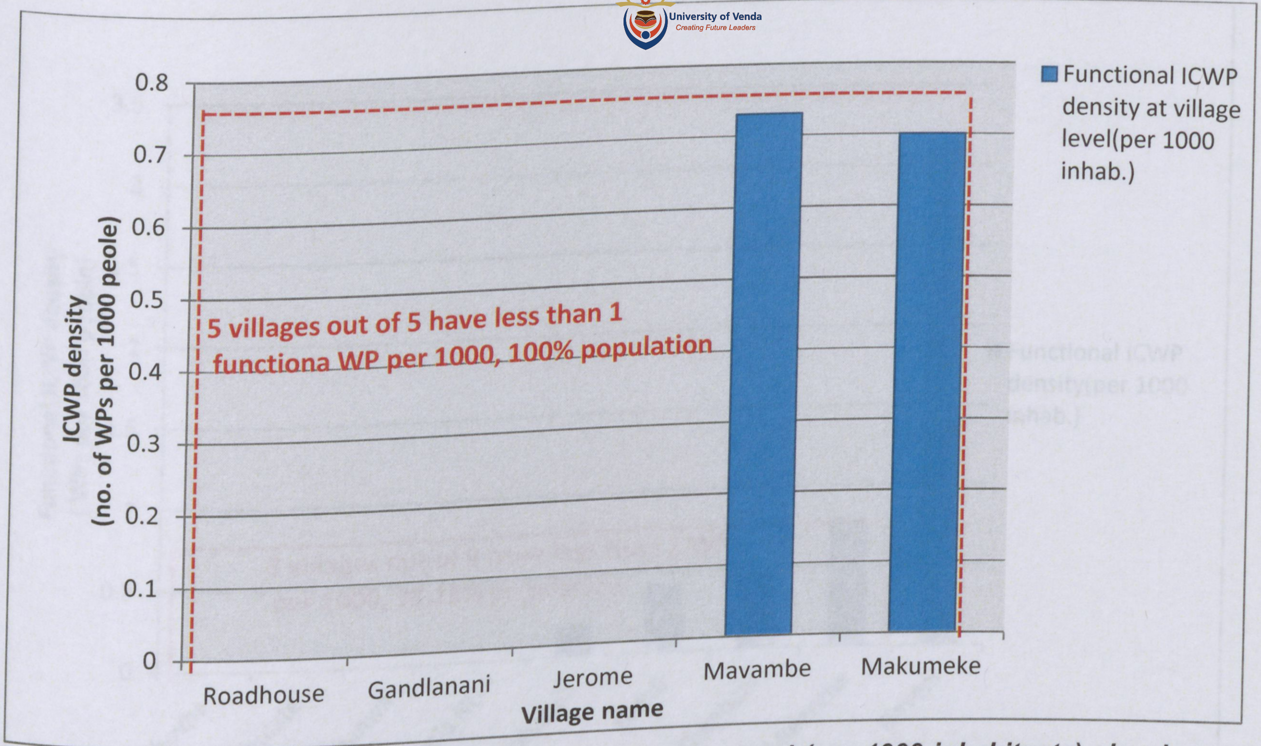


Figure 4.17: Ward 15 Functional ICWP density at village level (per 1000 inhabitants) showing percentage of population served by safe borehole water.

In ward 18, 98.18% of the rural population live in areas with zero or less than 1 functional borehole per 1000 people and Doveni was the only village that had people living in an area with a WP density >2 boreholes per 1000 people (Figure 4.18). The Phaphazela, Makovha (Tshithomboni), Thovhowani, Tambaulate and Gumbani villages generally complained of lack of a consistent flow of water throughout the day and the water situation was dire in these villages. Access to a continuous water flow was very poor which highlights a general water shortage to the inhabitants. Non-operating and intermittent water supplies place an increased health burden on communities (Majuru, 2010). Construction of boreholes are designed to serve, unfortunately in most of these villages, it is not the case. Unreliable water supply lead to household water storage in which is often practiced under unhygienic conditions and as a consequence increase health risks (WHO/UNICEF JMP, 2011).

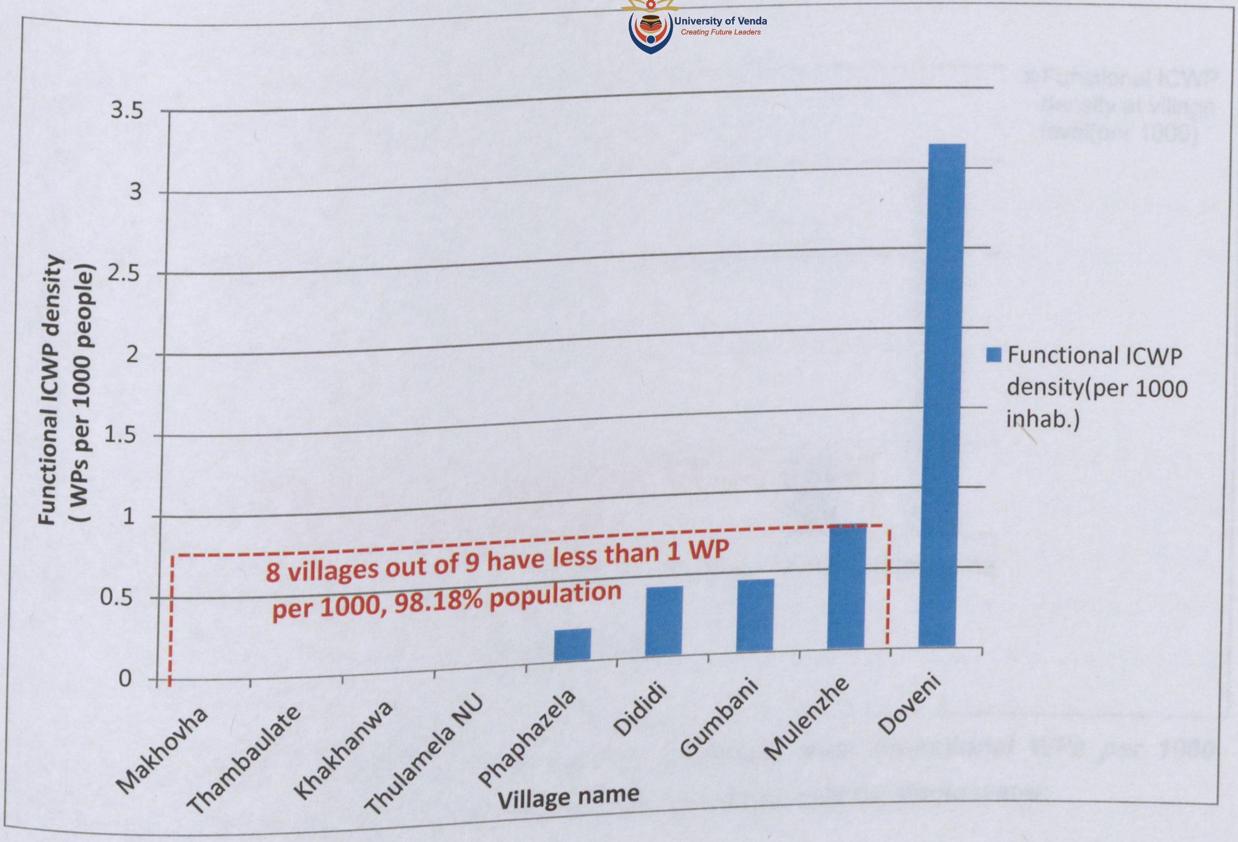


Figure 4.18: Ward 18 Functional ICWP density (per 1000 inhabitants) showing percentage of the population served by safe borehole water.

People living in the following villages live in areas with zero water point density, Makhovha (Tshithomboni), Thambaulate, Khakhanwa and Thulamela NU (Thovhowani). Under this situation people living in areas where the rural piped water scheme is interrupted they are experiencing serious water shortages. There was a serious complain by the inhabitants towards lack of water since the rural piped water scheme does not provide water all the time. In some areas residents indicated that they only get rural piped water in the morning and late in the evening. During the course of the day there was no flowing water in the pipes. All these problems emanate from low borehole functionality rates in these villages. The same trend was found in ward 19 where 6 out of the 7 villages in this ward had densities of <1 borehole per 1000 people. People in Mangondi A, Dumasi, Mutoti and Mphego villages live in areas with zero water point density. Makhuvha A village is the only village in ward 19 that had a functional water point density >1 but still less than 2 water points per 1000 people (Figure 4.19). It is clear from Figure 4.19 that 92.92% of the population lived in areas with zero or less than 1 functional borehole per 1000 inhabitants.

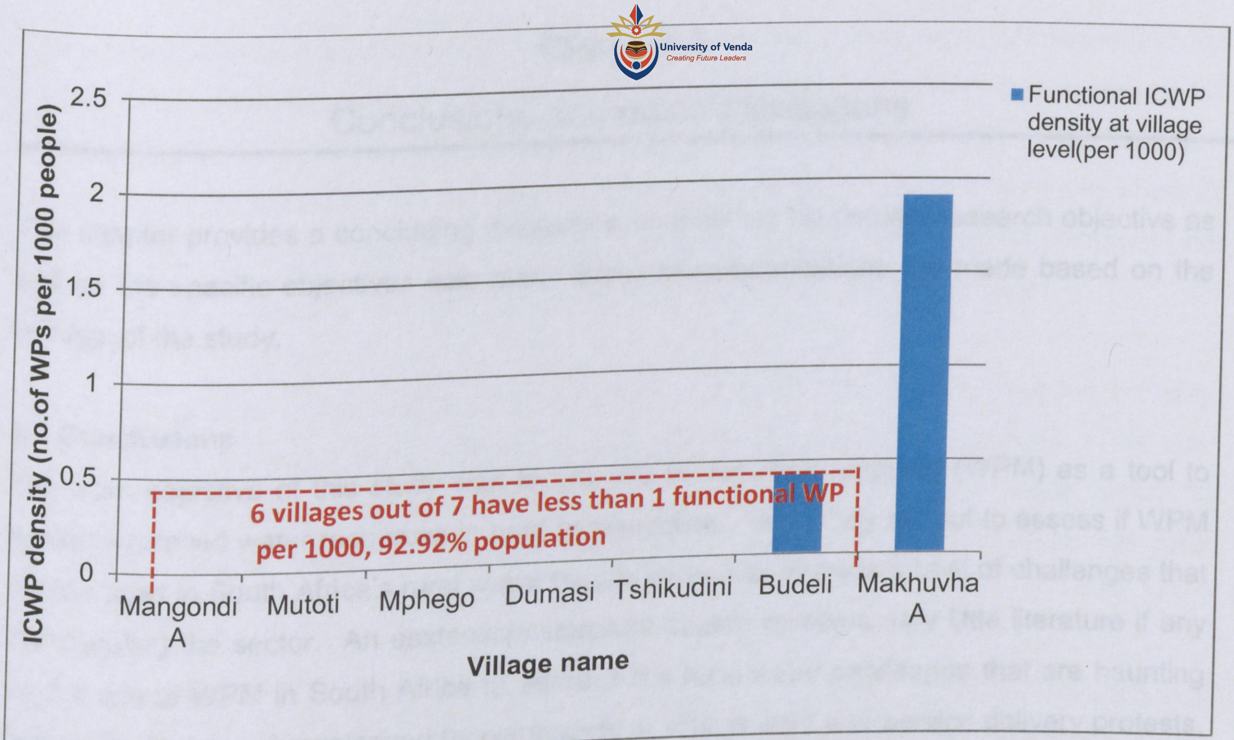


Figure 4.19: Ward 19 Functional ICWP density at village level (Functional WPs per 1000 inhabitants) showing the percentage of population served by safe borehole water.

Chapter 5

Conclusions and recommendations

This chapter provides a concluding discussion on whether the primary research objective as well as the specific objectives was met. Some recommendations are made based on the findings of the study.

5.1 Conclusions

The main objective of this study was to use the Water Point Mapping (WPM) as a tool to assess improved water resources in rural communities. This study set out to assess if WPM can be used in South Africa's rural water supply service to address a host of challenges that are haunting the sector. An eextensive literature search revealed very little literature if any on the use of WPM in South Africa to address the rural water challenges that are haunting this sector that are characterized by community or village wars and service delivery protests. WPM can be carried out at a district or Provincial level to assess the current access levels to determine where to channel resources and make informed decisions to curtail the delivery protest that are now the order of the day in the country.

The first objective was to record and assess distribution of improved water points (water boreholes) in the Thulamela Local Municipality (TLM), using a global positioning system (GPS) unit. This was achieved by the reproduction of a map that showed the distribution of boreholes within the three wards in the TLM. During the borehole survey, it was very difficult to get all the information that was initially supposed to be captured by the questionnaire's checklist. There was no knowledge in most cases on year of construction, the funder and the installer, year last maintained or repaired. It was impossible to determine the life span of the water boreholes since the information available was inconsistent. Information on year of construction was useful in assessing level of maintenance and water point sustainability comparing the current density to density that was there five or two years back. However, the WPM tool showed Functional ICWP coverage (density) of 0.29, 0.56 and 0.39 WPs per 1000 inhabitants in ward 15, 18 and 19 respectively. Functionality Rate (FR) was 12%, 10.35% and 8.57% in ward 15, 18 and 19 respectively. Assessment of ED showed that there was no equitable allocation of boreholes among villages in ward 15 and18, $p=0.023$ and $p=0.005$ respectively. When Stoupy and Sudgen (2003a)'s approach to determine ED was used, all wards were found to have unfair, uninformed or biased system of allocating water boreholes. ED values were 1.17, 3.66 and 1.90 respectively for Total ICWP density for ward 15, 18 and 19.

The second objective was to determine the microbiological and physico-chemical quality of all functional improved water points. Only functional water boreholes were assessed for water quality. (n = 12). This was achieved by the results showing 50% of the water samples of ther functional boreholes testing positive for diarrhoeagenic *E. coli*. The results showed that 58.3% of the water samples were microbiologically good, 16.67% were marginal and 25% were poor. Seventy five percent (75%) of the samples provided soft water.

The third objective was to assess the aesthetic parameters that cause rejection (notably colour, odour and taste) using reference tables (WHO Assessment Guideline). This was achieved by the results showing 100% of the samples providing clear water which is odourless and this would be useful in evaluating access to safe water in the rural communities.

The fourth objective was to develop digital maps using the collected data from the GPS and correlate it with the demographic, administrative and physical data. This was achieved by the use of the GIS ArcView software that reproduced digital maps which showed a visual picture of the issues relating to the quality of the water supply service to the rural communities. In general, all villages were found to have poor access to borehole water.

The study clearly showed that the WPM tool can highlight the levels of access to improved water in rural communities through the ICWP density service indicator. Scheme functionality, maintenance and sustainability were clearly shown through the Functionality Rate service indicator from WPM. It was clear from the WPM results that the allocation of water boreholes was biased or uninformed as was proved by the Equity of Distribution service indicator. In conclusion all objectives were achieved and the results showed that indeed WPM tool can assist authorities in making informed decisions relating to the water sector. This tool revealed where need was greatest and hence where resources could be channeled to improve the levels of equity in the distribution of water points in the Thulamela Local Municipality's rural communities. Therefore, WPM provides a holistic solution to the South African rural water sector problems as is indicated by the study results.

5.2 Recommendations

The most effective way of halving the population without access to safe water by 2015 in the Thulamela Local Municipality rural communities is to:

- Use the WPM tool to indicate those areas that need to improve the level of coordination between the stakeholders active in the water sector.

- Build and empower district, municipality, ward and village Water Coordinating Teams to effectively manage, monitor, control and evaluate the work being carried out in their respective areas. Match the extraction technology with the aquifer and increase local capacity to implement shallow well and handpumps. On this note, the end users of the boreholes must be trained on how to operate handpumps and repair them.
- Most vandalism takes place when the borehole stays for a long time without functioning or not being operated such that the importance of the infrastructure is lost and it ends up being vandalized. It is therefore necessary to maintain all non-functional boreholes and make them serve the communities.
- The District and Local Municipality Coordinating Teams should develop methodologies for ensuring that unserved communities are given priority in the resource allocation process and that funding levels is informed by the need that is there. Supporting the development of district based co-coordinating teams to ensure fairer methods of resource allocation is an extremely cost effective method of reaching the poor population.
- The results of this survey need to be disseminated to all stakeholders in the Vhembe District and the Thulamela Local Municipality and the process of developing a more strategic, pro-poor method of allocating improved water supplies initiated.
- Investigate the causes of the inequity in the allocation of resources and come up with solutions to overcome any barriers to equal access.
- Develop methods for keeping the data base of water points up to date.
- The communities should be made aware that all water points installed in their areas belong to the community and every community member is accountable to ensure the safety and long service of the boreholes. This is so because most boreholes were vandalized or damaged as a result of lack of knowledge on how to operate the handpumps.
- It was also noted during the survey that diesel powered Cemo pumps were targeted by thieves and would recommend for future investment to focus on electrically powered pumps. More studies should be carried out to ascertain this recommendation.
- The District should prioritize poverty alleviation in Mangondi A, Roadhouse, Dumasi, Budeli, Phaphazela and Dididi as the communities having a serious water shortage.
- Villages that had the privilege of getting the service of the rural piped water schemes should in addition have functional boreholes on standby so that when there is no water flow from their schemes they can still continue to get water. This would eliminate the need for water storage which risks re-contamination of the once safe

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water. The problem of lack of continuous access to safe water can be overcome, outbreaks of child dysentery can be prevented and the country would be on track to meet the MDG on water by 2015.

- Monitoring the sustainability and safety aspects of drinking water supply systems and services will need to be stepped up. In recognition of threats to quality of water, many drinking water supply operators and regulators are adopting an integrated risk assessment and management approach that takes risk spots and events into account along the chain of events from source to tap (WHO/UNICEF JMP, 2011). The recommended strategies include: quantitative microbial risk assessment (QMRA), sanitary inspections, the application of health-based targets and water safety plan (WHO/UNICEF JMP, 2011). The practice of household water treatment (HWT) and safe storage can help improve water quality at a point of consumption especially where piped water supplies is unpredictable and people have to store water to bridge the gaps between deliveries and people have to store water, or in cases where their borehole water is microbiologically poor.
- Service providers should design water systems that deliver water to the household which include measures to prevent risks and to verify water quality as is being advocated by WHO/UNICEF JMP (2014) in their vision beyond 2015 when the MDGs deadline ends. The broken water pipes would need urgent fixing since this borehole is the main source of drinking water for the Dididi community. The pools around the boreholes in Makhuva A and Doveni (Khakhan'wa borehole) need to be rehabilitated to assure the safety of the water from these water points see photo identity number 0253 and 0147 respectively in appendix two).
- Poorly managed water points present a significant health risk to the users like the situation in Dididi village where the broken pipes expose users to diarrheagic *E. coli.* Urgent attention is needed to repair the broken pipe in Dididi since safely managed drinking water services would reliably deliver water that is sufficient to meet domestic needs and does not present a significant risk to health (WHO/UNICEF JMP, 2014). The community of Dididi and Doveni should be assisted with household water treatment while the observed contamination problem is being attended to.
- If more than one aquifer is penetrated by a well bore, waters from several aquifers may mix. If one aquifer is contaminated then contaminated water could flow from it into the well bore, and from there into other aquifers (ADEM, 2001). Based on these reasons, service providers should properly seal wells and boreholes when they are no longer needed. In general, proper well abandonment involves three tasks. First, one must clean out any debris or equipment that may partially block the well bore

and prevent a proper seal (ADEM, 2001). Second, remove the casing (if possible), also for the purpose of ensuring a tight seal. Third, fill the well bore from bottom to top with material, such as cement bentonite (clay) grout, that will prevent mixing of water from different aquifers and also prevent surface water from entering the aquifers.

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APPENDIX ONE

Survey Questionnaire

Geographic

(1) Water point Id___________| ☐ no ID

(2)Date of record___/__/_____

(3) Region |______________

(4) District |______________

(5) Ward |______________

(6) Village/ site |______________

(7) TA name |______________

(7) GPS equipment number ☐☐☐

(8) GPS waypoint number ______________

(9) Elevation m ☐☐☐☐

(10) Easting x ☐☐☐☐☐☐☐ Dec°

(11) Northing y ☐☐☐☐☐☐☐ Dec°

(12) WP photo ID______________

General information (tick for applicable)

(13) water point type?

☐ 1-machine-drilled borehole
☐ 2-vonder "hand drilled" tube well
☐ 3-shallow well & handpump
☐ 4-windlass well
☐ 5-gravity fed communal standpipe
☐ 6-motorised communal standpipe
☐ 7-windmill
☐ 8- Improved spring
☐ 9-other______________

(14) Handpump type/ extraction system?

☐ 0- No pump
☐ 1-Mono
☐ 2- Cemo
☐ 3- Afridev
☐ 4- Climax
☐ 5-Maldev
☐ 6-Malda
☐ 7-National mark V
☐ 8- India mark
☐ 9-Gravity II
☐ 10- KSB
☐ 11-Submersible
☐ 12-Nira/Tanira
☐ 13- windmill
☐ 14-SWN 80
☐ 9 -Other______

(15) Status

☐ 1-functional ☐ 2- non-functional

(16) Main hardware problem

Tank out of use ☐
Source damaged ☐
Pump broken ☐
Pump stolen ☐
Engine broken ☐
Under construction ☐
Tap broken ☐
Engine stolen ☐
Pipe broken ☐
Tap poorly sited ☐
Tap broken ☐

Community & Committee

(17) Is there a committee? ☐ Yes ☐ No ☐ Unknown

(18) Was it trained? ☐ Yes ☐ No ☐ Unknown

(19) Community perception regarding water

Quantity/flow

☐ Enough
☐ Insufficient
☐ Seasonal
☐ Dry
☐ No answer

Quality

☐ 1-Clear
☐ 2-Milky
☐ 3-Coloured (reddish/blackish)
☐ 4-Soft
☐ 5-hard
☐ 6-Salty abandoned
☐ 7- Abandoned other______________
☐ 8- No answer

Construction/Installation

(19) is water point part of a scheme? (Specify name)

No ☐ YES ☐ ______________|

(20) when was water point installed?

☐☐☐☐ year ☐ 10- unknown

☐ 1- water point under construction

(21) who funded the water point?

______________| ☐ 10-unknown

(22) who installed the WP?

______________| ☐ 10-unknown

(23) Scheme Ownership & Management

Ownership

☐ VDM
☐ Company
☐ Trust
☐ Water Board
☐ DWA

Management

☐ VDM
☐ Company
☐ Water Board
☐ DWA
☐ Private operator

(24) Maintenance

When was the last Water Point problem?

☐ X-Never had a problem
☐ ☐☐☐☐ Year

Was it the first time?

☐ YES ☐ NO

What was the problem?

☐ 1- pump:______________
☐ 2-water dried up
☐ 3-tap:______________
☐ 9-other______________

Who repaired it?

☐ X-not yet repaired

______________| ☐ 10-unknown

(25) Payment& Public meetings about expenditure

Water payment

☐ Pay monthly
☐ Pay annually
☐ Pay when scheme fails
☐ Never pay
☐ Other

Public meetings about income and expenditure

☐ Yes
☐ No
☐ Don't know

Comments

Surveyor Name: Mr Taonameso S (MSc Microbiology- UNIVEN)

Appendix two

Water borehole data

	Borehole number	Borehole photo number	GPS coordinates		Altitude (ft)	Borehole Depth (m)	Installation Type	Power Type	Water Level
			Latitude	Longitude					
1	H15-0095	0033/34/36/37	22.59966	30.03829	1706	23m	Mono	Electric	5m
2	New	0038	22.59925	30.8269	1722	unknown	Mono	Electric	unknown
3	H15-0225	0041/42/43	23.00183	30.37598	1790	Unknown	Mono	DIESEL	unknown
4	H15-0224	0044	23.00111	30.37690	1818	34m	no pump	unknown	7.68
5	H15-0225	0046/47	23.00164	30.37585	1791	unknown	no pump	unknown	unknown
6	new 2014/01	0049	23.00090	30.41912	1748	unknown	Mono	Electric	unknown
7	Boh2014/02	0051	23.00763	30.38874	1746	unknown	Mono	Electric	unknown
8	H15-0786	0052/53/54	23.00777	30.38878	1756	unknown	no pump	unknown	unknown
9	H15-0200	0055/56	23.00756	30.38940	1745	70m	Mono	Electric	20m
10	H15-0220	0057/59	23.00755	30.38936	1741	unknown	no pump	unknown	unknown
11	H15-0222	0062	23.00530	30.38049	1712	84m	Mono	Electric	20m
12	T19628	0064/65	23.00362	30.38219	1714	unknown	no pump	unknown	unknown
13	100-0060	0061	23.01956	30.37436	1808	unknown	no pump	unknown	unknown
14	RHS 1	0084	22.58934	30.41169	1578	unknown	Mono	Hand	unknown
15	H15-0198	0086/87	22.56268	30.41552	1471	unknown	Mono	Hand	unknown

16	1974	0088/89	22.56974	30.41521	1566	unknown	no pump	unknown	unknown
17	H15-0199	0090/91/92	22.57569	30.40833	1527	unknow	no pump	unkno	unknown
18	H15-0206	0076	22.57746	30.39770	1655	unknown	Mono	unknown	unknown
19	H15-0204	0074/75	22.57269	30.39029	1595	unknown	Mono	DIESEL	unknown
20	H15-B253	0073	22.57189	30.38912	1592	unknown	Mono	Electric	unknown
21	H15-0205	0077	22.57749	30.39770	1659	unknown	no pump	unknown	unknown
22	H15-0200	0078	23.00094	30.41911	1454	unknown	no pump	unknown	unknown
23	H15-0208	0079	22.58284	30.41123	1701	unknown	no pump	unknown	unknown
24	H15-0202	0080	22.58387	30,4133	1732	unknown	handpump	Hand	unknown
25	H15-0201	0081	22.58338	30.41220	1725	unknown	no pump	unknown	unknown
26	Jerome 6	0082	22.58934	30.41169	1794	unknown	no pump	unknown	unknown
27	MAKUMEK 6	0066	22.58977	30.38565	1684	unknown	no pump	unknown	unknown
28	H15-0242	0067/68	22.58722	30.37810	1707	unknown	Mono	DIESEL	unknown
29	H15-0243	0069	22.58803	30.37968	1733	unknown	no pump	unknown	unknown
30	H15-0333	0070	22.58777	30.37917	1723	unknown	no pump	unknown	unknown
31	MAKUMEK 2	0071	23.00091	30.41905	1627	unknown	no pump	unknown	unknown
32	MAKU BUSH	0072	22.59289	30.38364	1666	unknown	handpump	Hand	unknown
33	H20-1331	0137	22.59826	30.34961	1724	12OM	Mono	Electric	13.11m
34	H20-1332	0138	22.59822	30.34955	1721	unknown	MONO	Electric	unknown
35	H20-1350	0139/0140	23.00119	30.34817	1718	unknown	no pump	unknown	unknown

36	H20-1460.	0205/6/8	23.01413	30.33507	1767	unknown	Mono	windmill	unknown
37	H20-1440	0203/2/4/9	23.03131	30.32131	1672	unknown	no pump	unknown	unknown
38	H20-1225	0214/0215	23.00877	30.32740	1733	72m	no pump	unknown	unknown
39	H20-1224	0211/12/13	23.00871	30.33780	1851	72m	no pump	unknown	unknown
40	H20-1351	0141	23.00169	30.34822	1726	73.28m	Mono	Electric	8.20m
41	TN01-699	0199	23.03256	30.32662	1920	unknown	no pump	unknown	unknown
42	H20-0194	0198	23.03136	30.33133	1959	unknown	handpump	Hand	unknown
43	H20-0193	0197	23.03031	30.32722	1964	unknown	handpump	Hand	unknown
44	H20-1487	0201/0202	23.03256	30.32138	1883	unknown	Mono	DIESEL	unknown
45	New-2014	0167	23.02662	30.30617	1904	unknown	no pump	unknown	unknown
46	T19917	0168/0170	23.02596	30.30590	1937	unknown	no pump	unknown	unknown
47	H20-0791	0174	23.02436	30.30326	1859	unknown	no pump	unknown	unknown
48	H20-0190	0175	23.02155	30.02155	1804	unknown	handpump	Hand	unknown
49	H20-0176	0282/0283	22.58032	30.31181	1877	unknown	Mono	Hand	unknown
50	H20-0175	0280/0281	22.58337	30.31651	1862	unknown	Mono	Electric	unknown
51	Tshk 1	0269	22.57713	30.31874	1973	unknown	no pump	unknown	unknown
52	H20-0793	0270/0271/2	22.57728	30.31693	1987	unknown	Mono	Hand	unknown
53	H20-0794	0273	22.57585	30.31967	1927	Unknown	handpump	Hand	unknown
54	Tshk 3	0274	22.57669	30.32504	1897	unknown	handpump	Hand	unknown
55	H20-1435	0275/0276/7	22.57917	30.32655	1935	unknown	Mono	Hand	unknown

56	H20-1360	0278	22.58007	30.32410	1856	unknown	handpump	Hand	unknown
57	H20-0169	0265	23.00096	30.41909	1939	unknown	handpump	Hand	unknown
58	H20-0171	0266	22.57343	30.33495	1866	unknown	no pump	unknown	unknown
59	H20-0173	0267	22.57435	30.33172	1929	unknown	handpump	Hand	unknown
60	H20-0796	0268	22.56955	30.32768	1819	unknown	Mono	Electric	unknown
61	H20-0803	0216	23.00876	30.32740	1382	unknown	no pump	unknown	unknown
62	H20-0162	0217	22.58133	30.36238	1611	unknown	no pump	unknown	unknown
63	H20-0161	0218/0219	22.57710	30.35901	1654	unknown	no pump	unknown	unknown
64	H20-0160	0220/0221	22.57846	30.36046	1645	unknown	no pump	unknown	unknown
65	H20-0163	0222/0223	22.57719	30.35344	1730	unknown	handpump	Hand	unknown
66	H20-0801	0224/0225	22.57762	30.35082	1774	unknown	handpump	Hand	unknown
67	H20-0146	0227/0228	22.57763	30.35082	1505	unknown	handpump	Hand	unknown
68	Mangond 1	0229-32	22.56558	30.36709	1571	unknown	handpump	Hand	unknown
69	H20-1525	0233	22.56365	30.37151	1606	unknown	handpump	Hand	unknown
70	H20-0144	0235/0236	22.56379	30.36564	1600	unknown	no pump	unknown	unknown
71	H20-0753	0237/0238	22.57949	30.36971	1484	unknown	Mono	Electric	unknown
72	H20-1513	0166	23.01239	30.31118	1838	unknown	no pump	unknown	unknown
73	H20-1512	0165	23.01549	30.30774	1841	unknown	Mono	Electric	unknown
74	H20-1509	0164	23.01537	30.30778	1836	unknown	no pump	unknown	unknown
75	Didi unknown	0163	23.01406	30.30839	1805	unknown	no pump	unknown	unknown

76	H20-1417	0160/0161	23.01032	30.31145	1763	100.04m	no pump	diesel	9.6m
77	H20-1394	0162	23.02052	30.30.956	1805	unknown	handpump	Hand	unknown
78	H20-0181	0158/0159	23.00804	30.51185	1644	unknown	no pump	unknown	unknown
79	H20-1507	0155-0157	23.00570	30.30181	1622	unknown	Mono	Electric	unknown
80	H20-1515	0153	23.00622	30.30622	1613	unknown	no pump	unknown	unknown
81	H20-1511	0154	23.00626	30.30230	1618	unknown	no pump	unknown	unknown
82	DID 152	0152	23.00931	30.30931	1675	unknown	no pump	unknown	unknown
83	H15-0211	0132/133/134	23.05745	30.32822	1956	103m	Mono	diesel	3.8m
84	H15-0464	0135	23.05687	30.32710	1979	unknown	no pump	unknown	unknown
85	12-11-93	0130	23.05783	30.33204	1899	unknown	Mono	Hand	unknown
86	031-Gumban	0131	23.05764	30.33199	1899	unknown	no pump	unknown	unknown
87	H15-0212	0101/0102	23.03410	30.31943	1640	59m	Mono	Electric	3.5m
88	29-10-93	0113	23.03525	30.32865	1793	unknown	Mono	Hand	unknown
89	No name 2	0118	23.03635	30.32624	1793	unknown	no pump	unknown	unknown
90	H15-0498	0124/125	23.04765	30.32977	1922	unknown	no pump	unknown	unknown
91	H15-0216	0126	23.03984	30.33016	1857	unknown	no pump	unknown	unknown
92	H15-0214	0128	23.03290	30.32786	1756	unknown	no pump	unknown	unknown
93	H15-0215	0112	23.03288	30.32797	1754	unknown	no pump	unknown	unknown
94	No name 3	0119/0120	23.03698	30.32780	1827	unknown	no pump	unknown	unknown
95	301-363	0110/0111	23.03290	30.32321	1694	unknown	no pump	unknown	unknown

96	H20-1193	0103	23.03380	30.31950	1657	unknown	Mono	unknown	unknown
97	No name	0106	23.05149	30.31955	1666	unknown	no pump	unknown	unknown
98	C003/070	0099	23.00092	30.41905	1715	unknown	Mono	Hand	unknown
99	H20-0192	0105	23.03382	30.31943	1648	unknown	no pump	unknown	unknown
100	H15-0213	0104	23.03630	30.32625	1789	unknown	Mono	unknown	unknown
101	1994-229	0123	23.04038	30.33100	1830	unknown	no pump	unknown	unknown
102	H15-0855	0121/0122	23.04213	30.33303	1841	unknown	Mono	Electric	unknown
103	H20-0158	0239/40/48	22.57037	30.35339	1643	unknown	Mono	Hand	unknown
104	H20-0156	0251	22.56962	30.35392	1674	unknown	handpump	Hand	unknown
105	Makhuvha 1	0252	22.56986	30.35417	1665	unknown	handpump	Hand	unknown
106	H20-0155	0253-55	22.57089	30.35454	1652	unknown	Mono	Electric	unknown
107	H20-01	0256	22.57130	30.34495	1818	unknown	handpump	Hand	unknown
108	H20-1634	0250	22.56990	30.35387	1661	unknown	Mono	Electric	unknown
109	H20-1274	0258/59	22.58117	30.34170	1720	81.43m	Mono	Electric	18.63
110	Budeli 1	0260	22.58263	30.34126	1704	unknown	no pump	unknown	unknown
111	H20-0167	0261	22.58422	30.34255	1681	unknown	Mono	Electric	unknown
112	H20-0168	0262	22.58245	30.34163	1710	unknown	handpump	Hand	unknown
113	R-H20-0168	0263	22.58245	30.34163	1710	unknown	Mono	Electric	unknown
114	H20-0075	0264	22.58234	30.34182	1710	unknown	Mono	Electric	unknown
115	Doveni 1	0148	22.59461	30.37254	1722	unknown	handpump	Hand	unknown

116	H20-1517	0149	22.59498	30.37327	1746	unknown	handpump	Hand	unknown
117	Doveni 2014	0150	23.00135	30.37224	1751	unknown	Mono	diesel	unknown
118	Doveni 014	0151	23.00144	30.37747	1808	unknown	handpump	Hand	unknown
119	Kh 1	0142	23.01407	30.35882	1780	unknown	handpump	Hand	unknown
120	H20-0186	0146/147	23.01282	30.36443	1800	unknown	Mono	Diesel	unknown
121	H20-0184	0143	23.01122	30.35670	1756	unknown	handpump	Hand	unknown
122	H20-0185	0144	23.00871	30.35941	1718	unknown	no pump	unknown	unknown
123	Thamba 1	0171	23.03056	30.30373	2005	unknown	Mono	Electric	unknown
124	Thamba 2	0172	23.03209	30.30604	1954	unknown	handpump	Hand	unknown
125	Thamba 3	0173	23.03212	30.30235	2009	unknown	no pump	unknown	unknown

Appendix three

Research photographs

0037 Abandoned borehole

0033 Borehole specifications

0034 Borehole Functional

0036 Abandoned and functional BH

0038 New functional borehole

0039 Water reservoir in Mavambe

0042 Abandoned borehole

0044 Pump broken but main hole is fine

0046 Abandoned borehole very old

0047 new borehole without power

0051 no power

0052 pump broken in Mavambe

0053 pump broken in Mavambe

0056 pump broken

0057 pump broken

0059 casing not removed cause contamination

0061 diesel engine was removed to T/A

0062 Functional Cemo pump

0065 old and abandoned

0066 old and abandoned

0068 old and abandoned

0069 Diesel pump functional

0070 old abandoned

0071 Pump broken, main hole still fine

0072 Submersible pump broken

0073 Handpump broken

0074 Cemo pump broken, abandoned

0076 Cemo pump broken, abandoned

0077 pump broken and abandoned

0078 borehole destroyed to pave way for a pipe

0079 abandoned ,choked with human hair

0080 Handpump broken

0081 abandoned main hole destroyed

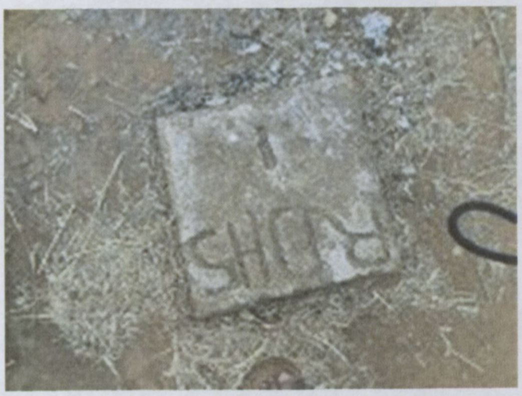
0082 pump broken and abandoned

0085 Handpump broken

0086 Handpump broken

0088 Borehole drilled in 1974 never fitted

0091 pump broken and abandoned

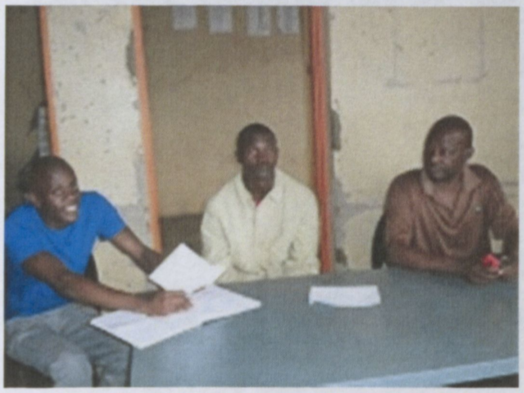


0092 Abandoned borehole no pump

0093 Phaphazela T/A meeting with Surveyor

0094 Phaphazela T/A meeting with Surveyor

0095 Phaphazela T/A meeting with Surveyor



0096 Phaphazela T/A meeting with Surveyor

0097 Phaphazela T/A meeting with Surveyor

0098 Phaphazela T/A meeting with Surveyor

0099 Mono handpump broken

0100 Phaphazela Elder showing pump fault

0103 Cemo pump broken

0104 Cemo pump broken

0105 Abandoned borehole

0106 Abandoned main hole covered in grass

0107 Old abandoned hand dug main hole

0110 Drilled never fitted with pump

0111 Drilled in 2012 and never fitted

0112 Old and abandoned broken borehole

0113 Pump broken, main hole is fine

0114 Abandoned old borehole

0115 Mono pump broken being GPSed

0116 broken Mono handpump

0118 broken old pump abandoned

0119 Drilled never fitted due to mining prospects

0120 drilled and never fitted

0121 Broken submersible pump

0123 Old and abandoned borehole

0126 Broken pump. Main hole still fine

0128 Abandoned borehole, source damaged

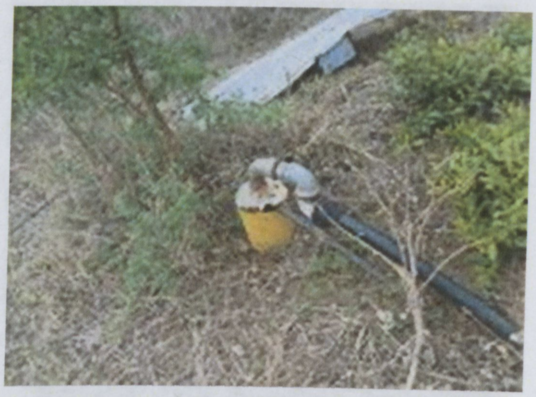
0130 Broken Mono pump in Gumbani

0131 Pump was broken and source was damaged

0134 Functional pump which was not connected

0135 Pump broken and is now on a road

0137 Pipe broken



0138 Submersible mono pump functional

0141 Functional Cemo pump in Mulenzhe

0139 Drilled and never fitted with a pump

0142 Bush pump broken and abandoned

0143 broken bush pump

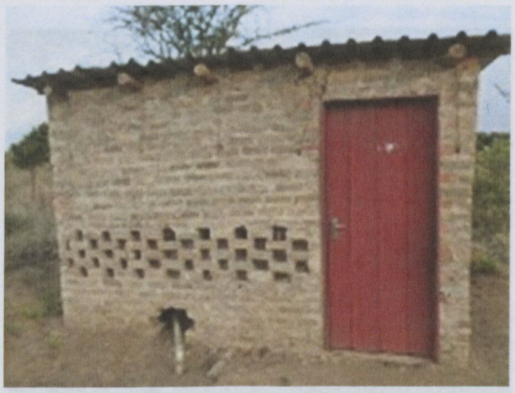
0144 Open abandoned main hole

0146 Functional Cemo diesel pump in Khakhan'wa

0147 Functional Cemo diesel pump in Khakhan'wa

0148 Abandoned handpump on a road

0149 Broken handpump



0150 Functional Cemo Mono pump in Doveni

0151 Broken handpump

0152 abandoned main hole filled with debris

0153 Drilled and never fitted

0154 drilled and never fitted due lack of water

0155 Functional submersible Mono pump

0156 Broken distribution pipe in Dididi

0157 Reservoir supplied by the broken pipe

0158 Old abandoned borehole

0161 Broken Cemo Mono pump

0162 Broken Handpump

0163 Drilled, never fitted and casing is exposed

0164 Drilled and never fitted

0165 No power, never worked

0166 Never fitted with pump

0167 Drilled in August 2014, never fitted

0168 Pump was broken now is abandoned

0171 Power box vandalized in Makhovha

0173 Old and abandoned borehole

0174 Pump broken, but main hole still fine

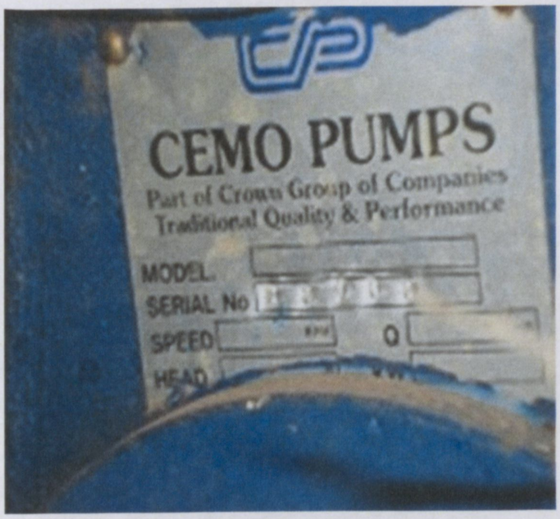
0175 Broken hand pump

0197 Broken handpump now abandoned

0198 Handpump broken

0199 Drilled and never fitted with pump

0201 Vandalized diesel Cemo Mono pump



0202 Vandalized Cemo diesel pump specifications

0204 Broken Mono pump

0205 Broken windmill powered pump

0212 Drilled and never fitted with a pump

0214 Drilled and never fitted with pump

0216 Abandoned main hole unclosed

0217 Broken handpump

0218 Abandoned main hole unclosed

0220 Abandoned borehole unclosed

0223 Mutoti elder shows a broken handpump

0225 Broken handpump

0226 broken handpump in Mangondi A

0229 broken handpump and its reservoir

0231 broken handpump

0233 One of the pump repair advertisements

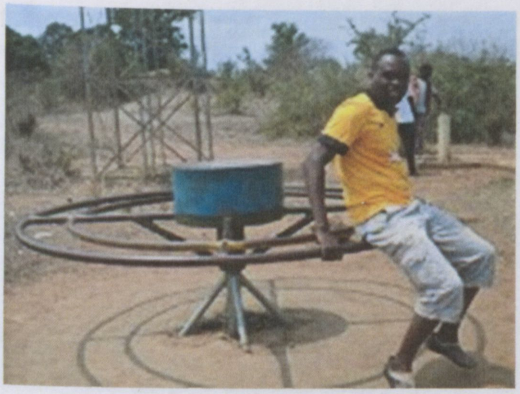
0234 broken handpump

0235 Vandalized Cemo diesel pump

0236 Dura wall for the vandalized Cemo pump

0237 Cemo pump under repair, needs power

0238 Housing for the pump under repair



0238 Functional handpump in Makhuvha A

0248 Functional handpump in Makhuvha A

0250 Broken submersible pump in Makhuvha A

0251 Broken handpump abandoned

0252 Broken handpump abandoned

0253 water sample collection in Makhuvha A

0255 Stagnant water at Makhuvha borehole

0256: Broken handpump abandoned

0259 Functional Cemo pump in Budeli

0260 Drilled and never fitted with a pump

0261 Broken Cemo in Nandoni Dam

0262 Broken handpump abandoned

0263 Vandalized submersible pump power unit

0264 Broken submersible pump

0266 broken handpump in Dumsi

0266 Abandoned borehole covered with debris

0267 broken handpump in Dumasi abandoned

0268 Dumasi borehole under repair

0269 drilled and never fitted with pump

0271 broken Mono pump in Tshikudini

0273 broken handpump in Tshikudini

0274 broken handpump abandoned

0275 broken and pump donated by Hellen G. Wood

0276 broken handpump donated by Wood

0278 broken handpump

0280 Cemo pump under repair in Mphego

0283 Broken handpump in Mphego

0284 Closer view of Mphego broken pump

0285 Pipe were vandalized