



UNIVERSITY OF ZIMBABWE

FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING



**ASSESSMENT OF PERFORMANCE OF
SMALL-SCALE WATER INFRASTRUCTURE FOR
MULTIPLE USE IN INSIZA DISTRICT, ZIMBABWE**

PRECIOUS THULEBONA MASUKU

M.SC. THESIS IN IWRM

HARARE, JUNE 2011

UNIVERSITY OF ZIMBABWE

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In collaboration with



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by

PRECIOUS THULEBONA MASUKU

Supervisors

**ENG. ZVIKOMBORERO HOKO
PROF. TIMOTHY SIMALENGA**

**A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science in
Integrated Water Resources Management of the University of Zimbabwe**

June 2011

DECLARATION

I, **Precious Thulebona Masuku**, declare that this research report is my own work. It is being submitted for the Degree of Master of Science in Integrated Water Resources Management (IWRM) at the University of Zimbabwe. It has not been submitted before for any degree of examination in any other University.

Date: _____

Signature: _____

The findings, interpretations and conclusions expressed in this study do neither reflect the views of the University of Zimbabwe, Department of Civil Engineering nor of the individual members of the MSc. Examination Committee, nor of their respective employers nor the supervision team.

DEDICATION

To my grandma Phumlile Nyawo:

Thank you for holding my hand throughout your living years;

To my mother and best friend Ntombemhlophe Nyawo:

Thank you for the sacrifices you 've made for me, your unconditional love and your faith in me;

To my angels Sphesihle, Ntobeko and Sukoluhle Masuku:

Thank you for being my reason for perseverance; and for encouraging me to be the best I can be.

ACKNOWLEDGEMENTS

My greatest gratitude goes to my pillar of strength, The God Almighty for being with me through it all.

My sincere appreciation to WaterNet and the University of Zimbabwe for an opportunity to enroll for the IWRM Master's Programme. Special thanks to my supervisors Eng. Hoko and Prof. Simalenga for their meaningful comments, encouragement and support through all the phases of this work. I particularly thank Eng. Hoko for provoking, panel-beating and molding my raw thoughts to a meaningful product.

I am grateful to the Department of Civil Engineering staff for personal and professional support provided. Special thanks to Mr. Mudzviti, Mr. Mabiza and Dr. Misi of the Department of Civil Engineering; and Dr. Onema of WaterNet, thank you for making time for me to see to it that I make progress with my work.

Thanks to the Limpopo Basin Challenge Program for Water and Food for financial support for my research work. I also want to thank very much the DA for Insiza District, Ms. Ncube for her support and Ms Mkandla for taking me under her wing during my field work. Many thanks to AGRITEX and DDF staff in Filabusi and ward extension officers for technical support and willingness to assist whenever they could. My sincere gratitude to Insiza District communities for all the efforts made to assist me during data collection phase.

My sincere gratitude to Ms Ndlovu, Mr. Njanike, Mr. Nkomo, Mr. Mabaya and Mr.Nkala: for the time they have put aside to assist me. Thanks to Mr. and Mrs. Mlungwana for all the support provided throughout this journey, I could not have asked for more from loving and supportive parents.

Lastly, I would like to the IWRM class of 2010/11 for being my family during the course of the programme; above all I would like to thank my friends Rose Mero, Bahal'okwibale Mulengera, Gode Bola Bosongo, and Yaone Monyamane for going an extra mile for me.

May God richly bless you all!

ABSTRACT

Small-scale Water Infrastructure (SWI) support livelihoods of rural communities by providing water for domestic, agriculture and livestock. The provision of water for agriculture and livestock gives secondary benefits of improved nutrition, food security and income generation. In the past the focus has been the provision of SWI to rural communities; with little attention paid to the performance of the infrastructure. The objective of the study was thus to assess the performance of SWI used for multiple purposes in Insiza District. Out of a total of 162 SWI in the four wards of Insiza District consisting of four types, namely boreholes, wells, windmills and small dams; 30 were selected for performance assessment. Field measurements, surveys, observations and secondary data were used to determine the types and extent of multiple uses of SWI. Questionnaires were administered to 300 SWI users and interviews were conducted with key informants. Performance indicators selected for assessment were availability, capacity, continuity and condition indices. The values for the indices should be between 0 and 1, and performance is considered bad if the value is 0.5 or below.

The availability of water ranged from fair to good ($0.60 < I_{av} < 0.99$). The capacity of SWI was generally poor ($0.19 < I_{cap} < 0.39$). The continuity of water supply ranged from bad to sufficient ($0.25 < I_{cont} < 0.88$) and the condition of SWI varied from poor to sufficient ($0.40 < I < 0.70$). The perceived benefits were found to be a major influencing factor to communities' willingness to maintain the SWI. Water availability was reduced due to dysfunctional SWI in the communities which resulted in increased density of users on those that are functional, further increasing the wear and tear and frequent breakdowns. Continuity of SWI was insufficient for multiple purposes and the communities resort to unsafe alternative water sources, thus creating health risks. Continuity of water supply was disrupted by lack of appropriate management structures and financial arrangements for maintenance in the rural communities. The condition was good where there has been NGO intervention in maintenance. The overall performance was generally poor with capacity as the major setback. It is recommended that water availability for specific areas must be established before multiple use projects are implemented and/or promoted and appropriate technologies for multiple use systems should be installed in conformity with the needs and preferences of the communities.

Keywords: Insiza District; Multiple use; Performance; Rural water supply; Small-scale Water Infrastructure

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LIST OF ABBREVIATIONS

ACF	–	Action Contre la Faim
AGRITEX	–	Agricultural, Technical and Extension Services
CBM	–	Community Based Management
CIDA	–	Canadian International Development Agency
CPWF		Challenge Program for Water and Food
DDF	–	District Development Fund
DFID	–	Department for International Development
EU	–	European Union
IRC		International Resource Centre
IWMI		International Water Management Institute
JMP		Joint Monitoring Programme
MDGs		Millennium Development Goals
MOHCW	–	Ministry of Health and Child Welfare
MUS		Multiple Use Services
NGO		Non-Governmental Organization
RHC	–	Rural Health Centre
SPSS		Statistical Package for Social Sciences
SWI		Small-scale Water Infrastructure
WASH	–	Water, Sanitation and Hygiene
WPC		Water Point Committee
WVI	–	World Vision International
ZimPro	–	Zimbabwe Project Trust
ZINWA	–	Zimbabwe National Water Authority

1. INTRODUCTION

1.1 Study background

Africa accounts for one-third of global population without access to improved water supply¹ and with lowest service coverage figures (UNICEF, 2010). Despite the investments made in water supply and sanitation in the past decades millions of people still lack access to safe water supply and proper sanitation facilities; and this is more pronounced in rural areas (Makoni *et al.*, 2004). The WHO/UNICEF Joint Monitoring Programme (JMP) report on progress towards meeting Millennium Development Goals (MDG) related to drinking-water and sanitation revealed that in 2008, for Zimbabwe rural population approximately 72% people had improved water supply and only 37% had access to improved sanitation² facilities (UNICEF, 2010).

Rural communities are generally poor and thus cannot afford piped water, in which case groundwater becomes their main water supply option. Rural water provision is typically by low-cost technologies that can be operated, maintained and financed by poor rural communities (Harvey and Reed, 2004). Where primary water sources are available such as boreholes and wells, these sources are used for more purposes other than domestic use. The same applies to small-scale irrigation infrastructure which is also used for other purposes such as livestock watering, domestic uses, beer brewing and other related uses (Makoni *et al.*, 2004; Katsi *et al.*, 2007; Mamba *et al.*, 2007; Smits *et al.*, 2008). People therefore draw multiple benefits from Small-scale Water Infrastructure (SWI) that was initially intended for single use due to their multiple water use needs.

In recent years, for most villages of Southern Africa, donors and NGOs have been providing water supply infrastructure that mostly depend on groundwater such as boreholes and wells that are fitted with different technologies for pumping water (Harvey and Reed, 2004). Research has

¹ An improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter (UNICEF, 2010).

²For MDG monitoring, an improved sanitation facility is defined as one that hygienically separates human excreta from human contact (UNICEF, 2010).

shown that the water supply systems become dysfunctional within a relatively short period after construction (Harvey and Reed, 2004; Hoko and Hertle, 2006; Rietveld *et al.*, 2009). Rietveld *et al.* (2009) further point out that even if the infrastructure is relatively new, the performance may be poor as a result of lack of maintenance.

The research done by Harvey and Reed (2004) revealed that less than 50 % of the estimated total of 250 000 hand pumps in Africa were functional. Due to the importance of groundwater as the main water supply source for rural communities it is imperative to conserve the resource, both in quantity and quality (Martinelli and Hubert, 1986; Robinson, 2002; Machingambi and Manzungu, 2003). One way of ensuring conservation of quantity and quality of water is by ensuring that the infrastructure used to abstract, convey and store water is performing optimally (SALA, 1990b; van Koppen *et al.*, 2006; Rietveld *et al.*, 2009). In their study to determine water availability in terms of quantity and quality, Chang *et al.* (2010) concluded that the availability of fresh water is a fundamental question to water infrastructure management.

In rural communities of Zimbabwe, like any other rural setting in the Southern Africa, SWI are used for various uses whether they were intended for multiple uses or not (Adank, 2006; Katsi *et al.*, 2007). The types of SWI generally used for multiple purposes in Zimbabwe include wells, boreholes and small dams (Adank, 2006; Guzha *et al.*, 2007; Katsi *et al.*, 2007). The Insiza District communities get water mainly from small dams, wells and boreholes which they use for domestic and productive uses (Ngwenya *et al.*, 2006; Onema and Mabiza, 2010). However, the communities are facing challenges in terms of water access due to the functional state of SWI in the district. In some villages of Insiza District the SWI are either dysfunctional or not operating optimally (DDF, 2010). The communities are resorting to unsafe sources of water such as rivers and swamps for domestic uses.

Large water infrastructure such as dams are an important source of surface water delivery to communities in the Limpopo River Basin, but the arid regions of the basin are highly dependent on small-scale supply of and groundwater (Mamba *et al.*, 2007). The Limpopo Basin is prone to frequent droughts, making access to water for domestic use, agriculture and livestock difficult. Furthermore, the catchment experiences frequent water shortages which induce considerable competition for water (Onema, 2004; Mamba *et al.*, 2007).

Located in Matabeleland South province of Zimbabwe in the Limpopo basin, Insiza District is one of the rural areas in the country that is mainly dependent on Small-scale Water Infrastructure (SWI) for multiple use (Ngwenya *et al.*, 2006; Sawunyama *et al.*, 2006). Technologies used include bush pumps on deep wells and boreholes; elephant pumps on deep wells; rope and washer pumps on family wells; buckets on ponds and springs; and storage tanks for rooftop rainwater harvesting in the homesteads. Multiple water uses from SWI include but not limited to, livestock watering, domestic use, garden irrigation, brick moulding and other related uses (Mamba *et al.*, 2007; Senzanje *et al.*, 2008).

Much of the districts' surface water is stored in the government dams in some former large-scale commercial farming areas, mines, and plantation estates (Gumbo, 2006). There are also a number of small dams constructed by NGOs and rural communities. Groundwater in the district is tapped mainly through boreholes. Records show that there are over 500 boreholes scattered across the district (DDF, 2010). Groundwater mainly used by rural communities for multiple purposes, but it is also being drawn for several Growth Points, Rural Service Centers and Institutions such as schools and health centers (Gumbo, 2006).

1.2 Problem statement

In the past, priority has mostly been given to delivering sufficient quantities of water by provision of water supply systems to rural communities. Very little attention has been paid to the performance of these systems and their sustainability after construction (Smits *et al.*, 2008; Rietveld *et al.*, 2009). The research studies by Harvey and Reed (2004) and Hoko and Hertle (2006) concluded that water supply infrastructure for rural areas break down up to five times a year after construction or rehabilitation. Water infrastructure failure or breakdown induces people to resort to other sources for drinking water which are usually not intended for consumption and therefore are not safe. Substantial progress has been made with respect to provision of water and sanitation services in Zimbabwe (UNICEF, 2010).

However, the economic decline has hindered success of development both at the household and the national level (Robinson, 2002). Although much work has been done on rural water supply and multiple use services in Zimbabwe (Makoni *et al.*, 2004; Robinson *et al.*, 2004; Guzha *et al.*,

2007) there is thin literature available on the performance and sustainability of the water supply infrastructure (van Koppen *et al.*, 2006).

1.3 Justification

Recently, multiple use of water infrastructure has been promoted as a means for improving livelihoods of rural communities (Adank, 2006; van Koppen *et al.*, 2006; Katsi *et al.*, 2007). Understanding SWI performance will thus contribute towards proper management and improved performance, which will in turn contribute towards realizing community's water needs. According to Robinson *et al.* (2004), Zimbabwe is one of the countries rich in terms of existing experiences with implementation of water services for multiple purposes. However, these experiences are only looked at in terms of water supply technologies (Katsi *et al.*, 2007).

Performance of rural water supply infrastructure has become an issue of concern in many developing rural areas (van Koppen *et al.*, 2006; Rietveld *et al.*, 2009), the situation is no different in Insiza District. Rural households in Insiza District get their water from groundwater sources through boreholes, wells and to a limited extent, windmills. The importance of groundwater and SWI to rural communities of Insiza District makes it important to determine the functional state of the SWI and evaluate performance. It is also important to investigate the factors affecting performance so as to identify corrective measures required to improve it. Implementation of corrective measures will also ensure sustainability of SWI.

More information is required by planners and community leaders on necessary measures required to improve SWI performance and thus enhancing the ability to meet community's multiple use water needs. Infrastructure sustainability needs to be prioritized in order to save costs. There is therefore a need to assess the available SWI performance in order to come up with possible strategies or approaches for improving SWI performance; and also to assist in planning for future IWRM development programmes in rural areas. Furthermore, the study will contribute towards the knowledge basket of the overall goal of the Challenge Program on Water and Food (CPWF), which is to improve levels of food security, poverty, health and environmental security.

1.4 Objectives

The main objective of the study is to evaluate the performance of existing Small-scale Water Infrastructure (SWI) for multiple use in Insiza District so as to contribute towards information required to improve performance of rural water supply infrastructure.

The specific objectives were:

1. To review the current water management practices at the district and community levels;
2. To assess performance using four indicators: availability, condition, continuity and capacity indices;
3. To investigate factors that have a significant impact on performance of SWI;
4. To identify, quantify and compare the benefits obtained from SWI.

1.5 Scope of the study and limitations

This research was conducted in Insiza District where the University of Zimbabwe and WaterNet are involved on the research for the Challenge Program on Water and Food (CPWF) in the Limpopo Basin in collaboration with other international organizations including Delft University of Technology (TUDelft), the French Centre for International Research Agricultural Development (CIRAD) and Stockholm Environment Institute (SEI). The study focused on different types of SWI that are currently available and used by rural communities for water supply in Insiza District. Assessment tools were used to assess only SWI that are fitted with pumps, are functional, and that are used and managed by communities. The SWI selected are used for multiple purposes by rural communities; the piped water supply systems for treated water were not part of the study. No computations were done for small reservoirs in terms of performance assessment; only qualitative assessment in terms of multiple water use by rural communities was considered. Water quality analysis is not the main focus of the study; therefore selection of water quality parameters was based on the potential human health impact.

2. LITERATURE REVIEW

2.1 Water supply in rural areas

The common practice in water supply services in the Southern African region has been focused on provision of domestic or productive water, but since the early 2000s multiple-use water services have emerged as a new approach to water services in rural and peri-urban areas (van Koppen *et al.*, 2006) as a way of promoting holistic approach in water services and cost saving. For rural communities in Southern African region, water is typically sourced from groundwater for domestic supply. A number of organizations, including International Resource Centre (IRC) on water supply, sanitation and hygiene, International Water Management Institute (IWMI) and Plan International, have been developing and advocating for a so-called Multiple Use Services approach (MUS) which is an integrated bottom-up, pro-poor approach to meeting poor people's water needs for multiple purposes (Adank, 2006; van Koppen *et al.*, 2006).

The types of technologies that provide more opportunities for multiple use for rural communities include rainwater harvesting tanks, family wells, spring water capturing etc., but these technologies tend to be restricted to NGO initiatives and donor funded programmes (Makoni *et al.*, 2004; Smits *et al.*, 2008). Amongst other factors, management, ownership and location of water supply infrastructure influence the number and types of uses from a particular source (Moriarty *et al.*, 2003; van Koppen *et al.*, 2006; Sutton, 2009).

2.2 Water supply infrastructure in the Limpopo Basin

SWI in the Limpopo basin is mainly used for irrigation and rural supplies (Barros, 2009), of which the majority of users are informal small-scale users in rural areas. The use is governed by informal local arrangements (van Koppen *et al.*, 2006). For rural communities, water is typically sourced from boreholes for domestic supply. According to Robinson *et al.* (2004), traditional water sources in Zimbabwe have always provided water for a number of uses such as drinking, washing, cooking, and livestock watering. Guzha *et al.* (2007) further points out that in Zimbabwe there is a mixed picture of water services for SWI uses: there are those that were originally planned for one specific use only, but are used for multiple purposes, and also those that are

specifically developed to meet people's multiple water needs. Table 1 shows some of the technologies for multiple uses in Zimbabwe.

Table 2.1: Technologies for multiple use of water in Zimbabwe

Level of use	Water source	Water extraction/lifting mechanism	Storage, distribution and application
Family	Family well	Windlass and bucket Rope pump Motorised pump	Drip kits Buckets
	Perennial stream or spring	Spring protection	Family water scheme
	Farm ponds	Buckets	Drip kits Buckets
	Rainwater	Rooftop harvesting	Storage tanks Buckets
Community	Borehole or tubewell	Bush pump Motorised pump	Drip kit Buckets
	Perennial stream or spring	Spring protection	Small piped water scheme

Source: Guzha et al., 2007

2.3 Multiple use of Small-scale Water Infrastructure (SWI)

SWI contribute significantly to the socio-economic development of rural communities and their environment (Mamba *et al.*, 2007). Sawunyama *et al.* (2006) identified lack of management tools and procedures for assessing sustainable use of small-scale water infrastructure as a constraint in water supply services, which makes access to water difficult. People's water needs are diverse, especially in the rural areas where people's livelihoods continue to be based on a range of water dependant activities (Adank, 2006; van Koppen *et al.*, 2006). Without access to sufficient and reliable water for multiple use in and around the households, people are constrained from doing activities that may improve their wellbeing by securing their sources of food and income (Katsi *et*

al., 2007). Restrictions that come with water supply provision has in the past led to poor cost recovery mechanisms and constraints to self supply (Adank, 2006), this has a strong bearing on the sustainability of facilities (Makoni *et al.*, 2004). In some cases in rural areas, there are restrictions of water use by responsible water authorities. Adank (2006) established that the more the uses that are derived from the water supply system, the more acceptable the system is to the community. Provision of multiple use water infrastructure enable people to source income at household level by using water for productive uses such as planting fruit trees, irrigating vegetable gardens etc. (Moriarty *et al.*, 2003).

Apart from the fact that many water resources are severely stressed (Maganga *et al.*, 2002; Mamba *et al.*, 2007), there are various constraints to developing rural water supply services. Maganga *et al.* (2002) identified the major constraints to developing rural water supplies as lack of appropriate investment and poor operation and maintenance of supply systems rather than water resource constraints. A study by Katsi *et al.* (2007) revealed that the extent and scale at which each particular water use is carried out depends on several factors such as quantity and quality of the water, accessibility, distance to the infrastructure, availability of alternative sources of water amongst other factors. Moriarty and Butterworth (2003) identified water quality as the limiting factor in multiple uses of water supply services. The argument was that multiple use approach does not take into consideration the possibility that some uses do not require high quality of water. Nonetheless, whether water is supplied through self supply or through communal systems; and whether it is used for only domestic or for multiple uses, achieving drinking water quality is in practice almost always a household level activity, where good hygiene education is key (Adank, 2006).

2.4 Water Quality

Increasing water pollution is a threat to water supplies (Maganga *et al.*, 2002), and water quality is often raised as a challenge in multiple use of water approaches (Adank, 2006; Katsi *et al.*, 2007). Water for human and animal consumption is required to meet drinking water requirements, that is, the water must be safe to drink and palatable (Love *et al.*, 2006). There are also requirements for irrigation water quality that must be met to ensure safety for plants and consumption of the irrigated produce (Love *et al.*, 2006).

Hoko (2005) determined that over 90 % of rural communities of Zimbabwe consume water without treatment, and as a result most water quality related deaths occur in the rural areas due to limited access to safe water and sanitation (Nare *et al.*, 2006). Water quality is thus one of the important determinant factors for success of rural water schemes (Mamba *et al.*, 2007). Water quality also has an impact on the volume of water consumed (Cisneros, 1996) by both human and livestock. Taste, colour and odour for examples may discourage human and animals from drinking from a certain water source.

2.5 Assessment of Performance

Substantial research has been done for measuring performance of water supply infrastructure (Cisneros, 1996; Misiunas, 2008; Masduqi *et al.*, 2009; Chang *et al.*, 2010)., However, most of the performance indicators were developed for the assessment of urban water supply systems (Rietveld *et al.*, 2009). The challenge that comes with rural water supply schemes is availability of (historical) data. Most African rural areas depend on government and/or Non-Governmental Organizations (NGOs) interventions for investment and operation costs for water infrastructure (Sunguro *et al.*, 2000). The NGOs only work in a particular area for a stipulated time (Hunter *et al.*, 2010), which makes access to information difficult, if at all possible.

Hunter *et al.* (2010) outlined six factors that determines whether water supply can provide good health: quantity, quality, access, reliability, cost of water and ease of management, but these factors were only analyzed qualitatively. Alegre *et al.* (2006) developed performance indices for water supply infrastructure looking at almost all aspects from technical to human factors including management, but these indicators are applicable to urban and peri-urban water supply systems. Masduqi *et al.* (2009) also developed a mathematical model for predicting sustainability of rural water supply systems which takes into consideration factors such as socio-economics and water supply management. The limitation in using Masduqi *et al.* (2009) model in rural areas are the variables required for input into the model. Rietveld *et al.* (2009) applied four criteria for measuring performance, namely, availability, capacity, continuity and condition indices.

Assessment tools developed by Rietveld *et al.* (2009) were adapted from the HESSET toolkit and modified for use in rural areas. These tools can be further modified to suit local conditions.

The indicators are quantified through sub-indices, which gives the possibility of comparison of performance for different systems. The four performance indices by Rietveld *et al.* are discussed in the following sections.

2.5.1 Availability Assessment

Earlier studies on performance assessment have been done with focus mainly on quantity or quality of water, but of late, water availability has been studied in terms of both quantity and quality (Cisneros, 1996; Rietveld *et al.*, 2009). Availability is thus measured against the quantity and quality standards for drinking water supply. Quantity is measured as the volume of water produced in order to meet the demand for water. According to Rietveld *et al.* (2009) quality is measured using parameters that have relatively high impact on health. These parameters are, coliform (TC), pH, turbidity (NTU) and electric conductivity (EC). Availability can be quantified as the percentage of time that the water table drops below the point of extraction and by checking whether the capacity of the reservoir is sufficient for the demand (Martinelli and Hubert, 1986; Masduqi *et al.*, 2009; Rietveld *et al.*, 2009). Hunter, (2010) defines quantity of water as the amount available and used, which is largely determined by the walking distance to the water source and the wealth of the user. The availability index is calculated from the following equation (Rietveld *et al.*, 2009):

$$I_{av} = \alpha_1 I_{av,quant} + \alpha_2 I_{av,qual} \quad (2-1)$$

Where:

$$I_{av,quant} = \frac{\eta V_{month} \times 1000}{30[(N \times D)_{sp} + (N \times D)_{yc} + (N \times D)_{hc}]} \quad \text{is the availability index in terms of quantity}$$

$$I_{av,qual} = \varepsilon_1 I_{pH} + \varepsilon_2 I_{EC} + \varepsilon_3 I_{NTU} + \varepsilon_4 I_{TC} \quad \text{is the availability index in terms of quality.}$$

The water quality sub-indices are defined by:

$$I_{pH} = e^{\mu_1(pH-7)};$$

$$I_{EC} = e^{-\mu_2 \times EC};$$

$$I_{NTU} = e^{-\mu_3 \times NTU}; \text{ and}$$

$$I_{TC} = e^{-\mu_4 \times TC}$$

N is the number of people with access to a standpipe or hand pump (sp), yard connection (yc) or house connection (hc);

D is the minimum demand related to one of the mentioned connections (l.c.d);

V_{month} is the monthly production ($m^3/month$);

η accounts for the water losses in the system;

μ_i are constants depending on the allowable values in the drinking water; and

ε_i and α_i are weighing factors for the sub-indices, where $\Sigma \varepsilon_i = \Sigma \alpha_i = 1$.

2.5.2 Capacity Assessment

Capacity is the adequacy of storage, transport and distribution to supply water in the community (Alegre *et al.*, 2006; Rietveld *et al.*, 2009). The capacity index aim to assess capability related to use of the system (Alegre *et al.*, 2006). Components considered include storage (capacity), pumping (flow), distribution (in terms of walking distance), and functionality. Factors that may affect capacity include per capita demand and population growth. Therefore capacity fails when the population grows and demand increases to the point whereby the system supply can no longer meet the required demand (Alegre *et al.*, 2006; Rietveld *et al.*, 2009). The capacity index is calculated from the equation below (Rietveld *et al.*, 2009).

$$I_{cap} = \beta_1 I_{pump} + \beta_2 I_{res} + \beta_3 I_{wp,dens} + \beta_4 I_{wp,funct} \quad (2-2)$$

Where:

$$I_{pump} = \frac{N_{ump,good}}{N_{wp,total}} \quad \text{is the pumping capacity from the source;}$$

$$I_{res} = \frac{V_{res}}{Q_{demand} \times T_{res}} \quad \text{is the storage volume (to overcome differences between demand and pumping capacity);}$$

$$I_{wp,dens} = \sum \frac{\rho_{wp}}{\rho_{wp,min}} \quad \text{is the number of water points with too low flowrates, and}$$

$$I_{wp,funct} = \frac{N_{wp,good}}{N_{wp,total}} \quad \text{is the distance of water points from consumers.}$$

Q_{pump} is the actual pumping capacity (m^3/h);

Q_{demand} is the required water flow for distribution, including losses in the system (m^3/h);

V_{res} is the installed reservoir volume (m^3);

T_{res} is the required minimum storage time (h);

ρ_{wp} is the actual water point (wp) density (wp/km^2);

$\rho_{wp,min}$ is the minimum required water point density (wp/km^2);

$N_{wp,good}$ is water point with a sufficient flow rate;

$N_{wp,total}$ is the total number of water points; and

β_i are weighing factors for the sub-indices, where $\sum \beta_i = 1$.

2.5.3 Continuity Assessment

Continuity is the stability of water delivery from the source to the water point (Alegre *et al.*, 2006; Rietveld *et al.*, 2009), but Alegre *et al.* (2006) looked at continuity in terms of failure of performance. The parameters though used by Rietveld *et al.* (2009) and Alegre *et al.* (2006) are similar, that is the duration that the system is not able to deliver water to the users in terms of days per month (or year) and in hours per day. Water supply can be interrupted when part or all the water supply system is damaged, or due to other external factors such as power shortage or lack of funds for repairs.

In cases of disruption in continuity of supply, people may have sufficient water stored for consumption until the problem is resolved (if it is short term disruption); but in cases of prolonged periods without supply people have to search for alternative sources, often of inferior quality. Two indicators are used to quantify continuity (Rietveld *et al.*, 2009):

$$I_{cont} = \gamma_1 I_{day,month} + \gamma_2 I_{hours,day} \quad (2-3)$$

Where:

$I_{hours,day} = \frac{T_{sup}}{T_{sup,min}}$ is the number of hours per day of unplanned interruption of water supply;

$I_{day,month} = e^{-\lambda(N_d - N_{d,max})}$ is the number of days per month without unplanned interruption of water supply;

T_{sup} is the supply time per day (h);

$T_{sup,min}$ is the minimum, predetermined supply time per day (h);

N_d is the number of days per month without water, while water was available;

$N_{d,max}$ is the maximum allowable number of days per month without water; and

γ_i are weighing factors for the sub-indices, where $\sum \gamma_i = 1$.

2.5.4 Condition Assessment

Condition refers to the status of a water supply system in terms of its serviceability (Rietveld *et al.*, 2009). For a water supply system, all the components must be assessed to give an overall picture of the system condition. Alegre *et al.* (2006) uses *inspection condition performance index* for condition assessment whereby different parts of the water supply system such as storage tank, pumps, pipes etc. are inspected for faults. However, inspection of all system components may be time consuming and impractical under time and resources constraints. Therefore the assessment tool by Rietveld *et al.* (2009) considers one element, for example, the outlet point, which is taken as the indicator for condition of the whole system with the assumption that one part of the system is an indicator of the state of other system components. Rietveld *et al.* (2009) defines condition index by the following equation:

$$I_{cond} = \delta_1 I_{outlet} + \delta_2 I_{platform} + \delta_3 I_{support} + \delta_4 I_{pump} \quad (2-4)$$

Where:

$I_{outlet} = \frac{N_{outlet,good}}{N_{wp,total}}$ is the condition of the outlet;

$I_{platform} = \frac{N_{platform,good}}{N_{wp,total}}$ is the condition of the platform;

$I_{support} = \frac{N_{support,good}}{N_{wp,total}}$ is the condition of the support; and

$I_{pump} = \frac{N_{pump,good}}{N_{wp,total}}$ is the condition of the pump;

$N_{wp,total}$ is the total number of water points in the community;

$N_{outlet,good}$, $N_{platform,good}$, $N_{support,good}$, $N_{pump,good}$ are the number of outlets, platforms, supports and pumps, respectively, that are in good state;

δ_i are weighing factors for the sub-indices, where $\sum \delta_i = 1$.

3. STUDY AREA

3.1 Description of study area

Insiza District is located in Matabeleland South Province in the Mzingwane Catchment. Zimbabwe is divided into seven catchments with the aim of managing water resources (Gumbo, 2006; AfDB, 2011). Mzingwane Catchment is one of the catchments of Zimbabwe which is part of the Limpopo River Basin. The Limpopo River Basin forms an international river basin shared among Botswana, Mozambique, South Africa and Zimbabwe. The catchment is divided into four sub-catchments, namely, Shashe, Upper Mzingwane, Lower Mzingwane, and Mwenezi. Insiza District is in the Upper Mzingwane Sub-catchment. Umzingwane, Gwanda, Mberengwa, Runde and Bubi Districts surround Insiza District. The map of Insiza District is shown in Figure 3.1.

The capital of Insiza District is Filabusi, which is situated 99 kilometres southeast of Bulawayo and 5 kilometres off the Masvingo-Mbalabala Road. The district is subdivided into Insiza South and Insiza North; the north part being the former commercial farming area and the southern part is mainly rural and is densely populated. There are 23 wards in Insiza District, Wards 1 to 9, 11 and 12 are located in the southern part while Ward 10, and Wards 13 to 23 are located in the northern part of the district. The number of villages per ward range from 5 to 10; and number of households per village range from 12 to 30 (DDF, 2010). The 2002 population in the district was estimated at 85, 600 according to CSO (2002) and a growth rate of 1 % per annum was suggested for the next 10 years. From this, the current population of Insiza is estimated at 102, 000.

3.2 Climate

The Mzingwane Catchment is located in the semi-arid region in southwest Zimbabwe. The catchment is susceptible to intermittent droughts (Onema, 2004; Ngwenya *et al.*, 2006; Sawunyama *et al.*, 2006). Insiza District falls on the drier and hotter part of the country with relatively low rainfall between November and March (Onema, 2004; Mamba *et al.*, 2007). According to the land classification in Zimbabwe, Insiza District falls mostly in natural region IV, which is a midland and highland agro-ecology. Temperatures in the district range from about 12⁰C to 29⁰C. The temperatures are lowest in the months of June and July; and highest in October (Mufute, 2007).

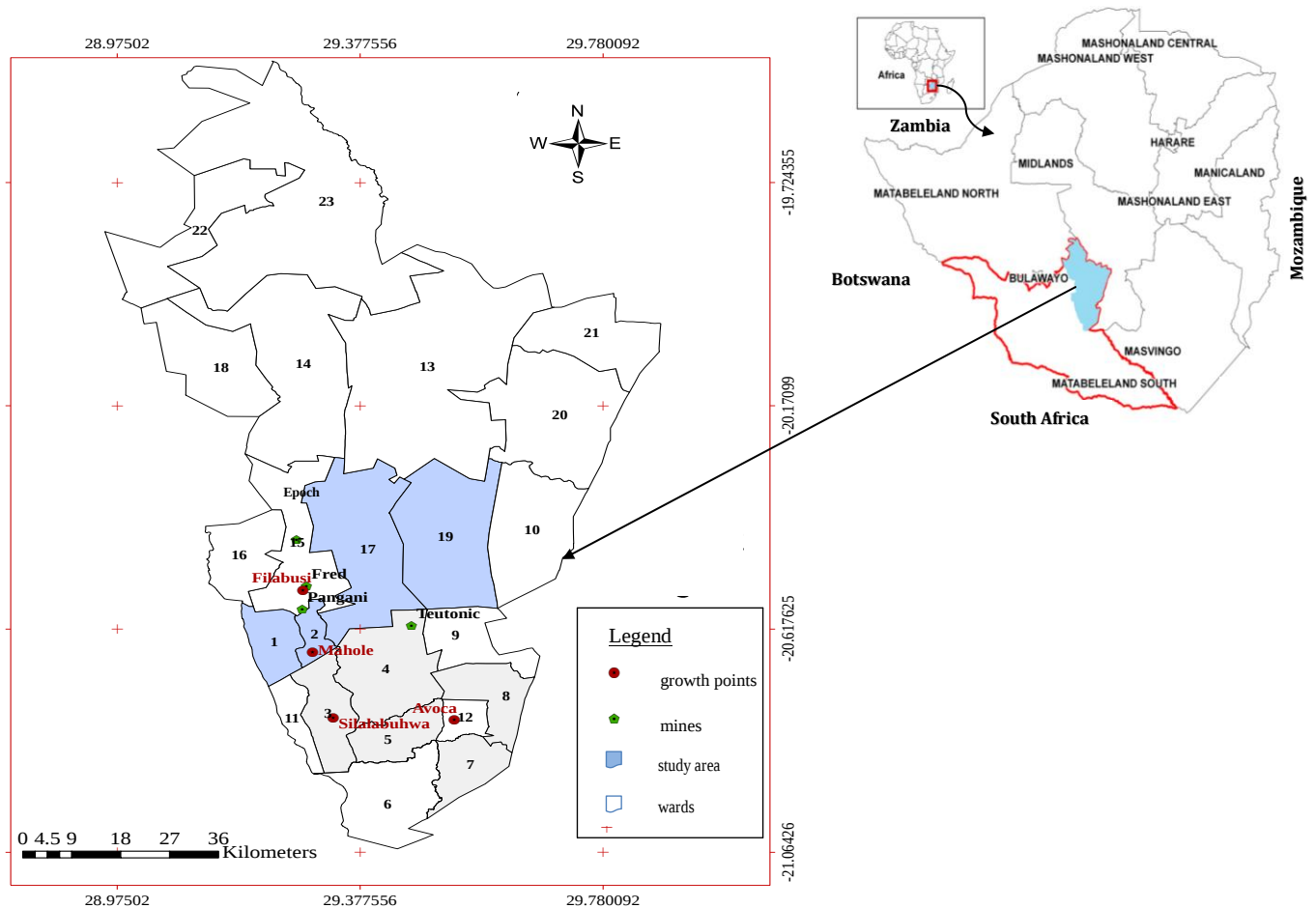


Figure 3.1: Map of Insiza District showing the study area

The mean annual rainfall ranges from 480 mm/annum on the southern lower part which is at an altitude of about 1100 m, to 690 mm/annum on the northern upper part with altitude of 1420 to 1500 m (Ngwenya *et al.*, 2006; Onema *et al.*, 2006). Soils in the area vary from clay loamy in the north to sandy soils in the south. Vegetation varies according to the soil types from woodland in the north to a low scrubland in the southern parts of the district.

3.3 Socio-economic activities

The livelihood system in Insiza District is based on crop and livestock production (Love *et al.*, 2005; TARSC/CWGH, 2009). The main crops cultivated are maize, sorghum groundnuts and cowpeas and these crops are mainly rainfed. Cropping includes commercial farming (largely resettled) in the north, often under irrigation, and rainfed smallholder farming in the south

(Onema *et al.*, 2006). Cattle and goats are important livelihood source in the district. Other than agriculture, some of the households depend on remittances from family members employed in the urban areas or in other countries in Southern Africa or abroad. A number of small scale mines in the district such as Epoch, Pangani, Teutonic and Fred used to provide employment to the local communities; but the economic crisis has led to shutting down of the mines leaving the Insiza communities with high unemployment rates and poverty. According to TARSC/CWGH (2009), unemployment rates in the district stood at approximately 95 % in the year 2009. Most people in the district, especially the youth, resort to illegal gold panning for survival.

3.4 Water supply

Institutions involved in rural water supply for multiple purposes include Zimbabwe National Water Authority (ZINWA), Rural District Councils (RDC), the District Development Fund (DDF), the Department of Agricultural Technical and Extension services (AGRITEX) and non-governmental organizations (NGOs) such as World Vision International (WVI), Zimbabwe Project Trust (ZimPro) and Action Contre la Faim (ACF). ZINWA is responsible for supplying piped water to small towns and rural service centres such as Filabusi, Mahole, Silalabuhwa and Avoca. The RDC is the coordinator for rural community development programmes. DDF works in collaboration with RDCs and NGOs in drilling and rehabilitation of water points. AGRITEX assists rural communities with their water permit applications for agricultural water. Table 3.1 below shows types and number of SWI available in the district (Sawunyama *et al.*, 2006; DDF, 2010).

Domestic water supply in the rural parts of the district is mainly sourced through boreholes and wells, and in some cases villagers use water from rivers and small streams for their multiple water needs. The number of people per water point ranged from 20 in the southern parts of the district to approximately 60 in the northern parts, depending on the village size and average number of people per household, and taking into account the density of functional water points in the area. The number of people per water point then becomes approximately 150 for Insiza South and 420 for Insiza North. According to Harvey and Reed (2004) the recommended number of people per water point is 250. Ideally, each ward consists of at least one pump mechanic and each water point has a Water Point Committee (WPC), with responsible chairperson and pump minder

(Gumbo, 2006). This is however not always the case in some of the water points as revealed by Hoko and Hertle (2006) on a study done in similar conditions in the neighbouring districts.

Table 3.1: Water supply infrastructure in Insiza District

SWI type	Number	Location	Main uses	% functional	Challenges
Boreholes	523	421 South, 102 North	Domestic, livestock, gardens	47%	Frequent break down, spares availability
Wells	26	26 South, 0 North	Domestic, livestock, gardens	19%	Drying up, spares availability
Windmills	38	31 North, 7 South	Domestic, livestock, gardens	10%	Spares availability, technical capacity
Dams	826	553 North, 273 South	Livestock, irrigation, gold panning, brick-making	93%	Siltation, broken/cracked dam walls

4. MATERIALS AND METHODS

4.1 Study design

The study was carried out from January to April 2011 in four wards of Insiza District. Selection of the wards was based on availability of different types of SWI, functional status, multiple-use of water from SWI and accessibility. Wards 1 and 2 are located in the south densely populated part of the district while the other two (Ward 17 and Ward 19) are in the north sparsely populated resettlement areas. In this study; small water infrastructure refers to any technical hardware that is available, used and managed by rural communities in capturing and collecting water for multiple water needs within their communal areas as defined by Senzanje (2011). The SWI studied in Insiza District were boreholes, wells, small dams and windmill pumps. Figure 4.1 shows the location of the SWI studied in Insiza District.

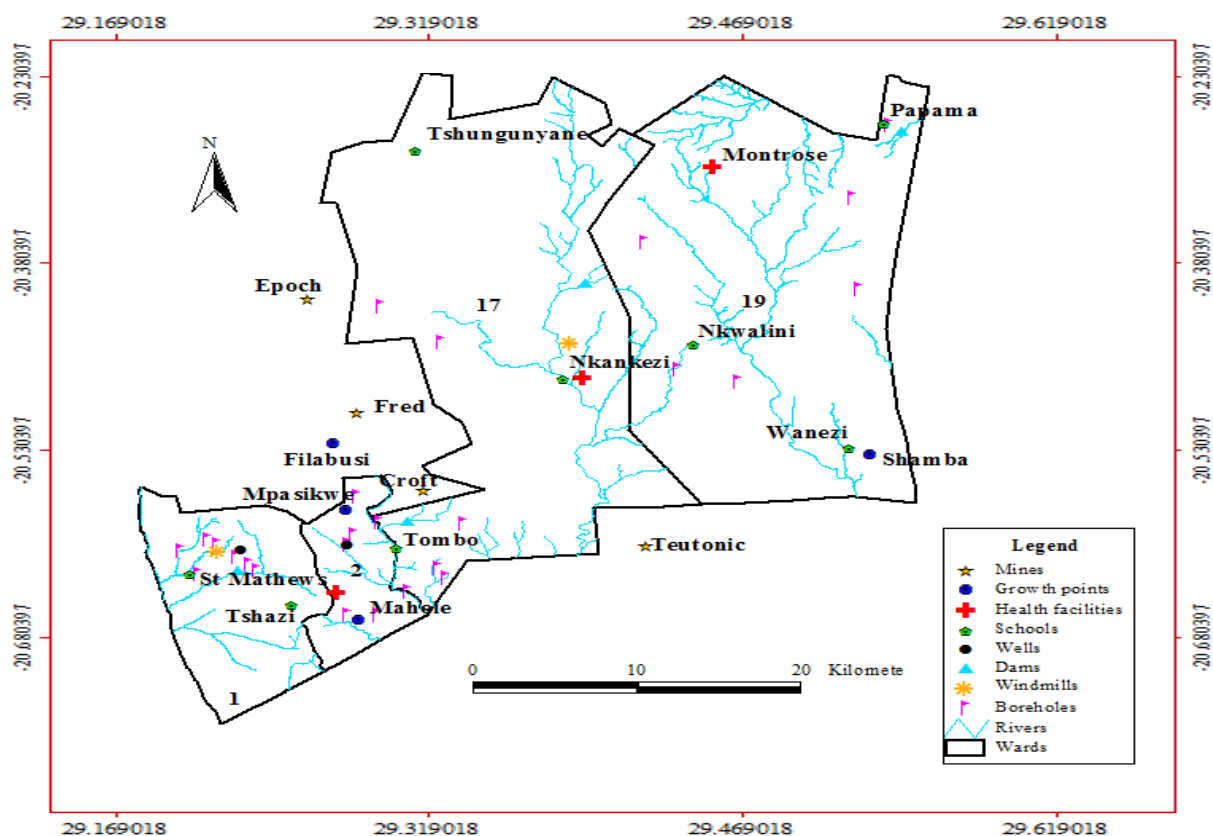


Figure 4.1: Location of SWI studied in the four wards

Multiple water use from SWI include domestic (such as laundry, bathing, cooking, cleaning and drinking); and productive uses (such as garden irrigation, brick making, livestock watering and gold panning). Small dams in Insiza District are mainly used for small-scale irrigation; livestock watering, fishing and brick-making, amongst other uses. However, in cases of SWI break down small dams in the district are also used for domestic purposes.

4.1.1 Selection of SWI for assessment

A total of thirty (30) SWI were selected for assessment in the four wards of Insiza District. Two wards selected were located in the south of the district and the other two in the northern part for comparison purposes. The selection of SWI assessed was based on availability of different types, functionality and nature of use of which those used for multiple-use were considered. The SWI density was higher in Insiza South in comparison with Insiza North (Table 3.1). In the southern part of the district the communities mostly use boreholes for all their water needs; while in the northern part they mostly rely on dams. Simple random sampling without replacement method was used to select SWI assessed in the selected wards (Bartlett *et al.*, 2001; EPA, 2003).

4.1.2 Sampling and sample size estimation

For each ward selected, the number and type of available SWI was taken into consideration in determining the number of SWI to assess. The most commonly used technology is the bush pump fitted on boreholes. The number of functional boreholes was higher in all wards compared to other types of SWI, that is, boreholes and wells. The number and types of SWI selected for assessment varied per ward depending on the total number and types available per ward. For the boreholes, which are the main type in the district, twenty percent (20 %) for each ward was selected for assessment with exception of Ward 19 where less than 20 % of boreholes were dysfunctional in the villages studied. In Ward 19, five boreholes were assessed (13 %). A total of twenty two boreholes, two wells, two windmills and four dams were selected for assessment in Wards 1, 2, 17 and 19 (see Table 4.1).

4.2 Data Collection

Global Positioning System (GPS) was used to collect points location for all the SWI assessed. Key informants interviews were conducted and secondary data reviewed with the aim of

understanding the existing management practices at the district and local levels. Semi-structured questionnaires were administered to 300 SWI users to collect data for analyzing factors affecting performance of SWI and to investigate the importance of SWI to users. Direct and indirect measurements were used to collect data for computation of parameters for performance indices calculation. For example, to estimate the monthly demand from SWI; the amount of water used per households was calculated from the amount collected per household per day. Secondary data from the government institutions (mainly DDF) and NGOs (mainly World Vision International) was used as a starting point to identify the types of SWI and their distribution in the district. Field surveys were used to validate the information obtained from the secondary data sources.

Pre-testing of the questionnaires was done in twelve households in the four wards studied during the reconnaissance visit, after which necessary amendments were made. Household and key informant interviews were the main source of information on water use, management and SWI performance. Household interviews were conducted in 300 household that use the 30 selected SWI for assessment. Information obtained from household interviews included: number of people per household, amount of water used per household per day, types of water uses, alternative water source(s) availability, operation and maintenance structures/procedures and perceptions on water supply and management issues.

The number of households per ward data was obtained from Rural District Council (RDC) documents. The size of wards was estimated from Arc View maps. Water quality parameters (pH, conductivity and turbidity) were measured on site using standard methods and Total Coliforms analyses were done in the mobile laboratory using the membrane filter method. The information on number of household per water point was obtained from community leadership such as kraal heads, village heads and pump minders. Water flow measurements were obtained by filling a 20 litre bucket and timing using a stopwatch.

Walking distance from households to water points and time taken to walk to the water point and back was measured using GPS and by observations, respectively. The condition of SWI was assessed by means of physical inspections. The condition of down-hole components for SWI was determined by assessing above ground components' functionality, for example, factors such as

counting the number of strokes before water comes out of the pump and measuring the amount of water that comes out per unit time were used to determine the status of the rods under-ground. Condition assessment is further explained in Section 4.3.1.

Table 4.1: Data collection specifications

Locality	Insiza South		Insiza North		Total
Wards	1	2	17	19	4
No. of villages	6	4	11	11	32
Total no. of water points	48	41	34	39	162
No. of water points assessed	10	8	7	5	30
Water point types	7 boreholes, 1well, 1 windmill, 1dam	6 boreholes, 1well, 1dam	5 boreholes, 1windmill, 1dam	4 boreholes, 1dam	22 boreholes, 2 wells, 2 windmills, 4 dams
No. of households interviewed / questionnaires	100	80	70	50	300

For each SWI selected for assessment, questionnaires were administered to ten percent (10 %) of the users (households) or to a minimum of ten households, whichever was greater. In all cases ten households was found to be greater than ten percent of the total users. In total, three hundred (300) households were therefore interviewed. Out of a total of one hundred and sixty two (162) SWI in the four wards, thirty (30) were selected for assessment. The interviews were conducted in the local language (Ndebele) and answers written in English. Field observations of the activities in different villages were used to verify some of the responses given by the respondents. The quantity of water used per household per day was estimated from the number of 20 litre containers the households use per day.

The SWI monthly production was calculated from the total number of households using the SWI multiplied by estimated quantity of water used per household per month. The flowrate was measured by measuring the time taken to fill a 20 litre bucket using a stopwatch. Potential storage from SWI was estimated from the borehole safe yield. The borehole safe yield was taken as 60 % of the drawdown for each SWI to safeguard the pump against running dry due to seasonal changes which has effects on rest water level (DWD, 1995). However, the drawdown tests were not done in this study; secondary data from government departments and NGOs were used.

Physical water quality parameters, namely, pH, conductivity and turbidity were carried out at the water points due to their sensitivity to temperature change. For biological water quality assessment (total coliforms), laboratory analysis was conducted using membrane filter method. A total of three sampling campaigns for water quality parameters analyses were conducted together with measurements for indices parameters.

4.3 Data analysis and interpretation

Statistical Package for Social Sciences (SPSS) was used as tool for statistical data analysis to investigate factors affecting the performance of SWI and the significance of SWI to users. Performance indices were calculated using modified assessment tools adopted by Rietveld *et al.* (2009) from the *HESET* toolkit. The assessment tools by Rietveld *et al.* (2009) have been used by researchers in the sectors of health and water supply such as Masduqi (2009) and, Hunter *et al.* (2010), but the analysis has been predominantly qualitative. Values for the four tier benchmarking system used in this study for the four indices were also slightly adjusted from that proposed by Rietveld *et al.* (2009). The benchmarking values were adjusted as follows:

- Bad was allocated to indices values between 0 and 0.5. Bad performance means SWI is not meeting the minimum demand
- Fair for indices values between 0.51 and 0.75. Fair performance means the SWI is meeting the minimum demand.
- Sufficient for indices values between 0.76 and 0.9. Sufficient performance means the SWI has satisfactory performance.

- Good for indices values between 0.91 and 1. Good performance means the SWI is performing above average.

The aforementioned benchmarking system was used for each index to make an overall conclusion on performance of the SWI. Chemical parameters for water quality were used as input into the (water) quality index equation which was then used to calculate the overall availability index.

4.3.1 Modification of performance indices

The tools by Rietveld *et al.* (2009) were developed and used for piped water supply system in a rural setup. There was therefore a need to further modify some of the parameters in order to adapt to local conditions for SWI type used in Insiza District. The modified equations for some of the indices calculations are outlined in the following subsections. Only SWI fitted with hand pumps were assessed using the performance indices. These SWI are used as primary water supply sources in rural villages of Insiza District. Open sources such as shallow wells and dams were only studied in terms of water use as secondary sources of water for multiple use.

Data used for indices calculations was obtained from measurements taken from SWI, secondary data from government departments and NGOs and household surveys conducted in Insiza District communities using the SWI assessed. The Sphere Project Guidelines (SCHR, 2004) and local standards (SALA, 1990a; DWD, 1995; Harvey and Reed, 2004) were used as reference in calculating the indices. Weighing factors were also used in computation for the indices (Cisneros, 1996; Rietveld *et al.*, 2009; Chang *et al.*, 2010). The scheme for judging SWI performance was adapted from Rietveld *et al.* (2009) as follows:

- Bad for $0 < I < 0.50$;
- Fair for $0.51 < I < 0.75$;
- Sufficient for $0.76 < I < 0.90$; and
- Good for $0.91 < I < 1.0$.

a) Availability assessment

Water availability in this study means both quantity and quality. Availability was determined by calculating the availability index (in terms of quantity and quality). Rietveld *et al.* (2009) suggests the use of the following equation for availability assessment:

$$I_{av} = \alpha_1 I_{av,quant} + \alpha_2 I_{av,qual} \quad (2-1)$$

Where:

$I_{av,quant} = \frac{\eta V_{month} \times 1000}{30[(N \times D)_{sp} + (N \times D)_{yc} + (N \times D)_{hc}]}$ is the availability index in terms of quantity, and

$I_{av,qual} = \varepsilon_1 I_{pH} + \varepsilon_2 I_{EC} + \varepsilon_3 I_{NTU} + \varepsilon_4 I_{TC}$ is the availability index in terms of quality.

However, for the SWI used in the district, there are no yard connections or standpipes, only the variables for hand pump were left in the equation for quantity index. The quantity index is a function of amount of water used from the SWI per month versus the minimum required per capita demand according to the local water supply requirements. The modified equation for availability in terms of quantity therefore becomes:

$$I_{av,quant} = \frac{\eta V_{month} \times 1000}{30[(N \times D)_{hp}]} \quad (4-1)$$

Where:

N is the number of people with access to a hand pump (hp);

D is the minimum demand related to the hand pump (l.c.d); that is, per capita minimum requirement according to the local standards

V_{month} is the monthly production from SWI ($m^3/month$); estimated from the amount of water used per household per day

η accounts for the water losses in the system which is taken as negligible for the case of the hand pump since there is no conveyance system from storage to the water neither point nor distribution network.

According to Gleick (1999), the minimum per capita water requirement is 50 l.c.d for drinking, bathing, food preparation and hygiene. The World Bank recommends a minimum of 20 l.c.d for cases where water has to be carried (Kalbermatten *et al.*, 1982) The local guidelines on water supply and sanitation (SALA, 1990a) recommends 15 – 25 l.c.d for walking distances of less than 250 m, and 10 15 l.c.d for distances of 500 – 1000 m.- At the time of the study the NGOs were the service provider for rural water supply, and according to DDF (2010), this has been the case for at least the past ten years. However, the main responsibility for water supply in Insiza District lies with government, that is, the District Development Fund (Sunguro *et al.*, 2000) .

The DDF work in cooperation with NGOs and they use The Sphere Project guidelines (SCHR, 2004) as a guide in water service provision which suggests a minimum per capita water requirement of 15 l.c.d. Therefore the minimum demand for human consumption was taken as 15 l.c.d in this study. Livestock water intake was estimated as follows: goat = 7.5 l/day; sheep = 10 l/day; chicken = 0.66 l/day; guinea fowl/duck = 1 l/day (Ward and McKague, 2007). The minimum demand from SWI was taken as a combination of human and livestock consumption depending on the number of livestock kept in a household. The exception for water use from SWI is cattle and donkeys which are normally watered in small dams. No modifications were made with respect to quality index calculation (refer to section 2.5.1). For calculation of water quality sub-indices μ_i , the table in Appendix E was used (Cisneros, 1996).

Amount of water used from SWI was estimated from the number of 20 litre containers used per household per day. The responses obtained from respondents on the quantities of water used allowed for estimating the amount of water used per household per month and hence SWI monthly production. SWI monthly production of water was weighed against the required minimum demand per capita per day to obtain the availability index. Water quantity index was given more weight (60 %) than water quality (40 %) with the view that quality may be improved when the quantity is available (Robinson, 2002; SCHR, 2004).

b) Capacity assessment

The equation for calculating capacity index as proposed by Rietveld *et al.* (2009) is as follows:

$$I_{cap} = \beta_1 I_{pump} + \beta_2 I_{res} + \beta_3 I_{wp,dens} + \beta_4 I_{wp,funct} \quad (2-2)$$

Where:

$I_{res} = \frac{V_{res}}{Q_{demand} \times T_{res}}$ is the volume required to overcome differences between demand and pumping capacity.

The other parameters in the capacity index equation are defined in section 2.5.2 and remain unchanged. For groundwater systems in Insiza District there are no storage facilities after pumping from SWI except for windmills in Ward 1 (Smart windmill) and Ward 17 (Village 18A Windmill). For the case of the wells and boreholes where there is no storage before or after pumping the water; and therefore no storage time, the *potential* storage was estimated from the

borehole safe yield. The borehole safe yield was taken as 60 % of the drawdown for each SWI to safeguard the pump against running dry due to seasonal changes which has effects on rest water level (DWD, 1995). However, the drawdown tests were not done in this study; secondary data from government departments and NGOs were used. Where data for a specific SWI was not available, data for the nearest SWI with similar hydrogeological conditions was used. The modified equation for reservoir volume storage sub-index is as follows:

$$I_{potstor} = \frac{0.6V_{potstor}}{V_{demand}} \quad (4-2)$$

Where:

$V_{potstor}$ is the potential storage volume in m^3

V_{demand} is the demand volume based on per capita demand in m^3

For calculation of water point density sub-index, the maximum allowable walking distance from household to nearest water source was taken as 500 m (SCHR, 2004; AfDB, 2011); making the required water point density to be 2 wp/ km^2 . The minimum required flowrate from hand pump was taken as 16.6 l/min (SCHR, 2004) in calculation of pumping capacity sub-index. Safe yield was taken as 60 % of tested yield (DWD, 1995) to safeguard the pump against running dry due to seasonal changes which has effects on the rest water level. The safe yield tests were not conducted in this study; secondary data from government departments and NGOs was used. Where data for a specific SWI was not available, data for the nearest SWI with similar hydrogeological conditions was used. Potential storage from SWI was then taken as the safe yield multiplied by the duration (time) of pumping.

Four dams were studied, one located in each of the four wards. A small dam in this study refers to a structure with an embankment height of less than eight metres and a reservoir capacity of up to one million cubic metres (GoZ, 2000). The dams that are widely available in the district are typically of the dam wall height less than eight metres and an average capacity of $0.5 Mm^3$ (Mamba *et al.*, 2007). Two of the dams studied were fitted with Trapezoidal (Tombo Dam) and V-notch (Zhulube Dam) weirs for flow measurements of water used for irrigation. The other two dams had no water measurement structures and the communities were using buckets to collect water for irrigation of the crops in the communal gardens.

For estimating amount of water abstracted from the small dams, the Trapezoidal weir and V-notch weir formulae were used to estimate the flow (Giles, 1962; DWD, 1995; USDA, 1997) . The flow was then multiplied by the duration that the flow control structures (gates for Tombo Dam and valves for Zhulube Dam) were opened for irrigation and other uses. The formulae for trapezoidal (Eq. 4-3) and v-notch (Eq. 4-4) weirs are shown below:

$$Q = 3.367bH^{3/2} \quad (4-3)$$

$$Q = 2.49H^{2.48} \quad (4-4)$$

Where:

Q is the flow in ft³/s

b is the length of weir crest in ft; and

H is the head of weir in ft. (height of level liquid surface above crest)

Before the measurements were taken, water was allowed to flow in the channels for ten minutes to allow for water level to stabilize. Measurements for height of water level and the length of the weir crest were measured using a standard ruler.

c) Continuity assessment

No modifications were made for continuity index calculation from that proposed by Rietveld *et al.* (2009). Supply time per day was taken as the pre-determined supply time according to the design specifications for SWI (SCHR, 2004) versus the actual supply time of water from the SWI per day. The number of days per month that the supply of water is discontinued due to breaking of SWI was obtained from interviews with pump minders and/or Kraal Heads. Continuity index was calculated using Equation 2-3. The minimum supply time per day was taken as 8 hours, and the number of days per month without water supply was taken as one day (SCHR, 2004)..

d) Condition assessment

Physical inspections were done to determine the condition of SWI studied (Alegre *et al.*, 2006). For boreholes and wells, the above-ground components were used to define the status of the down-hole components. The down-hole components was inferred from the number of strokes, the ease of operation (effort required to pull the pump handle) and the amount of water discharged per

stroke. The more the number of strokes means that the down-hole components need attention. According to Hoko and Hertle (2006), a maximum of 4 strokes is generally acceptable for Zimbabwe standards. Assessing the weight of the hand pump was also used as an indicator for the condition of the down-hole components. The harder it was to operate hand pump meant the down-hole components were not in good condition. Equation 2-4 for calculation of condition index (Rietveld *et al.*, 2009) has been modified as follows:

$$I_{cond} = \delta_1 I_{abovegr} + \delta_2 I_{downhole} + \delta_3 I_{funct} + \delta_4 I_{headwork} \quad (4-5)$$

Where:

$I_{abovegr} = \frac{N_{abovegr,good}}{N_{wp,total}}$ is the condition index for the for above-ground components;

$I_{downhole} = \frac{N_{downhole,good}}{N_{wp,total}}$ is the condition index for the for down-hole components;

$I_{funct} = \frac{N_{funct,good}}{N_{wp,total}}$ is the index for the number of SWI with good flowrates in the community;

$I_{headw} = \frac{N_{headw,good}}{N_{wp,total}}$ is condition index for the headwork.

$N_{wp,total}$ is the total number of water points in the community;

$N_{abovegr,good}$, $N_{downhole,good}$, $N_{headw, good}$ are the number water points with above ground, down-hole, and headwork, respectively, that are in good state;

$N_{funct,good}$ are the number of water points that are in good functional state,

δ_i are weighing factors for the sub-indices, where $\sum \delta_i = 1$.

e) Overall performance assessment

The overall SWI performance was calculated by giving equal weight to the four indicators described in the preceding sections: availability, capacity, continuity and condition indices. The equal weight was given to the indices with an assumption that all four indicators contribute equally to the overall performance.

5. RESULTS AND DISCUSSIONS

This chapter outlines and discusses the findings with regard to SWI used in Insiza District, uses of water, performance of SWI in terms of availability, capacity, continuity, condition and overall performance; and the factors affecting performance with respect to the four indices.

5.1 Current practices in water supply and management

This section presents the results obtained from key informants and households interviews on current practices with regard to water supply activities and management in the district. Key informants included government and NGO officials, and community leadership. Water supply management has been identified as one of the factors that impact on sustainability of water infrastructure (Montgomery and Elimelech, 2007; Misiunas, 2008; Hunter *et al.*, 2010).

Government departments in Insiza District and Non-Governmental Organizations (NGOs) are jointly engaged in rural water supply activities in the district. The government departments and NGOs involved in Water, Sanitation and Hygiene (WASH) activities include District Development Fund (DDF), Agricultural Technical and Extension Service (AGRITEX), Ministry of Health and Child Welfare (MOHCW), Zimbabwe Project Trust (ZimPro), and World Vision International (WVI) respectively. Water supply activities by government institutions and NGOs include drilling of new boreholes and rehabilitation of existing water points. The Rural District Council (RDC) facilitates implementation of water supply programs in the district through the District Administrator (DA) as mandated by the Water Act [chapter 20:24]. The institutions responsible for district WASH are also stakeholders in the District Water and Sanitation Sub-Committee (DWSSC) which is responsible for monitoring activities for water supply and sanitation in the district.

At the district level, DDF in collaboration with NGOs are in charge of larger maintenance operations mainly for water supply. At ward level, there is a trained pump mechanic responsible for repairing pumps, and keeps maintenance records. At the community level, the water point committee (WPC) which is chosen by the community from among the users is responsible for minor maintenance of SWI. Ideally, each WPC consists of a pump minder responsible for a number of community water points with each water point consisting of a caretaker (Gumbo, 2006)

The caretaker is responsible for continuous monitoring activities to enable appropriate actions initiated required to correct any detected potential problems before the SWI breaks down.

The management structures outlined above are not the reflection of water management in the communities according to the findings from field observations, household surveys and key informant interviews. The responses obtained from household interviews suggested that all the water points have WPCs and respective pump minder; but further probing revealed that 63 % of water points in the south wards (Wards 17 and 19) did not have WPC nor pump minders. Some 39 % and 54 % of SWI in Ward 17 and Ward 19, respectively, were dysfunctional. In Ward 1, 36 % of SWI were dysfunctional and in Ward 2 the figure was 34%. Reduced numbers of dysfunctional SWI in Wards 1 and 2 may have been because of the recent rehabilitation activities by NGOs that had taken place shortly before the study was conducted.

During the processes of rehabilitation and reconstruction of SWI, training sessions on Community Based Management (CBM) were carried out. It was during the CBM training sessions that the communities got a chance to re-construct WPCs which had been discontinued due to the functional state of the SWI. CBM approach allows communities to take the final decision on all important aspects in the planning, management and implementation of resources within their areas (Ramahotswa and Still, 1992; IWSD, 2010). When applied to rural water supply and sanitation the concept implies the management of water and sanitation resources by the communities. The ideology behind CBM is to encourage communities to take ownership of the SWI for water supply and to take care of all management costs as required. During the CBM training sessions the communities also get a chance to discuss water supply issues.

In Ward 19 and some parts of Ward 17, the communities have done very little to maintain their SWI, some of which they inherited from former commercial farmers (dams and windmills). The communities in these areas resort to unsafe water sources for water supply and they consume water without any form of treatment. Hoko (2005).also found that over 90 % of rural communities of Zimbabwe consume water without treatment. The management approach in the south part of the district (in Wards 1 and 2) is different from what was established in Insiza North. The WPCs in Wards 1 and 2 were operational, though in some cases they were not able to raise funds

required for SWI maintenance. The tradition in all the communities has been to wait for a SWI to break down before funds can be collected for repairs. However, not every household was willing and / or able to make a contribution towards SWI maintenance. There were no local constitutions compelling the communities to make contributions or be involved in activities of routine maintenance of SWI. The necessity for making a contribution towards maintenance costs was dependent on obedience and personality of individuals in the communities. The communities relied on assistance from government or NGOs intervention for operation and maintenance of their SWI.

Minimum effort has been made within the rural water supply and sanitation programs in the district to identify the water requirements of rural communities other than for domestic use, or to investigate people's needs and preferences for water supply. Despite the water reforms and IWRM strategies developed since 1990 (Nare *et al.*, 2006), there is still lack of stakeholder participation at village level. Failure to engage communities in the planning for projects results in wastage of financial resources. The villagers are mostly engaged in the implementation stages of the water supply projects when decisions have already been made on requirements and specifications for the type of SWI to be provided to the respective community.

In Ward 1, it was observed that some of the water points consisted of more than one water troughs for laundry while in other water points there were none or broken trough for either livestock watering or laundry. It was also found that in some of the SWI that consisted of more than one water troughs for doing laundry, there were restrictions for doing laundry next to the SWI. Thus the facilities for laundry in such cases were not utilized, which was a waste of resources that could have been useful elsewhere. Optimizing use of financial resources could be achieved through involving communities in planning stages of projects so that the water needs are known.

Apart from water challenges in the district, including lack of potable water supply, the rural communities are also faced with food shortages, insufficient health services and lack of sanitation facilities. The institutional structures for rural water supply are in place at the District and community levels, but lack of implementation at the community level was found to be a constraint. The capital and financial resources are centralized at the district level. There were

currently no institutions at the community level responsible for spares provision in case of SWI break down. The responsible community leader per village is required to seek assistance from DDF and or respective NGO at the district office in Filabusi, which leads to increased downtime for SWI before financial and technical assistance can be sourced.

5.2 Assessment of performance

Performance was measured using four indicators, namely, *availability*, *capacity*, *continuity* and *condition* in Wards 1, 2, 17 and 19 of Insiza District. Performance results for the SWI assessed were calculated from equation 4.1 to 4.5 and are presented in Table 5.1. The results for performance indices was obtained from households and key informants interviews, field measurements and also from secondary data obtained from government institutions and NGOs. The results for performance and factors contributing to performance are discussed in the following subsections (5.2.1 to 5.2.5) with reference to Table 5.1 and Appendix D.

5.2.1 Availability of water

Water availability in Ward 1 ranged from fair ($0.64 < I_{av} < 0.74$) for 22 % of SWI to good ($0.76 < I_{av} < 0.99$) for the remaining 78 %. In Ward.2, availability was sufficient for 71 % of SWI ($0.79 < I_{av} < 0.85$) while for 29 % availability was fair ($0.67 < I_{av} < 0.68$). Performance in Ward 17 in terms of availability was found to be fair for 33 % of SWI assessed ($0.71 < I_{av} < 0.74$) and sufficient for 77 % ($0.76 < I_{av} < 0.82$). In Ward 19 availability was sufficient for all SWI assessed ($0.76 < I_{av} < 0.87$).

Water quality was analysed taking into account the specific uses following the SAZ 560: 1997 standards. During the households interviews, some concerns were raised by communities about the (perceived) quality of water from some of the SWI especially those communities that are using it for consumptive uses. Table 5.2 shows measured water quality parameters. Out of the ten SWI assessed in Ward 1, three water samples tested positive for Total Coliforms (TC) and this reduced the value of availability index. In Ward 2, four out of the eight SWI assessed tested positive for TC while in Wards 17 two out of seven SWI tested positive while in Ward 19 one out of five SWI showed presence of TC. Results for water quality analysis are shown in Table 5.1. Detailed table for water quality parameters is shown in Appendix C.

Table 5.1: Performance indices for assessed SWI in Insiza District

SWI TYPE PER WARD	B _{1,1}	B _{2,1}	B _{3,1}	B _{4,1}	B _{5,1}	B _{6,1}	B _{7,1}	B _{8,2}	B _{9,2}	B _{10,2}	B _{11,2}	B _{12,2}	B _{13,2}	B _{14,17}	B _{15,17}	B _{16,17}	B _{17,17}	B _{18,17}	B _{19,19}	B _{20,19}	B _{21,19}	B _{22,19}	W _{1,1}	W _{2,2}	WM _{1,1}	WM _{2,17}
Households using SWI	27	33	26	22	63	35	35	35	20	36	25	22	35	55	28	35	28	33	48	58	29	26	42	23	27	45
Monthly prod (m ³ /month)	86	88	68	70	172	106	117	110	64	131	76	70	116	183	95	123	101	132	166	176	92	83	119	88	83	171
Quantity: <i>I_{av, quant}</i>	1	0.95	0.98	0.91	0.94	0.95	0.92	1	1	1	1	1	1	1	1	0.96	1	1	1	1	1	1	0.99	1	0.91	0.92
Quality: <i>I_{av, qual}</i>	0.83	0.40	0.39	0.15	0.13	0.39	0.40	0.41	0.16	0.41	0.41	0.19	0.22	0.41	0.41	0.41	0.24	0.40	0.39	0.40	0.40	0.41	0.40	0.41	0.39	0.40
AVAILABILITY: <i>I_{av}</i>	0.99	0.73	0.74	0.60	0.62	0.72	0.71	0.84	0.68	0.85	0.80	0.67	0.81	0.82	0.77	0.74	0.76	0.77	0.82	0.76	0.82	0.87	0.76	0.79	0.70	0.71
Pumping capacity: <i>I_{ump}</i>	0.84	0.55	0.53	0.24	0.21	0.53	0.56	0.49	0.24	0.48	0.51	0.28	0.28	0.50	0.53	0.55	0.32	0.52	0.48	0.53	0.48	0.47	0.53	0.52	0.56	0.57
Potential storage: <i>I_{pot, stor}</i>	0.038	0.041	0.043	0.047	0.017	0.041	0.038	0.037	0.074	0.034	0.040	0.039	0.034	0.026	0.029	0.034	0.036	0.030	0.041	0.034	0.076	0.075	0.044	0.055	0.052	0.029
Waterpoint density: <i>I_{wp, dens}</i>	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.37	0.37	0.37	0.37	0.37	0.37	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.18	0.37	0.18	0.03
Functional waterpoints: <i>I_{wp, funct}</i>	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.63	0.63	0.63	0.63	0.63	0.63	0.45	0.45	0.45	0.45	0.45	0.26	0.26	0.26	0.26	0.60	0.63	0.60	0.45
CAPACITY: <i>I_{cap}</i>	0.34	0.34	0.30	0.33	0.30	0.31	0.32	0.36	0.37	0.37	0.38	0.39	0.38	0.27	0.25	0.26	0.24	0.25	0.21	0.19	0.22	0.20	0.35	0.38	0.31	0.25
Daily continuity: <i>I_{hours, day}</i>	1	1	1	1	1	1	1	1	1	0.75	0.75	0.75	1	1	1	1	1	0.75	0.50	1	1	1	1	0.75	1	1
Monthly continuity: <i>I_{day, month}</i>	0.30	0.30	0.30	0.67	0.07	0.30	0.67	0.67	0.07	0.30	0.001	0.30	0.67	0.07	0.30	0.003	0.67	0.30	0.003	0.02	0.07	0.003	0.67	1	0.67	0.003
CONTINUITY: <i>I_{cont}</i>	0.65	0.65	0.65	0.84	0.41	0.65	0.84	0.84	0.54	0.53	0.38	0.53	0.84	0.54	0.65	0.50	0.84	0.53	0.25	0.51	0.54	0.50	0.84	0.88	0.84	0.50
Above-ground components: <i>I_{abovegr}</i>	0.88	1	1	0.83	1	0.80	0.80	0.92	0.92	0.75	0.75	0.50	0.81	1	1	1	1	1	0.50	0.33	-	-	0.83	0.81	1	-
Down-hole components: <i>I_{downhole}</i>	0.75	0.75	0.83	0.83	0.67	0.60	0.60	0.67	0.67	0.63	0.63	0.50	0.56	-	1	1	-	-	-	-	-	-	0.83	0.56	0.67	0.50
Functional status: <i>I_{funct}</i>	0.88	0.88	0.83	0.83	0.89	0.80	0.80	0.75	0.75	0.75	0.75	0.50	1	1	1	1	1	1	0.50	-	1	1	1	0.81	0.89	0.50
Headwork condition: <i>I_{headw}</i>	0.63	0.63	0.50	0.50	0.89	0.80	0.80	0.75	0.75	1	0.75	1	0.88	1	1	-	-	-	-	-	1	-	0.50	0.88	0.89	-
CONDITION : <i>I_{cond}</i>	0.80	0.80	0.77	0.77	0.67	0.76	0.76	0.77	0.77	0.73	0.73	0.25	0.78	0.30	0.60	0.40	0.30	0.50	0.30	0.20	0.20	0.4	0.77	0.78	0.87	0.30
PERFORMANCE: <i>I</i>	0.70	0.63	0.62	0.63	0.50	0.61	0.66	0.70	0.59	0.62	0.57	0.46	0.70	0.48	0.57	0.47	0.53	0.51	0.40	0.42	0.44	0.49	0.68	0.71	0.68	0.44
PERFORMANCE RATING	Fair	Fair	Fair	Fair	Bad	Fair	Fair	Fair	Fair	Fair	Fair	Bad	Fair	Bad	Fair	Bad	Fair	Fair	Bad	Bad	Bad	Bad	Fair	Fair	Fair	Bad

- SWI number per ward is the number allocated to SWI type per ward where B = borehole; W = well and Wm = windmill;
- I_i = sub-indices used to calculate the indices, namely, availability, capacity, continuity and condition; I = overall performance index,
- PERFORMANCE RATING is the overall performance rating for the individual SWI, where Bad is allocated to indices values between 0 and 0.5; Fair for indices values between 0.51 and 0.75; Sufficient for indices values between 0.76 and 0.9; and Good for indices values between 0.91 and 1.

Four cases of high turbidity were encountered; one in Ward 1 (9.1 NTU), one in Ward 17 (21.4 NTU) and two in Ward 19 (29.3 NTU and 27.9 NTU). Reasons for occurrence of TC could have been due to one or more of the following reasons: (i) location of sanitary pit latrines within a 30 m range or less from SWI (SCHR, 2004), (ii) access to water sources by wildlife and livestock, (iii) inadequate borehole/well head protection or casing and (iv) inadequate buffer zones to protect water points from rainwater runoff wash down. Protecting SWI through routine cleaning, lining (apron for boreholes and wells) and fencing to prevent livestock from polluting can significantly improve water quality.

Table 5.2: Water quality parameters for selected SWI in Insiza District

*SWI TYPE PER WARD	pH	Conductivity (μ S/Cm)	Turbidity (NTU)	<i>E.Coli</i> (cfu/100ml)	Total Coliforms (cfu/100ml)
B _{1,1} ; B _{3,1} ; B _{14,17} ; B _{18,17} ; W _{2,2}	6.8	720	3.3	0	<1
B _{12,2} ; Wm _{2,17}	7.0	720	3.5	0	1
B _{9,2}	7.1	1, 270	5	1	2
B _{8,2} ; B _{13,2}	7.0	720	4.1	0	3
D _{4,19}	7.1	870	321.2	8	8
D _{1,1} ; D _{3, 17}	7.6	800	380.5	11	12
Health related guidelines for water quality (SAZ 560: 1997)	6.0 - 9.0	700 – 3, 000	1 - 5	-	0

*SWI number per ward is the number allocated to SWI type per ward: B = borehole; W = well; Wm = windmill; D = dam

It was observed that reduced quantities of water were drawn from those SWI that the communities suspected were contaminated. According to Hoko and Hertle (2006) water quality may lead to reduced quantities being drawn from a water point or rejection of certain water points. Reduced quantities of water available per capita and reduced water quality therefore have a negative impact on availability. Availability is therefore affected by water quality and the amount of water available for multiple purposes. Performance in terms of availability was generally sufficient to meet multiple water needs of the communities in Insiza District.

5.2.2 Capacity of SWI

Capacity of SWI is not sufficient in all studied wards of Insiza District ($0.19 < I_{cap} < 0.39$). The amount of available water per SWI in terms of potential storage determines the quantity of water available per capita per day. The amount of water used per household per day increases due to population growth and per capita demand (Alegre *et al.*, 2006; Rietveld *et al.*, 2009). For the case of Insiza District the amount of water available per capita per day was reduced due to the increased number of users using one SWI as a result of high break down rate of SWI in the area which has resulted in increased density of users on the remaining functional SWI.

The problem of increased number of users arises when the other SWI in the communities breaks down, in which case the affected community resort to the nearest available water source. Therefore the condition (functional status) of SWI per community impacts indirectly on capacity, that is, the number of SWI per community may be sufficient, but when other SWI become dysfunctional then people have to walk longer distances to fetch water. According to (SCHR, 2004; AfDB, 2011), water should be accessed within a walking distance of not more than 500 m. In Insiza District, communities walk up to 2 km to fetch water either to the nearest water point or to the alternative water source (see Appendix F).

Increased walking distance to the nearest functional water source impacts on the water point density index which in turn reduce the capacity index. Water point density was found to be the major effect on the overall performance for Wards 17 and 19. For Wards 1 and 2, the potential storage of the available water was found to be the major drawback for the performance in terms of capacity due to increased water demand from SWI. One borehole in Ward 2 (Mkandla Borehole) was reported to be drying out during the months of July to October. Therefore performance in terms of capacity is dependent on the condition of the SWI within the community.

5.2.3 Continuity of water supply

Performance in terms of continuity in Ward 1 ranged from fair for 66 % of SWI assessed to sufficient for the remaining 34 % with minimum index value of 0.54 and maximum of 0.84. In Ward 2 continuity was found to be poor for 14 % of SWI ($0.25 < I_{cont} < 0.50$); fair for 43 % ($0.53 < I_{cont} < 0.54$); and sufficient for 43 % of the SWI ($0.84 < I_{cont} < 0.88$).

Out of the seven SWI assessed in Ward 17, only one SWI had good continuity with continuity index of 0.84. Continuity was found to be fair ($0.53 < I_{cont} < 0.65$) for 50 % of the SWI in Ward 17. The remaining 33 % of SWI had bad performance in terms of continuity with equal continuity index of 0.50. In Ward 19 continuity was bad for all the assessed SWI ($0.25 < I_{cont} < 0.50$).

Most of the dysfunctional SWI in Wards 17 and 19 have been down for a period of two years or more, hence the low continuity index in the two wards. Continuity is affected by the condition of SWI and by external factors such as socio-economic status of households in the community, and other factors linked to management. From the assessment and observations in the field, it was noted that the presence of organised Water Point Committee (WPC) played a major role in ensuring continuity of water supply. Montgomery and Elimilech (2007) recommended that operation and maintenance of water supply infrastructure plays a major role in improving the reliability of water supply systems.

Hoko and Hertle (2006) also concluded that the breakdown history, which has an impact on continuity, is linked to maintenance problems. If there is always readily available funding for maintenance, the downtime of SWI becomes less. This was not the case in the two poorly performing wards (Ward 17 and Ward 19). From the households interviews it was found that 63 % of water points in Wards 17 and 19 did not have WPCs nor pump minders. Absence of such important structures was evidenced by the observed state of SWI in the two wards which was bad or dysfunctional. In cases where there were no responsible WPCs or pump minders, the responsibility for maintenance was shifted to the respective kraal head or any respective community leader; otherwise the community would wait for assistance from NGOs.

The communities in Ward 1 and Ward 2 appeared to have the technical capacity for maintaining their infrastructure but the major limitation is funds for maintenance. It was observed that the down time for SWI was two days or less provided that no major parts are required for repairs. Spares unavailability was found to be a common problem for all four wards studied. The responsible institution for infrastructure provision and technical support is DDF but, the institution has been faced with challenges of poor financial base and limited capacity (Gumbo, 2006). The communities that are unable to maintain their SWI are relying on NGOs intervention, which is highly influenced by the Rural District Council (RDC) whose mandate is to facilitate

development in the rural areas as stipulated in the Zimbabwean legislation (Gumbo, 2006). Availability of funds for repairs or maintenance and availability of technical expertise within the community influence the continuity of water supply from SWI. The frequency of breakdown of SWI is also linked to maintenance problems (Hoko and Hertle, 2006). Lack of funds for maintenance lead to increased downtime of water points and this has also has a bearing on the condition of SWI.

5.2.4 Condition of SWI

The condition of SWI was determined by calculating the condition index. The condition of SWI was found to be sufficient for 46 % of SWI assessed; fair for 15 % and bad for 39 %. The majority of the SWI with bad condition (90 %) were located in Ward 17 and 19 where the condition index ranged from 0.20 to 0.60. The condition of SWI in Ward 1 and Ward 2 was generally fair to sufficient ($0.67 < I_{cond} < 0.8$), with exception of one borehole in ward 2 which was reported to be drying out during the months of July to October. According to SWI users, the borehole was also repaired on a regular basis due to the problem of old pipes and rods. A significant number SWI in the northern part of the district were dysfunctional; 39 % in Ward 17 and 54 % in Ward 19.

The SWI that are working in Wards 17 and 19 are over-utilised due to the increased number of people per water point as a result of non-functional SWI. Furthermore, 45 % of the households interviewed in the four wards claimed to walk for a distances of more than 500m to access water from alternative water sources in cases of SWI break down. The condition of SWI is mostly affected by the total number of dysfunctional SWI per ward. The good condition of SWI in Wards 1 and 2 may have been influenced by (i) the NGO rehabilitation program had recently taken place in the district, whereby the SWI assessed were rehabilitated during the program (ii) during the rehabilitation process, the Water Point Committees (WPCs) that had become inactive due to the (dysfunctional) state of SWI were re-formed and pump minders trained and (iii) the communities in Wards 1 and 2 depend mainly on SWI for their primary water supply with relatively less surface water resources. The communities for Ward 1 and Ward 2 therefore did not have many alternative water supply sources and they had to maintain their water points.

The latest rehabilitation program for water points had taken place in 2009 to 2011 in Insiza South and selected wards in Insiza North (Wards 16, 18 and 23). Some 69 % (9 out of 13) of SWI assessed in Ward 1 and Ward 2 were rehabilitated during the program. It was observed that people were paying less attention to SWI maintenance where there were alternative sources of water available, irrespective of the water quality from the alternative water source. In Ward 19, the communities were mainly using water from dams and unprotected shallow wells as alternative water sources for all their water needs. Some of the boreholes in the ward were dysfunctional for a period of at least two years due to either worn out short casing, worn out pipes or leather cups; or due to leaking cylinders and shortage of pipes. Therefore the SWI condition in the case of Ward 19 had less to do with inability to raise funds for maintenance and repairs, but rather more to do with availability of alternative sources of water. Availability of an alternative water source, whether it is a safe source for consumptive use or not, therefore contributes to the condition of the SWI.

The poor SWI condition in the other three wards (Wards 1, 2, 17) was mainly influenced by socioeconomic status of households. Households are not able to contribute the required amount for maintenance, which, according to interviewed household, ranges from USD 0.50 to USD 1.00 per month. The presence of other livelihood activities such as field cultivation and other NGO driven activities, for example food for work, were taken as priority by communities and as a result the water supply related activities such as SWI maintenance were neglected. In villages where there are other livelihood activities and/or where there are alternative water sources, such as in Wards 1, 2 and 17, neglect of SWI maintenance activities such routine cleaning, fencing, documentation of activities on the SWI were observed. Thus in poor communities food access becomes a priority as compared to water supply related activities; this is particularly the case in communities where there are alternative sources of water such as rivers, streams and open wells.

5.2.5 Overall performance of SWI in Insiza District

Overall performance for Ward 1 was fair for eight out of the nine SWI assessed ($0.50 < I < 0.70$). In Ward 2, performance was bad for one SWI and fair for the other six SWI ($0.46 < I < 0.71$). In Ward 17, performance varied from bad for 40 % of SWI ($0.47 < I < 0.48$) to fair for the other 60 % ($0.51 < I < 0.53$). In Ward 19, performance was poor for all five SWI assessed ($0.40 < I < 0.49$).

Figure 5.1 shows a comparison of the four indices in the four wards studied. The condition of SWI was found to be mainly dependent on factors such as funds availability for maintenance, availability of spares, technical capacity and ability and/willingness of the people to contribute towards maintenance costs. The condition of SWI was good in the two wards of Insiza South with an equal index of 0.81. The good condition of SWI may be because of the recent rehabilitation program that has taken place in the two wards.

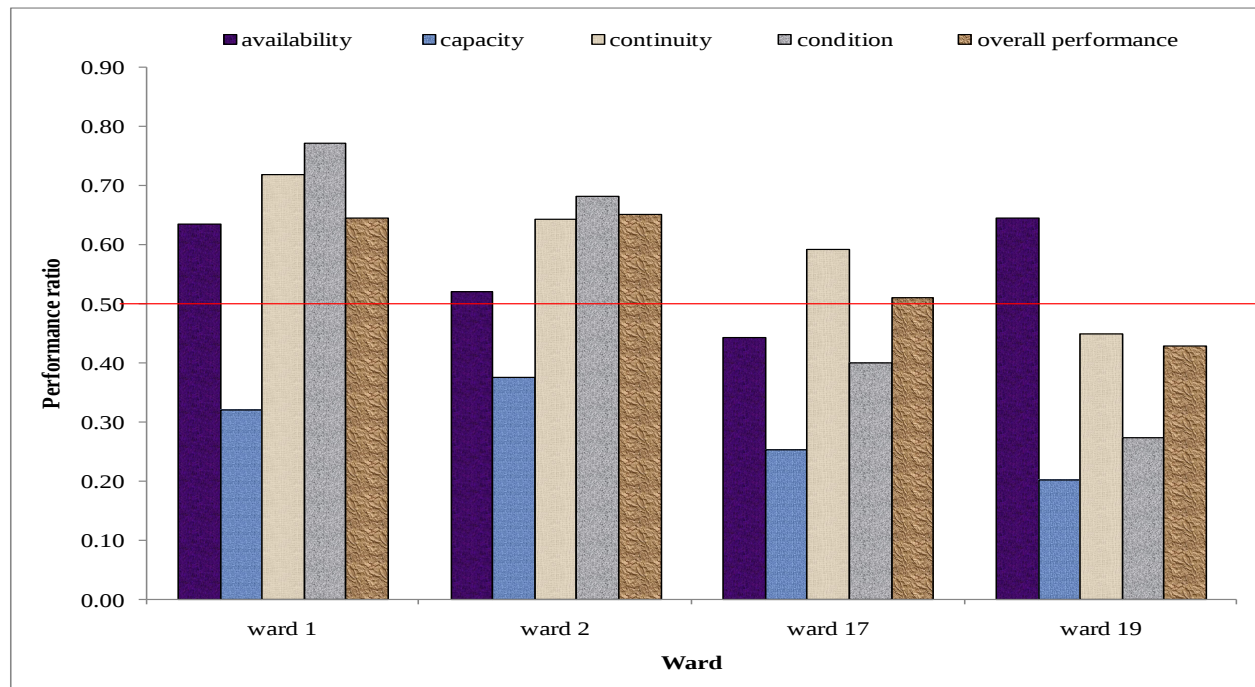


Figure 5.1: Performance indices for the four wards

SWI performance in Ward 17 and Ward 19 was mainly affected by capacity and condition of SWI. Contrary to the findings from Ward 1 and Ward 2, there were no interventions in SWI rehabilitation for Wads 17 and 19, at least not for the past two years according to the key informants. When asked on suggestions for improved water supply services, 7.3 % of respondents reported that they were satisfied with available SWI; 9 % of the respondents suggested mechanised systems (windmill pumps) as a better technology especially for the elderly; 11.7 % thought availability of spares would be helpful; and the remaining 72 % felt that an additional SWI in the community would improve water access.

From the responses on suggestions for improved water supply the observation was that the respondents that suggested mechanized water supply systems had preference of water sources that do not require pumping. Out of the 9 % of the respondents that suggested mechanized systems, the 7 % was from Ward 19. It was also observed that the respondents that were satisfied with water supply were within the 200 m walking distance range or less to the nearest SWI. From the variations in performance for different wards it was realized that the main contributors to performance (the performance indices) differ from one community to the other, depending on livelihood activities for different communities.

Preferences for certain types of SWI or technologies led to communities to not utilize the SWI optimally, which affected the availability (quantity), condition and, in the long term, continuity of water supply. Figure 5.2 shows the performance for different types of SWI in the four wards. Boreholes in Ward 1 and Ward 2 were found to have better performance ($0.59 < I < 0.61$) than boreholes in Ward 17 and Ward 19 ($I = 0.51$). The difference in performance for the wards may be influenced by the availability of alternative water sources in Ward 17 and 19, amongst other factors. The windmill in Ward 1 was found to be performing better ($I = 0.56$) than the windmill in Ward 17 ($I = 0.44$), but comparison of windmills could have been subjective since only two windmills were studied due to their functional status in the district. It is important to note that not all of the types of SWI are available in all four wards, thus the zero value for performance ratio in Figure 5.2 means ‘absence’ of that particular SWI type.

Availability index seemed to be the prevailing index with highest performance for all wards, which makes a significant contribution to the overall performance. Capacity on the other hand was found to be the limitation for performance in all four wards. The capacity and condition of SWI also affect continuity of supply both in the short and long term. However, there are also external factors that have an impact on the indices such as socio-economic status of individual households and presence of other livelihood activities. Some researchers have concluded that the way communities manage their SWI has a bearing on its condition and thus sustainability (Adank, 2006; Montgomery and Elimelech, 2007; Misiunas, 2008). Thus performance of SWI is also dependent on how the communities manage their SWI.

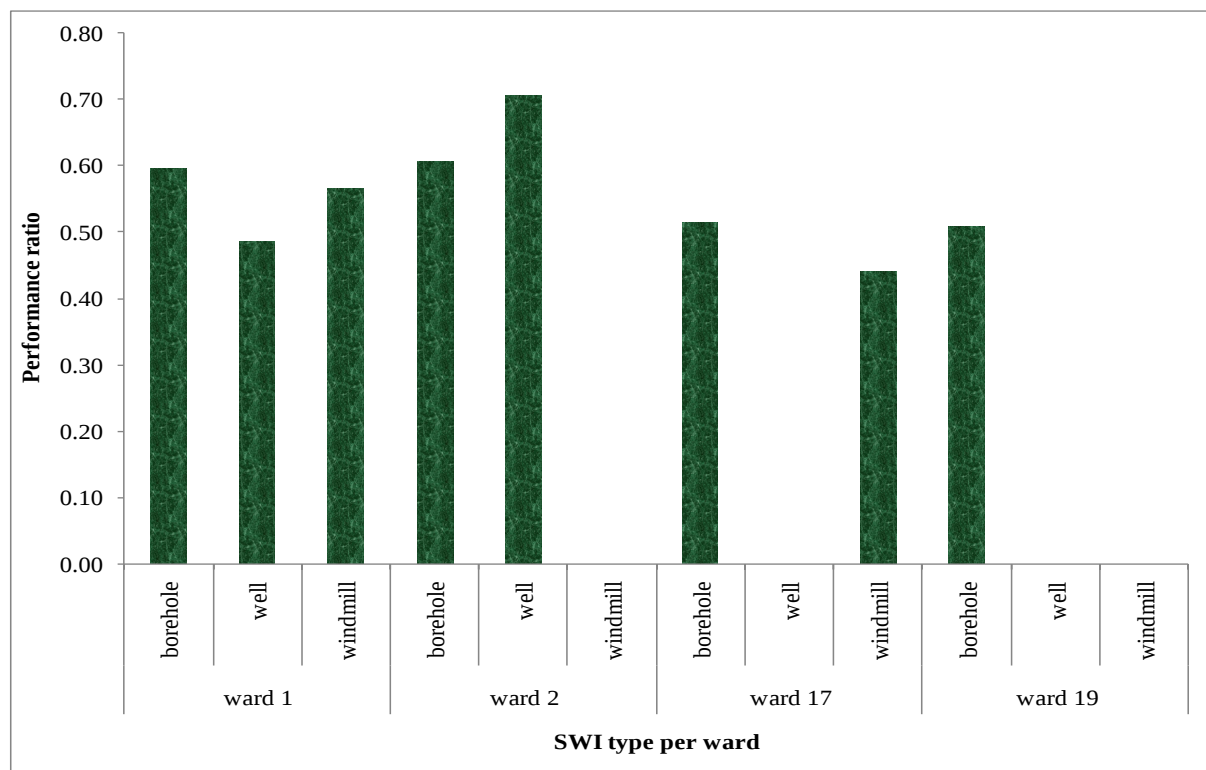


Figure 5.2: Overall performance indicators for each type of infrastructure per ward

It was observed that availability of active WPCs that meet regularly for discussions on maintenance, having powerful constitutions regarding use of SWI; and having support from local leadership would allow for the WPC be able to raise funds for purchasing minor tools that are needed for minor maintenance activities, and thus improving SWI performance.

5.3 Benefits obtained from using SWI

The results presented in this section are based on the household interviews and field observations. The benefits that the communities obtained from using SWI were investigated with respect to the number and types of uses the communities derive from using SWI. The types of SWI available per ward are not the same in the district as illustrated in Figure 5.2.

5.3.1 Multiple use of water from boreholes, wells and windmills

In Ward 1 and Ward 2, the communities were using water mainly from boreholes and wells for all their water needs, that is, domestic (100 %), garden irrigation (56 %), livestock watering (100 %),

brick moulding (6 %), and gold panning (3 %). The livestock watering from boreholes, wells and windmills excludes water for cattle, which was mainly watered at the dams or rivers. Statistics for quantities of water used for gold panning from boreholes and wells obtained could not have been true because the local rules do not permit water use for gold panning thus people could not be honest. The communities ‘steal’ water for gold panning purposes and this was evidenced by heaps of sand around some of the SWI especially in Ward 1.

A total of 60 % of the households responded positively on using water for gold panning purposes, but 53 % of the 60 % claimed that they use water from the dam for gold panning purposes. Figure 5.3 shows variations in amounts of water used and major types of water uses for Wards 1, 2, 17 and 19 from boreholes. Comparison of water used from the other SWI types, that is, wells and windmills, could not have been objective since these types were not available for the study in Ward 2 and Ward 19. Windmills in Wards 2 and 19 had broken down and there were no protected wells in the ward.

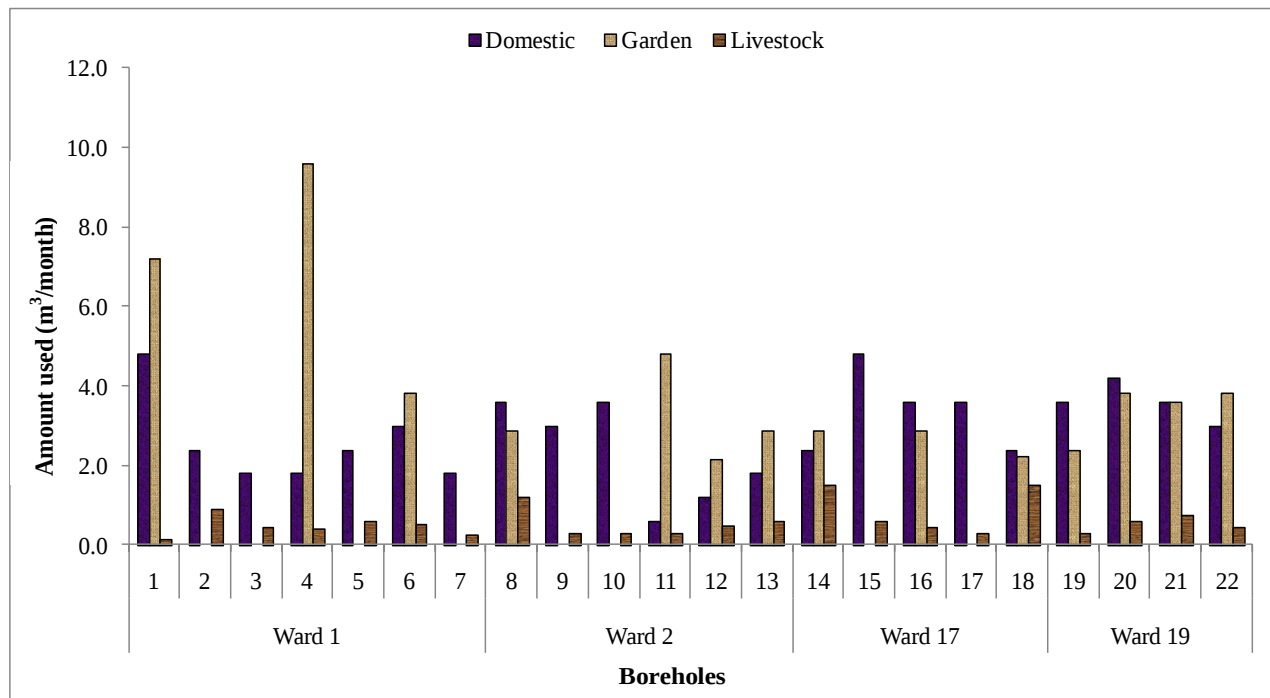


Figure 5.3: Multiple use of water from boreholes in the four studied wards

It was found that 36 % of the SWI were dysfunctional in Ward 1, 34 % in Ward 2, 39 % in Ward 17 and 54 % in Ward 19. An average amount of 6 m³/month was used from boreholes with 48 % used for domestic, 42 % for garden irrigation and 10 % for livestock watering. The quantities of water used per household per month ranged from 2.3 m³/month to 12.2 m³/month. The amount of water used per household was mostly influenced by the size of the vegetable garden irrigated. The communities were mainly using the gardens for subsistence, and in some cases for income Table 2 is showing the percentages of households that derive income from water use from boreholes for the four wards. Up to 90 % of the households amongst the four wards depend on agriculture for survival (irrigated and rainfed).

Table 5.3: Benefits derived from borehole water use

Benefits from water use	Ward 1	Ward 2	Ward 17	Ward 19
Subsistence	70 %	71 %	53 %	82 %
Subsistence and income	30 %	29 %	47 %	18 %

Though the percentages of dysfunctional SWI are 36% for Ward 1 in comparison with 39 % for Ward 19, it should be noted that area for Ward 19 greater than that of Ward 1 (479 km² for Ward 19 and 129 km² for Ward 1, and thus there are more points in Ward 1 (48) than in Ward 19 (39). Thus the water point density was also different for the two wards. The communities in Ward 17 and Ward 19 were mainly dependent on small dams (and shallow wells) for their multiple water needs. In Ward 1 and Ward 2, small dams are mainly used for irrigation and livestock watering. However, there were two SWI that were used mainly for communal irrigation in the two wards; those were Smart Windmill in Ward 1 and Mpasikwe Well in Ward 2 (see Box 1).

Box 1: The case of Mpasikwe Well in Ward 2

The Mpasikwe communal garden is a 0.42 ha plot shared by 30 Vusisizwe Village households for vegetable irrigation, each plot-holder having a plot of 140 m². The villagers are irrigating using water from Mpasikwe Well and they are paying for making use of rope pump to a private owner. The community make use of the rope pump and bucket to abstract water from the deep well. The well was previously fitted with an elephant pump which broke down some four years back according to the plot-holders. Due to the demand for water the community continued using the well without fixing the pump. The owner of the rope pump is charging USD 0.43 per potholder per irrigation session. On average the community irrigate four times a week which means that they pay USD7.00 per month for 'water'. Each plot holder has 6 beds from which an average of USD8.60 per month is made from selling the vegetables mainly to community members, and to a limited extent for selling at Mahole and Filabusi growth points. From the above figures, a profit of only USD 1.70 is made from this activity. The sales profit made per month cannot sustain the livelihoods of the plot-holders. As an example, a 10 kg bag of maize meal costs USD5.00 in Insiza District, which means by only depending on these activities, the villagers cannot afford it. Thus this just becomes a tough but non-productive activity.

Comparing this to the case of Smart Windmill in Ward 1 where the community is irrigating the same crop but not paying for 'water'; the community have nearly the same size of plots and they are making more or less the same profit from selling their crops, but at least they are able to improve their livelihoods since 80% of their savings are utilised for basic needs. The other 20% (USD0.70) goes towards monthly fees for maintenance of the windmill.

NOTE: the currency has been converted from ZAR which is used in Insiza District using 1USD:ZAR7.00

5.3.2 Multiple use from small dams

Dams are important SWI in the district mainly for storage of runoff water that can be used for irrigation of small irrigation schemes and household nutrition gardens, and also for livestock watering, amongst other uses. Four small dams were studied with respect to water use by Insiza District communities in the four wards. These dams were Zhulube Dam in Ward 1, Caterpillar Dam in Ward 2, Tombo Dam in Ward 17 and Village 4 Dam in Ward 19. Zhulube Dam and

Tombo Dam consisted of the canals used for irrigation of vegetables in the small communal irrigation schemes. Water used from the two dams was measured using V-notch weir for Zhulube Dam and Trapezoidal weir for Tombo Dam. Water for irrigation from the two dams was conveyed by gravity to the irrigation schemes. The estimated size of the irrigation schemes were 12 ha for Zhulube and 4 ha for Tombo, with 40 and 20 plot-holders respectively. The communities were using siphons to convey water from the canals to irrigate the field crops. The quantities of water abstracted from the dams were estimated by taking measurements of water from weirs and the results for calculations are shown in Appendix H. Figure 5.4 shows the amounts of water used from Zhulube and Tombo Dams.

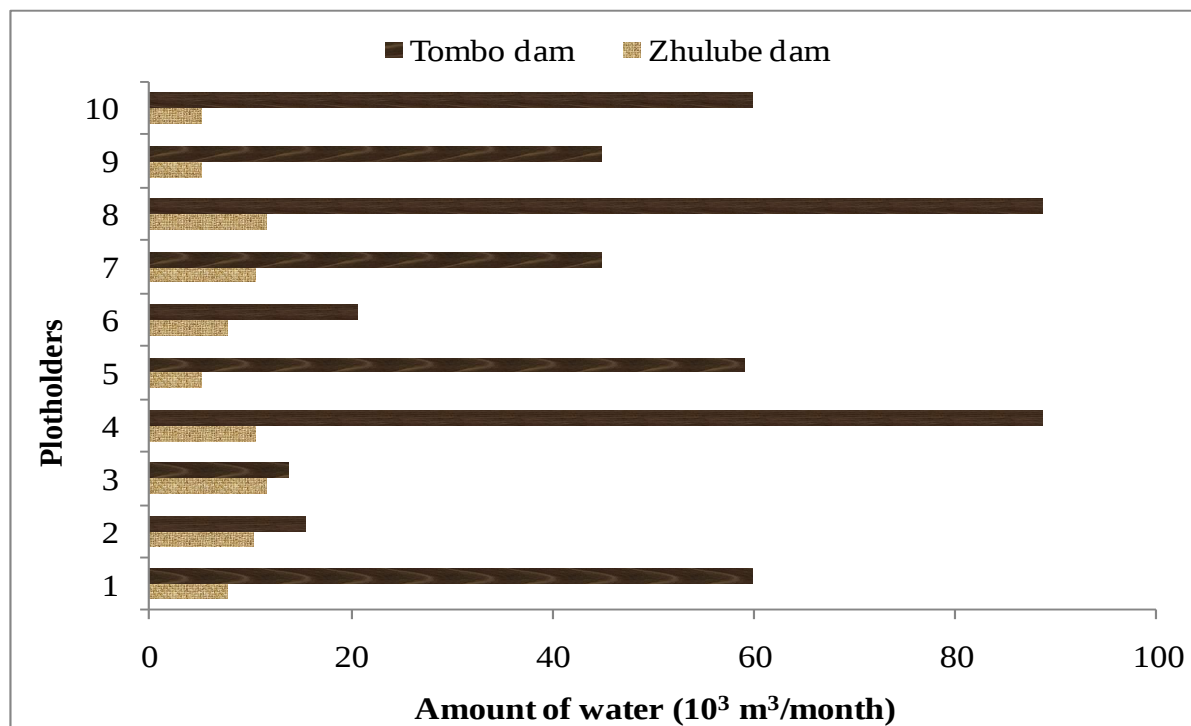


Figure 5.4: Multiple use of water from small dams

An estimated amount of 0.2 Mm³/ month was used from Tombo Dam and 2.5Mm³/month from Zhulube Dam. The differences in amount of water used from Zhulube and Tombo Dams may be due to the recent decision made by ZINWA to charge a levy of USD 18.00 per annum for water use, starting beginning of year 2011.

According to the key informants, the levy was based on the estimate by ZINWA that each plot-holder uses about 2.4 Mm³ of water per annum for water use for irrigation. In Tombo Dam the plot-holders were not being charged for water use and no indications of introducing the levies in the near future were given by key informants.

The other two dams, Caterpillar Dam and Village 4 Dam did not have any form of conveyance system. The communities were using buckets to fetch water for field crop irrigation. The area under irrigation for Caterpillar was approximately 0.4 ha and 0.6 ha for Village 4. The information obtained from the household surveys on amount of water used for irrigation per day suggested an estimated 416 m³/ month and 334 m³/month water use from Caterpillar and Village 4 Dams respectively. Figure 5.5 show the differences in amount of water used from Caterpillar and Village 4 Dams.

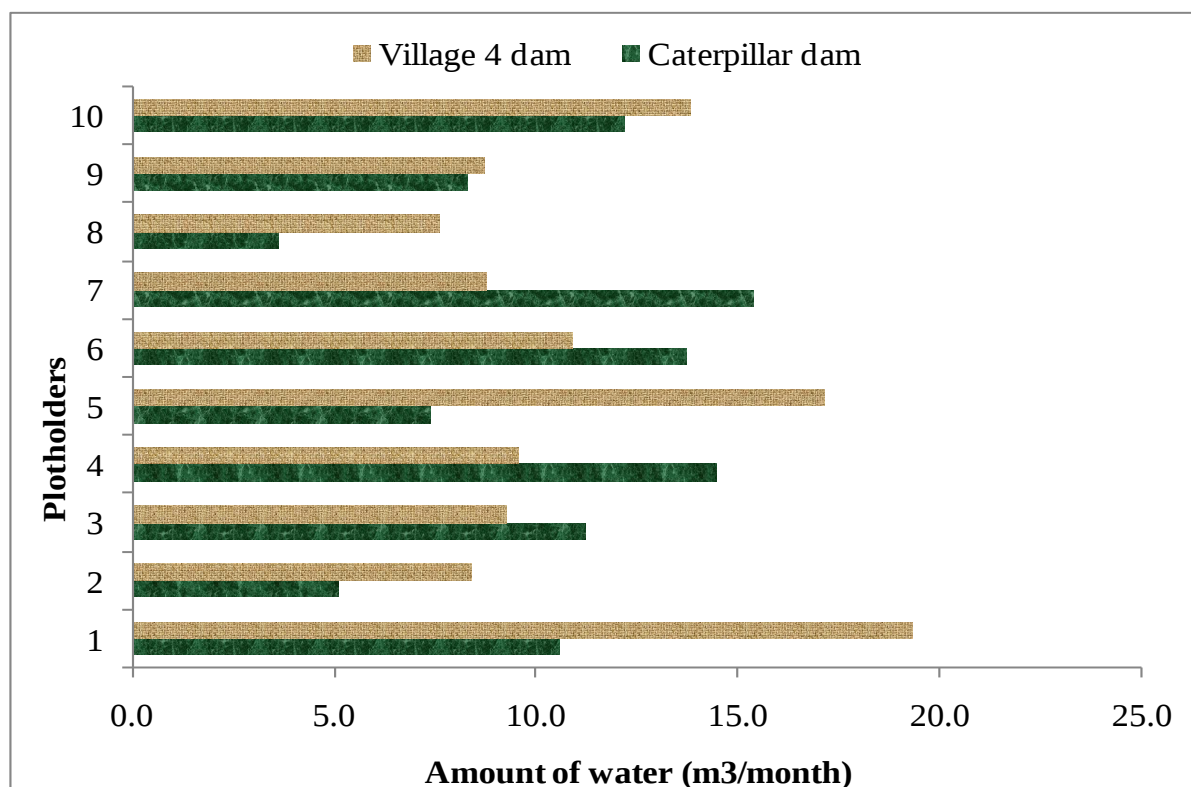


Figure 5.5: Multiple use of water from small dams

The differences in amounts of water used may be caused by availability of other dams in Village 4. The communities have options to use other sources for some of the uses. Ward 2 communities on the other hand mainly rely on Caterpillar for most uses other than domestic use. Detailed information on amounts of water use per household from Caterpillar Dam and Village 4 Dam is presented in Appendix F. Problems observed from the four studied dams include water seepage, canal breakage and water logging. According to Mamba *et al.* (2007) these problems are associated with poor maintenance. The condition of dams in Insiza North is worse with problems such as leaking spillways, water hyacinth, siltation and cracked or completely broken dam walls. The responses obtained from household and key informant interviews in Insiza North implied that the communities have never tried to fix their SWI especially dams, that were inherited from commercial farmers.

Findings from the other two wards of Insiza South (Ward 1 and Ward 2) differed from those of the southern part in terms of preferred SWI types and the extent of usage of SWI; hence the maintenance practices especially for small dams also differed. In Insiza South it was observed that those dams that were mainly used for irrigation and livestock watering, including Zhulube and Caterpillar Dams, the communities were trying their level best to maintain them. Thus the significance of SWI differs from one community to the other, depending major livelihood activities that the communities are engaged in.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The performance of SWI in Insiza District was generally poor. Availability of water in ranged from fair to good. Poor capacity of the SWI or inability to meet the water needs of the communities and poor condition contributed mostly to poor performance. The condition of SWI and continuity of water supply were also related to poor maintenance of SWI.

Factors affecting performance the most were found to be (i) lack of appropriate management structures and financial arrangements for maintenance of SWI; (ii) availability of other livelihood activities such as fields cultivation, which compels the communities to choose between such activities and maintenance of their SWI for water supply; and (iii) availability of alternative water sources which discourages communities maintain their SWI.

The benefits derived from use of SWI include subsistence and income for improved livelihoods. The benefits vary amongst the wards depending on the type and number of SWI available. The more the benefits derived from the SWI the more the communities were willing to make an effort towards maintenance of SWI thus ensuring SWI sustainability.

6.2 Recommendation

It is recommended that water availability for specific areas should be established before multiple use projects are implemented and appropriate technologies for multiple use systems should be installed in conformity with the needs of the communities. Thus necessary hydrogeological surveys should be conducted before implementing water supply projects for multiple use systems.

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8. APPENDICES

APPENDIX A: TYPES OF SWI USED IN INSIZA DISTRICT



(a) Nyelane Well in Ward 1 fitted with bush pump



(b) Mpasikwe Borehole in Ward 2 fitted with type C bush pump



(c) Smart Windmill in Ward 1



(d) Village 4 Dam in Ward 19



(e) Mpasikwe Well) in Ward 2 with windlass and bucket system



(f) Mpasikwe Garden in Ward 2, irrigated with water from Mpasikwe well



(g) Unprotected shallow well in Thuthuka Village, Ward 1



(h) Village 4 Dam in Ward 19

APPENDIX B: DETAILS FOR ASSESSED SWI

Ward	Village	SWI name	Type	Uses	Households	Depth (m)	GPS points	Elevation (m)	Seasonality	Remarks
1	Asibambaneni	Mahwaya	borehole	domestic, livestock, irrigation, panning	33	51	20°36'27.7"S, 29°13'43.5"E	1000	perennial	trough for livestock are cracked, fencing and apron are in good condition, water used two community gardens, the SWI is surrounded by heaps of sand for gold panning
1	Asibambaneni	Maduna	borehole	domestic, livestock, irrigation	27	48	20°36'07.9"S, 29°13'06.6"E	1002	perennial	troughs for livestock and laundry are cracked, the wooden block is loose, SWI is well fenced
1	Mpumelelo	Madebe I	borehole	domestic, livestock, irrigation,	26	51	20°36'53.7"S, 29°14'03.1"E	995	perennial	troughs and aproan are in good condition, surrounded by heaps of sand for gold panning
1	Mpumelelo	Nyelane	well	domestic, livestock, irrigation	42	20	20°36'35.4"S, 29°14'12.9"E	1012	perennial	well fenced, troughs and apron in good condition
1	Mpumelelo	Soul	borehole	domestic, livestock, irrigation, panning	22	42	20°36'21.4"S, 29°13'25.9"E	990	perennial	well fenced, troughs and apron in good condition
1	Mpumelelo	Zhulube dam	dam	domestic, livestock, irrigation, panning	40	-	20°37'26.2"S, 29°14'04.2"E	992	perennial	0.8Mm ³ dam, dam wall is cracked and leaking, weeds are blocking the pipeline
1	Thandanani	Smart	windmill	domestic, livestock, irrigation	27	60	20°36'37.9"S, 29°13'27.1"E	996	perennial	the SWI is regularly maintained , the rods are old, water used for community vegetable garden irrigation
1	Thandanani	Mkandla	borehole	domestic, livestock, irrigation	63	42	20°39'26.4", 29°16'58.50"E	1058	seasonal	livestock and laundry troughs are cracked, fencing new
1	Thuthuka	Zigamba I	borehole	domestic, livestock, irrigation, panning	35	48	20°36'37.3"S, 29°12'11.8"E	968	perennial	well fenced, good headworks , homesteads gardens irrigation
1	Thuthuka	Zigamba III	borehole	panning	35	36	20°37'36.4"S, 29°12'47.9"E	961	perennial	good headworks, community garden irrigation
2	Dingumuzi	Filabusi B. sch	borehole	domestic, livestock, irrigation	35	36	20°38'21.1"S, 29°19'40.4"E	1031	perennial	school garden irrigation, no trough for laundry
2	Dingumuzi	Philemon Ncube	borehole	domestic, livestock, irrigation	20	48	20°39'20.1"S, 29°18'41.9"E	1026	perennial	one vegetable garden, trough for washing broken, trough for livestock buried
2	Phikelela	Misiwe	borehole	domestic, livestock, irrigation	36	54	20°35'24.3"S, 29°18'42.0"E	1045	perennial	well fenced, trough for livestock cracked
2	Phikelela	Dube	borehole	domestic, livestock, irrigation	25	39	20°34'20.3"S, 29°17'58.7"E	1059	perennial	relatively hard to operate, good headwork, well fenced, apron and troughs in good condition

Assessment of performance of Small-scale Water Infrastructure in Insiza District, Zimbabwe

Ward	Village	SWI name	Type	Uses	Households	Depth (m)	GPS points	Elevation (m)	Seasonality	Remarks
2	Ukuzwisisa	Mtswirini	borehole	domestic, livestock, irrigation	22	42	20°35'56.6"S, 29°17'54.0"E	1062	perennial	fully functional, good headworks, stays locked
2	Ukuzwisisa	Caterpillar	dam	domestic, livestock, irrigation, panning	38	-	20°36'17.0"S, 29°18'37.3"E	1047	perennial	upstream of Marubamba dam (approximately 200 m), dam wall in good condition
2	Vusisizwe	Mpasikwe	well	domestic, livestock, irrigation, dipping	23	10	20°36'23.0"S, 29°17'42.2"E	1040	perennial	deep well, mainly used for communal irrigation garden rope and washer pump used
2	Vusisizwe	Maphosa	borehole	domestic, livestock, irrigation	35	45	20°39'20.2"S, 29°17'42.1"E	1031	perennial	good condition, easy to operate, three vegetable gardens, hard water
17	Angle C A 1	Mashologwane	borehole	domestic, livestock, irrigation	55	45	20°26'20.4"S, 29°18'47.9"E	1204	perennial	good headworks, recently rehabilitated
17	Sukasihambe	Sukasihambe	borehole	domestic, livestock, irrigation	28	42	20°27'51.2"S, 29°20'44.2"E	1170	perennial	fully functional, recently rehabilitated, no troughs
17	Tombo	Tombo	dam	domestic, livestock, irrigation, fishing	40	-	20°35'24.0"S, 29°19'39.4"E	1052	perennial	relatively good condition, water used for vegetable irrigation
17	Tombo B	Singeni	borehole	domestic, livestock, irrigation	35	45	20°35'29.8"S, 29°21'29.9"E	1070	perennial	no fence, apron ok, trough for livestock cracked
17	Tombo D	Enjinini II	borehole	domestic, livestock, irrigation	28	51	20°37'46.4"S, 29°20'54.4"E	1039	perennial	used to be operated by engine, fully functional
17	Tombo D	Tombo Garden	borehole	domestic, livestock, irrigation	33	45	20°37'22.5"S, 29°20'39.4"E	1046	perennial	relatively hard to operate, well fenced, community garden irrigation
17	Village 18A	Village 18A	windmill	domestic, livestock, irrigation	45	45	20°27'49.0"S, 29°25'00.0"E	1142	perennial	fully functional, closed tank leaking (2 tanks)
19	Village 3	Dzenya	borehole	domestic, livestock, irrigation,	29	48	20°21'45.3"S, 29°34'14.2"E	1176	perennial	fully functional, good headworks, no livestock nor laundry
19	Village 4	Village 4	dam	domestic, livestock, irrigation, fishing, brickmaking	35	-	20°18'56.4"S, 29°35'52.7"E	1139	perennial	community garden, dam wall in good condition, signs of good maintenance
19	Village 9A	Village 9A	borehole	domestic, livestock, irrigation	26	39	20°28'58.1"S, 29°28'32.2"E	1122	perennial	perennial, hard to operate (need more than one person to operate), 80 strokes, no troughs
19	Village 14	Village 14	borehole	domestic, livestock, irrigation	58	51	20°25'34.7"S, 29°34'25.7"E	1143	perennial	regularly maintained, 10 pipes out of 12 are used; the pipes removed were leaking, water used for home gardens irrigation
19	Village 17	Village 17	borehole	domestic, livestock, irrigation	48	39	20°23'36.3"S, 29°27'26.0"E	1211	perennial	fully functional, perennial, type A pump

APPENDIX C: WATER QUALITY PARAMETERS FOR ASSESSED SWI

Ward	SWI type	SWI name	pH	EC (μ S/cm)	Turbidity (NTU)	Total Coliforms (cfu /100 ml)	Faecal Coliforms (cfu /100 ml)	Colour (Hazen)
1	borehole	Maduna	6.8	720	3.3	0	0	5
1	borehole	Mahwaya	6.9	1, 250	4.8	0	0	5
1	borehole	Madebe	6.8	710	4.9	0	0	5
1	borehole	Soul	6.9	780	9.1	29	6	5
1	borehole	Mkandla	6.7	1, 370	4.2	13	9	5
1	borehole	ZigambaI	6.7	1, 160	4.8	0	0	10
1	borehole	Zigamba III	6.9	1, 210	4.8	0	0	5
1	well	Nyelane	6.8	720	3.6	0	0	5
1	windmill	Smart	6.8	720	3.6	0	0	5
1	dam	Zhulube	7.6	790	380.5	11	8	60
2	borehole	Filabusi	7.1	860	3.6	0	0	5
2	borehole	Philemon	7.7	860	3.2	12	1	5
2	borehole	Misiwe	7.4	850	4.1	0	0	5
2	borehole	Dube	7.7	840	4.1	0	0	5
2	borehole	Mtswirini	7.0	720	5	3	2	5
2	borehole	Maphosa	7.1	1, 270	3.2	2	0	5
2	well	Mpasikwe	7.6	840	4.2	0	0	5
2	dam	Caterpillar	7.0	750	366.2	20	11	70
17	borehole	Masholongwane	7.1	810	21.4	0	0	10
17	borehole	Sukasihambe	7.1	1, 620	3.8	0	0	5
17	borehole	Singeni	7.1	790	3.5	0	0	5
17	borehole	NjininiII	7.0	720	3.9	1	1	5
17	borehole	Tombo garden	7.0	1, 700	4.9	0	0	5
17	windmill	Village18A	6.9	730	3.1	0	0	5
17	dam	Tombo	7.3	800	423.4	12	11	60
19	borehole	Village17	6.8	720	4.6	0	0	5
19	borehole	Village14	6.9	730	29.3	0	0	5
19	borehole	Dzenya	6.8	820	3.2	0	0	5
19	borehole	Village9A	7.2	790	27.9	0	0	5
19	dam	Village4	7.1	870	321.2	8	8	60

APPENDIX D: PERFORMANCE INDICES RESULTS

SWI TYPE AND WARD	WARD 1									WARD 19			
	B1,1	B2,1	B3,1	B4,1	B5,1	B6,1	B7,1	W1,1	WM1,1	B19,19	B20,19	B21,19	B22,19
SWI NAME	Maduna	Mahwaya	Madebe	Soul	Mkandla	Zigamba	Zigamba	Nyelane	Smart	Village17	Village14	Dzenya	Village9A
Number of households using SWI	27	33	26	22	63	35	35	42	27	48	58	29	26
Amount of water used per household (m³/month)	3.2	2.7	2.6	3.2	2.7	3.0	3.3	2.8	3.1	3.5	3.0	3.2	3.2
Number of people per household	6	6	6	8	6	7	8	6	8	7	7	6	6
Amount of water used used by livestock (m³/month)	0.63	0.43	0.41	0.74	0.57	0.61	0.58	0.71	0.67	0.38	0.24	0.29	0.13
Livestock water requirements (l/d)	30.3	24.4	26.5	38.0	27.7	29.4	28.8	31.5	28.9	20.3	12.8	17.0	7.0
Amount of water used per capita per day (lpcd)	16.6	14.3	14.7	13.6	14.1	14.3	13.8	14.9	13.6	16.7	15.1	16.7	17.8
Monthly water use from SWI (m³/month)	86	88	68	70	172	106	117	119	83	166	176	92	83
Human minimum water requirement (l.c.d)	2592.0	3069.0	2301.0	2541.0	6048.0	3675.0	4200.0	3969.0	3037.5	4968.0	5829.0	2740.5	2340.0
QUANTITY INDEX: $I_{av, quant}$	1.00	0.95	0.98	0.91	0.94	0.95	0.92	0.99	0.91	1.00	1.00	1.00	1.00
IpH	0.81	0.89	0.84	0.94	0.74	0.79	0.94	0.92	0.83	0.84	0.94	0.84	1.00
IEC	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
INTU	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.03	0.01	0.01	0.04	0.01
ITC	1.00	0.37	0.37	0.00	0.01	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
QUALITY INDEX: $I_{av, qual}$	0.83	0.40	0.39	0.15	0.13	0.39	0.40	0.40	0.39	0.39	0.40	0.40	0.41
AVAILABILITY INDEX: I_{av}	0.99	0.73	0.74	0.60	0.62	0.72	0.71	0.76	0.70	0.82	0.76	0.82	0.87
Flowrate from SWI (m³/h)	0.571	0.545	0.381	0.493	0.385	0.419	0.477	0.600	0.375	0.550	0.462	0.558	0.450
Required water flow (m³/h)	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996
FLOW (CAPACITY) INDEX: I_{flow}	0.57	0.55	0.38	0.50	0.39	0.42	0.48	0.60	0.38	0.55	0.46	0.56	0.45
Potential storage capacity (m³)	2.4	3	2.4	2.88	2.4	3.6	3.84	4.2	3.84	4.92	4.68	5.04	4.2
Required storage capacity	62.9	74.2	55.9	61.9	145.8	88.9	101.5	96.0	73.6	119.7	140.2	66.2	56.3
POTENTIAL STORAGE INDEX: $I_{pot, stor}$	0.038	0.041	0.043	0.047	0.017	0.041	0.038	0.044	0.052	0.041	0.034	0.076	0.075
Area per ward (km²)	129	129	129	129	129	129	129	129	129	497	497	497	497
Total number of water points (wp) in ward	47	47	47	47	47	47	47	47	47	39	39	39	39
Actual water point density (wp/km²)	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.078	0.078	0.078	0.078
Required water point density (wp/km²)	2	2	2	2	2	2	2	2	2	2	2	2	2
WATERPOINT DESITY INDEX: $I_{wp, dens}$	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.04	0.04	0.04	0.04

SWI TYPE AND WARD	B1,1	B2,1	B3,1	B4,1	B5,1	B6,1	B7,1	W1,1	WM1,1	B19,19	B20,19	B21,19	B22,19
No. of water points that are with sufficient flowrate	28	28	28	28	28	28	28	28	28	10	10	10	10
FUNCTIONAL WATERPOINT INDEX: $I_{wp, funct}$	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.26	0.26	0.26	0.26
CAPACITY INDEX: I_{cap}	0.34	0.34	0.30	0.33	0.30	0.31	0.32	0.35	0.31	0.21	0.19	0.22	0.20
Supply time per day (h)	8	8	8	8	8	8	8	8	8	4	8	8	8
Minimum, predetermined supply time per day (h)	8	8	8	8	8	8	8	8	8	8	8	8	8
DAILY CONTINUITY INDEX: $I_{hours, day}$	1	1	1	1	1	1	1	1	1	0.5	1	1	1
Number of days per month without water	7	7	7	3	14	7	3	3	3	30	21	14	30
Allowable number of days per month without water	1	1	1	1	1	1	1	1	1	1	1	1	1
MONTHLY CONTINUITY INDEX: $I_{day, month}$	0.30	0.30	0.30	0.67	0.07	0.30	0.67	0.67	0.67	0.003	0.02	0.07	0.003
CONTINUITY INDEX: I_{cont}	0.65	0.65	0.65	0.84	0.41	0.65	0.84	0.84	0.84	0.25	0.51	0.54	0.50
components in good state	7	7	10	10	4	4	4	10	9	0	0	1	1
ABOVE-GROUND COMPONENTS INDEX: $I_{abovegr}$	0.88	1	1	0.83	1	0.80	0.80	0.83	1	0.50	0.33	-	-
in good state	6	6	10	10	3	3	3	10	6	0	0	0	0
DOWNHOLE COMPONENTS INDEX: $I_{downhole}$	0.75	0.75	0.83	0.83	0.67	0.60	0.60	0.83	0.67	-	-	-	-
No. of water points in village in good functional state	7	7	10	10	7	4	4	10	8	1	1	1	1
FUNCTIONAL STATE INDEX: I_{funct}	0.88	0.88	0.83	0.83	0.89	0.80	0.80	1	0.89	0.50	-	1	1
No. of water points in village with headwork in good state	5	5	6	6	9	4	4	6	8	0	1	0	0
HEADWORK CONDITION INDEX: I_{headw}	0.63	0.63	0.50	0.50	0.89	0.80	0.80	0.50	0.89	-	-	1	-
CONDITION INDEX: I_{cond}	0.80	0.80	0.77	0.77	0.67	0.76	0.76	0.77	0.87	0.30	0.20	0.20	0.40
OVERALL PERFORMANCE INDEX: I	0.70	0.63	0.62	0.63	0.50	0.61	0.66	0.68	0.68	0.40	0.42	0.44	0.49
INTERPRETATION	Fair	Fair	Fair	Fair	Bad	Fair	Fair	Fair	Fair	Bad	Bad	Bad	Bad

SWI TYPE AND WARD	WARD 2							WARD 17					
	B8,2	B9,2	B10,2	B11,2	B12,2	B13,2	W2,2	B14,17	B15,17	B16,17	B17,17	B18,17	WM2,17
SWI NAME	Filabusi	Philemon	Misiwe	Dube	Mtswirini	Maphosa	Mpasikwa	Masholoni	Sukasihwa	Singeni	NjininiII	Tombo ga	Village18A
Number of households using SWI	35	20	36	25	22	35	23	55	28	35	28	33	45
Amount of water used per household (m ³ /month)	3.1	3.2	3.6	3.0	3.2	3.3	3.8	3.3	3.4	3.5	3.6	4.0	3.8
Number of people per household	6	7	7	6	7	6	8	7	8	8	7	9	9
Amount of water used by livestock (m ³ /month)	0.78	0.54	0.68	0.46	0.38	0.58	0.47	0.35	0.29	0.63	0.27	0.38	0.32
Livestock water requirements (l/d)	34.8	23.6	31.4	20.7	20.6	27.6	21.6	16.0	15.6	31.6	16.6	17.9	17.2
Amount of water used per capita per day (lpcd)	17.0	15.4	17.3	16.0	15.0	18.0	15.7	16.5	15.1	14.4	16.7	15.3	13.8
Monthly water use from SWI (m ³ /month)	110	64	131	76	70	116	88	183	95	123	101	132	171
Human minimum water requirement (l/d)	3202.5	2070.0	3780.0	2362.5	2310.0	3202.5	2794.5	5527.5	3150.0	4252.5	3024.0	4306.5	6210.0
QUANTITY INDEX: $I_{av, quant}$	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	0.92
IpH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.96	0.92
IEC	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
INTU	0.03	0.04	0.02	0.02	0.01	0.04	0.01	0.01	0.02	0.03	0.02	0.01	0.04
ITC	0.37	0.01	0.37	0.37	0.06	0.10	0.37	0.37	0.37	0.37	0.14	0.37	0.37
QUALITY INDEX: $I_{av, qual}$	0.41	0.16	0.41	0.41	0.19	0.22	0.41	0.41	0.41	0.41	0.24	0.40	0.40
AVAILABILITY INDEX: I_{av}	0.84	0.68	0.85	0.80	0.67	0.81	0.79	0.82	0.77	0.74	0.76	0.77	0.71
Flowrate from SWI (m ³ /h)	0.431	0.400	0.507	0.550	0.558	0.533	0.522	0.595	0.497	0.522	0.431	0.507	0.511
Required water flow (m3/h)	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996
FLOW (CAPACITY) INDEX: I_{flow}	0.43	0.40	0.51	0.55	0.56	0.54	0.52	0.60	0.50	0.52	0.43	0.51	0.51
Potential storage capacity (m3)	2.88	3.72	3.12	2.28	2.16	2.64	3.72	3.48	2.16	3.48	2.64	3.12	4.32
Required storage capacity	77.7	50.2	91.5	57.2	55.9	77.5	67.6	133.0	76.0	102.8	73.0	103.8	149.5
POTENTIAL STORAGE INDEX: $I_{pot, stor}$	0.037	0.074	0.034	0.040	0.039	0.034	0.055	0.026	0.029	0.034	0.036	0.030	0.029
Area per ward (km ²)	58	58	58	58	58	58	58	493	493	493	493	493	493
Total number of water points (wp) in ward	43	43	43	43	43	43	43	31	31	31	31	31	31
Actual water point density (wp/km ²)	0.7414	0.7414	0.7414	0.7414	0.7414	0.7414	0.7414	0.0629	0.0629	0.0629	0.0629	0.0629	0.0629
Required water point density (wp/km²)	2	2	2	2	2	2	2	2	2	2	2	2	2
WATERPOINT DENSITY INDEX: $I_{wp, dens}$	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.03	0.03	0.03	0.03	0.03	0.03

SWI TYPE AND WARD	B8,2	B9,2	B10,2	B11,2	B12,2	B13,2	W2,2	B14,17	B15,17	B16,17	B17,17	B18,17	WM2,17
No. of water points that are with sufficient flowrate	27	27	27	27	27	27	27	14	14	14	14	14	14
FUNCTIONAL WATERPOINT INDEX: $I_{wp, func}$	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.45	0.45	0.45	0.45	0.45	0.45
CAPACITY INDEX: I_{cap}	0.36	0.37	0.37	0.38	0.39	0.38	0.38	0.27	0.25	0.26	0.24	0.25	0.25
Supply time per day (h)	8	8	6	6	6	8	6	8	8	8	8	6	8
Minimum, predetermined supply time per day (h)	8	8	8	8	8	8	8	8	8	8	8	8	8
DAILY CONTINUITY INDEX: $I_{hours, day}$	1	1	0.75	0.75	0.75	1	0.75	1	1	1	1	0.75	1
No. of days per month without water	3	14	7	60	7	3	1	14	7	30	3	7	30
Allowable number of days per month without water	1	1	1	1	1	1	1	1	1	1	1	1	1
MONTHLY CONTINUITY INDEX: $I_{day, month}$	0.67	0.07	0.30	0.00001	0.30	0.67	1.00	0.07	0.30	0.003	0.67	0.30	0.003
CONTINUITY INDEX: I_{cont}	0.84	0.54	0.53	0.38	0.53	0.84	0.88	0.54	0.65	0.50	0.84	0.53	0.50
components in good state	11	11	6	6	1	13	13	1	1	1	1	2	0
$I_{abovegr}$	0.92	0.92	0.75	0.75	0.5	0.81	0.81	0.5	1	0.5	1	1	-
in good state	8	8	5	5	1	9	9	0	0	0	0	0	1
DOWNHOLE COMPONENTS INDEX: $I_{downhole}$	0.67	0.67	0.63	0.63	0.50	0.56	0.56	-	1	0.5	-	-	0.5
No. of water points in village in good functional state	9	9	6	6	1	13	13	1	1	1	2	2	1
FUNCTIONAL STATE INDEX: I_{func}	0.75	0.75	0.75	0.75	0.5	0.8125	0.8125	1	1	0.5	1	1	0.5
No. of water points in village with headwork in good state	9	9	6	6	1	14	14	0	0	0	0	0	0
HEADWORK CONDITION INDEX: I_{headw}	0.75	0.75	0.75	0.75	1	0.875	0.875	0.5	1	-	-	-	-
CONDITION INDEX: I_{cond}	0.77	0.77	0.73	0.73	0.25	0.78	0.78	0.30	0.60	0.40	0.30	0.50	0.30
OVERALL PERFORMANCE INDEX: I	0.70	0.59	0.62	0.57	0.46	0.70	0.71	0.48	0.57	0.47	0.53	0.51	0.44
INTERPRETATION	Fair	Fair	Fair	Fair	Bad	Fair	Fair	Bad	Fair	Bad	Fair	Fair	Bad

APPENDIX E: PROCEDURE FOR CALCULATION OF WATER QUALITY SUB-INDICES

Calculation for water quality sub-indices μ_i (Cisneros, 1996)			
Parameter	Human consumption	Crop irrigation	Livestock watering
pH	5 - 9	NC*	-
Turbidity (NTU)	1 - 5	-	-
EC (microsiemens/cm)	700 - 3000	1.0	-
TC (CFU/100ml)	0	0	0

*NC = natural conditions

If measured value (MV) = country standard value (CS) and the CS is the required MAXIMUM value; $\mu_i = 1$

If measured value (MV) > country standard value (CS) and the CS is the required MAXIMUM value; $\mu_i = MV/CS$

If measured value (MV) = country standard value (CS) and the CS is the required MINIMUM value; $\mu_i = CS/MV$

If measured value (MV) > country standard value (CS) and the CS is the required MINIMUM value; $\mu_i = 1$

If $MV > 0$ AND $CS = 0$; $\mu_i = 1 + (MV)^{0.5}$

APPENDIX F: HOUSEHOLD QUESTIONNAIRE

Ward:.....Village.....Date:.....Questionnaire no.:.....

Section A: Personal details									
Respondent's sex (✓)	Male		Female						
Marital status	Single		Married		Divorced		Widowed		
Age of respondent									
Position (✓)	Village head		Councilor		Committee chair				
	Other (specify)								
Number of people in the household									
Main source of income									
Section B: SWI and water use data									
Type of SWI used									
Name of SWI									
What is the current status of the SWI?			Badly damaged		Working moderately		Regularly maintained		Fully functional
When was the SWI constructed?									
Who constructed the SWI? (✓). Specify.			Government						
			Village head						
			Water point committee						
			Community						
			NGO						
			Private						
			Other						
What was the intended purpose of construction? (✓). Specify.			Domestic						
			Irrigation						
			Livestock watering						
			Other (specify)						
What are the actual water uses? (✓). Specify.			Domestic						
			Irrigation						
			Livestock watering						
			Other (specify)						
What are the measures taken by community to ensure water quality?									

Who is mainly responsible for fetching water?			Time taken to fetch water	
What time of the day do you normally fetch water?				
Does the SWI dry out?	Y	N	When does it dry out?	
Domestic water use data				
How much water is used for domestic purposes per day?				
What are the specific domestic water uses from the SWI?				
When there's water shortage, what are the prioritized uses?				
What are the problems in terms of water access and use for domestic?.....				
Productive water uses data				
Brick making				
How many bricks are made per day / month?				
How much water is used per oven?				
How many bricks in one oven?				
For how much is a brick sold?				
Which months are bricks made				
What are the problems encountered regarding access and use of water for brick making?.....				
Beer making				
How much water is used for beer making (per day/week/month)?				
How often is the beer made				
For how much is beer sold?				
What is the money used for?				
Problems encountered regarding access and use of water for beer making.....				

Irrigation (garden/small-scale)		
Types of crops irrigated and size for each	Type	Size
	Maize	
	Vegetables	
	Sugar cane	
	Fruit trees	
	Other:	
Income derived from the crop(s) per month	Type	Amount
	Maize	
	Vegetables	
	Sugar cane	
	Fruit trees	
	Others:	
How many times do you irrigate per week		
Total amount of water used for crop(s) irrigation		
Irrigation method(s) used for watering the crops		
What are the problems faced concerning irrigation water from the SWI?		
.....		
.....		
Livestock watering		
What are the types and number of livestock kept in homestead?	Type	Number
	Goats	
	Cattle	
	Sheep	
	Donkeys	
	Pigs	
	Chickens	
	Other:	
Amount of water used by livestock per day		
What is the distance from homestead to the water source?		
How is the livestock watered: direct/indirect from source? (specify if indirect)	Direct	Indirect
	Goats	
	Cattle	
	Sheep	
	Donkeys	
	Pigs	
	Chickens	

Other:			
Type of services derived from livestock and the amount of money they are rendered for	Livestock	Service	Amount
	Goats		
	Cattle		
	Sheep		
	Donkeys		
	Pigs		
	Chickens		
	Other:		
Problems encountered regarding access and use of water for livestock			
.....			
.....			
.....			
Other uses/benefits			
Gold panning:			
How many times a week is gold panning done?.....			
How many grams are obtained per week?.....			
How much water is used for gold panning?.....			
What are the sources of water for gold panning?.....			
How much money do you get from gold panning?.....			
What is the money used for?.....			
Any other water uses?			
.....			
.....			
Section C: Governance			
Who owns the SWI? (✓). Specify.	Government		
	Village head		
	Community		
	NGO		
	Private		
	Other		

Who is responsible for maintenance (✓)	Government		
	Village head		
	Water point committee		
	Community		
	NGO		
	Private		
	Other		
Water point committee members	Females		Males
Who is responsible for setting the rules for water use (✓)	Government		
	Village head		
	Water point committee		
	NGO		
	Private		
	Other		
Who is responsible for enforcing the rules for water use? (✓)	Government		
	Village head		
	Water point committee		
	NGO		
	Private		
	Other		
How much are you paying for water?			
What are the basic rules (in terms of allowed water uses)?.....			
Do the users comply with the rules? Explain.....			
How are the rules enforced?.....			

What problems are faced in terms of water access and use from the SWI?			
Section E: Alternative source(s) of water			
Is there an alternative water source (s)? (✓)		Yes	No
Type(s) of alternative water source(s)			
What is the distance to the alternative water source(s)?			
What are the specific water uses from the alternative source(s)?	Domestic		
	Irrigation		
	Livestock watering		
	Other		
What are the problems associated with water use from the alternative source(s)?	<i>Source</i>	<i>Problem</i>	
<i>Domestic</i>			
<i>Livestock watering</i>			
<i>Irrigation</i>			
<i>Other uses</i>			
<i>Other problems</i>			
ANY SUGGESTIONS ON REQUIREMENTS/MEASURES TO IMPROVE WATER SUPPLY IN YOUR COMMUNITY?			

APPENDIX G: OUTPUTS FOR HOUSEHOLD SURVEYS

Statistical analysis for ward 1 SWI: boreholes, well and windmill

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18	1	1.1	1.1	1.1
	19	1	1.1	1.1	2.2
	21	1	1.1	1.1	3.3
	22	1	1.1	1.1	4.4
	25	2	2.2	2.2	6.7
	26	2	2.2	2.2	8.9
	27	3	3.3	3.3	12.2
	28	4	4.4	4.4	16.7
	29	3	3.3	3.3	20.0
	30	1	1.1	1.1	21.1
	31	1	1.1	1.1	22.2
	32	5	5.6	5.6	27.8
	33	2	2.2	2.2	30.0
	35	3	3.3	3.3	33.3
	36	1	1.1	1.1	34.4
	37	3	3.3	3.3	37.8
	38	2	2.2	2.2	40.0
	39	1	1.1	1.1	41.1
	40	3	3.3	3.3	44.4
	41	1	1.1	1.1	45.6
	42	3	3.3	3.3	48.9
	43	1	1.1	1.1	50.0
	45	1	1.1	1.1	51.1
	47	2	2.2	2.2	53.3
	48	2	2.2	2.2	55.6
	49	3	3.3	3.3	58.9
	50	1	1.1	1.1	60.0
	51	3	3.3	3.3	63.3
	52	5	5.6	5.6	68.9
	55	2	2.2	2.2	71.1
	56	3	3.3	3.3	74.4
	57	1	1.1	1.1	75.6
	58	3	3.3	3.3	78.9
	59	1	1.1	1.1	80.0
	60	2	2.2	2.2	82.2
	62	2	2.2	2.2	84.4
	64	1	1.1	1.1	85.6
	65	4	4.4	4.4	90.0
	66	3	3.3	3.3	93.3
	70	4	4.4	4.4	97.8
	71	1	1.1	1.1	98.9
	72	1	1.1	1.1	100.0
Total		90	100.0	100.0	

Respondent's sex		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	27	30.0	30.0	30.0
	Female	63	70.0	70.0	100.0
	Total	90	100.0	100.0	

Position of respondent in the village		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	64	71.1	71.1	71.1
	WPC member	19	21.1	21.1	92.2
	Kraal head	3	3.3	3.3	95.6
	Pump minder	3	3.3	3.3	98.9
	Village head	1	1.1	1.1	100.0
	Total	90	100.0	100.0	

Number of people per household		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	1.1	1.1	1.1
	4	6	6.7	6.7	7.8
	5	17	18.9	18.9	26.7
	6	15	16.7	16.7	43.3
	7	19	21.1	21.1	64.4
	8	14	15.6	15.6	80.0
	9	12	13.3	13.3	93.3
	10	6	6.7	6.7	100.0
	Total	90	100.0	100.0	

Source of income		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agriculture	64	71.1	71.1	71.1
	formal employment	8	8.9	8.9	80.0
	informal employment	11	12.2	12.2	92.2
	gold panning	3	3.3	3.3	95.6
	agriculture+gold panning	4	4.4	4.4	100.0
	Total	90	100.0	100.0	

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.4	2	2.2	2.2	2.2
	2.7	1	1.1	1.1	3.3
	3.0	4	4.4	4.4	7.8
	3.6	3	3.3	3.3	11.1
	3.9	1	1.1	1.1	12.2
	4.2	1	1.1	1.1	13.3
	4.5	1	1.1	1.1	14.4
	4.8	4	4.4	4.4	18.9
	5.4	9	10.0	10.0	28.9
	6.0	9	10.0	10.0	38.9
	6.6	6	6.7	6.7	45.6
	7.2	8	8.9	8.9	54.4
	7.4	1	1.1	1.1	55.6
	7.8	6	6.7	6.7	62.2
	8.1	1	1.1	1.1	63.3
	8.4	5	5.6	5.6	68.9
	9.0	10	11.1	11.1	80.0
	9.6	4	4.4	4.4	84.4
	9.9	1	1.1	1.1	85.6
	10.2	1	1.1	1.1	86.7
	10.8	6	6.7	6.7	93.3
	11.4	1	1.1	1.1	94.4
	12.6	2	2.2	2.2	96.7
	13.8	1	1.1	1.1	97.8
	14.4	2	2.2	2.2	100.0
	Total	90	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	48	53.3	53.3	53.3
	girls	27	30.0	30.0	83.3
	boys	5	5.6	5.6	88.9
	wife+girls	3	3.3	3.3	92.2
	wife+boys	6	6.7	6.7	98.9
	wife+husband	1	1.1	1.1	100.0
	Total	90	100.0	100.0	

Distance to waterpoint (m)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	150	2	2.2	2.2	2.2
	200	14	15.6	15.6	17.8
	300	12	13.3	13.3	31.1
	400	9	10.0	10.0	41.1
	500	24	26.7	26.7	67.8
	600	3	3.3	3.3	71.1
	800	7	7.8	7.8	78.9
	1,000	15	16.7	16.7	95.6
	1,500	4	4.4	4.4	100.0
	Total	90	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic+livestock	32	35.6	35.6	35.6
	domestic+irrigation	17	18.9	18.9	54.4
	domestic+livestock +irrigation	41	45.6	45.6	100.0
	Total	90	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence	63	70.0	70.0	70.0
	subsistence+income	27	30.0	30.0	100.0
	Total	90	100.0	100.0	

Alternative source of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	borehole	66	73.3	73.3	73.3
	unprotected well	8	8.9	8.9	82.2
	dam/river	16	17.8	17.8	100.0
	Total	90	100.0	100.0	

Respondent's view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	8	8.9	8.9	8.9
	additional waterpoint	50	55.6	55.6	64.4
	spares availability	25	27.8	27.8	92.2
	mechanized system	7	7.8	7.8	100.0
	Total	90	100.0	100.0	

Statistical analysis for ward 2 SWI: boreholes and well

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18	1	1.4	1.4	1.4
	20	1	1.4	1.4	2.9
	21	1	1.4	1.4	4.3
	22	1	1.4	1.4	5.7
	24	1	1.4	1.4	7.1
	25	1	1.4	1.4	8.6
	26	1	1.4	1.4	10.0
	27	1	1.4	1.4	11.4
	28	2	2.9	2.9	14.3
	29	2	2.9	2.9	17.1
	33	2	2.9	2.9	20.0
	34	1	1.4	1.4	21.4
	35	1	1.4	1.4	22.9
	36	3	4.3	4.3	27.1
	38	1	1.4	1.4	28.6
	39	2	2.9	2.9	31.4
	40	2	2.9	2.9	34.3
	41	3	4.3	4.3	38.6
	43	1	1.4	1.4	40.0
	44	2	2.9	2.9	42.9
	45	2	2.9	2.9	45.7
	46	1	1.4	1.4	47.1
	48	1	1.4	1.4	48.6
	49	3	4.3	4.3	52.9
	50	3	4.3	4.3	57.1
	52	1	1.4	1.4	58.6
	53	3	4.3	4.3	62.9
	54	1	1.4	1.4	64.3
	55	4	5.7	5.7	70.0
	56	2	2.9	2.9	72.9
	57	2	2.9	2.9	75.7
	58	2	2.9	2.9	78.6
	60	2	2.9	2.9	81.4
	61	4	5.7	5.7	87.1
	62	2	2.9	2.9	90.0
	65	2	2.9	2.9	92.9
	67	1	1.4	1.4	94.3
	68	1	1.4	1.4	95.7
	70	1	1.4	1.4	97.1
	72	1	1.4	1.4	98.6
	81	1	1.4	1.4	100.0
Total		70	100.0	100.0	

Respondent's sex	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Male	19	27.1	27.1	27.1
Female	51	72.9	72.9	100.0
Total	70	100.0	100.0	

Position of respondent in the village	Frequency	Percent	Valid Percent	Cumulative Percent
Valid none	51	72.9	72.9	72.9
WPC member	11	15.7	15.7	88.6
Kraal head	6	8.6	8.6	97.1
pump minder	2	2.9	2.9	100.0
Total	70	100.0	100.0	

Number of people per household	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 2	1	1.4	1.4	1.4
3	4	5.7	5.7	7.1
4	5	7.1	7.1	14.3
5	10	14.3	14.3	28.6
6	10	14.3	14.3	42.9
7	13	18.6	18.6	61.4
8	12	17.1	17.1	78.6
9	11	15.7	15.7	94.3
10	1	1.4	1.4	95.7
11	2	2.9	2.9	98.6
13	1	1.4	1.4	100.0
Total	70	100.0	100.0	

Source of income	Frequency	Percent	Valid Percent	Cumulative Percent
Valid agriculture	40	57.1	57.1	57.1
formal employment	7	10.0	10.0	67.1
informal employment	7	10.0	10.0	77.1
gold panning	6	8.6	8.6	85.7
agriculture+gold panning	8	11.4	11.4	97.1
agriculture+pension	2	2.9	2.9	100.0
Total	70	100.0	100.0	

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.5	1	1.4	1.4	1.4
	1.8	3	4.3	4.3	5.7
	2.4	5	7.1	7.1	12.9
	3.0	7	10.0	10.0	22.9
	3.3	1	1.4	1.4	24.3
	3.6	3	4.3	4.3	28.6
	4.2	3	4.3	4.3	32.9
	4.5	2	2.9	2.9	35.7
	4.8	9	12.9	12.9	48.6
	5.1	2	2.9	2.9	51.4
	5.4	7	10.0	10.0	61.4
	5.7	2	2.9	2.9	64.3
	6.0	8	11.4	11.4	75.7
	6.3	2	2.9	2.9	78.6
	6.6	1	1.4	1.4	80.0
	7.5	1	1.4	1.4	81.4
	7.8	1	1.4	1.4	82.9
	8.1	1	1.4	1.4	84.3
	8.4	3	4.3	4.3	88.6
	9.0	1	1.4	1.4	90.0
	10.2	1	1.4	1.4	91.4
	10.8	2	2.9	2.9	94.3
	12.6	1	1.4	1.4	95.7
	14.4	1	1.4	1.4	97.1
	15.0	1	1.4	1.4	98.6
	16.2	1	1.4	1.4	100.0
Total		70	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	29	41.4	41.4	41.4
	girls	24	34.3	34.3	75.7
	boys	4	5.7	5.7	81.4
	wife+girls	11	15.7	15.7	97.1
	wife+boys	1	1.4	1.4	98.6
	wife+husband	1	1.4	1.4	100.0
	Total	70	100.0	100.0	

Distance to waterpoint (m)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	100	2	2.9	2.9	2.9
	150	1	1.4	1.4	4.3
	200	7	10.0	10.0	14.3
	300	2	2.9	2.9	17.1
	400	6	8.6	8.6	25.7
	500	12	17.1	17.1	42.9
	600	5	7.1	7.1	50.0
	800	7	10.0	10.0	60.0
	1,000	22	31.4	31.4	91.4
	1,500	3	4.3	4.3	95.7
	2,000	3	4.3	4.3	100.0
	Total	70	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic	2	2.9	2.9	2.9
	domestic+livestock	17	24.3	24.3	27.1
	domestic+irrigation	19	27.1	27.1	54.3
	domestic+livestock+irrigation	32	45.7	45.7	100.0
	Total	70	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence	50	71.4	71.4	71.4
	subsistence+income	20	28.6	28.6	100.0
	Total	70	100.0	100.0	

alternative source of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	borehole	55	78.6	78.6	78.6
	unprotected well	8	11.4	11.4	90.0
	dam/river	7	10.0	10.0	100.0
	Total	70	100.0	100.0	

Respondent's view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	5	7.1	7.1	7.1
	additional waterpoint	43	61.4	61.4	68.6
	spares availability	9	12.9	12.9	81.4
	mechanized system	13	18.6	18.6	100.0
	Total	70	100.0	100.0	

Statistical analysis for ward 17 SWI: boreholes and windmill

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	17	1	1.7	1.7	1.7
	19	1	1.7	1.7	3.3
	20	1	1.7	1.7	5.0
	22	2	3.3	3.3	8.3
	25	1	1.7	1.7	10.0
	26	4	6.7	6.7	16.7
	28	1	1.7	1.7	18.3
	29	3	5.0	5.0	23.3
	33	1	1.7	1.7	25.0
	34	2	3.3	3.3	28.3
	35	1	1.7	1.7	30.0
	36	3	5.0	5.0	35.0
	37	1	1.7	1.7	36.7
	38	1	1.7	1.7	38.3
	40	2	3.3	3.3	41.7
	41	3	5.0	5.0	46.7
	42	2	3.3	3.3	50.0
	43	2	3.3	3.3	53.3
	44	1	1.7	1.7	55.0
	45	1	1.7	1.7	56.7
	46	1	1.7	1.7	58.3
	48	1	1.7	1.7	60.0
	50	2	3.3	3.3	63.3
	52	1	1.7	1.7	65.0
	53	3	5.0	5.0	70.0
	54	1	1.7	1.7	71.7
	55	1	1.7	1.7	73.3
	56	1	1.7	1.7	75.0
	59	1	1.7	1.7	76.7
	62	2	3.3	3.3	80.0
	63	2	3.3	3.3	83.3
	65	2	3.3	3.3	86.7
	66	2	3.3	3.3	90.0
	68	1	1.7	1.7	91.7
	70	1	1.7	1.7	93.3
	71	1	1.7	1.7	95.0
	76	1	1.7	1.7	96.7
	77	1	1.7	1.7	98.3
	79	1	1.7	1.7	100.0
Total		60	100.0	100.0	

Respondent's sex		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	19	31.7	31.7	31.7
	Female	41	68.3	68.3	100.0
	Total	60	100.0	100.0	

Respondent's position in the village		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	41	68.3	68.3	68.3
	WPC member	16	26.7	26.7	95.0
	Kraal head	1	1.7	1.7	96.7
	pump minder	1	1.7	1.7	98.3
	Village head	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

Number of people per household		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4	2	3.3	3.3	3.3
	5	6	10.0	10.0	13.3
	6	9	15.0	15.0	28.3
	7	13	21.7	21.7	50.0
	8	7	11.7	11.7	61.7
	9	7	11.7	11.7	73.3
	10	11	18.3	18.3	91.7
	11	2	3.3	3.3	95.0
	13	2	3.3	3.3	98.3
	14	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

Source of income		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agriculture	52	86.7	86.7	86.7
	formal employment	4	6.7	6.7	93.3
	informal employment	1	1.7	1.7	95.0
	agriculture+informal employment	1	1.7	1.7	96.7
	agriculture+gold panning	2	3.3	3.3	100.0
	Total	60	100.0	100.0	

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.4	2	3.3	3.3	3.3
	3.0	2	3.3	3.3	6.7
	3.3	2	3.3	3.3	10.0
	3.6	4	6.7	6.7	16.7
	3.9	2	3.3	3.3	20.0
	4.2	2	3.3	3.3	23.3
	4.5	4	6.7	6.7	30.0
	4.8	7	11.7	11.7	41.7
	5.1	2	3.3	3.3	45.0
	5.4	8	13.3	13.3	58.3
	5.7	2	3.3	3.3	61.7
	6.0	7	11.7	11.7	73.3
	6.6	4	6.7	6.7	80.0
	6.9	1	1.7	1.7	81.7
	7.5	1	1.7	1.7	83.3
	8.1	1	1.7	1.7	85.0
	9.0	2	3.3	3.3	88.3
	10.2	1	1.7	1.7	90.0
	12.0	2	3.3	3.3	93.3
	14.4	2	3.3	3.3	96.7
	15.6	1	1.7	1.7	98.3
	21.0	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	25	41.7	41.7	41.7
	girls	12	20.0	20.0	61.7
	boys	12	20.0	20.0	81.7
	wife+girls	7	11.7	11.7	93.3
	wife+boys	4	6.7	6.7	100.0
	Total	60	100.0	100.0	

Distance to waterpoint (m)		Frequency	Percent	Percent	Percent
Valid	100	6	10.0	10.0	10.0
	150	3	5.0	5.0	15.0
	200	12	20.0	20.0	35.0
	300	4	6.7	6.7	41.7
	400	7	11.7	11.7	53.3
	500	8	13.3	13.3	66.7
	600	4	6.7	6.7	73.3
	800	7	11.7	11.7	85.0
	1,000	9	15.0	15.0	100.0
	Total	60	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic+livestock	6	10.0	10.0	10.0
	domestic+irrigation	23	38.3	38.3	48.3
	domestic+livestock+irrigation	29	48.3	48.3	96.7
	domestic+livestock+irrigation+brickmaking	1	1.7	1.7	98.3
	domestic+irrigation+brickmaking	1	1.7	1.7	100.0
	Total	60	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence	32	53.3	53.3	53.3
	subsistence+income	28	46.7	46.7	100.0
	Total	60	100.0	100.0	

Alternative source of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	borehole	17	28.3	28.3	28.3
	unprotected well	9	15.0	15.0	43.3
	dam/river	34	56.7	56.7	100.0
	Total	60	100.0	100.0	

Respondent's view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	6	10.0	10.0	10.0
	additional waterpoint spares availability	37	61.7	61.7	71.7
	mechanized system	9	15.0	15.0	86.7
		8	13.3	13.3	100.0
	Total	60	100.0	100.0	

Statistical analysis for ward 19 SWI: boreholes and windmill

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	26	2	5.0	5.0	5.0
	31	1	2.5	2.5	7.5
	32	1	2.5	2.5	10.0
	33	2	5.0	5.0	15.0
	35	1	2.5	2.5	17.5
	40	2	5.0	5.0	22.5
	42	1	2.5	2.5	25.0
	43	1	2.5	2.5	27.5
	44	1	2.5	2.5	30.0
	45	1	2.5	2.5	32.5
	46	1	2.5	2.5	35.0
	48	1	2.5	2.5	37.5
	49	2	5.0	5.0	42.5
	50	1	2.5	2.5	45.0
	51	1	2.5	2.5	47.5
	52	1	2.5	2.5	50.0
	53	2	5.0	5.0	55.0
	55	3	7.5	7.5	62.5
	56	1	2.5	2.5	65.0
	57	1	2.5	2.5	67.5
	58	1	2.5	2.5	70.0
	60	2	5.0	5.0	75.0
	61	1	2.5	2.5	77.5
	63	2	5.0	5.0	82.5
	65	3	7.5	7.5	90.0
	67	2	5.0	5.0	95.0
	70	2	5.0	5.0	100.0
	Total	40	100.0	100.0	

Respondent's sex		Frequency	Percent	Percent	Percent
Valid	Male	12	30.0	30.0	30.0
	Female	28	70.0	70.0	100.0
	Total	40	100.0	100.0	

Respondent's position in the village		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	28	70.0	70.0	70.0
	WPC member	7	17.5	17.5	87.5
	Kraal head	3	7.5	7.5	95.0
	pump minder	1	2.5	2.5	97.5
	Village head	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

Number of people per household		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4	5	12.5	12.5	12.5
	5	9	22.5	22.5	35.0
	6	8	20.0	20.0	55.0
	7	6	15.0	15.0	70.0
	8	6	15.0	15.0	85.0
	9	4	10.0	10.0	95.0
	10	2	5.0	5.0	100.0
	Total	40	100.0	100.0	

Source of income		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agriculture	36	90.0	90.0	90.0
	informal employment	3	7.5	7.5	97.5
	gold panning	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.5	1	2.5	2.5	2.5
	1.8	2	5.0	5.0	7.5
	2.4	1	2.5	2.5	10.0
	3.0	3	7.5	7.5	17.5
	3.6	1	2.5	2.5	20.0
	4.8	6	15.0	15.0	35.0
	5.4	5	12.5	12.5	47.5
	5.7	2	5.0	5.0	52.5
	6.0	3	7.5	7.5	60.0
	6.3	2	5.0	5.0	65.0
	6.6	3	7.5	7.5	72.5
	7.8	1	2.5	2.5	75.0
	8.4	1	2.5	2.5	77.5
	9.0	1	2.5	2.5	80.0
	10.8	2	5.0	5.0	85.0
	11.4	1	2.5	2.5	87.5
	12.0	1	2.5	2.5	90.0
	12.6	1	2.5	2.5	92.5
	14.4	1	2.5	2.5	95.0
	15.0	1	2.5	2.5	97.5
	16.2	1	2.5	2.5	100.0
Total		40	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	16	40.0	40.0	40.0
	girls	13	32.5	32.5	72.5
	boys	3	7.5	7.5	80.0
	wife+girls	7	17.5	17.5	97.5
	wife+boys	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

Distance to waterpoint (m)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	200	1	2.5	2.5	2.5
	300	4	10.0	10.0	12.5
	400	5	12.5	12.5	25.0
	500	9	22.5	22.5	47.5
	600	2	5.0	5.0	52.5
	800	5	12.5	12.5	65.0
	1,000	9	22.5	22.5	87.5
	1,500	4	10.0	10.0	97.5
	2,000	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic	2	5.0	5.0	5.0
	domestic+livestock	4	10.0	10.0	15.0
	domestic+irrigation	17	42.5	42.5	57.5
	domestic+livestock+irrigation	17	42.5	42.5	100.0
	Total	40	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence	33	82.5	82.5	82.5
	subsistence+income	7	17.5	17.5	100.0
	Total	40	100.0	100.0	

Alternative source of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	borehole	6	15.0	15.0	15.0
	unprotected well	23	57.5	57.5	72.5
	dam/river	11	27.5	27.5	100.0
	Total	40	100.0	100.0	

Respondent's view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	2	5.0	5.0	5.0
	additional waterpoint	33	82.5	82.5	87.5
	mechanized system	5	12.5	12.5	100.0
	Total	40	100.0	100.0	

Statistica analysis for Zhulube dam (ward 1)

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	39	1	10.0	10.0	10.0
	41	1	10.0	10.0	20.0
	43	1	10.0	10.0	30.0
	45	1	10.0	10.0	40.0
	53	1	10.0	10.0	50.0
	55	1	10.0	10.0	60.0
	62	2	20.0	20.0	80.0
	70	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Respondent's sex		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	3	30.0	30.0	30.0
	Female	7	70.0	70.0	100.0
	Total	10	100.0	100.0	

Respondent's position in the village		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	6	60.0	60.0	60.0
	WPC member	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

Number of people per household		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4	1	10.0	10.0	10.0
	5	3	30.0	30.0	40.0
	6	3	30.0	30.0	70.0
	7	1	10.0	10.0	80.0
	8	1	10.0	10.0	90.0
	10	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Source of income		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agriculture	8	80.0	80.0	80.0
	agriculture+informal employment	1	10.0	10.0	90.0
	agriculture+gold panning	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5,143.1	1	10.0	10.0	10.0
	5,147.6	1	10.0	10.0	20.0
	5,148.8	1	10.0	10.0	30.0
	7,795.0	1	10.0	10.0	40.0
	7,797.0	1	10.0	10.0	50.0
	10,391.5	1	10.0	10.0	60.0
	10,441.4	1	10.0	10.0	70.0
	10,451.1	1	10.0	10.0	80.0
	11,683.7	1	10.0	10.0	90.0
	11,696.9	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	8	80.0	80.0	80.0
	wife+boys	1	10.0	10.0	90.0
	wife+husband	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Distance to waterpoint (m)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	500	3	30.0	30.0	30.0
	600	1	10.0	10.0	40.0
	800	2	20.0	20.0	60.0
	1,000	2	20.0	20.0	80.0
	1,500	1	10.0	10.0	90.0
	2,000	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic+livestock+irrigation	1	10.0	10.0	10.0
	domestic+livestock+irrigation+fishing	3	30.0	30.0	40.0
	domestic+livestock+irrigation+gold panning	4	40.0	40.0	80.0
	domestic+livestock+irrigation+brickmaking	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence	1	10.0	10.0	10.0
	subsistence+income	9	90.0	90.0	100.0
	Total	10	100.0	100.0	

Respondent' view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	spares availability	9	90.0	90.0	90.0
	mechanized system	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Statistical analysis for Caterpillar dam (ward 2)

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	23	1	10.0	10.0	10.0
	32	1	10.0	10.0	20.0
	44	1	10.0	10.0	30.0
	48	1	10.0	10.0	40.0
	55	1	10.0	10.0	50.0
	58	1	10.0	10.0	60.0
	62	1	10.0	10.0	70.0
	67	1	10.0	10.0	80.0
	69	1	10.0	10.0	90.0
	70	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Respondent's sex		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	3	30.0	30.0	30.0
	Female	7	70.0	70.0	100.0
	Total	10	100.0	100.0	

Respondent's position in the village		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	7	70.0	70.0	70.0
	WPC member	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

Number of people per household		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	1	10.0	10.0	10.0
	6	2	20.0	20.0	30.0
	7	1	10.0	10.0	40.0
	8	1	10.0	10.0	50.0
	9	1	10.0	10.0	60.0
	10	2	20.0	20.0	80.0
	11	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Source of income		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agriculture	10	100.0	100.0	100.0

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3.6	1	10.0	10.0	10.0
	5.1	1	10.0	10.0	20.0
	7.4	1	10.0	10.0	30.0
	8.3	1	10.0	10.0	40.0
	10.6	1	10.0	10.0	50.0
	11.2	1	10.0	10.0	60.0
	12.2	1	10.0	10.0	70.0
	13.7	1	10.0	10.0	80.0
	14.5	1	10.0	10.0	90.0
	15.4	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	8	80.0	80.0	80.0
	wife+girls	1	10.0	10.0	90.0
	wife+husband	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Distance to waterpoint (m)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	500	3	30.0	30.0	30.0
	1,000	3	30.0	30.0	60.0
	1,500	1	10.0	10.0	70.0
	2,000	2	20.0	20.0	90.0
	3,000	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic+livestock+irrigation	3	30.0	30.0	30.0
	domestic+livestock+irrigation+fishing	2	20.0	20.0	50.0
	domestic+livestock+irrigation+brickmaking	2	20.0	20.0	70.0
	domestic+livestock+irrigation+brickmaking+fishing	1	10.0	10.0	80.0
	domestic+livestock+gold panning	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence	1	10.0	10.0	10.0
	subsistence+income	9	90.0	90.0	100.0
	Total	10	100.0	100.0	

Respondent's view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	additional waterpoint	2	20.0	20.0	20.0
	mechanized system	7	70.0	70.0	90.0
	expansion of water source	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Statistical analysis for Tombo dam (ward 17)

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	23	1	10.0	10.0	10.0
	37	1	10.0	10.0	20.0
	38	1	10.0	10.0	30.0
	41	1	10.0	10.0	40.0
	43	1	10.0	10.0	50.0
	51	1	10.0	10.0	60.0
	56	1	10.0	10.0	70.0
	62	1	10.0	10.0	80.0
	70	1	10.0	10.0	90.0
	71	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Respondent's sex		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	4	40.0	40.0	40.0
	Female	6	60.0	60.0	100.0
	Total	10	100.0	100.0	

Respondent's position in th village		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	6	60.0	60.0	60.0
	WPC member	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

Number of people per household		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6	3	30.0	30.0	30.0
	7	1	10.0	10.0	40.0
	8	2	20.0	20.0	60.0
	9	2	20.0	20.0	80.0
	10	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Source of income		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agriculture	8	80.0	80.0	80.0
	formal employment	1	10.0	10.0	90.0
	agriculture+informal employment	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	13,758.3	1	10.0	10.0	10.0
	15,444.2	1	10.0	10.0	20.0
	20,623.8	1	10.0	10.0	30.0
	44,852.9	1	10.0	10.0	40.0
	44,855.1	1	10.0	10.0	50.0
	59,088.7	1	10.0	10.0	60.0
	59,808.1	1	10.0	10.0	70.0
	59,809.2	1	10.0	10.0	80.0
	88,630.5	1	10.0	10.0	90.0
	88,637.9	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	5	50.0	50.0	50.0
	wife+girls	1	10.0	10.0	60.0
	wife+boys	1	10.0	10.0	70.0
	wife+husband	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

Distance to waterpoint (m)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,000	2	20.0	20.0	20.0
	1,500	3	30.0	30.0	50.0
	2,000	4	40.0	40.0	90.0
	3,000	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic+livestock+irrigation	3	30.0	30.0	30.0
	domestic+livestock+irrigation+fishing	2	20.0	20.0	50.0
	domestic+livestock+irrigation+gold panning	2	20.0	20.0	70.0
	domestic+livestock+irrigation+brickmaking	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence+income	10	100.0	100.0	100.0

Respondent's view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	2	20.0	20.0	20.0
	additional waterpoint	2	20.0	20.0	40.0
	spares availability	1	10.0	10.0	50.0
	mechanized system	3	30.0	30.0	80.0
	expansion of water source	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

Statistical analysis for Village 4 dam (ward 19)

Age of respondent		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	43	1	10.0	10.0	10.0
	45	1	10.0	10.0	20.0
	52	1	10.0	10.0	30.0
	53	1	10.0	10.0	40.0
	55	1	10.0	10.0	50.0
	59	1	10.0	10.0	60.0
	60	1	10.0	10.0	70.0
	69	1	10.0	10.0	80.0
	76	1	10.0	10.0	90.0
	77	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Respondent's sex		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	4	40.0	40.0	40.0
	Female	6	60.0	60.0	100.0
	Total	10	100.0	100.0	

Respondent's position in the village		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	6	60.0	60.0	60.0
	WPC member	2	20.0	20.0	80.0
	Kraal head	1	10.0	10.0	90.0
	Village head	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Number of people per		Frequency	Percent	Valid	Cumulative
Valid	4	1	10.0	10.0	10.0
	5	1	10.0	10.0	20.0
	6	1	10.0	10.0	30.0
	7	1	10.0	10.0	40.0
	9	2	20.0	20.0	60.0
	10	2	20.0	20.0	80.0
	13	1	10.0	10.0	90.0
	14	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Source of income		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agriculture	10	100.0	100.0	100.0

Amount of water used per household (m ³ /month)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	7.6	1	10.0	10.0	10.0
	8.4	1	10.0	10.0	20.0
	8.7	1	10.0	10.0	30.0
	8.8	1	10.0	10.0	40.0
	9.3	1	10.0	10.0	50.0
	9.6	1	10.0	10.0	60.0
	10.9	1	10.0	10.0	70.0
	13.8	1	10.0	10.0	80.0
	17.2	1	10.0	10.0	90.0
	19.3	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Responsibility for fetching water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wife	10	100.0	100.0	100.0

Distance to waterpoint (m)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	500	2	20.0	20.0	20.0
	1,000	3	30.0	30.0	50.0
	1,500	2	20.0	20.0	70.0
	2,000	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

Uses of water		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	domestic+livestock+irrigation	6	60.0	60.0	60.0
	domestic+livestock+irrigation+fishing	2	20.0	20.0	80.0
	domestic+livestock+irrigation+brickmaking	1	10.0	10.0	90.0
	domestic+livestock+irrigation+brickmaking+fishing	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Benefits derived from water use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	subsistence	7	70.0	70.0	70.0
	subsistence+income	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

Respondent's view on improved water access		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	additional waterpoint	7	70.0	70.0	70.0
	spares availability	1	10.0	10.0	80.0
	mechanized system	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

APPENDIX H: ESTIMATED AMOUNT OF WATER USED FROM BOREHOLES, WELLS AND WINDMILLS

Domestic (l/day)	Domestic (l/month)	Domestic (m ³ /month)	Irrigation (l/day)	Irrigation (l/month)	Irrigation (m ³ /month)	Livestock (l/day)	Livestock (l/month)	Livestock (m ³ /month)	Total m ³ /month	People per household
160	4800	4.8	600	7200	7.2	5	150	0.2	12.2	9
80	2400	2.4	0	0	0.0	30	900	0.9	3.3	4
60	1800	1.8	0	0	0.0	15	450	0.5	2.3	4
60	1800	1.8	800	9600	9.6	14	420	0.4	11.8	5
80	2400	2.4	0	0	0.0	20	600	0.6	3.0	7
100	3000	3.0	320	3840	3.8	17	510	0.5	7.4	9
60	1800	1.8	0	0	0.0	9	270	0.3	2.1	5
120	3600	3.6	240	2880	2.9	40	1200	1.2	7.7	9
100	3000	3.0	0	0	0.0	10	300	0.3	3.3	9
120	3600	3.6	0	0	0.0	10	300	0.3	3.9	11
20	600	0.6	600	4800	4.8	10	300	0.3	5.7	2
40	1200	1.2	180	2160	2.2	16	480	0.5	3.8	2
60	1800	1.8	180	2880	2.9	20	600	0.6	5.3	4
80	2400	2.4	240	2880	2.9	50	1500	1.5	6.8	5
160	4800	4.8	0	0	0.0	20	600	0.6	5.4	7
120	3600	3.6	240	2880	2.9	15	450	0.5	6.9	7
120	3600	3.6	0	0	0.0	10	300	0.3	3.9	9
80	2400	2.4	280	2240	2.2	50	1500	1.5	6.1	5
120	3600	3.6	200	2400	2.4	10	300	0.3	6.3	8
140	4200	4.2	320	3840	3.8	20	600	0.6	8.6	9
120	3600	3.6	300	3600	3.6	25	750	0.8	8.0	10
100	3000	3.0	320	3840	3.8	15	450	0.5	7.3	13
60	1800	1.8	80	960	1.0	18	540	0.5	3.3	8
120	3600	3.6	240	2880	2.9	15	450	0.5	6.9	8
40	1200	1.2	300	3600	3.6	20	600	0.6	5.4	5
80	2400	2.4	360	2880	2.9	20	600	0.6	5.9	6
20	600	0.6	0	0	0.0	10	300	0.3	0.9	2
80	2400	2.4	0	0	0.0	15	450	0.5	2.9	5
120	3600	3.6	180	2160	2.2	18	540	0.5	6.3	6
100	3000	3.0	0	0	0.0	10	300	0.3	3.3	7
80	2400	2.4	200	1600	1.6	16	480	0.5	4.5	3
100	3000	3.0	200	2400	2.4	10	300	0.3	5.7	7
60	1800	1.8	100	1200	1.2	15	450	0.5	3.5	9
140	4200	4.2	240	6720	6.7	10	300	0.3	11.2	8
140	4200	4.2	0	0	0.0	25	750	0.8	5.0	6
90	2700	2.7	0	0	0.0	16	480	0.5	3.2	3
120	3600	3.6	0	0	0.0	20	600	0.6	4.2	9
120	3600	3.6	280	2240	2.2	50	1500	1.5	7.3	5

APPENDIX I: ESTIMATED QUANTITIES OF WATER USED FROM SMALL DAMS

Amount of water abstracted from Zhulube and Tombo dams were estimated using V-notch and Trapezoidal weirs equations (Eq. 4-3 and Eq. 4-4) respectively.

Zhulube dam: V-notch weir measurements were taken to estimate discharge using the equation $Q = 2.49 H^{2.48}$

Tombo dam: Trapezoidal weir measurements were taken to estimate discharge using the equation $Q = 3.367 bH^{3/2}$

Conversion factors: 1cm = 0.0328 ft; 1ft³ = 28.32litres

Livestock water use estimation: cattle = 25 l/day, goat = 7.5 l/day; donkey = 15 l/day; sheep = 10 l/day

Water abstracted from dams from dams for irrigation = Q*abstraction time per day

Time for irrigation=hours/day*days/week*4 weeks/month

	H (ft)	b (ft)	Q (ft ³ /s)	Q (m ³ /month)
Zhulube dam	0.197	-	0.044	1298
Tombo dam	0.492	0.656	0.762	22381

Estimated consumptive water use from Zhulube dam in ward 1

No. of households =40

Livestock kept	Types of uses	Irrigation (m ³ /month)	Domestic (m ³ /month)	Livestock (m ³ /month)	Brick-making (m ³ /month)	Gold panning (m ³ /month)	Amount used per household (m ³ /month)
7 goats, 12 cattle	domestic, livestock, irrigation, fishing	7786	0.32	10.575	-	-	7797
5 cattle, 8 goats	domestic, livestock, irrigation, panning	10381	0.48	5.55	-	4	10392
3 cattle, 5 goats, 3 sheep	domestic, livestock, irrigation	11679	0.20	4.275	-	-	11684
6 cattle, 20 goats, 8 sheep	domestic, livestock, irrigation, panning	10433	0.32	11.4	-	6	10451
4 cattle, 4 goats	domestic, livestock, irrigation, fishing	5139	0.32	3.9	-	-	5143
6 cattle, 3 goats	domestic, livestock, irrigation, brickmaking	7786	0.48	5.175	3.2	-	7795
2 cattle, 4 goats	domestic, livestock, irrigation, panning	10433	0.60	2.4	-	5	10441
14 cattle, 7 goats	domestic, livestock, irrigation, panning	11679	0.40	12.075	-	5.2	11697
7 cattle, 5 goats, 7 donkeys	domestic, livestock, irrigation, fishing	5139	0.40	9.525	-	-	5149
10 cattle, 4 goats	domestic, livestock, irrigation, brickmaking	5139	0.32	8.4	-	-	5148

Estimated consumptive water use from Tombo dam in ward 17

No. of households = 40

Livestock kept	Types of uses	Irrigation (m ³ /month)	domestic (m ³ /month)	Livestock (m ³ /month)	Brick-making (m ³ /month)	Gold panning (m ³ /month)	Amount used per household (m ³ /month)
7 goats	domestic, livestock, irrigation, fishing	59802	0.40	5.25	-	-	59808
4 goats	domestic, livestock, irrigation	15443	0.64	0.9	-	-	15444
3 cattle, 2 goats	domestic, livestock, panning, irrigation	13754	0.48	2.7	0.8	-	13758
5 goats	domestic, livestock, irrigation, panning	88629	0.30	1.125	-	7	88638
6 goats, 1 cow	domestic, livestock, irrigation, brickmaking	59086	0.32	2.1	-	-	59089
12 cattle	domestic, livestock, irrigation, brickmaking	20590	0.56	9	24.0	-	20624
3 goats	domestic, livestock, irrigation	44852	0.40	0.675	-	-	44853
2 goats	domestic, livestock, irrigation	88629	0.64	0.45	-	-	88631
3 cattle, 2 goats	domestic, livestock, irrigation, fishing	44852	0.48	2.7	-	-	44855
1 goat, 5 cattle	domestic, livestock, irrigation, brickmaking	59802	0.32	3.975	2.4	-	59809

Estimated consumptive water use from Caterpillar dam in ward 2

No. of households =38

Livestock kept	Types of uses	Irrigation (m ³ /month)	Domestic (m ³ /month)	Livestock (m ³ /month)	Brick-making (m ³ /month)	Gold panning (m ³ /month)	Amount used per household (m ³ /month)
8 cattle, 7 goats, 2 donkeys	domestic, livestock, irrigation	1.9	0.20	8.475	-	-	11
4 cattle	domestic, livestock, irrigation, fishing	1.4	0.64	3	-	-	5
9 cattle	domestic, livestock, irrigation, brickmaking, fishing	1.4	0.40	6.75	2.6	-	11
3 sheep, 2 goats, 6 cattle	domestic, livestock, panning	-	0.64	5.85	-	8	14
5 cattle	domestic, livestock, irrigation, brickmaking	1.7	0.36	3.75	1.6	-	7
4 donkeys, 9 cattle	domestic, livestock, panning	-	0.36	8.55	-	4.8	14
16 cattle, 6 goats	domestic, livestock, irrigation, fishing	1.6	0.45	13.35	-	-	15
4 goats, 3 donkeys	domestic, livestock, irrigation	1.0	0.40	2.25	-	-	4
5 goats, 2 cattle	domestic, livestock, irrigation, brickmaking	1.9	0.56	2.625	3.2	-	8
10 cattle, 4 donkeys, 6 goats	domestic, livestock, irrigation	1.2	0.32	10.65	-	-	12

Estimated consumptive water use from Village 4 dam in ward 19

No. of households =35

Livestock kept	Types of uses	Irrigation (m ³ /month)	Domestic (m ³ /month)	Livestock (m ³ /month)	Brick-making (m ³ /month)	Gold panning (m ³ /month)	Amount used per household (m ³ /month)
10 cattle, 4 donkeys	domestic, livestock, irrigation, brickmaking	1.9	2.72	8.7	6	-	19
5 cattle	domestic, livestock, irrigation	2.4	2.28	3.75	-	-	8
3 cattle, 8 goats	domestic, livestock, irrigation	3.2	2.00	4.05	-	-	9
7 cattle, 4 goats	domestic, livestock, irrigation	1.9	1.52	6.15	-	-	10
9 cattle	domestic, livestock, irrigation, brickmaking, fishing	2.9	2.72	6.75	4.8	-	17
11 goats, 4 cattle, 6 sheep	domestic, livestock, irrigation	1.9	1.74	7.275	-	-	11
5 goats, 2 cattle	domestic, livestock, irrigation	2.6	3.60	2.625	-	-	9
6 sheep, 9 goats	domestic, livestock, irrigation, fishing	1.6	2.20	3.825	-	-	8
16 goats, 3 donkeys	domestic, livestock, irrigation	2.2	1.60	4.95	-	-	9
8 cattle, 16 goats	domestic, livestock, irrigation, fishing	2.9	1.36	9.6	-	-	14

APPENDIX J: DATA COLLECTION TEMPLATE FOR CONDITIOIN ASSESSMENT

A. Identification details

GPS:.....

Ward:.....

SWI type:.....

SWI name:.....

B. SWI condition - Physical inspection

Above ground components

- | | | | | |
|------------------------------|----------------------|----------|-------------------|----------|
| 1) wooden block and handle | <input type="text"/> | (1) good | (2)need attention | (3) poor |
| 2) bolts(M24) and hinge pins | <input type="text"/> | (1) good | (2)need attention | (3) poor |
| 3) pump discharge assembly | <input type="text"/> | (1) good | (2)need attention | (3) poor |
| 4) pump stand / U-bolts | <input type="text"/> | (1) good | (2)need attention | (3) poor |
| 5) Rubber buffer | <input type="text"/> | (1) good | (2)need attention | (3) poor |
| 6) U-bracket | <input type="text"/> | (1) good | (2)need attention | (3) poor |

Down-hole components

- | | | | | |
|---------------------------------|----------------------|------------|--------------|-------------|
| 1) number of strokes | <input type="text"/> | | | |
| 2) handle weight | <input type="text"/> | (1) normal | (2) heavy | (3) v-heavy |
| 3) quantity of water discharged | <input type="text"/> | (1) normal | (2) v-little | |

General condition

- | | | | | |
|----------------------------|----------------------|----------|-------------------|----------------------------|
| 1) above ground components | <input type="text"/> | (1) good | (2)need attention | (3) poor |
| 2) down-hole components | <input type="text"/> | (1) good | (2)need attention | (3) poor |
| 3) functional status | <input type="text"/> | (1) good | (2)need attention | (3) poor (4) dysfunctional |
- If (4) what caused the breakdown?

Headwork condition

- | | | | | | |
|-----------|----------------------|----------|-------------------|----------|----------|
| 1)apron | <input type="text"/> | (1) good | (2)need attention | (3) poor | (4) none |
| 2)fencing | <input type="text"/> | (1) good | (2)need attention | (3) poor | (4) none |
| 3)troughs | <input type="text"/> | (1) good | (2)need attention | (3) poor | (4) none |

C. SWI Management (CBM)

- 1) Is there a trained pump mechanic for the SWI? (1) yes (2) no
- 2) Does the community have their own tools? (1) yes (2) no
- 3) Is there a water point committee? (1) yes (2) no
- 4) Is the water point committee trained? (1) yes (2) no
- 5) How often does the SWI breakdown? (1) hardly (2) often
- 6) What is the usual downtime for the SWI? (1) yes (2) no
- 6) Is the community collecting/saving money for maintenance? (1) yes (2) no
- 7) Is there a constitution for the SWI use? (1) yes (2) no

D. SWI Performance data

- 1) Number of households with access to SWI
- 2) Nearest homestead
- 3) Furthest homestead
- 4) Supply time per day
- 5) Appearance of water (1) clear (2) muddy (3) rusty (4) milky
- 6) Taste of water (1) acceptable (2) bitter (3) saline
- 7) Odour of water (1) none (2) present
- 8) Water quality parameters

pH	TC	NTU	EC	T
- 9) Flowrate (l/s)
- 10) borehole depth