A Comparative Assessment of Communal Water Supply and Self Supply Models for Sustainable Rural Water Supplies: A Case Study of Luapula, Zambia

by

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ABSTRACT

Over the last couple of decades, a significant amount of research has been carried out on rural water supplies in developing countries, and have identified the fact that the communal water supply model is not sustainable everywhere, especially in sparsely populated rural areas; factors obstructing sustainability include lack of spare parts, management systems and private/public capacity. Despite their enormous contribution to the water sector, the extant studies stay within the subsidized communal water supply and capacity building, post construction support or management system. In other words, very few studies have been done into household (private) level water supply. The Self Supply model is an approach which provides support to households/communities to complement their efforts and accelerate sustainable access to safe water incrementally through improvement to traditional water sources (hand dug wells) by putting in their own investment. The Self Supply model may give significant benefits for sustainable safe water supplies, especially in sparsely populated rural areas, in comparison with the communal water supply though to date there has been little monitoring and systematic analysis of what impact these changes have made at the grassroots level.

The standpoint of this study is pragmatic, and herein, mixing quantitative and qualitative methods was justified in order to design the research methodologies. The research was conducted in the Luapula Province of Zambia using a concurrent triangulation strategy to offset the weakness inherent within one method with the strengths of the other. The data was collected through inventory and sanitary surveys, water quality testing, household surveys, document analyses, focus group discussions and key informant interviews to determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective and acceptable water supplies for households in sparsely populated rural areas of Zambia.

The principal argument of this study is that *reliance only on a communal water supply model limits the achievement of increased sustainable access to a safe water supply; hence a Self Supply model is needed which does not compete with the communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.* It was strongly defended by the overall findings that a Self Supply model could significantly reduce the faecal contamination risk in water quality and deliver a higher per capita water use and better convenience of access than the communal model; however its reliability with respect to the water source drying up needs to be monitored. Further, this does not mean that the communal model is not sustainable anywhere, rather that it is important to build blocks for a sustainable environment to access safe water in a symbiotic way between the communal and Self Supply models under the condition that the government and NGOs/external support agencies overcome the temptation to provide a water supply to rural dwellers as a giveaway social service.

Keywords: Rural water supply, Self Supply model, Communal water supply model, Water quality, Per-capita water use, Acceptability, Sparsely populated area, Zambia

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ABBREVIATIONS

AA	Artisan Association
APM	Area Pump Mender
ACO	Area Community Organiser
CBO	Community Based Organisation
CSO	Central Statistical Office
DAPP	Development Aid from People to People
DC	District Council
DFID	Department for International Development
EHT	Environmental Health Technician
FC	Faecal Coliforms
HDW	Hand Dug Well
HH	Household
HWTS	Household Water Treatment and Storage
IMS	Information Management System
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme
MDG	Millennium Development Goal
MLGH	Ministry of Local Government and Housing
NGO	Non-Governmental Organisation
NHC	Neighbourhood Health Committee
NRWSSP	National Rural Water Supply and Sanitation Programme
O&M	Operation and Maintenance
POOM	Private Ownership, Operation and Maintenance
PPOM	Public-Private Operation and Maintenance
PVC	Poly-Vinyl Chloride
RiPPLE	Research Inspired Policy and Practice Learning in Ethiopia and the Nile Region
RWSN	Rural Water Supply Network
SI	Sanitary Inspection
SOMAP	Sustainable Operation and Maintenance Project
SPSS	Statistical Package Social Science
SS	Self Supply

TOM	Technician in Operation and Maintenance
TTC	Thermo Tolerant Coliforms
UAP	Universal Access Plan
UNESCO	United Nations
UNICEF	United Nations Children's Fund
USEPA	United Nations Educational, Scientific and Cultural Organisation
VAG	Village Action Group
VLOM	Village Level Operation and Maintenance
WASHE	Water, Sanitation and Hygiene Education
WEDC	Water, Engineering and Development Centre
WHO	World Health Organization
WSP	Water and Sanitation Programme
WP	Water Point
ZMK	Zambia Kwacha

Chapter 1 INTRODUCTION

1.1 Background

Responding to the world's main developmental challenges, the provision of basic services to developing countries has become an important area of concern and research. Sub-Saharan Africa and Southern Asian regions account for a large degree of the deficit, and therefore those regions have been provided with foreign aid assistance (UNDP 2007). In fact, in the past fifty years, more than $1 trillion in development aid has been given to Africa by developed countries (Moyo 2009). Low income countries receive a large amount of external development assistance from rich countries, multilateral organizations, nongovernmental organizations and private foundations.

For about the last 20 years, drinking water supplies and sanitation have received significant attention internationally because at least 40% of the world's population was faced with the lack of a safe water supply and adequate sanitation (Carter 1993). As the beginning of longitudinal change with unprecedented global attention, the United Nations Drinking Water Supply and Sanitation Decade ran from 1981 to 1990 and achieved an increase in coverage of water supplies although the target of a safe water supply and adequate sanitation for all was not met because of the unrealistic and unachievable goals set.

The WHO/UNICEF Joint Monitoring Programme (JMP) reports on the status of water supply and sanitation, and supports countries in their efforts to monitor this sector; according to them although an enormous number of additional people gained access to improved water supply and sanitation facilities between 1990 and 2000, with approximately 816 million additional people gaining access to water supplies and 747 million additional people gaining access to sanitation facilities, the percentage increase in coverage appeared modest because of the global population growth during that time (WHO and UNICEF 2000).

Following up this international issue, sustainable access to safe drinking water and basic sanitation became one of the Millennium Development Goals (MDGs) signed in 2000 (UN 2008). The specific water target of the MDGs is to ensure environmental sustainability i.e. 'Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation compared to 1990'. External development aid is provided in various ways, including budget support, and funding for sector projects, as well as advocacy, education, and sector monitoring. (WHO and UNICEF 2010, p.9)

Although most countries were on track to meet the MDG drinking water target, a number of countries in Sub-Saharan Africa were more than 10% below the water coverage rate needed for the country to achieve the MDG target in 2006 (WHO and UNICEF 2008). According to the latest 2010 JMP report, 884 million people worldwide still do not get their drinking water from improved sources (WHO and UNICEF 2010). According to the U.S. Census Bureau (2008), the global population will become more than 7 billion by 2015, with a particularly large increase in the population of Africa. The Sub-Saharan Africa region requires intensive support to accelerate the progress due to the fact that it accounts for more than a third of those using unimproved drinking water sources (WHO and UNICEF 2010).

In the latest JMP report 2010, at the current rate of progress, the world is expected to achieve the MDG water target of; "halving the proportion of the population without sustainable access to safe drinking water" (WHO and UNICEF 2010, p.9). Nonetheless, the safety of many water supplies remains unknown despite all the efforts made by governments and donor organizations in an attempt to meet the MDGs water target, and 672 million people will still lack access to improved drinking water sources in 2015. As noted by Gleick (2002), even if the MDGs water target is achieved, as many as 76 million people will die between 2000 and 2020 of preventable water-related diseases. There is therefore a further risk of an increase in the number of people dying in the current slow progress towards the MDG targets in Sub-Saharan Africa.

1.2 Statement of the Problem

The JMP report (WHO and UNICEF 2010, p.34), 'Improved drinking water sources' includes sources that "by nature of their construction or through active intervention, are protected from outside contamination, particularly faecal matter." In this report, drinking water supplies can be broken down into three categories which are summarized in Table1.1.

Table 1.1: UNICEF/WHO drinking water supply sources

Piped into dwelling, plot or yard	Other improved	unimproved
・Piped household water connection located inside the user's dwelling, plot or yard	・Public taps ・Tube wells ・Boreholes ・Protected dug wells ・Protected springs ・Rainwater collection	・Unprotected dug well ・Unproteced spring ・Cart with small tank/drum ・Tanker truck ・Surface water (river, dam, lake, pond, stream, canal, irrigation channels) ・Bottled water

Source: WHO and UNICEF (2010)

'Piped' drinking water remains the dominant water source in urban areas and rural dwellers are more than twice as likely as urban dwellers to use 'other improved' sources of drinking water. As of 2008, an estimated 743 million of rural dwellers were without improved drinking water supplies globally, compared with 141 million of urban residents (WHO and UNICEF 2010).

Boreholes categorized as 'Other improved' sources defined by JMP (WHO and UNICEF 2010), have a generally better water quality than other point sources because they are sunk deeper into the ground and often have greater structural protection against contamination by the use of handpumps. Handpumps have become the principal technology for lifting water as nearly half of all rural Africa's protected water supplies, and consequently the handpumps, supply water to over 1 billion people in rural areas in at least 40 African countries (RWSN 2005). Thus, the provision of water supply using handpumps is the conventional *communal model* for rural communities by mostly subsidised means.

Despite the fact that communal water supply models have delivered significant amounts of safe water to community members and 40 varieties of handpump have been installed, more than half of specific designs of handpump, distributed over 250,000 units, are dysfunctional in Africa (RWSN 2005). From the research by Parry-Jones et al. (2001), it is clear that the low sustainability of communal models using handpumps results from many issues, but one of the principal causes is the lack of provision of spare parts for repair and maintenance. In fact, improved access to rural water supply in Sub-Saharan Africa has been progressing from 1990 to 2006 although it was 7% below the water coverage target in 2006 (WHO and UNICEF 2008)

Sutton (2008) assumes that this slow progress towards the MDG target results from the fact that rural water supply remains almost totally donor dependent. According to a study by the WHO (2008), the grant and loan aid commitment of bilateral and multilateral external support agencies to the sanitation and drinking water sectors amounted to US$6.4 billion in 2006. Recent costings, on the other hand, estimate that in order to attain the MDG target for new coverage of sanitation and drinking water, the required annual spending in developing countries is US$14.2 billion for sanitation and US$ 4.2 billion for drinking water (Hutton and Bartram 2008). In addition, the cost of maintaining existing water supply facilities was estimated at a further US$ 21.6 billion annually for sanitation and US$ 32.2 billion annually for drinking water. These required costs are obviously beyond the support capacity of donor organizations and governments, and typically 90-100% of the cost of communal water supply model is subsidized by the Government or support agencies. Consequently, there is a significant demand for finding the most cost-effective and sustainable strategies for a rural water supply model.

The areas being left behind in sustainable access to safe water can be found especially in sparsely populated rural areas (Sutton 2009b) in contrast with highly populated rural areas. It may derive from the fact that "potable water supplies will be more profitable to the water supply operator where population densities and incomes are higher, businesses are located, and communications are good which all lead to lower delivery costs and greater effective demand for water supplies" (Kleemeier 2010b, p.1). Communal water supply models, therefore, may be inadequate for such areas because the nature of the water supply model is communal and thus requires higher delivery costs or significant amounts of time and energy for the end-user in a sparsely populated rural area. In addition, availability of spare parts for the communal water supply, skilled persons for operation and maintenance and communal ownership are also obstacles for rural water supply sustainability.

Given the foregoing fact that communal water supply models are not sustainable everywhere, this sheds light on a different water supply model, namely "Self Supply". The concept of Self Supply is to deliver a water supply model at the household/community level which enables them to meet their demand incrementally by building blocks for a sustainable environment in which to access safe water. Although it is acknowledged that people living in any part of the world find water on a self-reliant basis if the public water supply model is non-existent or intermittent, the "Self Supply" is an approach to support a household's motivations and investment which already exist and/or encourage their self-reliant development in order to accelerate a sustainable safe water supply.

This approach is not a hardware subsidized model like the conventional communal one, rather it provides software service components. The Hardware in this study refers to the equipment for water supply whilst the Software in this thesis refers to the component of capacity building, education or training of involved stakeholders. The Self Supply model enables rural dwellers to improve traditional water sources, such as family hand dug wells or springs, from unprotected to protected condition step by step. Therefore, the technology selection of Self Supply depends on individual affordability with simple, local materials, and within the capacities of local artisans. Indeed, several African countries have carried out Self Supply projects and achieved some water supply improvement. In contrast with the communal model, the Self Supply model may fill the gap where people live in a sparsely populated rural area in that they can cover water supply at the grassroots (households) level. Further, vis a vis the conventional communal water supply, Self Supply may have the strong advantages of accessibility and ownership because a traditional water source is generally owned by a family member within their premises.

Nonetheless, to date there is no monitoring and systematic analysis of what impact these changes have made to rural water supplies and the livelihoods of rural dwellers. An individual household water supply may have significant positive impacts on their accessibility, ownership and acceptability in contrast with a communal water supply, yet these points were missing from the extant literature. Further, it may require specific efforts to achieve political acceptability by the decision makers in those African countries who have not yet considered Self Supply models as they relate mainly to poor water quality, unreliability, and high per capita cost (Sutton 2004c). In fact, Zambia is one of the countries that is implementing the project of Self Supply model by UNICEF, WaterAid and DAPP as a pilot model in Luapula Province in order to debate with the Zambian government as to whether or not the Self Supply model should become part of the national policy.

"There are policy issues that can be influenced by surveillance data by indicating where improvements to water supplies should be prioritized, what types of improvement should be implemented and what additional needs are required to support sustainability (Howard 2002, p.36).” Meanwhile, current information about water supply technologies does not allow us to establish a relationship between access to safe water and access to improved sources (WHO and UNICEF 2010, WHO and UNICEF 2004, United Nations 2009). The reports also noted that any correlation between them will be country specific and dependent on definitions of improved and unimproved water sources in each country.

Overall, notwithstanding the fact that household level water supply has been the subject of widespread activities in Africa, the Self Supply model has been slow to take off (Sutton 2009a). In other words, little assessment exists today of the relative merits of the communal water supply and Self Supply models in relation to water safety regarding quality and quantity, accessibility, sustainability, cost-effectiveness and acceptability. Sutton (2010c, 2010b) highlights that monitoring of water quality, user satisfaction, water use and purposes of use, social status and economic benefits is required to develop national policy.

1.3 Purpose of the Research

In the light of this debate, this research has the following purpose:

AIM: *To determine the most appropriate water supply model for safe, accessible, cost-effective, sustainable and acceptable water supplies for households in sparsely populated rural areas of Zambia*

The thesis is directed by the principal argument that:

Reliance only on a communal water supply model limits the achievement of increased sustainable access to a safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.

The principal argument stands against the background that conventional communal water supplies, which is the predominant model in the rural water supply strategy, do not fulfil all concepts of safety, accessibility, cost-effectiveness, sustainability and acceptability everywhere, especially in sparsely populated rural areas of developing countries. The communal model results in an undesirable environment for rural dwellers especially in sparsely populated areas because the communal model may create considerable distance from the households, a lack of spare parts and skilled persons and generate ambiguous ownership for O&M. Meanwhile, Self Supply may complete and bridge the gap which communal models cannot reach, although governments and donor organizations are sceptical that the Self Supply model is able to deliver a safe, accessible, cost-effective, sustainable and acceptable water supply. Therefore, this study addresses whether the Self Supply model can deliver water sources that are safe, accessible, cost-effective, sustainable and acceptable in comparison to the communal water supply model. The interpretation of technical and environmental sustainability being used in this study relates to scheme longevity and reliability and not to environmental damage, carbon use etc.

In sparsely populated rural areas, the communal model may constrain rural dwellers to going far away to fetch water and perhaps force them to carry back inadequate amounts of water to the settlement because of the location of the communal supply. Further, operation and maintenance may also face difficulties in sparsely populated rural areas since spare parts or skilled persons are not available locally everywhere. In fact, small communities, widely scattered households and remote areas are left behind from water supply or are found with inadequate water supplies (Sutton 2009b). On the other hand, the Self Supply model would be significantly suited to the grassroots (household) level water supply to complement the communal model without having to just wait for the subsidised physical infrastructure.

To recap, the concept of Self Supply is one in which an individual household or small groups take a decision to improve their traditional water source or hand dug well and put in their own investment. This enables them to fulfil their demand incrementally and build a sustainable environment in order to access safe water by improving their water source from an unprotected to a protected condition. This approach is not a hardware subsidized model like the communal model (e.g. borehole equipped with handpump), rather it supports the household motivations and their investment which already exists and/or encourages their self-reliance development by providing software components, such as private sector capacity development, technical advice, financial mechanism and policy change. Such traditional water source improvement through a

Self Supply model may give significant benefits for sustainable safe water supply in comparison with a communal water supply though to date there has been little monitoring or systematic analysis of what impact these changes have made. Thereby, this study explores the five main objectives presented below related to the water safety, accessibility, technical and environmental sustainability, cost-effectiveness and acceptability of different water supply models for both communal and Self Supply in order to increase the knowledge required to form a sustainable rural water supply strategy. Considering only two water supply models (communal water supply and Self Supply) in this study can be justified by the fact that the communal water supply model is the predominant approach in the rural water supply strategy and the Self Supply model is relatively new concept but has not been well researched (Moriarty and Verdemato 2010, Lockwood *et al.* 2010, Sutton 2010b). In the light of water supply types, the hand dug well (*Not Protected*, *Partially Protected* and *Protected*) is the main target of this study to investigate the improvement through a Self Supply model, whilst a borehole with handpump represents the facility of communal water supply (some subsidized hand dug wells with full lining are also in the category of communal water supply). The main objectives of this study are:

1) To assess intervention of water source protection and sanitary conditions to reduce microbiological water contamination, and to measure the change of water quality at source and the point of use
2) To look into the accessibility of water supply models in terms of distance and time, and find out how accessibility impacts on per capita water use of households
3) To measure the technical and environmental sustainability of water supply models, and to find out O&M systems that are likely to develop these sustainabilities
4) To measure the cost-effectiveness of water supply models from the viewpoint of household and government
5) To ascertain the user acceptability and preference with respect to water supply models

The research will embed a wide variety of issues including technical, managerial and financial as well as users' considerations pertinent to sustainability. Chapter 4 details further the objectives, principal argument and research questions governing this thesis.

1.4 Justification for Research

Over the last couple of decades, a significant amount of researches have been carried out on rural water supplies in developing countries. Many of these studies have demonstrated that the communal water supply models delivered a significant amount of safe water to community members. These studies have even identified the fact that the communal model is not sustainable everywhere, especially in sparsely populated rural areas, and the factors obstructing sustainability include a lack of spare parts, management system, private and public capacity and so forth. Despite their enormous contribution to the water sector, the extant studies concentrate on the subsidized communal water supply and capacity building, post construction support and/or management systems. In other words, very few studies have been done about household (private) level water supply and the approach of establishing water supply models at the household level. In this research a Self Supply model is looked into in-depth to explore how the model, through household level water source (hand dug well) improvements, impacts on water safety, accessibility, technical and environmental sustainability, cost-effectiveness and acceptability, compares with conventional ones. The selection of these five concepts is justified by extant literature for the assessment of sustainable rural water supply (Sutton 2009a, Sutton 2010c, Harvey and Reed 2004, Fonseca *et al.* 2010a, Skinner 2003, NRWSSP 2007). A field study was conducted in Luapula Province of northern Zambia in collaboration with UNICEF, WaterAid and Development Aid from People to People (DAPP) who are piloting a Self Supply project. This study is, however, not intended to limit the focus to the piloting project of Self Supply model in Zambia, but rather look at the Self Supply model as a case study of Zambia in order to take on the strengths and challenges of the Self Supply model for wider application.

Further, this study will contribute to knowledge generation and the development of policy. Firstly, the main expected outcome of this research will provide end users with practical information for selecting an appropriate water supply technology based on its affordability. Selection of water supply technology has been predominantly that of community based water supply so that individual acceptability or preference is often overlooked or ignored. Secondly, as for the government, NGOs/ external support agencies' side, this research will support them in evaluating the degree to which the Self Supply model can be a viable approach to assist and complement the communal model in improving water coverage at the micro level. Thirdly, at a macro level, the results will feed into the Ministry of Local Government and Housing in Zambia grounds for debating whether Self Supply has a role to play in the National Rural Water Supply and Sanitation Programme (NRWSSP 2006-2015). In addition, such knowledge and the development of policy would guide the development of the JMP water coverage definition.

1.5 Methodology

The standpoint of this research was pragmatic. Using a mixed method of both quantitative and qualitative approach was justified as an appropriate design for a pragmatic paradigm (Denzin and Lincoln 2005). While data collection in Zambia was a five phase approach, concurrent triangulation strategy was addressed as a means to offset the weakness inherent within one method against the strengths of the other (Creswell 2009). The first phase of the data collection was the preliminary study in order to select study sites for the main study in parallel with testing the research methodologies. Categorization of water supply sources was also administered in the first phase. In the second phase, a technical field survey was done to collect data associated with the technical sustainability of water supply sources, whilst data for water quality and sanitary condition were tested by environmental investigation in the field. A household survey, in terms of accessibility, acceptability and water quality at households, was implemented as a source of quantitative data in the third phase.

Financial data collection for cost effectiveness was also addressed in the third phase through looking at the management records and document analyses. Focus group discussion was used in the fourth phase as a qualitative measure in order to test cross-validation of quantitative data from the household survey, and further explain and interpret the quantitative results. Key informant interview emerged as the fifth phase in contrast with the first to fourth phases in that the points of view from macro (government/ external support agencies) interest was underscored to capture their perception and attitude towards different water supply models for policy development; previous phases had highlighted micro viewpoints. Justification of the methodologies and details of the entire research design was discussed in Chapter 4.

1.6 Outline of Thesis

Chapter 1 introduces the subject, the scope and aims of the study. Chapter 2 presents the background information on Zambia and the status of water supply in study sites. Chapter 3 details a review of the background literature. The objective of the literature review is to provide insight on the current studies and areas of empirical weakness with regard to sustainable rural water supply. The chapter concludes with a summary of the knowledge gap which the research seeks to address. Chapter 4 presents the methodology, research questions, objectives, design and methods in collecting relevant field data, as well as an overview of the data analysis techniques used. Chapter 5 presents the study findings and data analysis whilst Discussion of findings and further implications are looked into in Chapter 6. Conclusions and recommendations are summarized in Chapter 7. Each Chapter begins with an outline of the contents and concludes with a short summary of key points.

1.7 Definition of Key Terms Used

The following key terms used in this study are defined below in order to clearly establish the positions taken in this research:

- Sparsely populated rural area: For the purpose of this study, a *sparsely populated rural area* is a settlement where population density is very small either because the population in a community is very small or the community is very scattered. The area where population density is lower than 20 persons/km^2 is referred to a sparsely populated area in this study.

- Well: For the purpose of this study, a *well* is a hand dug excavation in the ground by either skilled artisans/well diggers or non-trained persons, rather than using a machine, in order to draw groundwater. All protection categories of hand dug well (*Protected*, *Partially Protected* and *Not Protected*) are referred to in Chapter 5.2. The well is used to extract relatively shallow groundwater i.e. from less than 20m below ground level.

- Borehole: For the purpose of this study, a *borehole* is a narrow shaft bored into the ground by drilling a machine which is generally equipped with a casing pipe for preventing it from collapse and contamination. The *borehole* is usually equipped with a handpump facility in order to draw groundwater.

- Communal water supply model: For the purpose of this study, a *communal water* *supply model* is a water supply model largely subsidized (more than 85% of capital costs) by government, NGOs or external support agencies and managed by the community. Small piped supply system, borehole/well and handpump, or lined well with windlass, are the types of water supply in communal water supply.

- Self Supply model: For the purpose of this study, a *Self Supply model* is an approach to provide support to households/communities to complement their efforts and accelerate sustainable access to safe water incrementally through traditional water source (hand dug well) improvement. The support could be through building blocks for a sustainable environment by software components provision (technical advice, private sector capacity building, financial mechanism and policy development) rather than subsidizing physical infrastructure. Thereby, an individual household or small group takes a decision to improve their traditional water source (hand dug well) from an unprotected to protected condition, by putting in their own investment. In other words, "the *Self Supply model* encourages step by step improvement of private and small group owned traditional water sources using the beneficiaries' own investment" (Mukonge *et al*. 2010).

1.8 Delimitation of Scope of Research

This research addressed sustainable rural water supply strategy by comparing the different water supply models of the communal and Self Supply models within the five key concepts of: water safety; accessibility; technical and environmental sustainability; cost-effectiveness; and acceptability. However, a number of boundaries were deliberately imposed so as to keep the research within manageable limits. Firstly, this research looked into water usage for human consumption and hygiene purposes predominantly rather than water disposal. Although it is acknowledged that water disposal is part of hydrological cycle, the practice is generally categorised as a drainage and sanitation process (Addo-Yobo 2005). Secondly, this study looked at the Self Supply model in comparison with the communal water supply model. However, the study was based exclusively on research in Zambia so that it may not have captured the overall Self Supply model, but rather may be country-specific, although implications of the findings beyond these boundaries were drawn in the Discussion and Implication chapter. Moreover, this study was limited to rural water supply models that were managed by communities because private or public institutions for O&M were either non-existent or failures in many rural areas in Zambia. Other limitations that emerged during the process of this study are acknowledged in the Conclusion chapter.

1.9 Chapter Summary

To ensure environmental sustainability by 2015, sustainable rural water supply is a key component, especially in the region of Sub-Saharan Africa. However, despite all the efforts by governments and donor organizations, the global water challenge is still enormous, and slow progress towards the MDG targets has resulted in a significant adverse health impact. The provision of water supply based on technology strategies might lead to a slowing down in the supply improvement and mislead the stakeholders involved.

Even though the communal water supply model is prevalent, dependence on the communal model is not sustainable in rural areas because it is beyond the technological capacities of local management bodies, and consequently successful operation and management requires outside assistance when breakdown occurs. Further, the areas being left behind in sustainable access to safe water can be found in sparsely populated rural areas, and these are unlikely to be covered by the communal model. Meanwhile, perhaps a Self Supply model can fill such a gap since it is an approach of delivering a water supply model to household/small group level to complement their efforts and accelerate sustainable access to safe water by enabling an environment with software component support rather than by subsidizing physical infrastructure. Therefore, the technology selection of Self Supply depends on individual affordability with simple, local materials, and within the capacities of local artisans. Policymakers, however, often remain an obstacle, as they view the Self Supply model as inferior to the provision of conventional communal or technical solutions because there is a limitation of practical achievements.

Even though the idea of Self Supply clearly has the potential to spread, complement and speed up water supply improvement without just waiting for subsidized support, there is little empirical research on the monitoring of water quality, user satisfaction, water use and purposes of use, and impacts on social status and economic benefits. Further, less is known about its sustainability and linkage with the communal supply model. The focus of this research therefore is to investigate the most appropriate water supply models for safe, accessible, sustainable, cost-effective and acceptable water supplies in a sparsely populated rural area of Zambia. Assessment of the relative merits of the communal and Self Supply models and their symbiosis or separate use will provide significant guidelines for a rural water supply strategy. In this regard, carrying through a detailed piece of independent research seeking for the relative merits of different types of water supply model and different levels of protection would contribute to the development of a cornerstone in the determination of safe, accessible, sustainable, cost-effective and acceptable strategies for rural water supply which will achieve the MDG targets.

Chapter 2 THE STUDY AREA

2.1 Chapter outline

Prior to the literature review, pertinent general background information is presented on Zambia, and both the status of water supply and existing rural water supply models which are the focus areas of this study. More details of the methodological reasons for the study location will be given in Chapter 4.5.4.

2.2 Background to the Study Area

Zambia is an inland state located in southern Africa, surrounded by eight countries. The average precipitation in Zambia is from 1,200mm in the North to 600mm in the South (FAO 2010). Zambia has a total population of 12 million (CIA 2009) and more than 65% of the population, estimated at 8 million in 2005, lives in sparsely populated rural area with an average rural population density of around 10 persons/km^2 compared with the rural population density in other African countries, such as 140 persons/km^2 in Uganda, 67 persons/km^2 in Ethiopia and 7 persons/km^2 in Mali (Sutton 2011). The rural dwellers have low access to basic facilities including schools, health clinics, transport, safe water supply and sanitation.

In 2006, 67% of rural populations were unable to meet basic minimum food requirements based on a monthly cost of the food market (UNDP 2008). "Rain-fed agriculture is the main income for rural dwellers, and often their settlements are vulnerable to drought and floods, especially in the rainy season" (Sutton 2010c).

2.2.1 Status of Rural Water Supply

Water supply coverage in rural Zambia in 2008 was 46% which was double that of 23% in 1990 (WHO and UNICEF 2010). The country has ambitious plans to achieve 75% coverage rates by 2015 alongside UN Millennium Development Goals (MDGs) target, which translates to increasing access to safe water for at least five million people between 2006 and 2015. The Government of Zambia through the Ministry of Local Government and Housing (MLGH) developed the National Rural Water Supply and Sanitation Programme (NRWSSP) in order to address the MDGs target for water and sanitation. Luapula Province, located in northern Zambia has the lowest water supply coverage in Zambia at just 37% whilst they have the highest availability of surface and groundwater at a shallow depth (Zulu Burrow 2008). In fact, "over 40% of rural dwellers have their own traditional hand dug well, especially in the areas of the North-western, Western, Northern and Luapula provinces although conventional subsidised communal boreholes account for only 13% of all water supplies." (Sutton 2007, p.3) Luapula Province is divided into seven districts (Chiengi, Kawambwa, Mansa, Milenge, Mwense, Nchelenge and Samfya). Selected Districts, Milenge and Nchelenge, are described in further detail below.

Fig. 2.1: **Map of Republic of Zambia**
Source: World Travels (2011)

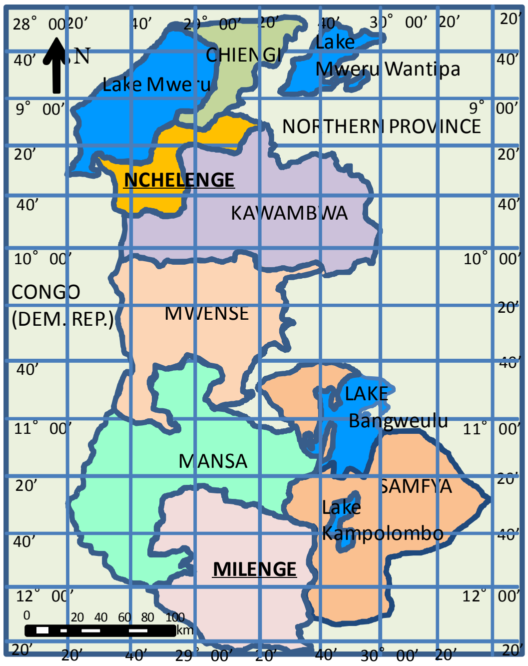


Fig. 2.2: **Map of Luapula Province**
(*Source: Author*)

1) Milenge District

Milenge District had a population of 32,651 people in 2000 (CSO 2006) with a population density of approximately 5.9/km^2. The District has three distinct seasons. Cool-dry, which occurs between April and July; hot-dry, which occurs between August and October and Hot-wet season which occurs between November and March. Most of the employed people in the District are employed in the civil service whilst the rest of the community members are mostly engaged in subsistence farming. Less than 4% of the communities in the District have access to safe and clean water through the use of handpumps as there is also a river and some surface water (Zulu Burrow 2008). The district is relatively new and two new persons had just been allocated as Water, Sanitation and Hygiene (WASH) officers in the council at the time of the preliminary study in August 2009.

2) Nchelenge District

With an annual growth rate of 4.6%, the projected total population for the year 2008 was 148,671 for Nchelenge District with a population density of approximately 15.1 persons/km^2. Nchelenge district has a tropical climate with a rainy season starting in November which is followed by a dry season beginning in April. The population is mostly concentrated along the shores of Lake Mweru and Luapula River as fishing is the main economic activity, while agriculture is mainly done for subsistence. It is believed that Lake Mweru is the source of much of the Cholera epidemic. Many refugees from the Democratic Republic of Congo are found in the district but most of them are just transiting as the Kala refugee camp is located in Kawambwa District on the East side of Nchelenge (Madavine 2008).

2.2.2 Water Supply Models in the Study Area

The Department of Water Affairs under the Ministry of Energy and Water Development has been drilling boreholes equipped with handpumps and constructing communal wells as the giveaway model. Although there is less donor activity around the conventional means for communal water supply in the sector for Luapula, a number of borehole water supply facilities equipped with handpumps have been constructed by the Japan International Cooperation Agency (JICA) during 2008-2010. JICA has three components in its project which are water supply, capacity development and operation and maintenance.

- Water supply is mainly centred on the construction of boreholes equipped with handpumps free of charge
- Capacity development is centred on training community members so that they can manage their water and sanitation matters
- Under Operation and Maintenance, communities have been empowered with tools to enable them to operate minor maintenance in order to run their facilities.

As for further water sector activity in Luapula Province, World Vision Zambia has also been operating water and sanitation programmes in Luapula Province. Those are:

- Water supply: prominence is given to the construction of new facilities such as boreholes equipped with handpumps and protected wells equipped with windlasses in villages and public institutions such as schools and rural health centres.
- Sanitation: mainly focuses on the construction of VIP and San Plat toilets in schools.
- Capacity Development: community members are trained and sensitised on various issues in the management of water and sanitation sub-sector such as training village water, sanitation and health education committees (V-WASHE committees).
- Operation and Maintenance: mainly focuses on the provision of tools and spare parts to enable communities to run and repair the facilities.

In contrast with the above communal water supply models, a project using the Self Supply model has been implemented as a pilot project in three Districts, namely Milenge, Nchelenge and Chiengi in Luapula Province since 2008 in order to accelerate water coverage for achieving the MDG water targets alongside communal water supply model provision under the NRWSSP. In Zambia, Self Supply is defined as the "step by step improvement of private and communally owned traditional water source using the beneficiaries' own investment" (Mukonge *et al.* 2010, p.45) which aligns with the concept of Self Supply (see Chapter 3.4). In particular, four components of Self Supply are established: those of creating awareness of the Self Supply concept by sensitisation of multiple stakeholders, private sector capacity building, technology advice and financial mechanism. A step ladder of water source improvement by using a Self Supply model has the scope to increase the scale as people are able to copy from neighbours, do things in affordable steps, and reach further up the ladder.

In partnership with UNICEF, local government, WaterAid and Development Aid from People to People (DAPP) have implemented the Self Supply model in Luapula Province. WaterAid has been working in four Wards (Chiswishi, Mulumbi, Itemba and Milambo) in the western part of the Milenge District with one full-time officer since 2008. One field officer has been deployed from Milenge District Council to take partnership with WaterAid since August 2009. On the other hand, DAPP covers two districts, Nchelenge and Chiengi in Luapula province. In Nchelenge, 20 villages are targeted for piloting Self Supply. DAPP has one coordinator in both Nchelenge and Chiengi whilst nine Area Leaders are allocated for each ward in the two districts. Table 2.1 below adapted from Mukonge *et al.* (2010) sets out the process which has been followed by two different organisations implementing the Self Supply model in Zambia.

Table 2.1: Self Supply model in Zambia

Year	Milenge District (WaterAid Zambia)	Nchelenge District (DAPP)
	PROJECT SET UP	
1st	Introducing project to Full Council	District Stakeholders meeting
	District Stakeholder meetings (orientation of District level staff and selecting the project areas	Sensitisation meetings in Ward (Self Supply & Hygiene promotion)
	Meeting with Senior Chief to introduce the project and seek permission to operate in the Chiefdom	Community Dialogue meeting (Self Supply & Hygiene promotion)
	Orientation meetings at sub-District level	Situation Analysis
	Baseline Survey	Preliminary water quality monitoring
	CREATE AWARENESS FOR SELF SUPPLY	
1st	Community Sensitisation	Identification of demonstration water points
	Social marketing (Demo plot, identification of champions of self supply, talking walls, community fairs, distribution of IEC materials to advertise availability of skilled labour, technological options and services)	Formed Artisans' Associations
	PRIVATE SECTOR CAPACITY BUILDING/ TECHNICAl ADVICE	
2nd and 3rd	Capacity Building (roles & responsibilities, water source improvements, hygiene promotion, water quality monitoring and basic financial management	Training of Area Community Organisers (ACOs)
	Identification and engagement of Suppliers: a. Mansa Traders Skills' Training Institute-skills development & Rope pump production, b. Two Metal fabricators (Windlass, buckets, well mouth cover, ropes) c. Local traders i.e. shop owners	Training of Artisans (Masons, pump menders, blacksmiths & Rope pump producers) No comprehensive well improvement training
	Water Source improvements	Upgrading of wells
	Hygiene promotion	Rope pump production & selling
	Water quality monitoring (pre improvement)	Social marketing (Rope pump)
	FINANCIAL MECHANISM SET UP	
End of 2nd and 3rd	Setting up of the revolving fund (Key stakeholder meeting, consultancy procurement, signing of MOU, development of procurement plan, disbursement of grant to Loan Scheme committee, disbursement of loans to shop owners and HDW owners/households	Established revolving fund for rope pump loans
	Exchange Visit	Project Monitoring
	Project Monitoring with LA & WAZ Staff	Exchange Visit
	POLICY DEVELOPMENT	
3rd	Documentation of the approach	
	Evaluation of Self Supply Pilot	
	Dialogue process with Government to adopt Self Supply as a rural water supply strategy in Zambia	

Source: Mukonge et al. (2010)

PROJECT SET UP

The idea of the Self Supply model was introduced to various stakeholders in the first stages because the concept of Self Supply is totally different from the communal model which is predominant in the water sector. The District Water, Sanitation and Health Education Committee (D-WASHE) and District council members worked out what could be achieved by partner organisations (WaterAid and DAPP) and made budget estimates for UNICEF (Sutton 2010c) because UNICEF Zambia has been initiating the pilot project of Self Supply model taking partnership with WaterAid and DAPP since end of 2007. The implementing organisations (WaterAid and DAPP) have conducted baseline surveys to understand the status of water supply and to assess the feasibility of the Self Supply model.

CREATE AWARENESS FOR SELF SUPPLY

The second stage of the piloting approach was for creating awareness in the multiple stakeholders; political leaders, traditional leaders, civil servants and community based organisations. This resulted in an increased level of information, knowledge and skills in the Self Supply model leading to communities having a clear understanding and project acceptability. The approach put great importance on enabling a sustainable environment based on creating awareness of the Self Supply by any means of social marketing and knowledge sharing to develop selection criteria for priority areas. Further detail of social marketing is discussed in Chapter 6.8.

PRIVATE SECTOR CAPACITY BUILDING/ TECHNICAL ADVICE

Strengthening local artisan participation is one of the crucial components of the Self Supply model in order to enable a sustainable environment to be created for rural water supply. Even if the external support agency leaves the project site, rural dwellers can sustain and act on their desire for improving their water sources where local private sectors are strongly involved in rural water supply. This stage was approached in slightly different ways by the two NGOs.

✓ WaterAid

WaterAid have put their emphasis on the capacity development of local artisans. In the first year, 16 artisans were trained both in theoretical and practical learning for well protection, ring making, basic metal fabrication and laying bricks. In the second year, an additional eight artisans were trained and they have been working as a team of six artisans in each of the four Wards in Milenge. Meanwhile, WaterAid also worked with village level committees including Neighbourhood Health Committees (NHC), Area Development Committees (ADC) and Village-WASHE to encourage their support for well-owners and artisans. Milenge District council have deployed one field officer related to water and sanitation in Milenge to take partnership with WaterAid. In addition, WaterAid encourages local traders/shop outlets participation into the Self Supply model in order to build a sustainable supply chain. Milenge District has been facing severe shortage in basic services, such as electricity, mobile-phone reception, transportation, shops and so forth. The involvement of local traders/shop outlets has enabled well owners and artisans to find materials for water source improvement, rather than having to travell to town (Mansa District) which is located over 70km away. Currently two local traders in Milenge have agreed with the Self Supply concept and stock the material for water source improvement using revolving loans to fund the procurement (explained below).

✓ DAPP

In contrast with the WaterAid approach, DAPP has addressed capacity development of Area Community Organisers (ACOs) first. The ACOs were originally involved in the DAPP programme with respect to training and promotion of sanitation, maternal and child health, and then assigned to lead the Self Supply model with their own focal villages (average 20 villages) in their Wards. Their Self Supply model is to encourage rural dwellers to improve their own water sources by simple improvement using local materials in parallel with behaviour change, rather than improvement by skilled artisans. ACOs also set up Village Action Groups (VAGs) who act as house to house promoters of water source improvement and hygiene practice, and encourage model households. In the third year of the project, DAPP has started training local artisans to accelerate water source improvement. Furthermore, they have devoted efforts to the establishment of ropepump production in Nchelenge as a new technology for water supply. DAPP has also trained local artisans at the middle of the third year which was not addressed in detail in this research.

FINANCIAL MECHANISM SET UP

To accelerate water source improvement, WaterAid has established a revolving loan fund at the end of the second year of the project in Milenge. The revolving loan fund enables well owners to improve their water sources even when they may not be able to meet the costs of improvement, particular, for example, before the harvest season.

WaterAid set up a consultant to design a revolving loan fund and train loan management committees consisting of Artisans, NHC, ADC and V-WASHE). Chapter 5.8 discusses further detail of a revolving loan fund. DAPP has also followed the establishment of a revolving loan fund in the middle of the third year which was not captured in this study.

POLICY DEVELOPMENT

The Self Supply model has not been accepted into the national policy by the Zambian government due to the uncertainties as to whether the model can achieve safe and sustainable water. As for the donor side, practical evidence and results of traditional water supply source improvement are necessary to support them for evaluating the degree to which a Self Supply model can assist in improving water coverage. In addition, grounds for debating whether Self Supply has a role to play in the National Rural Water Supply and Sanitation Programme (NRWSSP 2006-2015) must feed into the Ministry of Local Government and Housing in Zambia.

2.3 Chapter summary

This chapter reviewed the background of the study area and the status of rural water supply in Luapula Province of Zambia. Two different water supply models were operational in the study area: those were communal water supply by the government, JICA and World Vision Zambia, and a Self Supply model by WaterAid and DAPP in partnership with UNICEF. Table 2.2 shows a brief summary of two different water supply models.

Table 2.2: **Rural water supply models in the study area**

Communal water supply	Self Supply
Construction of subsidised communal boreholes equipped with handpump and/or communal lined well with windlass	Create awareness of Self Supply
Community capacity development for minor O&M	Private sector capacity development/ Technical advice
Provision of tools for operation and minor maintenance	Financial mechanism set up
	Policy development

(*Source: Author*)

Chapter 3 LITERATURE REVIEW

3.1 Chapter Outline

Chapters 1 and 2 provided an introduction to the scope of the research and the background of the study area. This chapter considers the conceptual and theoretical foundation for the research by focusing on a review of relevant literature in order to identify the key research gaps associated with sustainable rural water supplies. As outlined in Chapter1, the aim of this study is to determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective and acceptable water supplies for households in sparsely populated rural areas of Zambia.

This thesis bases its research on the premise that by comparison with urban area water supply, rural water supply makes crucially slower progress as noted in Chapter 1. This research, therefore, addresses the issues related to rural water supplies, especially in sparsely populated rural areas, and many of those issues explored may not be appropriate for urban areas. Since water supply sustainability interacts with many factors such as technology, finance, planning and socio-economic factors, the study of sustainable rural water supply strategy cannot be achieved by focusing on one or two of these aspects independently. It is significant, therefore, that it is reviewed and analyzed with a holistic approach. The purpose of this research is to complement the rural water supply strategy by providing crucial informed choices for appropriate water supply models. The literature review is therefore organized around the dimensions of models of sustainable rural water supply provision consisting of:

- Social issues
- Technical and environmental aspects
- Financial and economic issues

Social aspects cover those domains that impact on the selection of source types and the sustainability of the rural water supply models. Special attention is given to the Self Supply model since this approach is evolving as a result of the slow progress from communal models in developing countries. The remaining sections analyze the literature on the key issues dealing with the technical and financial domains which impact on the sustainability of the water supply strategy. The chapter concludes with an appreciation of the areas of theoretical and empirical weakness identified from the review.

3.2 Literature Review Methodology

The necessity for research into safe water supply in rural Africa has been realized for a few decades. As noted in Chapter1, there is an increasing recognition of the importance of assuring "safe" drinking water, based on a range of multiple different types of supply technology (Sutton 2008). It is recommended by Sutton (2008, p.1) that "broadening water supply options to include progressively improved household access and water treatment may increase rates of progress towards the MDG target, as well as cost-effectiveness, and may also improve the lot of many more consumers without jeopardizing water quality." The sources for the literature review were collected from internationally accessible academic journals, articles and reports, relevant literature and books in the Loughborough University Library, the WEDC Resource centre and Cranfield University Library on the subject of sustainable water supply models in rural Africa.

3.3 Transition of Rural Water Model

Water is absolutely essential for all living organisms on this earth. Demand for safe water access increases continually alongside the world population explosion. People in many areas of the world lack the fresh, drinkable water essential for survival. Not everywhere can we access surface water so groundwater becomes the vital fresh water for a number of people in the world. Groundwater comprises 0.6% of the world's water, which is 67 times as much as the 0.009% in lakes and streams (Kiad 1981). The rest of the world's water is in glaciers and ice caps (2%) or is salty water in oceans (97%). In many areas most drinking water is therefore groundwater- up to 80% in Asia, Europe and Russia, and even more in North Africa and the Middle East (planetearth 2005). Maintaining secure water supplies for drinking, industry and agriculture would be impossible without groundwater, the largest and most reliable of all fresh water resources (planetearth 2005), and has proved the most reliable resource for meeting rural water demand in sub-Saharan Africa (Macdonald and Davis 2000).

As noted in Chapter 1, following the water supply crisis and the effort made to address this international issue, a sustainable water supply model is sought for achieving the

MDGs water target achievement. When selecting technology for sustainable water supplies, during the 1980s, donors began focusing their efforts on handpumps due to the belief in their low cost and ease of operation and maintenance, and the availability of shallow groundwater resources beneath much of Africa and Asia (Arlosoroff *et al.* 1987). Handpumps installed in the wells and boreholes were therefore the principal rural water supply option in many developing countries. Thus, the provision of a water supply using handpumps is the conventional communal model for rural communities from mostly subsidised means. In fact, over 1 billion rural dwellers in at least 40 developing countries have become beneficiaries of handpumps to lift groundwater in the past two decades (RWSN 2005).

However, Morgan and Chimbunde (1997) highlighted the overwhelming evidence that, for the more remote areas of Africa, where the poorly developed infrastructure and the capacity of the recipients to manage their own supplies is limited, an alternative approach must be sought. Indeed, there are approximately 250,000 handpumps in Africa but less than half of them are operational (RWSN 2005). According to the studies by Harvey and Reed (2003), achievement of the MDG target will be hard in rural Africa due to the low levels of existing coverage, unless sustainability levels can be improved.

"The lessons learned from two decades of experience with participatory approaches, decentralization, cost sharing and technological adaptation mean that donors, NGOs and national governments have all the evidence they need to show that demand-driven community-led approaches deliver better results than the supply-driven government-led models that prevailed up to the 1980s (Lockwood 2004, p.1)." The shift from supply-driven water supply interventions to programmes rooted in demand is easily understood. In general, supply-driven interventions have not succeeded in providing poor communities with sustainable water supplies (Breslin 2003). The demand-driven approach implies that communities must take responsibility for the actions (O&M) and decisions that will link with their lives.

While technology does not affect sustainability exclusively, it can have a major impact, especially on ongoing operation and maintenance needs (Harvey and Reed 2004). As there is no permanent water supply technology, operation and management is essential for sustainable water supply. According to the studies by Harvey and Reed (2004), the different maintenance models can be divided into the following three categories:

- **Village Level Operation and Maintenance (VLOM)** is the predominant approach used at present and refers to maintenance systems which are managed by the user community.

- **Public-Private Operation and Maintenance (PPOM)** refers to situations where a private sector organization is responsible for managing and delivering maintenance models, regulated by the government.
- **Private Ownership, Operation and Maintenance (POOM)** refers to situations where the water supply facility is owned and maintained by a private organization or individual.

Table 3.1 describes the key advantages and challenges of each category of maintenance system.

Table 3.1: Advantage and disadvantages of different maintenance options

Option	Advantages	Disadvantages
VLOM	Fast initial response Community control Community pride	Needs motivation Needs local skills/tools Access to spare parts
PPOM	Access to spare parts Skills/resources provided Community choice	Higher cost Slower response times Active regulation required
POOM	Access to spare parts Clear ownership/responsibility Skills/resources provided incentive for paid repair	High initial cost to owner

Source: (Fisher 2005)

"Although over the last two decades or so it is the community-based management model that has emerged as the leading paradigm for providing water to rural communities, by and large this approach failed to achieve the ultimate goal of reliable and sustainable water supply at scale" (Lockwood *et al.* 2010, p.4).It has not delivered anticipated levels of sustainability because of the lack of skill, motivation and spare parts. New and innovative maintenance systems are required, especially those that encourage indigenous private sector participation; however there is a lack of incentives for the private sector or others to assist with O&M and the supply of spare parts (Harvey and Reed 2004).

A significant number of rural water supply models and experiences were discussed and shared in the International Symposium on Rural Water Models "Providing Sustainable Water Models at Scale" in Uganda in 2010. These included examples from countries as diverse as El Salvador (The Circuit Rider Model), Nicaragua (Municipal UNOM Promotors), Honduras (the Technician in Operation and Maintenance or TOMs) and Senegal (urban water utilities supplying rural communities) and so forth (Lockwood *et* *al.* 2010, Kayser *et al.* 2010, Rivera 2010). These typically started by looking at what needs to be done to support and maintain water supplies in the post construction period, addressing not only technical tasks, but also administrative, legal, training and other 'software' needs (Lockwood *et al.* 2010). Therefore, in the conclusions of the symposium, community management is likely to be at the heart of what the sector does and how it works (Moriarty and Verdemato 2010, p.8), and they highlighted that "community management needs a 'plus': an additional supporting framework of legal provisions, technical and financial backstopping, and proper regulation and oversight that will allow it to emerge as a fully fledged model for service delivery."

In other words, they retained their attention within the community management water supply model or transformative (plus software) model; in either case, the models are conventionally mostly subsidised for both hard and soft components. This tendency can be seen in Table 3.1 that established different maintenance options standing within the domain of communal water supply. In fact, Sutton (2010d) pointed out that most of extant studies in the water sector on costs, designs, management structures, efficiency and sustainability of water supplies are all for communal supplies. The communal water supply model referred to in this study, thereby, is largely the water supply model subsidized by government, NGOs or external support agencies (more than 85%) and managed by the community. Small piped supply, borehole/well and handpump, or lined with windlass are the types of water supply found in the communal model.

The sustainable action needed in a given case depends on the extent to which the availability of water resources adequately meets the health, poverty, and environmental sustainability objectives of the MDGs (WWC 2008). In the studies of the demand responsive approach in Mozambique, Breslin (2003) underscored the fact that the technology choice is important, and O&M has greatly worked out when communities have been allowed to select a technology which they believe is within their capacity to sustain. Meanwhile, the communal water supply model has all too often taken the form of a top down approach, where the implementing organization prescribes certain standard levels of technologies and management structures for water supplies, without the full participation of the community in finding out what they want, and how they can sustain the source. It was also emphasized by Deverill *et al.* (2002) that an innovative change is necessary for water supply and sanitation strategy to improve the use and sustainability of the water supplies provided by reflecting the user demand.

Rarely is emphasis placed on a water supply model for the individual household. In contrast to these community models, there is a different water supply model, called "Self Supply", which is gradually developing especially in sub-Saharan Africa. The concept of Self Supply is to deliver a water supply model at household or small group level to enable households to fulfil their demand incrementally by building blocks for a sustainable environment. The approach encourages households to improve their traditional water sources within their own capacities. The next section will therefore detail the concept of Self Supply models by the use of some country case studies.

3.4 The Self Supply Concept

Self Supply is an approach to encourage individuals, households or small groups to incrementally improve their own water supply through their own investment without just waiting for give-away hardware assistance from government or NGOs. In order to complement and accelerate households' efforts of water supply on a self-help basis, the Self Supply model is enabled through: 1) Technology/technical advice, 2) Financial market mechanisms, 3) Private sector capacity and 4) Enabling policy by the government or support agencies (Sutton 2009a). The Self Supply approach enables rural dwellers to improve their traditional water source, such as a family hand dug well or spring, from an unprotected to a protected condition step by step.

Therefore, the technology selection of Self Supply depends on individual affordability with simple, local materials, and within the capacities of local tradesmen. In this regard, the individuals, households or groups provide most of the investment cost of the water source. This implies strong ownership but also the sharing of the water sources with nearby households, usually at no charge (Zulu Burrow 2008). Although Carter (2006) refers to 'Self Supply' model as internally driven, self initiated, fully participatory, and responsive to social and economic realities, this study defines Self Supply an approach to provide support to households to complement and accelerate households' efforts to improve traditional water sources using households' investment. It is acknowledged that people living in any part of the world find water on a 'self-reliant' basis if public water supply is non-existent or intermittent, but the "Self Supply" approach is to support their self-reliant supply through software component development.

Sutton (2009b) describes areas where water supply inadequacies are likely to be found at present:

a) *Small communities (less than 200 people), widely scattered households and remote areas where access to maintenance model and spares is difficult*
b) *Communities with weak and/or fragmented management*
c) *Area where potable ground and surface water are lacking*
d) *Zones within larger communities which are peripheral to communal supplies and with closer access to household ones*
e) *Households which cannot afford to pay water tariffs*

These areas are also justified by a World Bank report that "*as a rule of thumb, one assumes that potable water supply will be more profitable where population densities and incomes are higher, businesses are located, and communications are good which lead to lower delivery costs and greater effective demand for water models, and these factors also correlate with settlement size*" (Kleemeier 2010b, p.1). Therefore, rural dwellers who live in areas a) ~ e) above tend to be ignored in rural water supply strategy because communal water supply models are unlikely to fulfil lower delivery costs and greater effective demand for water supplies. Therefore, the Self Supply model has great potential for filling those gaps that are unlikely to be covered by the communal models. The Self Supply model can adopt numerous strategies not only for small groups and communities but also for individual households based on their demand and affordability to access safe water.

Self Supply does not have one model of well for people to replicate and does not grant subsidies of any sort in the case of Zambia. The role of the organizations involved in the programme is simply to facilitate and mobilise community awareness towards water source improvement that needs to occur in order to increase the water quality of the traditional water supplies. According to the study by Sutton (2009a, p.839), "some engineers feel that the concept may have something to offer and want to look further into it, while others feel it is a retrograde step which offers no technical challenge and imperfect solutions". A desk study by Sutton (2004b) examined the potential for Self Supply in sub-Saharan Africa. Overall the study concluded that the potential for promoting and supporting Self Supply was likely to be significant in Cote d'lvoire, Benin, the Democratic Republic of Congo, Liberia, Mali, Nigeria, Sierra Leone, Zambia and parts of Chad, Malawi, Mozambique, Tanzania and Uganda.

The concept of Self Supply is not an approach to replace the communal model, but rather to try to complement the communal ones taken by governments, NGOs and donors. The communal water supply models rely heavily on the provision of material and labour by external organizations and do not focus on building up the existing capacities of the communities. In the demand responsive approach used in Mozambique, Breslin (2003, p.9) noted that "the conventional communal approach has all too often taken the form of a top-down approach, where the implementing organization prescribes certain standards levels of technologies and management structures for water sources, without the full participation of the community in finding out what they want, and how they can sustain the source."

Although Self Supply is a relatively new concept and model in Sub-Saharan Africa (Joel 2009), in the early 1990s, an accelerated programme to support the improvement of family wells was undertaken, initially in Zimbabwe. A study by Sutton (2009a) notes the steps towards Self Supply scaling up as below.

- Potential- scope, demand, physical suitability, links and possible conflicts with government policy
- Piloting- testing out and demonstrating possible solutions, monitoring impact and user satisfaction/lessons learnt
- Package- developing models relevant to geographic, socio-economic and political conditions
- Policy and plans- integration of Self Supply into policies and plans for scaling up
- Promotion/partnerships- a continuous advocacy and communications process with government, donors and NGOs to encourage assessment of relevance and effects on policies, budgets and plans.

Projects to strengthen relevant Self Supply have been carried out in Ethiopia, Zimbabwe, Zambia, Mozambique, South Africa, Uganda and Mali, although instances of supported Self Supply model are relatively few in number. In fact, none of the case studies below operated non-hardware subsidy for traditional water source improvement, but rather they conducted upgrading the water source as a demonstration to look at the future potential for Self Supply model. The studies from Zimbabwe, Uganda, Mali, Ethiopia and Zambia are briefly reviewed in the next section.

3.4.1 Self Supply in Zimbabwe

One of the longest lasting water supply projects on a self help basis was in Zimbabwe which started in the 1940s where hand dug wells were lined with rocks, had a backfill of clay, a raised head wall and were covered with wooden logs (Morgan and Chimbunde 1996). In the late 1970s and mid 1980s tens of thousands of families were using hand dug wells for their water supply. However, hand dug wells were not recognized by the government as the government focused on providing water at community level in order to serve a large number of people (WSP 2002). During this time, there was no assistance from government, donors or NGOs for family owned water sources. A Survey conducted by the Ministry of Health's Blair Institute in the mid 1980s showed the O&M problems that community owned water sources were facing (WSP 2002). The high costs of maintenance and the challenge of supplying spare parts were the main problems for the handpump-based rural water supply.

Upgraded family wells provided a solution for the technical and financial challenges of the rural water supply programme, but government officials and policy makers still did not consider the support of family wells to be appropriate (Morgan and Chimbunde 1991). Effective implementation projects were established in a project in Chihota during 1991, funded by several NGOs like Sida, Save the Children Fund UK and UNICEF (WSP 2002). All wells constructed were lined with fired bricks and furnished with apron, head wall and drainage (Morgan and Chimbunde 1996). Although this resulted in significant improvements in the water quality without the use of high technology solutions, upgraded family wells have not been completely accepted by the decision makers in the water sector in Zimbabwe in terms of geographical considerations, reservations about water quality, funding and staffing (Morgan and Chimbunde 1997).

3.4.2 Self Supply in Zambia

In Zambia, approximately three million rural people depend on traditional sources as their villages are too small or too poor to be provided with a borehole or drilled wells and handpumps. In Zambia, Prior to the project of Self Supply model by WaterAid and DAPP in partnership with UNICEF during 2008-2010 (see Chapter 2),the up-grading of existing sources approach was given a major boost through a Department for International Development (DFID) funded study in 1997 by subsidised means (Zulu Burrow 2008). Recognizing this situation, the Zambian government endorsed a DFID-funded research project to look at ways to mobilize the rural poor to improve their own water supplies sustainably and with minimal subsidies.

During a three year implementation phase (1999-2001), the project was highly successful in stimulating local demand and identifying alternative water supply models for rural areas (Sutton 2004c). The water quality from the sources reached showed that wells with aprons, drainage, covers, communal buckets and windlasses had on average better quality than water from scoop holes. The results of water quality analysis exhibited that the water from lined wells significantly improved water quality over unlined wells and were also more reliable than unlined wells. The outcome of the three year implementation study (1999-2001) suggested that even small improvements like a head wall and an apron can reduce faecal coliforms (FC) from 100-200 FC/100ml to less than 10FC/100ml (Sutton 2005).

One of the challenges of the project was to overcome the initially strong negative reactions from water sector professionals and politicians, as upgrading traditional water sources was seen as a retrograde approach (Sutton 2004c). This project showed that the upgrading of traditional wells has a potential which fits alongside high technology solutions and does not compete with them. It also provided communities and households with a potential to obtain a safer and more reliable source at minimum cost (Sutton 2004c). However, "the transfer of responsibility for water supply from the Department of Water Affairs to the Ministry of Local Government and Housing meant that momentum was temporarily lost, but the Head of the Rural Water Supply and Sanitation Unit has identified the singular problems of Zambia to serve all of its rural population with communal supply models and had requested plans for further piloting" (Sutton 2007, p.3). The project of a Self Supply model described in Chapter 2 emerged from these backgrounds and the chronological change of the movement towards a Self Supply model.

3.4.3 Self Supply in Uganda

According to the United Nations World Water Development Report (UNESCO 2005), water coverage rates in rural areas of Uganda, where over 80% of the population live, rose from 20.3% in 1990 to 55% in 2002. It is acknowledged that Uganda had a significant improvement of water access in the 1990s, progress towards rural water supply targets has slowed in the 2000s, with new water supply construction unable to keep pace with the current population growth (UNESCO 2005). During 2005 to 2008, an investigation was undertaken into traditional water source improvements in south and east Uganda (Carter 2006, Alford 2007, Dillon 2008, McGourty 2006, Mills 2006, Rogenhofer 2005, Tillet 2007). As much as 39% of the rural population relied on traditional water sources, ranging from very shallow unlined water holes, to drilled boreholes fitted with a range of water lifting devices (Carter 2006).

Average faecal contamination in upgraded sources was 29FC/100ml which is 20times lower than before the upgrading of wells, and average turbidity reduced by over 50% (Tillet 2007). Although Self Supply models have the potential to be more cost-effective and sustainable than conventional communal models, there are some barriers to the wider use of Self Supply initiatives (Carter 2006, Alford 2007):

- The different perceptions of water users and water sector professionals
- Almost no hardware subsidy to householders who supply water within a community

Studies by Joel (2009) of the Uganda Self Supply pilot project 2006-2008 demonstrating upgraded traditional water sources noted that a new mechanism needs to be found to fully mainstream the Self Supply model into local government annual work plans and budgets. Furthermore, the studies highlight that much needs to be done to help mobilise NGOs' staff in their own recognition of the Self Supply concept.

3.4.4 Self Supply in Mali

The Self Supply study in Mali was started in 2005 by WaterAid and the Ministry of Health (Sutton 2006). In 2007, the results of the study on the potential of this concept were generally accepted by national and regional bodies, and it was agreed that UNICEF and WaterAid should support the piloting of Self Supply (Osbert and Sutton 2009). "The potential of Self Supply was underpinned by the fact that the widespread use of household and family wells, coupled with the slower than planned increases in coverage and limited sustainability of conventional communal supplies, has led to considerable interest by health professionals to reduce health risks incrementally through up-grading the traditional water sources" (Sutton 2010b, p.4). However, most source up-grading was still at the demonstration stage with subsidy in the pilot study and there has been no monitoring of the impact of these changes (e.g. in terms of water quality, user satisfaction, quantity of water use, purposes of use, social status, economic benefit, and replication by other well-owners) (Sutton 2010b).

3.4.5 Self Supply in Ethiopia

The Government of Ethiopia has ambitious targets towards water coverage presented in their Universal Access Plan (UAP), aiming for 98% coverage with improved supplies by 2012 (or 100% coverage by 2015 in the UAP2) in comparison with 68% targeted in the MDG water goal for Ethiopia. At present UNICEF Ethiopia has been implementing the study of Benchmarking Standards for technical aspects of Self Supply (family wells) in order to provide the government with empirical data on whether the Self Supply approach can be incorporated into the reformulation of the UAP to complement the conventional communal model and accelerate the water supply coverage using low cost technology. UNICEF Ethiopia has also supported the research on the assessment of local manufacturing capacity for Rope Pumps as a component of low cost technologies for rural water supply models. Other organizations, including Research inspired Policy and Practice Learning in Ethiopia and the Nile Region (RiPPLE), are also conducting research and looking to further the Self Supply model. Ethiopia is the only country where they are going to promote the Self Supply model without piloting the approach on a small scale as in Zambia.

3.4.6 Summary of Self Supply

A basic principle behind accelerating Self Supply is the dissemination of knowledge about low cost water source improvement and the creation of awareness (Mills 2006). However, the existing literature does neither conduct monitoring and systematic analysis of what impact the Self Supply model has made (Sutton 2010c) nor embed the impact of the different supply models in any great depth on the sustainability of water supply strategy associated with technical, social, financial and economic issues. As noted by Workneh *et al.* (2009) in the study of the potential of the Self Supply model in Ethiopia, although Ethiopia has the potential to achieve water supply targets with less time and resources through household investment in line with UAP, formal evaluation of the experiences of household level water supply is yet to be made.

Without proven practical answers as to what are the effects of improving wells by the Self Supply model from an unprotected to a protected condition, it is difficult to know what is expected of those who support the concept of Self Supply. The studies of Self Supply in Mali by Osbert and Sutton (2009, p.665) emphasize that “impact assessment is required to provide data from which decision makers can evaluate the degree to which the Self Supply model can assist in improving coverage and respond to grass-roots demand". Moreover, conflict may occur between the communal and Self Supply models because they are definitely at the opposite ends of the spectrum in terms of rural water supply provision. Therefore, a comparative assessment of different water supply models between the Self Supply and communal supplies is a crucial study for the selection of an appropriate water supply; viewpoints from both micro (household) and macro (government/donor) level are needed as the literature so far sheds very little light on this important issue.

3.5 Water Supply Interventions at Source and Use

With regard to sustainable and safe water supply provision, there is little consensus on the effectiveness of different water, sanitation, and hygiene interventions. For instance, there is debate as to whether improving water quality at the source, increasing water quantity, or household water treatment (water consumption point) are the most cost effective interventions for reducing diarrhoea (Kremer *et al.* 2009). For almost two decades, studies by Esrey *et al.* (1991) have provided guidance on the relative reduction in diarrhoea that was believed to be possible through interventions in water quality, water quantity, sanitation, and hygiene. Esrey *et al.* (1991, p.616) attempted to separately estimate the impacts of water supply, sanitation, and hygiene education interventions on diarrhoea morbidity, and concluded that "the median reduction in diarrhoea morbidity from either sanitation or hygiene education is nearly twice the reduction from water quality interventions alone or water quantity and quality interventions together." They updated their review in 1996 and concluded that "the benefits of water quality gains occur only in the presence of improved sanitation, and only when the water source is present within the home" (Esrey 1996, p.608); however Kremer *et al.* (2009) observed that these results were inaccurate since they were subject to an omitted variable bias related to community, household, maternal, and child factors.

In contrast to the Esrey conclusion that conventional interventions to improve water supplies at the source are effective in preventing diarrhoea, recent meta-analysis studies by Fewtrell *et al.* (2005) pointed out that water quality interventions at point-of-use were more effective than had been previously acknowledged because of the recontamination through carrying water to the household storage, although publication bias may have been present in the subset of studies on water quality. The publication bias raises the potential that some researches with unfavourable results (i.e. no health benefit relating to the intervention) were not submitted or were not accepted in the paper (Fewtrell et al. 2005). Studies by Wright (2004, p.106) also noted that "the installation of protected sources such as boreholes, standpipes or wells to provide water of better quality has the potential for recontamination because such communal water sources are located some distance from the home, requiring collection and transport from the source and subsequent storage of water within the household." Moreover, this view was also supported by the meta-analysis studies of Clasen *et al.* (2009) that household interventions are likely to be as effective an approach for minimising diarrhoea risk as other environmental approaches, such as improved sanitation, hygiene, and improved water supply.

Kremer *et al.* (2009), however, insisted that the existing evaluations of water source interventions remain less methodologically rigorous than those of household interventions, making it difficult to compare their relative impacts. Indeed, protected traditional hand dug wells as a Self (household) Supply model were excluded in the meta-analysis studies of Clasen *et al.* (2009) which did include handpumps, shallow hand dug wells with no casing and covers, pipes and protected springs as source-based interventions in nine published papers. In addition, as noted by Clasen and Haller (2008), the studies highlighted that among all water quality interventions, household based chlorination is the most cost effective; however, this was based on the fact that the cost estimation of chlorination used the low end of the cost range, whilst other interventions were related to an average cost. Despite the need for careful consideration of different water source interventions or different water supply models in the context of communal and Self (household) Supply models, very little attention has been given to the assessment so far.

There is no other study measuring household water quality following an exogenous change in source quality, nor are the effectiveness of point of use water treatment and source water quality interventions compared in the same setting (Kremer *et al.* 2009). Further studies by Sutton (2008) also emphasized the lack of enough data about the long term improvement to water quality from water supply source interventions. If water quality at the point of source is poor, water treatment at household storage is necessary. This is generally not cheap for the long term and represents an additional burden on the rural and urban poor (ARGOSS 2001). In fact, it was recognized that a variety of cheap household water treatment solutions are available in the market such as water filtration, chlorination and flocculation and so forth, but their poor marketing systems hamper their sustainable use (Morris 2004, Heierli 2008). Meanwhile, where the water source is well protected, hygiene practice could be as central an activity as lower cost interventions such as safe handling and storage practices require little additional expense. Studies of small scale water supply by Skinner (2003, p.100) also emphasized that "treatment should only be considered if it can be afforded and be reliably operated." In terms of safety and reliability, there is therefore a need to review water source interventions which are not unaffordable or unsustainable for rural water supply in contrast to the conventional communal models.

3.6 Interventions at Water Supply Sources

The use of engineering interventions may be needed for all kinds of water sources from springs to complex water distribution and treatment systems in developing countries. Although the size and complexity of water supply varies dramatically from cities to rural villages, the principle purpose of using the technology is to access water (Walski *et al.* 2001). There needs to be careful consideration and planning to reflect both the community capability to maintain improvements in water supply, and affordability. There is no single ideal technology option which can be used in all situations and each technology has specific advantages and disadvantages.

3.6.1 Types of Water Supply Interventions at Source

Supplies of drinking water can be developed from a variety of different sources, and by a variety of different methods. Rural African populations tend to consist of fairly low population density or scattered settlements (Kleemeier 2010b). Appropriate water supply model options therefore tend to be small-scale and low-cost (Harvey and Reed 2004). Possible engineering water supply interventions at water source may include:

- Boreholes
- Hand dug wells
- Protected springs

Boreholes:

A borehole is a narrow shaft bored in the ground which is generally equipped with a casing pipe for preventing it from collapse and contamination. The choice of appropriate drilling technology and the depth and diameter of the borehole drilled is dependent on the environmental condition, such as aquifer and geological formation. "The most successful practice is to drill until a yield of 25l/min is obtained and then to drill a further 10m to allow for water table fluctuations and drawdown levels, although this is not the same as the 'safe' or 'sustainable' yield of an aquifer" (Harvey 2004, p.139). Boreholes with handpumps can serve up to 200~300 people.

According to the study by Harvey and Reed (2004), the key aspects of borehole design are:

- Casing and screens

Low cost PVC casing and screening is normally used for handpump boreholes.

- Borehole development

It is important to draw out fine material from the aquifer to prevent clogging

- Gravel packs or other filters

Studies by Godfrey (2006) highlight the importance of a graded gravel pack within the annulus between the drill screen and the bore wall to avoid the ingress of contaminated fine material.

- Protection

It is important to prevent water seepage from surface by concrete apron, drainage and top slab.

Hand dug well:

The most simple and traditional approach to access groundwater in rural areas is by means of hand dug wells. Historically, dug wells are excavated by hand shovel to below the water table. The well is lined with stones, bricks, tiles, or other material to prevent collapse, and is covered with a cap of wood, stone, or concrete (USEPA 2001). Depths of hand dug wells range from shallow wells about 5m deep, to deep wells over 20 m deep.

"It is important to excavate a well which is more than 1m in diameter; an excavation of about 1.5m in diameter provides adequate working space for the diggers and will allow a final internal diameter of 1.2m after the well has been installed" (WaterAid 2007, p.12) although according to the informal discussion with Dr Sally Sutton, the average inner diameter is 0.8m. According to the JMP definition (WHO and UNICEF 2006, p.8); a ***Protected*** **dug well** is "*a dug well that is protected from runoff water by a well lining or casing that is raised above ground level and a platform that diverts spilled water away from the well. A Protected dug well is also covered, so that bird droppings and animals cannot fall into the well.*"

An ***Unprotected* dug well** is a dug well for which one of the following conditions is true

1) *The well is not protected from runoff water*
2) *The well is not protected from bird droppings and animals.*

If at least one of these conditions is true, the well is *Unprotected*. Even privately owned traditional family hand dug wells can serve about 30 people (Sutton 2005). Well owners share sources with neighbouring households.

Protected spring:

Surface springs can be found where groundwater emerges at the surface because an impermeable ground layer prevents further penetration. "A flow in excess of 0.1 l/sec is sufficient to fill a 20l container in just over 3minutes, which is an acceptable waiting time" (WaterAid 2007, p.29).

The following steps are the stages in the protection of springs (WaterAid 2007, Walker 1999)

- *A cut-off drain to divert surface water*
- *Clearance of vegetation above the eye of the spring*
- *A temporary diversion of the spring water to allow construction of a collection chamber*
- *Large stones placed above the eye of the spring*
- *The construction of a collection chamber*
- *Further protection of the eye by layers of impervious material above it*

Studies of microbiological contamination in Uganda by Howard (2003) also highlight the importance of the immediate surroundings and engineering interventions, meanwhile the studies note the overriding importance of hydrogeological conditions for springs. Moreover, studies by Godfrey (2006, p.41) of microbiological assessment in Mozambique, for spring protection, show that "it is important to broadly understand the prevailing hydrogeological conditions, and that there is less dependence on the specifics of the engineering barriers at the point of abstraction." Because of these views, springs are excluded from this research.

Boreholes and hand dug wells are specifically assessed and their performance compared in this study. In the light of water supply sources, a hand dug well is the main target of this study to investigate the improvement through Self Supply, whilst a borehole represents the facility of communal water supply (some subsidised hand dug wells with full lining are also in the category of communal water supply).

3.6.2 Types of Lifting Devices

A variety of water lifting devices are used for raising groundwater from wells that allow users easy access to water. Communities should be able to choose from a range of water lifting devices, and each option should be presented with its advantages, limitations and implications (WHO 2003). The following water lifting devices may be included for rural water supply:

- Motorized pump
- Handpump
- Rope pump
- Rope and Bucket

Motorized pump:

Where plenty of water needs to be pumped a mechanically powered pump is usually used (Skinner 2003). Rotodynamic pumps are most common pumps, but other types include reciprocating piston pumps, progressive cavity pumps and diaphragm pumps. In terms of sustainability, however, the motorized pump is likely to be much more difficult and more expensive to maintain than other pumps, handpumps, rope pumps and bucket pumps (Skinner 2003, Baumann 2003). Skinner described the main factors of the difficulties in applying these technologies in developing countries including;

- Poor availability of fuel (especially in the rainy season)
- Poor reliability of electricity (e.g. variable voltage and regular power cuts)
- Lack of skills to maintain the pump

Motorized pumps are therefore excluded in this research since sustainable rural water supply models are the focus of this study, and in fact there were no such motorized pumps for household usage in the study areas.

Handpump:

The handpump remains a major method of delivery for rural water supply models in Africa because of the belief that the handpump is easy and has a low cost of O&M in relation to many other technologies. Also it has the ability to pump groundwater from depths and widespread user acceptability (Harvey and Reed 2003). There are huge ranges of different handpump types but the most common pumps in Zambia are India

Mark Ⅱ and Afridev as a reciprocating piston pump.

A supply chain of spare parts, skilled labour and community affordability are crucial aspects of sustainable handpump operation and maintenance. A standardization policy for handpumps has also been introduced in some countries but has rarely been acknowledged. According to Harvey and Reed (2004, p.145), the term 'standardization' as applied to handpumps is defined as "A policy which limits the range of handpumps that can be used within a particular country". Based on the research undertaken by Harvey et al. (2004), countries which currently have handpump standardization policies in place, such as Ghana and Zambia, do not demonstrate significantly higher levels of handpump sustainability than those that do not, such as Kenya and South Africa where they have a larger range of pumps in country and there is a greater level of local innovation.

Rope pump:

The rope pump is easy to understand, reproduce and maintain. The device is mainly used with hand dug wells (WHO 2003). It consists of a rope, rubber washers, a pulley wheel and a rising main which is usually made of uPVC pipe but if not locally available, it can be made using bamboo (Harvey and Reed 2004). By rotating the wheel with a handle, a continuous rope with washers lifts the water through the pipe towards the outflow. It is noted in the Rope Pump Manual in Ethiopia that "more durable versions can be produced at a much lower cost than most handpumps but the "Stone age" image hampers acceptance by water organizations, institutes and users" (Wal *et al.* 2006, p.8).

Rope and Bucket:

The Rope and bucket is mainly used with hand dug wells (WHO 2003). A bucket on a rope is lowered into the water until the bucket hits the water, fills, and is pulled up with the rope. The rope may be held by hand, run through a pulley, or a windlass (WHO 2003).

Of all the water lifting devices, the handpump is that predominantly used for the communal (borehole) water supply model, whilst the rope and bucket, and rope pump represent the lifting devices of the Self Supply model in this study. The windlass is also used for both the subsidised communal (HDW) water supply and the Self Supply models. This section sheds light on the interventions of each water supply technology. In order to assess the existing rural water supply model from both communal and Self Supply models, the next section will therefore review the water supply model choice.

3.7 Water Supply Model Choice

The choice of rural water supply model will vary according to environmental conditions, affordability and social acceptance (Harvey 2007). According to Skinner (2003), a water supply model should be:

- *Acceptable to the community* (e.g. in relation to **convenience** and traditional beliefs and practices) and also acceptable from environmental and **health perspectives**
- *Feasible* (i.e. Suiting the relevant local social, **financial** and technological factors); and
- *Sustainable* (i.e. **Reliability** and possibility to **operate and maintain** in the future within the available financial, human and material resources).

This section therefore reviews the performance of water supply sources in terms of each category.

3.7.1 Acceptable to the Community

Most people have access to some form of water supply source that is sufficient to meet basic physiological needs, although these sources may represent risks to their health because of quality or because there is not enough water for basic hygiene (Howard 2002). Therefore, this section discusses acceptability to the community in terms of both water quality and water quantity.

Water quality

Water quality is a significant and key factor in the acceptability to the communities and water sector professionals of a water supply model selection from the viewpoint of the protection of public health. If the consumption of water from intervened water supply sources has adverse effects, it can hardly be said to meet the criteria either for a successful or a sustainable water supply model. Generally, groundwater is cleaner than surface water and protected against contamination from the surface by soils and covering rock layers (planetearth 2005). However, other factors related to the water supply can increase the risks that individuals or communities are exposed to through poor water quality or an inadequate quantity of water (Howard 2002). Potential contaminants of water supply sources are in three categories: pathogens, chemicals and other contaminants. Details of these are summarized below (Skinner 2003).

- Pathogens: these are disease causing organisms such as bacteria, viruses or larvae of parasitic worms. Human and animal faeces contain many of these pathogens, and water can be threatened by poor hygiene, sanitation or unprotected water sources.
- Chemicals: chemical contamination comes from agricultural or industrial activity. Some exist in the natural environment.
- Other contaminants: these include suspended solids and algae.

"The chemical quality of water is of lower priority as in general the effects on health are long term (i.e. chronic) although there are some exceptions to this, for instance arsenic, nitrates and fluoride may all produce short-term effects" (Howard 2002, p.11). Parameters of water quality such as colour, odour or taste are also important because people's preferences determine whether or not they accept even a low microbiological risk (WHO 2006). Moreover, user satisfaction with the quality of water they use also relates to willingness to pay for the water source (Harvey and Reed 2004).

The majority of pathogens that affect humans are derived from faeces and transmitted by the faecal-oral route through a variety of ways including food, water, poor personal hygiene and flies. According to the studies by ARGOSS (2001), there are two main pathways of contamination of groundwater sources.

a) *Aquifer pathway*- where pathogens migrate through the subsoil from a faecal source to the water table.
b) *Localised pathway*- a rapid bypass mechanism where pathogens enter the intake of the water supply.

Studies by Godfrey (2006) of microbiological risk assessment in Mozambique highlight the importance of top soils both on increasing residual time for limiting aquifer pathway contamination, and also on the impact of the localized pathway of contamination. In terms of a direct route of contamination, construction of the water supply source is a significant factor in water deterioration (ARGOSS 2001). Contamination at point sources may occur due to poor design, siting, construction or operation and maintenance (Harvey and Reed 2004, Harvey 2004). The next section will therefore review the effectiveness of various engineering interventions from the perspective of risk of water contamination through a localized pathway.

Borehole:

It is a commonly recognised that boreholes have a better water quality than other point sources as they access deep groundwater and provide a protection measure against contamination (Howard 2002). However, there may be a contamination risk in the process of borehole design and construction. What is essential is that the water source is adequately protected, and that the borehole head protection can avoid any contamination from entering the well even if casing is not used (Harvey and Reed 2004). Adequate width of apron and drainage length from the apron are also important, especially for shallow aquifers which are more susceptible to surface pollution from a nearby water source.

Hand dug well:

Hand dug wells are often more vulnerable to contamination than boreholes where the well lining is imperfect and/or water lifting device is insanitary (Howard 2002). Studies of the risk of microbiological contamination to groundwater supplies in Ghana, noted that direct infiltration of contaminants through insanitary well completion was the primary route of contamination (Amuzu 1993). Studies by Dillion (2008) of comparative testing of microbial water quality in Uganda noted that unprotected hand dug wells were contaminated by faecal coliforms and more affected by the direct surface water intrusion with inadequate intervention. The study also highlighted that microbial water quality from protected hand dug wells was improved compared with unprotected hand dug wells; however 76% of the wells tested qualified as high risk or greater of adversely affecting the health of users with >100FC/100ml.

Meanwhile, a study by Sutton (2005) of the upgrading approach in Zambia noted that the access to safe water was achievable by even minimal improvements to traditional hand dug wells. The study showed that afterwards 94% of improved partially lined wells contained water with less than 10FC/100ml although prior to improvement only 35% of hand dug wells had water with less than 10FC/100ml. Furthermore, baseline surveys by Zulu Burrow (2008) and Munkonge and Harvey (2009) in Zambia underlined the fact that even traditional unprotected hand dug wells generally contained water of similar quality to that of protected hand dug wells. Zulu Burrow (2008) presumed the reason to be the rapid turnover of water since storage of water in the source was more limited and the number of the users was high.

Rope pump:

Microbiological water quality is obviously the most common argument against the use of the rope pump (Gorter *et al.* 1995) and the reason comes from the rope pump design i.e. the rope is exposed to air and water may easily enter the well (Bartle 2009). While this may be theoretically true, so far there are no published data or empirical data to support this argument (Harvey and Reed 2004). In fact, studies by Harvey and Drouin (2006) of the comparative water quality between rope pumps and conventional handpumps in Ghana noted that there was no significant difference between the two pump types in terms of microbiological water quality. In a detailed study in Ghana, the mean count for the rope pumps was 2,015FC/100ml compared to 2,474cfu/100ml of handpumps, indicating little difference between the two pumps. However, based on informal discussion with Dr Sally Sutton, these figures are not reliable because these figures are beyond the measurable values for faecal coliforms. Furthermore, a study by Holtslag and Mgina (2009) of smart technologies underlined that the belief that a rope pump cannot deliver safe water is not correct based on their experiences. No specific details, however, are described in their paper.

Rope and Bucket:

The Rope and bucket has the potential for water quality deterioration especially when the rope or bucket is left on the ground or has touched the user's hands (WHO 2003). In addition, the risk of contamination increases if each person uses their own bucket and the area is not well fenced to prevent animals from having access to the well (WHO 2003). A baseline survey for Self Supply in Zambia by Zulu Burrow (2008) noted that the wells using rope and bucket had higher coliforms counts while boreholes installed with handpumps were within the range of the WHO standards. Meanwhile, an improved measure for using the rope and bucket is to run the rope through a pulley, or wind it on a windlass which may reduce the risk of contamination since it can avoid the rope being left on the ground or being touched directly by the user's hands.

From these studies of water quality from different types of water supply, there are limitations in providing guidance on reducing water quality deterioration throughout the technological choices. Sutton (2009a) highlights the importance of water quality monitoring in the Self Supply pilot as users and decision makers are given an opportunity for further assessment of the relevance and potential of the Self Supply model within government policy and strategy. Also it does not shed light on how the different water supply models influence water quality for either communal or Self Supply models, in that the former model is community owned and the latter is owned by the individual household. Furthermore, no available data is found in terms of water quality at the point of use (households) in Self Supply models. Water quality at the point of use might be improved in the Self Supply model by the means of accessibility which is discussed in detail in the next section.

A borehole with handpump for a communal water supply is relatively safe with a protected structure, but a protected hand dug well for the Self Supply model also shows evidence of improved water quality. Indeed, whilst 'sustainable access to an improved water source' is the indicator for the achievement of MDGs water target, there is an ambiguous relationship between 'improved water sources' and 'safe water" which might lead to under or over estimation of real achievement. For instance, according to the WHO report (2008), differences exist between JMP-reported and country-reported coverage figures for drinking water. "JMP considers that wells (Well types not specified in the paper) without handpumps constitute an improved water source, meanwhile Mongolia records such wells as unimproved" (WHO 2008, p.20).

In the studies of microbial water quality in Uganda, Dillon (2008, p.44) also highlights that "An 'improved' source does not necessarily mean a safe drinking water source since water quality below the WHO standard had been noted at protected shallow wells." The study concluded that "determining the proportion of the population with access to a water source categorized 'improved' by JMP inflated the actual number and misled the stakeholders involved." In fact, the MDG goals report published by the United Nations (2009, p.47) highlighted that "the drinking water obtained from improved sources has not met the microbiological standards set by WHO."

Current existing literature has limitations not only in clarifying the improvement of water quality with step by step intervention through a Self Supply model, but also in assessing the impact of the different characteristics of each water supply type such as their sanitary condition or distance from households which have the potential to affect water quality. This view is also supported by Workneh *et al.* (2009) who stress the importance of undertaking a baseline survey of water points before starting any intervention. Moreover, evidence of water quality/safety of the Self Supply model will contribute to the government in its debate on rural water supply strategies to achieve the MDG water target and in local planning (Osbert and Sutton 2009). Addressing such "***Water safety (water quality and sanitary condition)***" difference from water supply types and water supply models, both communal and Self Supply, is therefore one of the crucial aspects for overall safety and acceptability to the community.

Water Quantity

The importance of adequate water quantity for human health, as well as water quality, has been recognized for many years. "Lack of access to safe and adequate water supplies leads to ongoing poverty both through the economic costs of poor health, as well as through the high cost of household expenditure on water supplies in many poor communities, arising from the need to purchase water and the time and energy expended in collection" (Howard 2003, p.1). According to the Global Water Supply and Sanitation Assessment Report (WHO and UNICEF 2000, p.77), "Reasonable access was broadly defined as the availability of at least 20 litres per person per day from a source within 1 km of the user's dwelling." As of 2000, it was estimated that about 1.1 billion people lacked "reasonable access" to any form of improved water supply (WHO and UNICEF 2000). If the time spent collecting drinking water is between 3 and 30 minutes, the amount collected is fairly constant and suitable to meet basic needs but if the water collection time exceeds 30 minutes, people tend to collect less water, thus compromising their basic drinking water needs (WHO and UNICEF 2008). In the latest JMP report, in many African countries, one third of the improved drinking water sources excluding piped water need a collection time of more than 30 minutes (WHO and UNICEF 2010).

The location of a borehole with handpump for the communal water supply is normally in a central position within the community, and on community owned land (Harvey and Reed 2004). Meanwhile, traditional hand dug wells are generally located near, or within households. Studies of Self Supply in Zimbabwe highlight the health benefits arising from increased consumption of water due to closer access to a water source and easier lifting devices, rather than from improved source water quality (WSP 2002). This is also supported by the study of the impact and potential of Self Supply in Uganda where Self Supply models increase water access at the household level; there is considerable potential for future increased access should upgrades achieve proper drinking water standards, negating the need to collect drinking water from a distance (Alford 2007). Moreover, a study of Self Supply in Mali by Osbert and Sutton (2009, p.663) noted that "people within 100m of a supply used almost twice as much water in the home as those walking more than 500m, but it may also be that at that distance people tend to wash clothes at the source rather than carry water home." According to the study in Uganda by Carter (2006), however, sector professionals tend to believe that objectionable quality alone can be enough to condemn a source although convenience of access is of significantly greater importance to most (especially rural) consumers than water quality.

"*Accessibility*" to safe water has great potential for the improvement of public health in terms of not only water quantity but also water quality. Generally, it is believed that where people need to fetch water from a distant source or where water supplies are unreliable, water will have to be stored in the home and this may increase the risk of contaminating the water through poor handling or storage practices (Howard 2002). In fact, despite poor sanitary and hygiene practice, very little consideration is given to research of the contamination during transport or storage (Mills 2006). In the systematic meta-analysis of household drinking water in developing countries, Wright (2004) noted there is a great deal of opportunity for the water to become contaminated before consumption e.g. during collection, transport, storage and drawing in the home regardless of water safety at the source. In this regard, a Self Supply model has significant potential to mitigate the risk by "accessibility" which will reduce the opportunities for water quality deterioration in that the Self Supply model is embedded in household and small group water supply rather than in the community.

Despite holding such potential for alleviating water quality deterioration by use of a Self Supply model, few studies investigate this aspect as an indicator for a part of sustainable rural water supplies. Furthermore, water collection patterns, such as preferences for water supply sources for different water uses or the numbers of drawing times and queuing times, has yet to be assessed where both communal and Self Supply models exist. An assessment of the different water source types associated with their different water supply models must therefore consider in this study not only "Water quality" but physical changes such as "Accessibility", litres per capita water use, water usage pattern, and also overall water collection time.

3.7.2 Feasible (i.e. suiting the relevant local social, financial and technological factors)

Financial aid from external development assistance may cover the majority (in some countries, near 90%) of national spending on the sanitation and drinking water sector (WHO 2008). In working towards the MDG target for water and sanitation, understanding resource requirements, resource gaps and where resources need to be deployed is critical (Hutton and Bartram 2008). However, in the WHO report (2008, p.16), "most of the countries were unable to provide accurate estimates of the budget specifically targeted at water or sanitation. This is because sanitation, hygiene and drinking water supply are often aggregated in government budgets, and responsibilities are spread over different institutions." This implies that there are great limitations to the assessment of proper budget allocation.

Carter (1999, p.292) pointed out that "this prevalence of unacceptable, unaffordable or impracticable financing strategies provokes poor levels of sustainability in existing rural water supply systems. This has resulted in the failure of a significant number of water and sanitation projects in developing countries to deliver benefits to society over the long term". Studies by Harvey (2007) of cost determination and sustainable financing for rural water supply models in sub-Saharan Africa also underlined that "estimation of the cost of ongoing model delivery is essential, so that communities, local authorities and implementing agencies are aware of the long term costs involved and can act accordingly. This can be achieved only when the comprehensive assessment and costing of the operating and maintenance, repair and rehabilitation needs of different water supply technologies is carried out; however the vast majority of implementing agencies do not do this and it is consequently unclear what selected tariffs can be expected to cover and what additional financing may be required" (Harvey 2007, p.389).

In the paper on sustainable financing for rural water models in sub-Saharan Africa, Harvey (2007) also noted that full cost recovery for rural water supply is an unrealistic goal because most of the rural communities cannot afford to pay for the capital costs in the context of communal models. For instance, studies of assessing the cause of poor operation and maintenance of communal water supplies in rural Kenya by Rukunga *et al.* (2007) and similar studies in Tanzania by Maganga *et al.* (2002) noted that operation and maintenance water supply costs are often incurred by the governments as hidden costs and result in constraints of scale up. However, studies into the financial analysis of water supply models in both communal and Self Supply have received very little attention.

According to the studies by Alford (2007, p.48) on the impact and potential of Self Supply in Uganda, "boreholes (communal supply) are by far the most expensive technology of the four (borehole, shallow well, community upgrade and private upgrade) both in total and per capita cost, and this is due to the high costs involved in the hydrogeological survey, the drilling itself, labour costs and installation costs." Where we consider different water supply models, there is commonly a trade-off between the three factors (access, water quality and reliability) and the two factors (cost and management) (Carter 2006).

As noted by Alford (2007, p.48), "shallow wells (Self Supply) are constructed at a far cheaper average cost though they remain beyond the reach of the majority of the population in rural Uganda. While the per capita cost of private hand dug wells is higher than communal upgrades or shallow wells, this is largely in kind rather than financial, and might be spread over time through the use of additional incremental steps to spread the cost over several seasons" (Alford 2007). Indeed, in the Self Supply model in Mali, several neighbours have already contracted the trained artisans to conduct improvement work for their wells at their own cost (Osbert and Sutton 2009). 'Ownership' is a key parameter for a sustainable rural water supply model which is discussed in the next section in detail.

In fact, currently the IRC International Water and Sanitation Centre has started a five year action research project 2008-2012, which aims to investigate the life-cycle of water, sanitation and hygiene models in rural and peri-urban areas in four countries (Fonseca *et al.* 2010, Fonseca 2009). They do not take much account of the assessment and costing of the operation and maintenance, repair and rehabilitation needs of different water supply technologies based on Self Supply models rather than communal water supply models. Also, the implementation costs incurred by government or support agencies might show a significant difference between the communal and Self Supply models because the focuses of the two models are different i.e. the former model is for hard components support whereas the latter one is for software component. Further detail of the lifecycle cost is discussed in the data analysis chapter 5.8. There is therefore a requirement to assess the financial aspects not only of the unit installation costs but also for the O&M, rehabilitation and expansion costs in terms of the

"*Cost-effective*" rural water supply model, both communal water supply and Self Supply.

3.7.3 Sustainable (i.e. Possible to reliably operate and maintain in the future with the available financial and material resources)

Harvey and Reed (2004) underlined the importance of the distinction between 'sustainable water supply' and 'successful water supply' in that successful water supply is achievable even in the short period but sustainable water supply must be a longitudinal vision for sustaining the programme without the abandonment of funding, time and resource. A sustainable rural water supply has been defined as one in which:

"*the water sources are not over-exploited but naturally replenished, facilities are maintained in a condition which ensures a reliable and adequate water supply, the benefits of the supply continue to be realized by all users indefinitely, and the model delivery process demonstrates a cost effective use of resources that can be replenished"* (Harvey and Reed 2004, p.7).

Even if a conventional communal water supply source breaks down, communities often neglect to repair it because they regard repair as a responsibility of the government (Carter 2006). This view is also supported by the studies of Fouegue (2007) of analysis of ways to improve water supplies in Bundibugyo District, Uganda where "It is a thing of the government" was the view of most of the water users who did use communal water supply.

On the other hand, Self Supply is fully participatory, and responsive to social and economic realities (Carter 2006). The concept of Self Supply is that an individual household or community takes a decision to improve communal or private water supplies with little or no external assistance from the government or NGOs. Therefore, the technology selection of Self Supply depends on individual affordability with simple, local materials, and within the capacities of local artisans which promote ownership of the water supply. "Although the private ownership model may not work in every situation, particularly where there are no individuals with sufficient wealth, where it does work, it often demonstrates very high levels of sustainability" (Harvey and Reed 2004, p.179).

The advantage of the approach adopted in a Self Supply model is the ease of maintenance since the simple technology can be repaired by local artisans and collected labour using local materials, such as local bricks for lining a well. Harvey and Reed (2006) made a distinction between 'community participation' which they see as a pre-requisite, and 'community management' which they do not see as a pre-requisite because community management cannot be sustainable without external support to some extent. Indeed, even if the technology of the Self Supply source is simple, O&M is required to keep the water supply source sustainably. Nonetheless, the O&M of the Self Supply model has received little focus in existing literature which may be either because of its simplicity or little available data. As noted by Holtslag and Mgina in the studies of smart technologies (2009, p.373), "Simple is not easy". Although a rope pump is indeed easy to make, some basic design rules are needed in order to avoid damage (Holtslag and Mgina 2009).

Further, sustainability should take into account water source sustainability, especially of hand dug wells where the level of groundwater fluctuates (Harvey and Reed 2004). In fact, one of the concerns among water professionals is whether traditional water source improvement through the Self Supply model can create a reliable water source (Carter 2006). However, it is too limited in the extant literature to be able to clarify a sustainable water source environment for the Self Supply model. Thereby, "***Technical and environmental sustainability***" is also one of the essential aspects to assess in both communal and Self Supply models for sustainable water 'access'.

This Self Supply model derives from the recognition that communal supplies are not sustainable in all situations (Sutton 2004c) and the fact that less than half are operational in Africa (RWSN 2005). From the research by Parry-Jones *et al.* (2001), it is clear that the low sustainability of handpumps in the communal water supply model is due to the lack of the provision of spare parts for repair and maintenance.

Nonetheless, the model of Self Supply may be weakened by more communal models despite their low sustainability. Once a government focuses on a community water supply project in a given area, it may discourage rural dwellers from improving their private water sources. Despite its high potential for accessing safe water by traditional water source improvement, policymakers often remain an obstacle, regarding the traditional water intervention as inferior to the communal model. The studies of Self Supply in Uganda by Rogenhofer (2005) noted that a high technology solution like a drilled well with a handpump can be seen as a kind of status symbol from the viewpoint of both the community and the external support agency.

In addition, NGOs and donors find it difficult to fund individual water sources as compared with public water sources in a community. In particular, Japanese aid in Zambia did not allow districts to use a small proportion of funds scheduled for boreholes into source improvement even though the District expressed their desire to upgrade existing traditional water sources (Sutton 2002). There is a strong demand for the provision of a practical answer to what is expected of those who support the Self Supply concept although very few studies have investigated the long term assessment of the sustainable water supply model. Moreover, what remains to be explored is the "***Acceptability***" by the end user where both communal and Self Supply models exist within the same community. Acceptability or demand might be changed by their preferences or priorities for different water supply models in terms of accessibility, water quality, quantity, ownership, cost and reliability. In fact, the Drawers of Water Ⅱ stated that the current rural water supply strategy is apt to undermine user acceptability and constrain rural dwellers' choices (Thompson *et al.* 2001). By understanding their acceptability of different water supply models and what factors impact on their satisfaction/preference, the empirical research forges a sustainable rural water supply strategy.

3.8 Chapter Summary

The literature review has provided insight into the technical, environmental, social and financial issues associated with sustainable rural water supply. The following points are highlighted from the review.

- **Rural water supply**- which refers to both the communal and Self Supply models depends on acceptability, feasibility and sustainability aspects. A strategy for a rural water supply model must therefore be a holistic approach including all of these factors.

- **Water supply intervention**- Whilst conventional communal interventions to improve water supplies at source have long been recognized as effective for public health, more recent reviews have shown household based interventions to be significantly more effective than those at the source. However, the literature has overlooked the assessment of different levels of water supply interventions at the water source including Self Supply models. The literature also points to the need to investigate cost effective interventions for a sustainable rural water supply.

- **Approach to safe drinking water**- Even though addressing the MDG water target is the priority, there is no guarantee that people access safe drinking water, because 'improved' water sources defined by JMP as 'Safe' are uncertain in terms of WHO drinking water standards. On the contrary, small improvements to water sources can show a significant impact on the water quality.

- **Area being left behind from communal model**- Sparsely populated rural areas tend to be ignored in rural water supply strategy because communal water supply models are unlikely to fulfil delivery costs and greater effective demand for water supply from individual households i.e. distance, water collection time, acceptability and/or cost. However, the Self Supply model can adopt numerous strategies not only for small groups but also for individual households based on their demand and affordability to access safe water.

- **Limited studies on the Self Supply model**- Valuable studies of upgrading traditional water sources have been undertaken in some sub-Saharan African countries including Zimbabwe, Zambia, Mozambique, Uganda, Ethiopia and Mali. However, the literature review indicates that few projects focused solely on software support for traditional water source improvement and very few publications have shown monitoring and systematic analysis of what impact these changes have made to rural water supplies and livelihoods of rural dwellers. In fact, the literature has highlighted the importance of study for monitoring of water quality, user satisfaction, water use and purpose of use, social status and economic benefits under a Self Supply model in order to develop a water supply strategy.

In particular, no substantive information was found which relates to the following important issues regarding the sustainability of a rural water supply model.

- The impact on water quality/quantity of the different water source interventions in rural areas

From the literature, it was found that the communal water supply model is relatively safe with a protected structure, but protected hand dug wells for Self Supply also show evidence of improved quality of water. However, it is too limited to clarify the improvement of water quality with step by step intervention through a Self Supply model. Furthermore, valuable parameters, such as water quantity, distance to households and number of users, which have potential to affect water quality both at source and use point, are little investigated in Self Supply models.

- The accessibility to the different water supply models and its impact on communities and households

From the literature, it is found that a communal water supply is normally in a central position within the community whilst a Self Supply model is generally near or within households. Despite 'Accessibility' to a Self Supply model having great potential to not only increase water consumption but also to mitigate water quality deterioration at the point of use, yet few studies have investigated this impact of Self Supply.

- The relative technical and environmental sustainability of the different water supply models

Operation and Maintenance is essential for the technical sustainability of rural water supply. From the literature, it was found that communal water supply has failed because of the high technology costs or lack of spare parts/skills and ownerships. Self Supply refers to small group or individual initiatives to improve their water supplies through households' investment whilst the government and support agencies provide software support to complement the households' efforts. However, no matter how simple the technology is, breakdown will occur which cannot be maintained and refurbished by the well owners themselves. Nonetheless, no studies have been conducted on O&M in the Self Supply model. Further, very few studies showed water source reliability especially where community members rely on hand dug wells using shallow groundwater.

- The cost-effectiveness of the different water supply models

Financial analysis is significant in the sustainable rural water supply approach for reasons of developing acceptable, affordable or practicable strategies. From the literature, however, it was found that little account within the assessment is given to the costing of the operating and maintenance, repair and rehabilitation of the different water supply models, especially for the Self Supply model.

- The user acceptability of different water supply models

From the literature, it was found that the Self Supply approach is weakened by communal water supply models. Policymakers often regard the Self Supply model as a step backward or inferior to the provision of communal and more technical approaches. It is easy for the concept of Self Supply to be misunderstood as a Stone Age image. However, no substantive information was found on end user acceptability of the different water source types where both communal and Self Supply models exist within the same communities. Comparative assessment of the relative merits of the communal and Self Supply models and their symbiosis or separate use has yet to be carried out.

These gaps in knowledge and practice were used in the definition of the key research questions stated in Chapter 4 of this thesis.

Chapter 4 RESEARCH METHODOLOGY

4.1 Chapter Outline

After identifying the gap in knowledge concerning the models for the provision of a rural water supply, the next step is to appropriately design a methodology which will investigate the research questions that arise. This chapter presents the methodology adopted for the research and covers presentation of the;

- Objectives of the research and research questions
- Key concepts
- Research paradigm
- Planning for research
- Research design
- Research methods
- Data source and variables
- Data collection methods and sampling
- Data analysis
- Ethical considerations
- Limitations of the methodology

The overall research design, the process of fieldwork and the analytical framework for data analysis are described and explained. To recap, the aim of the study was to *determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective and acceptable water supplies for households in sparsely populated rural areas of Zambia*.

4.2 Conceptual Framework

The conceptual framework reflects the vision, research framework and variables. This section presents the research aim, its objectives, principal argument and indicators in order to capture the essential components of inquiry with respect to a sustainable rural water supply.

4.2.1 Objectives and Research Questions

The aim of the preceding literature review was to provide the necessary background, to demonstrate the importance of the study and to identify the specific knowledge gaps in terms of the provision of water supply models in rural Africa. Having examined the existing literature on rural water supply models, the next most important stage is the clear articulation of the research objectives and questions that arise in order to address the research aim. Research questions for a project should

- *"be clear, researchable and linked to each other*
- *have the potential for making a contribution to knowledge*
- *be neither too broad nor too narrow"* (Bryman 2004, p.33)

Table 4.1 presents the gaps identified in the literature, the associated research questions and the objectives.

Table 4.1: Research gaps, objectives and questions

Gap in Literature	Objectives	Research questions
In the existing indicators there is an ambiguous relationship between safe water and water supply technology at source and point of use. Creating awareness of hygiene conditions may reduce the contamination.	To assess the intervention of water source protection and sanitary conditions to reduce microbiological water contamination, and to measure the change of water quality at the source and the point of use	What impact do the water supply models have on the quality of water? What are the factors likely to affect water quality? What is the status of sanitary conditions? What are the sanitary risks likely to affect the water quality? How does water quality change at the source and the point of use, and what are the contributory factors?
What remains to be explored is the accessibility of the different water supply models and its impact on households and communities.	To look into the accessibility to water supply models in terms of distance and time and find out how accessibility impacts per capita water use of households.	What is the status of accessibility towards the different water supply models? What are the factors likely to affect accessibility in terms of distance and time? What is the status of per capita water use among different models and how is this likely to be affected by accessibility?

Gap in Literature	Objectives	Research questions
Little empirical research on the relative technical and environmental sustainability of the different water supply models. In addition, a post-construction model will support their sustainability.	To measure the technical sustainability and environmental sustainability of water supply models and find out O&M systems that are likely to develop sustainability.	What is the status of technical sustainability of the different water supply models? What is the status of the water reliability of the different water supply models? What are the factors likely to affect technical sustainability and water reliability? In what way are water supply models providing O&M systems to the communities?
Lack of understanding the cost-effectiveness of different water supply models may undermine the water supply strategy.	To measure the cost-effectiveness of water supply models viewpoints from household and government.	What costs constitute lifecycle cost for the different water supply models? How do lifecycle costs impact on project costs and household/community costs? When are the costs incurred?
End user acceptability and preference towards water supply models is seldom understood.	To ascertain user preferences with respect to different water supply models.	What is the status of acceptability towards water supply models for end users in terms of water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability? What are the factors likely to affect user satisfaction? How are user preferences in selecting a water supply model likely to affect community water supply dynamics?

(*Source: Author*)

The research aims to determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective and acceptable water supplies in sparsely populated rural areas of Zambia. The study incorporates a wide variety of issues including technical, social and financial aspects with a focus on the comparative assessment between communal water supplies and Self Supply models. This is important because a Self Supply model builds on those initiatives, continuing people's progress towards achieving better water supplies by improving the protection status of hand dug wells at a potentially much lower unit cost than that of the communal model, and with a greater likelihood of sustainability (Carter 2006). By contrast the communal model of water supply provision is externally driven by governments, donors, external agencies and NGOs. Self Supply is clearly different from communal water supply in terms of the approaches towards it. A comparison of the water supply models used for Self Supply and for communal water supply will enable the policy makers and donors to decide whether to support both models or adopt one in favour of the other when designing the rural water supply strategy.

4.2.2 Key Concepts

The principal argument of the study to be examined for the purpose of answering the research questions can be stated as follows:

Reliance only on a communal water supply model limits the achievement of increased sustainable access to a safe water supply; hence a Self Supply model is needed which does not compete with the communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.

This research aims to determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective and acceptable water supplies in sparsely populated rural areas where the water safety, accessibility, sustainability, cost-effectiveness and acceptability issues are embedded as the key concepts for developing a water supply strategy. In connection with the different concepts and research questions, the following key concepts and indicators are selected to address the research objectives.

Table 4.2: Key concepts, research questions and indicators

Key concepts	Research questions	Indicators
Water quality and sanitary condition	What impact do the water supply models have on the quality of water?	Water quality at source
	What are the factors likely to affect water quality?	Protection feature

Key concepts	Research questions	Indicators
Water quality and sanitary condition	What is the status of sanitary conditions? What are the sanitary risks likely to affect the water quality?	Sanitary condition and water quality
	How does water quality change at the source and the point of use, and what are the contributory factors?	Water quality at the point of use
Accessibility	What is the status of accessibility towards the different water supply models?	Distance from house to water source
	What are the factors likely to affect accessibility in terms of distance and time?	Water collection time
	What is the status of per capita water use among different water supply models and how is this likely to be affected by accessibility?	Per capita water use
Technical and environmental sustainability	What is the status of technical sustainability of the different water supply models, and what are the factors likely to affect the technical sustainability?	Technical sustainability
	What is the status of the water reliability of the different water supply models, and what are the factors likely to affect the water reliability?	Environmental sustainability
	In what way are water supply models providing O&M systems to the communities?	O&M system for water source
Cost effectiveness	What costs constitute lifecycle cost for the different water supply models? How do lifecycle costs impact on project costs and household/community costs?	Lifecycle cost
	When are the costs incurred?	Cost time frame
Acceptability	What is the status of acceptability towards water supply models for end users in terms of water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability? What are the factors likely to affect user satisfaction?	User satisfaction
	How are user preferences/satisfactions in a selecting water supply model likely to affect community water supply dynamics?	Community dynamics for water supply selection

(*Source: Author*)

From the literature review, the emerging research can be categorised into five key concepts:

1) Water quality and sanitary condition
2) Accessibility
3) Technical and environmental sustainability
4) Cost-effectiveness
5) Acceptability.

These concepts were identified as the gap in knowledge about rural water supply models between communal and Self Supply. Thus, investigating these concepts are crucial elements in this study in order to address the most appropriate rural water supply models for households, especially in sparsely populated rural areas. It is acknowledged that additional aspects such as hygiene practices and hygiene education are of great significance when assessing sustainable water supplies. However, as the primary focus of this research is that of physical interventions, the scope of this study was not extended to include a study of human hygiene practices and hygiene education in detail although sanitary conditions were looked into in the fieldwork. The following are the detailed descriptions of the key concepts and the indicators outlined above.

Water Quality and Sanitary Condition

Water quality testing within selected parameters is required in order to compare the effectiveness of different water supply source interventions. The water quality testing protocol is that sampling water is carried out both at the source and point of use (household) and analysed in the laboratory. The reason for taking water samples from both sites is to assess any deterioration of water quality. Although a broad range of substances can be found in water, only a few of these commonly occur in concentrations high enough to concern drinking water users (DWAF 1998). The indicator organisms selected for this study that are of main concern to the domestic user are based on the substances categories of DWAF (1998), Water Quality Surveillance (Howard 2002) and Guidelines for Drinking Water Quality (WHO 2006). DWAF groups a great many substances in order of priority in 4 classifications.

A) Substances which are general parameters of water quality
B) Substances which are more likely to be present in concentrations which may lead to health problems
C) Substances which are less likely to be found in concentrations of real concern to

health

D) Substances which are likely to be present in concentrations of aesthetic or economic concern in domestic water sources

The variables of this study are encompassed in 'classification A' which are indicators of potential problems and should be frequently tested at all points in the water supply system, irrespective of the source of the water and other variables from 'classifications B & D' because of the characteristic features of the study sites (DWAF 1998). As noted in Section 4.5.5, however, it was apparent from available data in the preliminary study in 2009 that chemical and physical parameters in the study areas had no harmful levels for public health apart from the iron content in deep groundwater. In general, deep groundwater is accessible by drilling borehole rather than hand dug wells. This study also shed light on the effectiveness of different water supply source interventions for water quality. Thereby, the study focuses on the microbiological parameters for water quality testing in the classification A.

There are many different types of pathogens in water, and analyses are relatively expensive and take a while to complete. The action of water testing therefore should only concentrate on critical bacteria. By doing this, the variety of tests is reduced which reduces both costs and time while retaining a good means of assessing whether the water represents a risk to the health of the users (Howard 2002).

Faecal coliforms:
This is an indicator of the possible presence of illness-producing organisms and sub-group of bacteria which are in the category of the total coliforms group. In water it is supposed to be 0/100ml by WHO standard (WHO 2006). Related pathogens cause typhoid fever, Salmonellosis, Shigellosis, cholera and tularemia.

Accessibility

Different water supply types each have characteristics in terms of usage. For instance, hand dug wells are generally located near the households or on the premises of well owners (Sutton 2005). In this regard, such wells are shared with the well owner's family and neighbours, which means a relatively small number of people (Fouegue 2007). Meanwhile, the ideal location of boreholes with handpumps is in the centre of the community for equity because they are able to serve up to 250 people (Sutton and

Nkoloma 2003). In addition, ownership status is also an important factor to consider relating to accessibility because no matter if the water supply source is a borehole or a well, ownership status by community or household leads to different degrees of accessibility. Furthermore, the dimension of time is also a crucial factor to look into as well as distance, since time for travelling to the water supply source and for queuing at the source are significant norms for evaluating accessibility (Fonseca *et al.* 2010a, NRWSSP 2007). Last but not least, it is necessary to consider per capita water use as both a single factor and in relationship to other variables such as distance, queuing time and ownership status. In assessing different water supply models, the following variables therefore need to be investigated because accessibility to water supply sources is significant for public health as discussed in detail in Chapter 3.

- Distance to source
- Queuing times
- Water quantities available to be transported
- Water usage pattern, Number of times to draw
- Primary and alternative water source

Technological and Environmental Sustainability

Poor siting and poor construction of the water supply have the potential to lead to the risk of a direct intrusion of a contaminant into the groundwater. Good design and construction of water supplies is essential to prevent water contamination. As noted by ARGOSS (2001, p.37), "in addition to the actual designs utilized and construction practices followed, the ongoing maintenance of the infrastructure and protection measures is critical to ensure that the risk of contamination remains low." Surveying of technical and environmental aspects of water supply sources is therefore required in order to capture the actual condition and assess technical sustainability. Based on the literature review in Chapter 3, technical and environmental variables are summarized below:

Protected condition of water supply sources based on:

- Well types including boreholes and hand dug wells (including iron removal plant, materials used for lining, apron, soak away, drainage, top slab and well cover)

Although JMP defines dug well types as either *Protected* or *Unprotected*, water source types would be re-categorized by their protection level in this study.

- Types of lifting devices (including handpump and rope pump)
- Depth of well and lining

Sustainability of water supply sources and environment:
- Average downtime
- Frequency of lifting device breakdown
- Frequency of water source dry up

Further, these variables which may enhance sustainability are also examined
- Operation and Maintenance model of water supply source
- Restriction placed by owner on use of the source

Cost-effectiveness

Cost-effective analysis is one of the useful approaches for economic evaluations designed to compare the costs and benefits of an intervention to assess whether it is worth doing (Phillips 2001). Where there are limited financial resources in households or communities, cost effectiveness analysis will support the provision of several options for efficiently improving their water supply sources or for achieving defined goals at the lowest possible costs (Hutton *et al.* 2007). Estimates of cost for a water supply model must capture all relevant costs including project design, hardware installation, labour, as well as any other costs that result from an intervention (Hutton and Bartram 2008). This study encompasses those variables described below:

Investment costs:
- Planning and supervision
- Unit hardware installation costs
- Education that accompanies an investment in hardware

Recurrent costs:
- Labour/transport costs
- Maintenance of hardware and replacement of parts
- Improvement and rehabilitation costs

User acceptability

Investigating user acceptability and preference/demand for different water supply models is important because water supply sustainability is associated with ownership of the water supply sources (Sutton 2004c). Due to the top-down form of the conventional communal model, communities neglect to maintain or repair the source since the water source is subsidised (Breslin 2003), whilst the Self Supply model develops ownership by the households or community when they improve water sources themselves. Ownership might accelerate their willingness to pay for O&M or improvement of water supply sources. On the other hand, in the studies by Mills (2006, p.32) of investigation into stakeholder perceptions of Self Supply, a district community development officer in Uganda observed that "Self Supply approach will cause conflict since it is quite different, even contradictory, to the conventional water supply approach."

Level of user satisfaction towards different water supply sources and reasons for the satisfaction or preferences will be explored through household survey. In parallel with user satisfaction, the motivation for having one's own water source and the factor of water source selection will be addressed in order to capture the community dynamics for a sustainable rural water supply strategy. Moreover, ownership status and willingness to pay for different water supply types will be investigated to look into their relationship with user acceptability.

4.3 Planning for Research

This section presents a schematic of the steps involved in the planning process for this study. There are six key steps in the process.

- Establishing research objectives and questions
- Choosing a research design
- Deciding research methods
- Choosing data sources and variables
- Deciding data collection methods and sampling
- Conducting Data analysis

Fig. 4.1 outlined schematic diagram of these steps with the following sections explaining each step in detail.

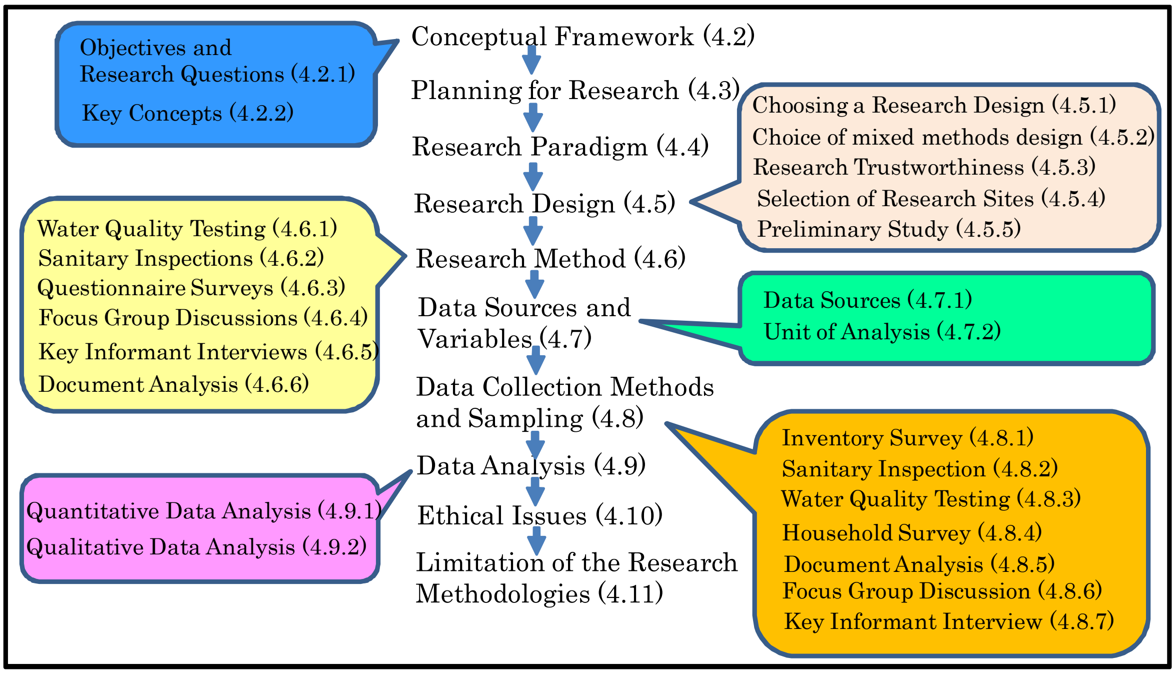


Fig. 4.1: Schematic diagram of research plan

(*Source: Author*)

4.4 Research Paradigm

Paradigms represent a distillation of what we think about the world. "A paradigm is a world view, a general perspective, a way of breaking down the complexity of the real world" (Lincoln and Guba 1985, p.15). Science has distinguished two research traditions on how 'social reality' should be addressed. In the first tradition (positivist /post-positivist), the focus is on quantitative measures. Thus, in this tradition researchers are primarily interested in manipulating numbers to model reality (Denzin and Lincoln 2005). In the second tradition (constructivism), the focus is on understanding human behaviour. Thus, in this tradition, researchers are primarily interested in collecting qualitative data which explains and highlights individuals' motivations for their preferences and behaviour.

The concept of positivism provides "a new rationale for the doing of science that amounted to a literal paradigm revolution" (Lincoln and Guba 1985, p.63). The strengths of the quantitative paradigm are that "its methods produce quantifiable and reliable data that can usually be generalized to some larger population" (Bryman 2004, p.77). The greatest weakness of quantitative research is that it de-contextualises human behaviour "*in a way that removes that event from its real world setting and ignores the effects of variables not adequately captured in the model*" (Bryman 2004, p.78).

In contrast to positivism/postpositivism paradigms, "constructivism puts its emphasis on clarification of the process of meaningful construction and addresses what and how meanings are embodied in the language and actions of social actors through connecting action praxis and builds on anti-foundational arguments while encouraging experimental and multi-voiced texts in the nature of qualitative research" (Denzin and Lincoln 2005, p.24). It is often combined with the term interpretivism (Creswell 2009). The vantage point of qualitative research is that "it can be employed to investigate quite specific, tightly defined research questions of the kind normally associated with a natural science model of the research process and "reason why" differentiates it from quantitative research" (Bryman 2004, p.266). Conversely, qualitative research may have weak points in the nature of unscientific, or only exploratory methods (Denzin and Lincoln 2005).

In comparison with the above discussion, there is an alternative paradigm called 'pragmatism' which adopts a mixture of both qualitative and quantitative methods. "*Pragmatism is the philosophy of considering practical consequences and real effects to be vital components of meaning and trust. Although it seems paradoxical to positivists, with their episteme-based view of knowledge, pragmatic researchers strongly advocate the use of scientific methods and emphasize the importance of the creation of valid knowledge in social research"* (Denzin and Lincoln 2005, p.53). The actions of pragmatic research are purposeful and aim to achieve desired outcomes by using both qualitative and quantitative questions, research methods, data collection and analytical procedures and/or inferences (Creswell 2003, Patton 2002).

This study aims to determine the most appropriate water supply model for safer, accessible, sustainable, cost-effective and acceptable rural water supplies for households based on scientific and social research. Apart from the quantitative nature of the water safety aspect (water quality and sanitary condition), the nature of other variables of the research, namely accessibility, sustainability, cost-effectiveness and acceptability, is explored both quantitatively and qualitatively in order to determine what are the appropriate water supply models and how these aspects impact on sustainable rural water supply. The study encompasses a wide variety of subjects including technical, social and financial aspects. For these reasons, this research is appropriate for the 'pragmatism' paradigm using both quantitative and qualitative research methods.

4.5 Research Design

A research design provides a framework for the collection and analysis of data. A research design selection reflects decisions about the priority being given to a range of dimensions within the research process (Bryman 2004). The following sections present the rationale for the design adopted in this research.

4.5.1 Choosing a Research Design

There are three main conditions for deciding the choice of research strategy appropriate to the research questions identified, and those criteria are presented in Table 4.3

Table 4.3: Research design selection criteria

Strategy	Case study	Survey (cross-sectional)	Archival analysis	History	Experiment
Form of research question	how, why	who, what, where, how many, how much	who, what, where, how many, how much	how, why	how, why
Control over behavioural events	no	no	no	no	yes
Focus on contemporary events	yes	yes	yes/no	no	yes

Source: Yin (2003b)

By referencing the parameters in each cell, an appropriate research design is defined. This study of rural water supply models focuses not on history but on contemporary issues. In addition, there is no control over behavioural events in this study. Consequently, 'Case study' and 'Survey' are the most suitable research designs for this study.

According to Yin (2003a, p.3), "a case study is technically defined as the method of choice when the phenomenon under study is not readily distinguishable from its context though the basic case study entails the detailed and intensive analysis of a single case."

"Case studies are in-depth studies of particular events, circumstances or situations which offer the prospect of revealing understanding of a kind which might escape broader surveys" (Allison *et al.* 1996, p.15). The method of case study is important in this study in that the design enables the generation of rich, detailed data that leaves local people's perspectives intact and provides a context for the behaviour being studied. The research design of the case study in this thesis uses case study tools to measure the Acceptability, Accessibility, Technical and Environmental Sustainability of two different rural water supply models.

This is done by using appropriate data collection techniques such as open-ended questionnaires, focus group discussion and semi-structured interview for seeking views associated with acceptability or preferences for the different water supply models which are discussed in detail in the next chapter. In one of the main aspects of the research, Acceptability is investigated both qualitatively and quantitatively in order to compare the acceptability of the different water supply models quantitatively and to understand the details and given rich data from each rural dwellers' experience and opinion. In connection with the Acceptability aspect, Accessibility, Technical and Environmental sustainability and Cost-effectiveness aspects are also investigated qualitatively through focus group discussion to validate the data collected quantitatively through the household survey as noted below. The case study is the prime generator of a large amount of rich qualitative data which is useful in triangulating the quantitative data obtained from a survey (Robson 1993).

Meanwhile, the Survey is concerned with collecting data about the occurrence or incidence of events or instances in varying situations and circumstances by means of observation schedules, questionnaires and interviews (Allison *et al.*1996). The research design of the survey in this thesis therefore supports the use of survey tools to measure the Sanitary condition, Cost-effectiveness, Accessibility, Technical sustainability and User acceptability of rural water supply models. Furthermore, within the survey design format, comparative design is appropriate to this study. "Comparative study typically sets out to determine the relationship between different factors, variables or dimensions in order to explain either their coincidences or their interdependence. It embodies the logic of comparison in that it implies that we can understand social phenomena better when they are compared in relation to two or more meaningfully contrasting cases or situations" (Allison *et al.* 1996, p.16). This is significantly suitable in this study because the research should encompass the different models of water supply and different communities in order to assess and compare each case. Overall, in terms of the key concepts, the data on Accessibility, Technical and Environmental sustainability, Sanitary condition, Cost-effectiveness and Acceptability are all collected and analysed quantitatively since the relevant research questions form "What" enquiry and comparisons between different water source types can be made quantitatively.

As noted previously the case study falls predominantly within the qualitative research while quantitative research is the nature of the survey. Based on the research questions as stated in section 4.2.1 above, this study aims to answer essentially a "How" and "What" question which suggests that both qualitative and quantitative methods would be required for answering these questions. Therefore, using a mixed method approach of both quantitative and qualitative methods rather than an exclusively qualitative or quantitative methodology is justified in the choice of the pragmatic paradigm. The combination of survey and case studies can generate fruitful information in a mutually complementary manner (Robson 1993).

4.5.2 Choice of mixed methods design

Having settled on the pragmatic paradigm and a mixed methods approach, the next step was to choose between mixed method designs. In mixed method strategies, Creswell (2009, 2003) claims six major strategies below Fig. 4.2.

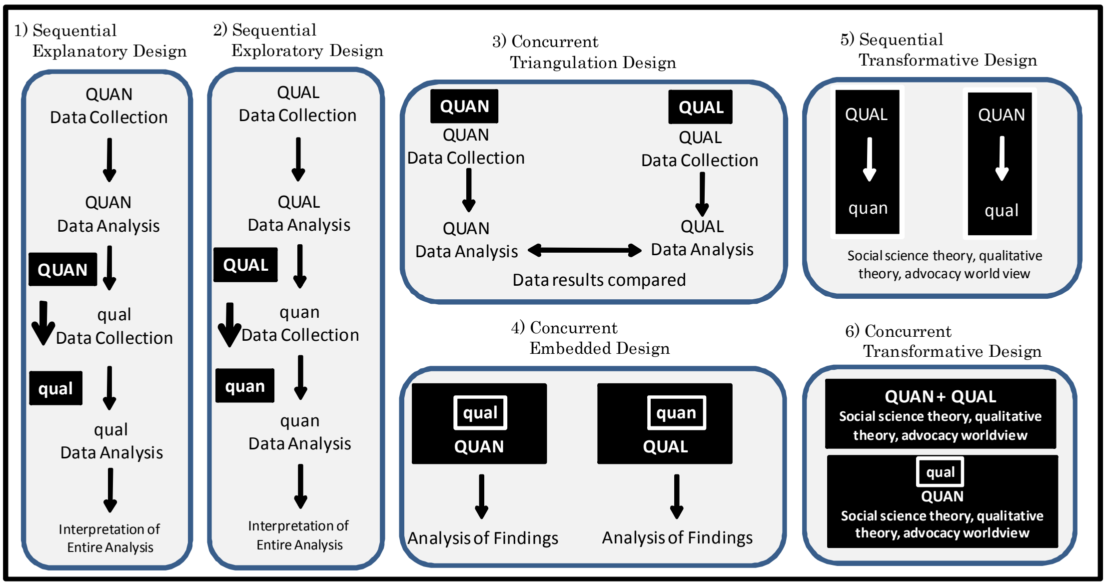


Fig. 4.2: **Mixed method designs**

(*Source: adapted from Creswell* (2009))

- The words *qualitative* and *quantitative* have been shortened in the figure to read "*qual*" and "*quan*", respectively.

- Capitalization (QUAL & QUAN) indicates a weight or priority on the qualitative or quantitative data, analysis and interpretation in the study
- Boxes (■) highlight the qualitative and quantitative data collection

The above mixed method designs can be categorised as sequential or concurrent among the above six mixed method designs. The purpose of the **Sequential explanatory** strategy (1) is to use qualitative data to explain and interpret quantitative results (Creswell 2009). This strategy requires two separate phases which may take too long for data collection (Tashakkori and Teddlie 2003). **Sequential exploratory** strategy (2) is in reverse order from the sequential explanatory strategy to support the interpretation of qualitative data collection and analysis by using quantitative data and results. "Unlike the sequential explanatory and exploratory approaches, the **sequential transformative** model has a theoretical perspective to guide the study with a theoretical lens (e.g. gender, race, social science theory), and little has been written to date on this approach. **Concurrent triangulation** design is the most familiar of the six major mixed methods models, and generally uses separate quantitative and qualitative methods as a means to complement underlying weaknesses of one method with the strengths of the other" (Creswell 2009, p.212). "**Concurrent embedded** strategy of mixed methods is useful to analyse similar topics or different questions in different degree, while **Concurrent transformative** approach seeks for rational perspective from both quantitative and qualitative data collected concurrently (Tashakkori and Teddlie 2003, p.229)."

In these mixed research designs, this study selected the concurrent triangulation design to fill in the gaps of quantitative and qualitative research between survey and case study designs as described in the previous section. In addition, by conducting a preliminary field study in 2009, research questions emerged which could then be embedded into the sequential main field study in 2010 and enabled the researcher to focus the research design on concurrent mixed methods in the main field study. Further, it turned out from the preliminary study that study sites where settlements are very scattered in rural Zambia (1-3HH/km^2) require considerable time for data collection so that the concurrent approach is more appropriate than one of the sequential approaches. Further details of the data collection methods and samplings are discussed in Section 4.8.

4.5.3 Research Trustworthiness

There are important criteria in establishing and assessing the quality of research for both quantitative and qualitative research. Lincoln and Guba (1985, p.290) suggest that the basic issues are:

"1) True value: How can one establish confidence in the truth of the findings of a particular enquiry for the subjects with which and the context in which the inquiry was carried out?
2) Applicability: How can one determine the extent to which the findings of a particular enquiry have applicability in other contexts?
3) Consistency: How can one determine whether the findings of an enquiry would be repeated if the inquiry were replicated with the same subjects in the same context?" (Lincoln and Guba 1985)

The following two sections (4.5.3 a and 4.5.3. b) address these issues from quantitative and qualitative perspectives respectively.

4.5.3.a Reliability and Validity

The issues of reliability and measurement validity are primarily matters relating to the quality of the measurements (Bryman 2004, Yin 2003b, Robson 1993). These are categorized below (Bryman 2004).

- Reliability
  - "This means the research methods are neutral in their effects and would measure the same result when used in similar circumstances. Reliability may be threatened by the researcher's error or bias" (Bryman 2004, p.71). To minimize error or bias which threatens reliability, several strategies were used in this study, such as peer reviewing of the questionnaire for household surveys and triangulation of methods. The bias was also minimized by collecting data from various local people-communities and end users. Different methods such as surveys, use of management records and focus group discussions enabled the researcher to capture the topic from different points of view and achieve more complete and comprehensive findings. The questionnaire was peer reviewed and pre-tested in the preliminary field study before the main field study.

- Validity

- Internal validity: "The extent to which a causal relationship can be established, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships" (Bryman 2004, p.71). Randomization is the way to address the threat of internal validity (Robson 1993). A case is made for this study in that the selection of water sampling points or households to take part in this survey helped to offset the effect of hidden factors. The details are in the Data collection and sampling section.
- Construct validity: "This encourages the deduction of hypothesis from a theory that is relevant to the concept. There is no easy single way of measuring construct validity, and the methodological complexities of determining construct validity can lead to an unhealthy concentration on this aspect of carrying out an enquiry" (Robson 1993, p.68). In this research, multiple data collection techniques were used to enhance the validity and reliability of the data rather than relying on any single measure.
- External validity: "The extent to which the study can be generalized. It can establish how far the findings and conclusions fit with the existing knowledge of the area and how far they translate to other comparable situations" (Yousuf 2005, p.81). There is a fear of criticism in a single case study because it may offer a poor basis for generalization (Robson 1993). In this study therefore multiple cases were undertaken to develop a generalized model which could fit other places with similar rural areas.

4.5.3.b Credibility, Transferability and Dependability

In contrast to quantitative data, Lincoln and Guba (1985) propose that it is necessary to specify terms and ways of establishing and assessing qualitative case study data. They propose alternative criteria to validity and reliability. i.e. credibility, transferability and dependability.

- Credibility

- This is the parallel structure to 'internal validity'. "The significance of this stress on multiple accounts of social reality is especially evident in the trustworthiness of credibility" (Robson 1993, p.403).
- Triangulation and peer debriefing have been proposed to improve credibility (Patton 2002).

a) Triangulation: The uses of different information sources, and measures of data collection are both triangulation techniques which enhance credibility (Robson 1993). Different participants of focus group discussion in different communities enhanced credibility in this study. Moreover, both the qualitative and quantitative data were collected and analyzed to reach a high degree of credibility.

b) Peer debriefing: Debriefing of colleagues or other peers on a continuous basis provides an initial and searching opportunity for testing a principal argument. Water sector and social science experts' checking by UNICEF and WaterAid Zambia on a continuous basis enhanced credibility.

- Transferability
- This is the construct corresponding to external validity or generalizability in conventional quantitative research. Transferability cannot be defined as a synonymous word with 'external validity' since purposeful sampling, which is common in qualitative research, does not represent a population (Patton 2002, Robson 1993). Therefore, this study can generate only the rich description of focus group discussion and open-ended questions in the household surveys which may transfer the conclusion to a relevant context.

- Dependability
- Dependability is analogous to reliability. "If it is possible, using the techniques outlined in relation to credibility, to show quality, it ought not to be necessary to demonstrate dependability separately. Triangulation, as noted in credibility, is a direct technique to develop dependability as an 'overlap method'" (Robson 1993, p.405). Different methods such as focus group discussion and open-ended questionnaire in household survey enabled the researcher to capture their views to enhance dependability.

4.5.4 Selection of Research Sites

Zambia and specifically Luapula Province were chosen as the research site for this research based on macro and micro level considerations. At the macro level, Zambia was chosen on the basis that:

- It is one of the countries in which water coverage in 2006 was more than 10% below the rate it needed to be for the country to achieve the MDG water target (WHO and

UNICEF 2008). This low level of progression towards the MDG water target is widely found in the Sub-Saharan African region and will allow research results of the rural water supply approach to be generalized to some extent in other Sub-Saharan African regions.

- It has many existing activities in both the conventional communal and Self Supply models for rural water supply carried out by government institutions, international organizations and NGOs.
- It has a low population density which is likely to generate sparsely populated rural areas. The sparsely populated rural area has been defined in different ways, such as "populations in the range of 200 people in the community" (Sutton 2009b, p.4) or "5,000 inhabitants in the rural area" (Kleemeier 2010b, p.v). However, for the purpose of this study, a sparsely populated rural area is a settlement where population density is very small (less than 20 persons/km^2). The rural population densities (persons/km^2) where the Self Supply model has been introduced are around: 140 in Uganda, 67 in Ethiopia, 10 in Zambia and 7 in Mali (Sutton 2011).

At the micro level, Luapula Province was targeted in this research due to its lowest level of rural water coverage in the country (Zulu Burrow 2008). For an appropriate selection of study sites within Luapula Province, the first important activity in the preliminary study was to select suitable places in Luapula, and then to choose appropriate sample sites within those Districts for the main study. In order to select appropriate places within Luapula province, a stratification approach based on the following selection criteria was used. Milenge and Nchelenge Districts were selected because they:

1. Have a variety of water supply sources (*Not Protected*, *Partially Protected*, *Protected* well and borehole)
2. Have different water supply models (communal and Self Supply)
3. Have a link with UNICEF, WaterAid and JICA, who implement the Self Supply model in their projects as well as the conventional communal model
4. Have management records
5. Have sparsely populated areas. The population density (persons/km^2) in Milenge is 5.9 and in Nchelenge 15.1.

4.5.5 Preliminary Study

Following the choice of Zambia, a preliminary study was carried out to identify specific locations through a technical and social evaluation, visiting water source points, households and communities. According to Allison *et al.* (1996), a preliminary study is a scaled down version of the full study and this step is fully prepared before carrying out a main study. Equally, a pilot study is important in order to (Fink and Kosecoff 1985, Mikkelsen 1995):

- Collect a small portion of the data
- Assess how it has gone
- Test methodologies

Thus, the research methodologies, including the variables for assessing different water source types, were pilot tested in Zambia. From August to September 2009, the researcher visited Zambia for a preliminary study in Luapula province. The main objectives of the preliminary study were as follows:
1) Meeting with experts, UNICEF, WaterAid, DAPP, JICA and District Council
2) Reconnaissance visits to Self Supply and communal water supply sites; those were Mansa, Milenge, Nchelenge and Chiengi
3) Preliminary testing of methodologies (Technical Inventory Survey, Sanitary Inspection, Household Survey and Water quality testing) for the main study in 2010.

The preliminary study led to the following conclusions and adjustments to be made:

- Although the data from water quality monitoring was expected to be shared with NGOs or local authorities, there was observed to be discontinuous monitoring data, especially for microbiological water quality. This finding enabled the researcher to prepare water quality test kits and complete training prior to the main field study in 2010.
- In the obtained water quality data from JICA, chemical parameters such as arsenic, nitrate, fluoride and iron, were no serious risk for public health in Luapula Province (though high iron content affected user preferences as an aesthetic element). These data supported the decision of the researcher to conduct water quality tests in the main study focusing only on microbiological parameters.
- It was realized that much time was spent in collecting data in sparsely populated

areas. Contacts with key personnel in UNICEF and WaterAid were made during the preliminary study period which enabled the researcher to conduct the main field study smoothly.

- The preliminary study made it possible for the researcher to realise the need for an interpreter to conduct effective household questionnaire surveys.
- During the preliminary study, the subjects of the questionnaire surveys were mostly well owners or caretakers of communal water sources. This study helped the researcher to expand the subjects in the main study to include non-well owners using neighbour's water points or communal sources in order to determine their accessibility to or acceptability of the different water supply models.
- The testing data collection tool in the preliminary study enabled the researcher to refine the methodology for the main study, with the help of reviews by water sector and social science professionals.

4.6 Research Methods

Using a mixed method was justified in Section 4.5.1 in order to answer research questions by both quantitative and qualitative methods. This section, thereby, describes the various research methods that were employed in collecting information during the fieldwork.

4.6.1 Water Quality Testing

In the water quality test, a membrane filtration method is one of the most reliable microbiological water quality tests for the analysis of pathogens in the water (Howard 2002, WHO 2006). Justification for the selection of variables was explained in Section 4.2.2. The research methods are described below.

- Faecal coliforms- Measurement of faecal coliforms was carried out using membrane filtration under the protocol of Wagtech international (2009) below. 50 ml samples are filtered through a Millipore 45 μ m nitro-cellulose filter. Membrane lauryl sulphate media is prepared in a specially developed membrane sulphate media measuring device using 50ml batches with deionised water following standard methods. 2ml of the solution is applied to each filter pad. The filtered membrane is then placed on a pad and incubated at an ambient temperature of 28℃ for 4hours to permit bacterial resuscitation, before transferring to 44℃ for 14 hours incubation. Post incubation, all yellow colonies are counted using a hand lens and then the results recorded as FC (Faecal coliforms)/100ml.

4.6.2 Sanitary Inspections

"Sanitary Inspection is a form of risk assessment and is designed to evaluate the water supply source to see whether there is a likelihood of contamination occurring" (Howard 2002, p.14). The obtained data from the Sanitary Inspection often shows the current water supply status and helps to find the clues to potential risks of contamination. Sanitary Inspection at the point of use (household) is also important to assess the risk of water quality deterioration. The Sanitary Inspection form has a series of questions that all have a YES/NO answer. For every question that has a 'Yes' answer one point is allocated and for every 'No' answer zero points are allocated.

4.6.3 Questionnaire Surveys

"A survey is practical in that to make policy decisions, evaluate programmes and conduct research, the information needed should come directly from the people concerned" (Fink and Kosecoff 1985, p.3). The questionnaire survey is the method to collect set of cases systematically that selected from a defined population in order to make inferences from the results (Greenfield 1996). Surveys refer specifically to the act of 'obtaining data for mapping' (Denscombe 2007). House to house surveys therefore formed a part of the data collection process using questionnaires. Also, an inventory survey for a water supply source was designed to cover the structural design of the water supply interventions and facility conditions. Further, sanitary inspection was also a part of the survey method to collect quantitative data on the selected variables as a visual survey method.

The questionnaire contained both closed and open-ended questions. Closed questions enable the researcher to collect data quantitatively with pre-selected options (answers). Use of the closed question is also a direct technique for developing reliability from emerging answer to the same options (Fink 2005). On the other hand, Open-ended questions provide an opportunity for the respondents to respond and express their ideas and opinions, but interpreting the data can be difficult unless they are accompanied by an elaborate coding system which is the nature of qualitative research (Fink 2005). However, "properly designed and coded, questions that are answered in narrative form can be important contributions to good surveys" (Fowler 1995, p.59). Key statements that come up from open-ended questions might constitute some subsidiary topics for the focus group discussions.

4.6.4 Focus Group Discussions

Focus group discussion has been selected because of the significance of interaction between participants in focus group discussions. "This technique allows the researcher to develop an understanding about why people feel the way they do" (Bryman 2004, p.346). While the household survey questionnaires will generate expected answers to some extent, focus group discussion can provide a variety of opinions without enforcing opinions or ideas from pre-selected answers. In addition, the significant difference between focus group discussion and individual interview is the interaction among the group members. The measure of focus group discussion provides participants with a window of opportunity to create new ideas that they probably would not have thought of without the chance of hearing the views of others (Bryman 2004, Patton 2002).

4.6.5 Key Informant Interviews

Semi-structured interviews were conducted with the key personnel who had experiences and a high degree of responsibility and were familiar with the research topics. The interview guide was semi-structured, thus giving interviewees the freedom to speak for themselves in their own words on the research area as the interviewer was more likely to control the interview with a certain set of questions (Yin 2003b).

4.6.6 Document Analysis

Document analysis is a useful research method which treats documents as a source of data in their own right (Denscombe 2010). The documentary sources can be found from any government publications, newspapers, record of meetings and official management records. Use of management records, especially the financial records, is a critical methodology, in order to assess the indicators of cost effective water supply models.

4.7 Data Sources and Variables

In order to form each objective for a sustainable rural water supply model as stated in Section 4.2, the relevant primary and secondary data were explored. The primary data sources of this research were 'households' and 'water sources' in order to address the five key concepts (see Section 4.2.2). For secondary data sources, internationally accessible academic journals, articles and books, institutional, administrative reports and management records were relied on in the analysis for this study.

4.7.1 Data Sources

The data source and variables selected for this study (see Section 4.2.2) are presented under the five key concepts below:

1. Water quality and sanitary condition- Microbiological parameters and sanitary condition are selected (Water sources).
2. Accessibility- Conditions of user access to a water supply, water collection time and per capita water use are selected to measure the impact of the different water supply types (Households)
3. Sustainability- Technological and environmental variables are selected to measure both the sustainability and reliability of water supply sources (Households and Water sources)
4. Cost-effectiveness- Costs of investment and recurrent costs are selected to assess the cost effectiveness associated with different water supply sources (Institutional reports, Management record and Households)
5. User acceptability- Amount of user satisfaction for water supply options is selected to measure the impact on socio-economic indicators (Households)

The selected variables for comparing different water supply models are shown in Table4.4 and relate to the five key concepts.

Table 4.4: Research variables

Key Concepts	Water quality	Accessibility	Sustainability	Cost-effectiveness	User acceptability
Variables	・Faecal coliform	・Distance to source	・Water supply types	・Planning and supervision	・Satisfaction
	・Sanitary conditions	・Waiting times	・Frequency of water source dry up	・Unit hardware installation	・Preference
		・Water quantities available	・Average down time	・Education that accompanies an investment in hardware	・Ownership
		・Per capita water use	・Frequency of lifting device breakdown	・Labour/ transportation	・Willingness to pay
			・Depth of well and lining	・Maintenance of hardware	・Previous water source and reason of the transition
			・Depth of water table	・Replacement, rehabilitation	
			・O&M system	・Improvement	

(*Source: Author*)

4.7.2 Unit of Analysis

"Decisions about samples, both sample size and sampling strategies, depend on prior decisions about appropriate unit of analysis for the study. Often individual people, clients, or students are the unit of analysis" (Patton 2002, p.228).

In this study setting the primary unit of analysis is the 'household', given that the aim of this study is to determine the most appropriate water supply model for a household in sparsely populated rural areas of Zambia. The study included sub-units such as, the water supply model and factors involved in the water supply models leading to the most appropriate water supply in terms of water quality, accessibility, cost, sustainability and acceptability. "Each unit of analysis implies a different kind of data collection, a different focus for the analysis of data, and a different level at which statements about findings and conclusions would be made" (Patton 2002, p.228). For each aspect, the focus was placed on both water point owner/caretaker groups and non-water point owner groups.

4.8 Data Collection Methods and Sampling

As discussed in Section 4.5, the mixed method approach involving both quantitative and qualitative methods was used for this study. Figure 4.3 shows a schematic representation of the sequence in which data collection methods were used in the field. Research strategy flows in a left-to-right direction. Those shown by dotted lines are iterative collection methods. The data collection exercise was carried out in phases so that interesting issues emerging from previous phases could be refined and incorporated into the subsequent phases. "This strategy also enables the researcher to play an active part in each step of the data collection methods" (Addo-Yobo 2005, p.72).

One of the six major mixed method approaches, concurrent triangulation strategy, was implemented in this research. The concurrent triangulation strategy is characterized by collecting both quantitative and qualitative data concurrently to offset the weaknesses inherent within one method with the strengths of the other as mentioned in Section 4.5. This strategy can generate well-validated and substantiated findings (Creswell 2009, Creswell 2003). "This integration is commonly described in published mixed method studies in which a discussion section first provides quantitative statistical results followed by qualitative quotes that support or disconfirm the quantitative results" (Creswell 2009, p.213).

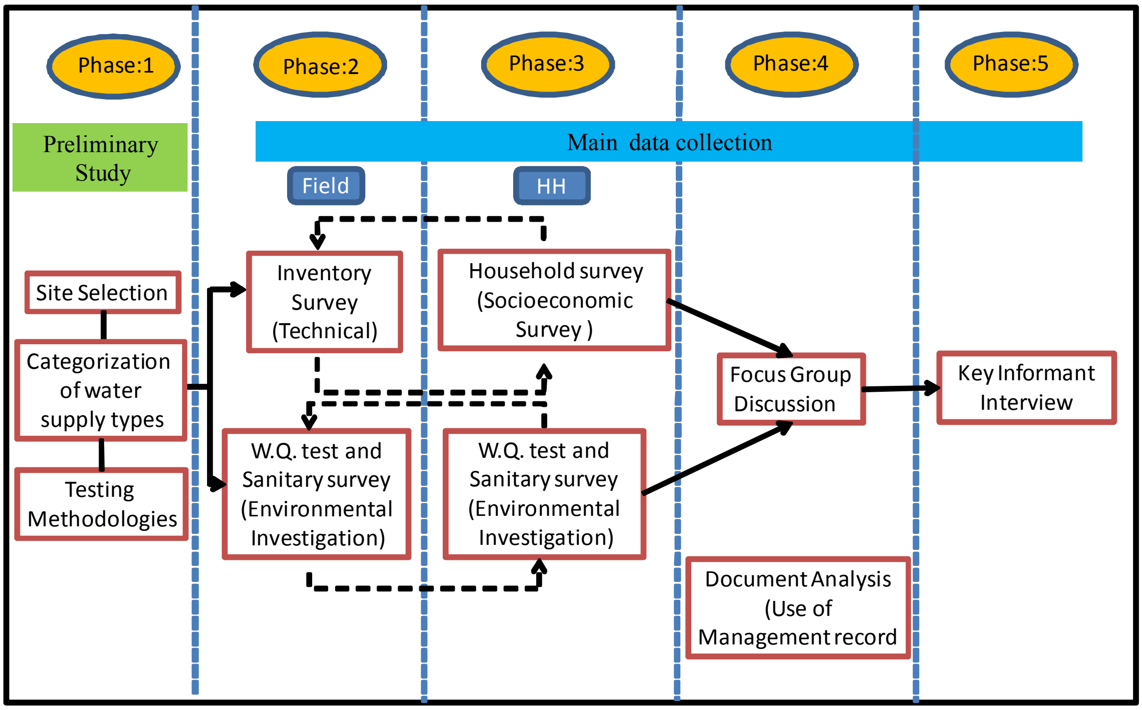


Fig. 4.3: **Schematic representation of the data collection procedure**
(*Source: Author*)
Note: W.Q.: Water quality

In the meantime, a concurrent embedded strategy was integrated as a fifth phase in which the viewpoints of the government and external support agencies towards water supply models were explored in contrast with the viewpoints of the households towards water supply sources and models through the second and third phases. This enabled the researcher to test the principal argument not only from the viewpoints at the micro level, but also from the macro point of view. The micro level refers to community or end users whilst the macro level corresponds to the government or donor organisations in this context.

The first phase of the data collection was the preliminary study. As noted in Section 4.5.4, the preliminary study was carried out for selection of the study sites for the main study and for checking the methodologies. Categorization of water supply sources was also implemented in the first phase. A technical inventory survey was practised in the second phase to collect data associated with the technical sustainability of water supply sources whilst data for water quality and sanitary condition were tested by environmental investigation in the field. Household surveys in terms of accessibility, user acceptability and water quality data at households were implemented in the third phase.

Financial data for cost effectiveness was also sought in the fourth phase through a document analysis method using management records. This is because it took a while to obtain financial data from relevant organisations (i.e. JICA and WaterAid). Although focus group discussion was also carried out in the fourth phase, similar questions were addressed both in the household survey in the third phase and in the focus group discussion of the fourth phase in order to interpret or compare the data sources in the concurrent triangulation approach. Meanwhile, key issues that emerged during the first to third phases of the data collection exercise also made up supplementary topics for the focus group discussions when looking for user acceptability or preference for the different water supply models in the fourth phase. Key informant interviews were emerging as the fifth phase in contrast with the third and fourth phases in that the points of view from macro (government/ donor organisations) interest were underscored to capture their perception and attitude towards different water supply models for policy development, while previous phases had highlighted micro viewpoints.

As discussed in Section 4.5.1, survey and case study are suitable research strategies for this study in a mixed method approach. The data collection methods used in this study were survey (inventory, sanitary and household), water quality testing, key informant interview, document analysis and focus group discussion. "The use of mixed methods has the benefit of enhancing the validity of the results through data triangulation, getting the best understanding of the phenomenon under study, and for drawing stronger inferences" (Tashakkori and Teddlie 2003, p.37). Survey and case study, however, have obvious fundamentally different sampling methods because of the natures of quantitative and qualitative research. Because of the manner of quantitative research, the survey sampled does not stand in its own right but acts as a means of understanding the population from which it is drawn (Robson 1993). Sampling in survey design is done primarily in the model of generalizing from the sample selected to the population from which it comes. The sampling method in case studies, on the other hand, is very different from those which are used in survey research. It is based on informational, not statistical considerations so that the purpose of the qualitative measure is to maximize information, not facilitate generalization (Lincoln and Guba 1985). In order to clarify the data collection process, the following sections explain the detail of each data collection method and sampling.

4.8.1 Inventory Survey

The first step was to carry out an inventory of sources available to the population who rely on traditional hand dug wells and boreholes. An inventory of water supply sources was designed to cover the structural design of the water supply interventions, facility conditions and socioeconomic aspects of water sources (see Appendix A):

- Name of water source owner/location
- Village
- Ward
- Date
- Water supply type (well types, types of lifting devices and depth of wells)
- Protection condition
- Ownership status of the water supply source
- Improvement work
- Years of construction
- Number of users
- Contribution system
- Availability of water
- Frequency of break down
- O&M system, restriction

The classification of water supply sources predominantly followed the JMP definitions (2006) but was further subdivided especially for the level of protection of the wells.

Therefore, categorization of different water supply models, especially Self Supply, was carried out in the preliminary study of the first phase in Fig. 4.3. The sample number for categorization in the preliminary study was not intended to obtain statistically representative samples because the emphasis was on the trustworthiness, and not on the generalizability of the findings. The aim of the categorisation was to get sufficient data to help identify the major characteristics of the condition of water supply sources and to find the protection level of sources. The protection levels of the hand dug well (HDW) were classified into three categories (*Protected*, *Partially Protected* and *Not Protected*) based on the preliminary study and informal discussion with Dr Sally Sutton using scoring of protection levels (see Appendices A, B and Section 5.2).

Many of the details about the source, such as the name, location and when it was constructed may have already been available from records in the local offices or water supply aid organizations. However, "in most cases, each area covered by the survey should be visited and the available sources recorded" (Howard 2002, p.7). Furthermore, these parameters were measured using survey data both in the field and in households. Using a combination of field survey and household survey, triangulation of results is possible in order to reduce potential errors and to validate individual results (Godfrey 2006). It will be noted that there was some overlap between questions in the survey and those in the sanitary inspection forms. Reliability of field survey data was enhanced by peer reviewing of technical inventory and questionnaire forms. Size of sample for the inventory survey followed by the environmental investigation is discussed in the Section 4.8.3.

4.8.2 Sanitary Survey

Following the inventory survey, Sanitary Inspection forms were used to collect quantitative data on the selected variables as a visual survey method within the environmental investigation (see Fig. 4.3 and Appendices C & D). Sanitary Inspection of each well was undertaken alongside a water quality test. Sanitary Inspection is significant in order to grasp the process for improving the well protection to be undertaken in phases in the Self Supply model. Also, Sanitary Inspection took place at the household where water was sampled from the household storage. This was to investigate the potential risk of water contamination and if the quality of water had deteriorated when compared with the quality at the water source (see Appendix E). Size of sample for the Sanitary Inspection is discussed in the next Section 4.8.3.

4.8.3 Water Quality Testing

A water quality test is discussed in this section as a physical survey method within the environmental investigation (see Fig. 4.3). Appropriate sample sizes for water quality at sources, inventory and sanitary survey were decided by means of simple random statistical methods determined by using the equation (4.1) applicable to estimating proportions (Thompson 2002).

$$n = \frac{Np(1-p)}{(N-1)(\frac{d^2}{z^2}) + p(1-p)} = \frac{N}{(\frac{d}{z})^2 \left\{ \frac{N-1}{p(1-p)} \right\} + 1} \qquad (4.1)$$

Where, n is the sample size

N is population size (i.e. number of water points)

z is the value of standard normal distribution. This value is 1.64, 1.96 and 2.58 for confidence probabilities 90, 95 and 99%, respectively (Thompson 2002, Curwin and Slater 2008).

p is the proportion of success

d is a maximum allowable difference between the estimate and the true value

The number of hand dug wells and boreholes were equated to the number of water points in this study. According to the baseline surveys done by Zulu Burrow (2008) and Madavine (2008) in 2008, the approximate number of water points was 530 at the study sites including both Milenge and Nchelenge. A maximum 5% error with a confidence of 95% is set for the desired reliability. Where no information is available about an appropriate value of p to use in the calculations, a value of 50% is used for p (Thompson 2002, Curwin and Slater 2008, Burt and Barber 1996). Therefore,

$$n = \frac{N}{(\frac{d}{z})^2 \left\{ \frac{N-1}{p(1-p)} \right\} + 1} = \frac{530}{(\frac{0.05}{1.96})^2 \left\{ \frac{530-1}{0.5(1-0.5)} \right\} + 1} = 223 \textit{water points}$$

In all, a total of 269 water points at source had received completed water quality tests, sanitary and inventory surveys at the end of the field work. Meanwhile, 44 water points at use level (household) had a water quality test and sanitary inspection since the emphasis was on the trustworthiness, and not so much on the generalizability of findings at the point of use. The calculated sample size was distributed on the basis of the proportion of each water supply source in the study area (see Section 5.2). In the main study, technical and environmental surveys were implemented together in the field in the second phase (see Fig. 4.3).

WEDC, (Water, Engineering and Development Centre) provided training on water quality testing for the researcher in the Loughborough University Laboratory in April 2009 and February 2010. During this training, an analytical chemist undertook the development of the standard procedures for the field work to be used by the researcher, and training was given on the chemical and microbiological analysis. However, chemical and physical water quality tests were not done by the researcher in the main field study because the implementing NGOs (WaterAid and DAPP) and JICA had been conducting these tests since 2006, and results showed no harmful contents for public health apart from a high iron content, and no significant change in the chemical water quality because project sites have neither intensive agriculture nor industry. Therefore, the chemical and physical water quality parameters were not addressed in this study in order to focus on the assessment of the quality of water by water supply intervention. The testing was limited to the microbiological parameter.

4.8.4 Household Survey

The household survey is designed to elicit information on water user activities/ social and economic, and to measure accessibility, user acceptability, preference and intention towards improving water supply sources (see Appendix F). The questionnaire survey was drawn up in attempt to answer the research questions about the impact of different water supply options associated with user acceptability and accessibility and sustainability. Questionnaires were drafted for the preliminary study and the full household survey form for the main study was developed as a result of the preliminary study, literature review and a discussion with water sector and social science experts in the field. The questionnaire was pre-tested in the preliminary study in a community with similar characteristics to the research communities. Respondents for the pre-tests were chosen for convenience, instead of via a rigid sampling framework as was used in the main survey.

The household survey questionnaire was administered by the researcher using the face-to-face method. Households were surveyed based on the availability of suitable respondents including heads of households, housewives, and other adult members of the household. The questionnaire for household survey included (see Appendix F):

- Sex, occupation of household heads or respondents, household size
- Primary water source
- Distance to primary water source and queuing time
- Usage of water
- Quantity of water (number and volume of container)
- Number of trips to collect water
- Alternative water source
- Distance to alternative water source
- Satisfaction/preference of the water supply source
- Reason for having own water source
- Previous water source, distance and reason for changing water supply source
- Willingness to pay for water source types
- Practice of household water treatment

Each household survey lasted for between thirty to sixty minutes, and all responses were written down on the questionnaire by the researcher. All household surveys were administered by the researcher with the help of an experienced assistant. All surveys were conducted using one of the major local languages (Bemba or English), so that respondents were able to express themselves fluently. Assistants for the survey were recruited from both Milenge and Nchelenge Districts with the help of WaterAid and DAPP who were implementing the projects of the Self Supply model. The assistants were selected based on their basic education level, fluency of local language and knowledge and experience of water supply programmes and projects. In addition, being members of the communities, they were more familiar with the community people and unlikely to dominate respondents when conducting the survey.

Two days survey training for assistants was conducted by the researcher prior to conducting the main household surveys for assuring the quality of survey. On the first day of the training programme, the researcher explained the research purposes and objectives of the household survey to the assistants. Further, the meaning and relevance of each question was explained in the training session. On the second day of the training programme, the assistants tried their hand at conducting the interpretation of the household survey to households with the researcher. Some of the lessons learned through the trial surveys were:

1) Ideas for good icebreakers with respondents

2) Self introduction and purpose of survey
3) The moderation of the survey

Stratified random sampling was used as a means of conducting the household surveys. A stratified random sample is obtained by forming classes in a population and then selecting a simple random sample from each class (Burt and Barber 1996). The basis for stratification was the water supply point. Each research site was divided into water points, then participating households selected systematically from each water point owner/caretaker and neighbours sharing that water point. Selecting water points would ensure a fair distribution of respondent water point owners/caretakers across the research site, and in the meantime participating households who share the water sources were chosen randomly from the designed sampling framework to enhance the reliability and validity. The size of sample from the selected community is determined by using the equation (4.1). Total number of households (N) including Milenge and Nchelenge is about 30,131. Therefore,

$$n = \frac{N}{(\frac{d}{z})^2 \left\{ \frac{N-1}{p(1-p)} \right\} + 1} = \frac{30{,}131}{(\frac{0.05}{1.96})^2 \left\{ \frac{30{,}131-1}{0.5(1-0.5)} \right\} + 1} = 379 \, households$$

in all, a total of 447 household surveys were administered by the end of the field work. As reported in the above Section 4.8.3, a total of 276 water points were technically assessed (no water quality tests at 5 water source because of water source drying up or lifting device break down) so that out of 447 household surveys, 276 water point owners/caretakers were surveyed and the remaining 171 household surveys were from non-water point owners who shared a neighbour's water point. To enhance the main reliability and validity with regard to data collection through the survey, the following efforts were made.

- Sample selection bias: Samples were selected randomly for each household to stand an equal chance of being selected.
- Non response error: The researcher was trained and practised in being pleasant and establishing a rapport with the respondents.
- Item non-response error: The researcher administered questionnaires minimizing non -response error. The researcher ensured that no item was skipped unless respondents were not willing to respond to the question for specific reasons.

All the measures mentioned above during the survey therefore helped to ensure the validity and reliability of the study.

4.8.5 Document Analysis

Document analysis was done by using management records. However, there is generally a very limited amount of management records for water supplies in developing countries (Doe 2004). Therefore, the case study site has to be selected where management records are available in order to analyze the cost effectiveness of rural water model provision in this study.

The data relevant to financial records were collected during the fieldwork in order to examine the cost effectiveness aspects. Also, data obtained from management records were combined with those from the other data collection techniques of household surveys and focus group discussions. The data on maintenance costs for the communal water supply model were collected from the caretakers of communal facilities while the data for the costs relevant to the traditional water source construction, maintenance and improvement were obtained from individual households during the household surveys. These costs were also gathered from handpump menders and local artisans in order to enhance their validity and reliability. Also, project costs for the communal and Self Supply models in Zambia were obtained from the involved organisations i.e. JICA and WaterAid.

Lifecycle cost analysis is used to develop sustainable financing mechanisms for ensuring cost-effective water model provision. Sustainable financing mechanisms need to be developed, so that rural water models can be sustainable. The figures regarding life span, served numbers and amount of delivered safe water were derived from the data collected from a combination of published information (JICA 2007), WaterAid and household/caretaker surveys.

4.8.6 Focus Group Discussion

The use of focus group discussions at the later stages of the data collection exercise (Fig. 4.3) thus supports and allows better interpretation of information obtained from the methods used in the previous phases of the data collection exercise (Addo-Yobo 2005). The focus group discussions therefore enhance the interpretative validity of the research.

According to the studies by Sutton (2009a) in Zambia and Carter (2006) in Uganda, there are demands from local people to know the options for water supply technologies or to have knowledge in rural areas on how to improve their own sources, and even some people without wells are now planning to construct them. However, not many people know the variety of rural water supply technologies and water supply models, or understand the advantages or disadvantages of each model. As noted in section 3.7.3 in Chapter 3, there is a discrepancy between local people's demand and existing facilities and models which are provided by external support organizations. By establishing a forum for discussion within the local community, they can express their preferences or desires for water supply models and learn from the neighbourhood's knowledge and ideas. In the meantime, the researcher can investigate their acceptance of the different water supply models, as well as accessibility, technical and environmental sustainability aspects in order to cross-validate the data from household surveys.

In focus group discussion participants are able to bring issues to the fore that they deem to be important and significant in relation to the selection of water supply sources, operation and maintenance of water supplies and improvement of their sources. To stimulate group discussion, a few general questions should be set such as:

- What kinds of water supply sources/technologies do you know/want/improve?
- What are your preferences for different water supply sources and why?
- What is the priority for water supply sources?

Participants for each group discussion can then be selected randomly or through some kind of purposeful sampling method rather than through statistical sampling. "The aim of focus group discussion is to establish whether there is any systematic variation in the ways in which different groups discuss a matter" (Bryman 2004, p.348). The use of focus group discussion is intended to maximize variation of acceptability/preferences for the different models of water supply.

In the purposeful strategy, snowball sampling has taken place in this study where the researcher makes an attempt to contact specific persons who are familiar with the research topic and then expand networks from these initial contact persons (Robson 1993). It was selected to be maximally contrasting not only from water point owner/caretaker but also from non-water point owner, and thereby to acquire as much different information as possible. The number of participants in each discussion was 5-8 people which are a typical number for focus group discussion (Bryman 2004, Patton 2002). Overall six groups were involved in focus group discussion. All the focus group discussions were administered by the researcher with the help of an experienced assistant in the same way as the household survey. The discussions were recorded on voice recorder consensually taking into account the flow of group discussion, whilst some of the group discussions were taken down in notes where participants were reluctant to have the discussions recorded. Debriefings were held to review the transcripts of the focus group discussions with water sector and social science experts from WaterAid in order to enhance the credibility.

4.8.7 Key Informant Interview

The key informant interviewees were selected from water sector professionals to capture their perception and attitude towards the different water supply models; Self Supply and communal models as a macro interest in contrast with household surveys as a micro viewpoint (see Fig. 4.3). Details of key informants interviewed are presented in Table 4.5.

Table 4.5: Key Informants interviewed

No.	Name	Position and organisation	Main issues of interview
1	Mr Danny B. Chibinda	District planning officer, Nchelenge District council	Sustainability of different water supply models
2	Mr Kasongo Christpher	District planning officer, Chiengi District council	Sustainability of different water supply models
3	Mr Sinkala Steave	Water engineer, Provincial Water Affairs Office	Competition and symbiosis of water supply models
4	Mr Mubyana Munyangwa	Water and Sanitation project coordinator, Africare	Self Supply model
5	Ms Miku Okada	Groundwater development project officer, JICA	Conventional communal water supply model

(*Source: Author*)

The role of the District Planning Officer is to coordinate the various stakeholders in the water and sanitation sub-sector in order to ensure prudent investment in the sub-sector and avoid duplication of efforts by conducting planning, review and evaluation meetings for all stakeholders. The role of the Provincial Water Affairs Office is to support the water sector by establishing an informal forum aimed at enhancing cooperation and the coordination of policies, strategies and approaches in support of water supply and sanitation development at the Provincial level. Africare is one of the NGOs implementing the water and sanitation project in Luapula Province and currently they are piloting play pump facilities at school sites. JICA is also a donor agency for developing the water situation in Luapula Province with provision of 200 boreholes between 2008 and 2010 as presented in Section 2.2 research background.

Appointments were made with the key informants prior to having the interview with an explanation giving 1) Self introduction, purpose of interview and the objectives of study, 2) Confidentiality obligation 3) The approximate length of interview and 4) Confirmation of language to be used for interview. Three of the interviews were recorded on audio and transcribed on the day of interview while the other two interviews were noted and transcribed immediately after the interviews based on their preferences. The excerpts from the interview transcripts of the highlighted key informants were used in the analysis and discussion in this thesis.

In conclusion of this section, the research generated a large amount of quantitative and qualitative data relating to rural water supply models through the main field data collection in Zambia for 6 months. A summary of the data used in this study is provided in Table 4.6.

Table 4.6: Summary of information available in research data base

Research Methods		Quantity		
		Milenge	Nchelenge	Total
Technical inventory survey		110	164	**274 (WP)**
Environmental investigation	Water quality tests at source Sanitary surveys at source	108	161	**269 (WP)**
	Water quality tests at use Sanitary surveys at use	44	0	**44 (HH)**
Household survey		174	273	**447 (Persons)**
Key informant interview		3	2	**5 (Persons)**
Focus group discussion		10 members in 2 groups	22 members in 4 groups	**6 (Group)**
Document analysis		1	1	**2 (Set)**

(*Source: Author*)

Note: HH: Household, WP: Water Point

4.9 Data Analysis

Typical of mixed method research, the information gathered from the fieldwork included both quantitative and qualitative data. Both sets of data were analyzed separately using suitable data analysis techniques. As noted in Sections 4.5.1 and 4.5.3, data from different sites were comparatively assessed for their differences or similarities in the characteristics and behaviour trends. A description of the data analysis processes for both quantitative and qualitative data is presented below.

4.9.1 Quantitative Data Analysis

The quantitative data was primarily obtained from the technical, environmental and household surveys and use of management records. After those surveys were completed, they were codified and analyzed using Microsoft Office Excel 2007 and Statistical Package Social Science (SPSS) software (version 18.0). The methods used for analysis of numerical data were:

- Descriptive statistics- Descriptive statistics are numbers that summarize sets of data. These include counts, frequency distribution, proportions and measure of variations.
- Chi-square- Chi-square provides descriptive statistics to determine the probability of a statistical association between nominal variables, categorical and ordinal, or dichotomous variables.
- Correlation- Correlation is used to evaluate the strength and direction of the relationships with ordinal variables, or ordinal and interval variables.

A Categorical variable is made up of categories (Kendrick 2005). Ordinal variables are those variables in which the categories are ordered while an Interval variable is that equal intervals on the scale represent equal differences in the property being measured. (Kendrick 2005). Numbers not pre-determined by the researcher are referred to as Numerical (scale) variables (Kendrick 2005). In this study, Categorical variables consist of water supply types and ownership status while ordinal variables are comprised of number of users, frequency of lifting device break down, frequency of water source dry up, distance to water supply source, per capita water use and user satisfaction collected from field and household surveys.

Numerical variables are water quality and financial data obtained from environmental investigation and use of management records. A frequency distribution was used to compare water quality between different types of water supply while the safe water quality proportion was subject to WHO drinking water quality guideline values. To determine the strength and direction of the relationship between the risk score of the Sanitary Inspection and water quality level, Spearman's rank order correlation was used. The financial data collected from management records associated with the water supply interventions was processed into a lifecycle cost analysis.

4.9.2 Qualitative Data Analysis

The qualitative data was generated from the focus group discussion, open-ended questionnaires in the household surveys and key informant interviews. The qualitative data analysis has two main strategies, one is analytic induction and the other is grounded theory. Analytic induction is an approach to "*the analysis of data in which the researchers seek universal explanations of phenomena by pursuing the collection of data until no cases that are inconsistent with a hypothetical explanation of a phenomenon are found*" (Bryman 2004, p.398). Grounded theory is defined as that theory that was derived from data, systematically gathered and analyzed through the research process. Qualitative data analysis is conducted concurrently with gathering data, making interpretations, and writing reports (Creswell 2009). The analyses of qualitative data followed four major sequences generalized from the literature, and discussed below (Creswell 2009, Bryman 2004, Robson 1993).

1) Organise and prepare the data for analysis
   Shortly after the data collection phase has taken place, the data was processed, and summarized using a word processor (Microsoft Office Word 2007). Audio recording of some focus group discussions and key informant interviews also required transcription and editing.

2) Development of coding categories
   A coding was the next step to classify or categorize unstructured writing up data.

3) Indicate how the description will be represented in the qualitative narrative
   This was an attempt to summarize what the researcher has found out through organising code relationships which enable the researcher to quote or use them in explaining statements where found applicable in the data analysis and discussion chapter.

4) Making an interpretation or giving the meaning of the data

This process helped the researcher interpret and compares the findings from different techniques such as quantitative data or extant literature.

To sum up the data analysis section, Table 4.7 presents the summary of the data analysis used for this study.

Table 4.7: Summary of data analysis

Key concepts	Data Collection Method	Data Analysis
Water quality and sanitary condition	Water Quality Testing Sanitary Survey	Quantitative (SPSS-correlation)
Accessibility	Household Survey Focus Group Discussion	Quantitative (SPSS-correlation) Qualitative (Analytic induction)
Technical and Environmental Sustainability	Inventory Survey Household Survey Focus Group Discussion	Quantitative (SPSS-descriptive, χ square, correlation) Qualitative (Analytic induction)
Cost-effectiveness	Document Analysis Household Survey	Lifecycle cost analysis
Acceptability	Household Survey Focus Group Discussion Key Informant Interview	Quantitative (SPSS- χ square) Qualitative (Analytic induction)

(*Source: Author*)

4.10 Ethical Issues

Moral correctness has to be considered in the research process. Israel and Hay (2006) highlighted that the most important issues and concerns a researcher has to address are: 1) personal disclosure, 2) authenticity and credibility of the research report, 3) the role of researchers in cross-cultural contexts and 4) issues of personal privacy through forms of Internet data collection. It is important to consider these throughout the entire research process including research design and writing up, not simply taking account of them at the research implementation stage (Creswell 2009). The ethical issues that were taken into consideration in this study are listed below:

Table 4.8: Checklist for ethical issues

Ethical issue	Mark
Permission obtained from the relevant authorities, and traditional leaders in Zambia prior to conducting the field work	✓
Identification of the sponsoring institution (UNICEF, WaterAid and DAPP)	✓
Non enforcement of research assistants taking part in the research	✓
Guarantee of confidentiality and degree of anonymity	✓
Consent of record prior to survey, interview and focus group discussion	✓
Provision of names of the researcher to contact if questions arise	✓
Debriefing between the researcher and assistants in the research report	✓

(*Source: Author*)

4.11 Limitation of the Research Methodologies

Research methods applied in the study were presented in the foregoing sections. The study addressed all measures to assure the protocol of consistent methodologies and the documentation was sufficient to ensure trustworthiness of the data. However, a number of limitations have been found in the study. Firstly, the sampled number of key informant interviews might have been inadequate to articulate the macro viewpoint although the interview structure was not intended to generalise the findings. Secondly, the sampled number for water quality at household level did not represent the number of households in the study areas. Further, data collected from JICA with respect to costs of communal water supply projects might not show accurate costs because the data were derived from estimated cost (Exchange of Notes). In addition, data obtained from the household survey might have small inaccuracies. For instance, the data on water quantities drawn by household from the water source were based on self-reporting by households rather than by measuring, which might be not accurate all of the time. In order to overcome the limitations, data obtained from the study were compared with relevant studies or reports to ensure credibility in parallel with the concurrent triangulation design addressed in this study.

4.12 Chapter summary

This chapter reviewed the objectives, principal argument and key research questions that guided this research. The research questions were designed around five key concepts, namely a) Water quality and sanitary condition b) Accessibility c) Technical and environmental sustainability d) Cost-effectiveness and e) Acceptability. The research questions were derived from the extant literature:

a) **Water quality and sanitary condition**- What impact do the water supply models have on the quality of water? What are the factors likely to affect water quality? What is the status of sanitary conditions? What are the sanitary risks likely to affect the water quality? How does water quality change at source and the point of use, and what are the contributory factors?
b) **Accessibility**- What is the status of accessibility towards the different water supply models? What are the factors likely to affect accessibility in terms of distance and time? What is the status of per capita water use among different water supply models and how is this likely to be affected by accessibility?
c) **Technical and environmental sustainability**- What is the status of technical sustainability for the different water supply models? What is the status of the water reliability of the different water supply models? What are the factors likely to affect technical sustainability and water reliability? In what way are water supply models delivering operation and maintenance systems to the households/communities?
d) **Cost-effectiveness**- What costs constitute lifecycle cost in different water supply models? How do lifecycle costs impact on project costs and household/community costs? When are the costs incurred?
e) **Acceptability**- What is the status of acceptability towards the water supply models for end users in terms of water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability? What are the factors likely to affect user satisfaction? How are user preferences/satisfactions in selecting a water supply model likely to affect community water supply dynamics?

The principal argument is that **reliance only on a communal water supply model limits the achievement of increased sustainable access to safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in rural areas of developing countries for the purpose of increasing access and achieving sustainability**.

Case study and comparative design in the context of the survey were the most suitable research designs for the primary data collection because pragmatism is the principle governing this research paradigm, using quantitative and qualitative methods in a complementary fashion. Various indicators were selected corresponding to the objectives including water quality, technological and environmental sustainability, cost effectiveness, accessibility and user acceptability. Further, this chapter has reviewed the data collection techniques and data analysis in terms of selected variables. Table 4.9 summarizes each corresponding variable parameter and data collection methods.

Table 4.9: Summary of data collection method

Key concepts	Water quality and Sanitary Condition	Accessibility	Technical and Environental Sustainability	Cost-effectiveness	User acceptability
Indicators	･Water quality at source ･Protection feature ･ Sanitary condition ･Water quality at use and water treatment	･Distance ･Water collection time ･Per capita water use	･Technical sustainability ･Environmental sustainability ･O&M model	･Lifecycle cost ･Cost time frame	･User satisfaction ･Community water supply dynamics
Variables	･Faecal coliform ･Sanitary conditions	･Distance to source ･Queuing times ･Distance to alternative water source ･Water quantities (number of container and volume, number of trip)	･Water supply types ･Average downtime ･Frequency of lifting device breakdown ･Depth of water table ･Frequency of water source dry up ･Availability of water ･Depth of well and lining ･O&M system	･Planning and supervision ･Unit hardware instllation costs ･Education that accompanies an intervention in hardware ･Labour/transportation costs ･Maintenance of hardware and replacement of parts ･Rehabilitation and expansion costs ･Improvement costs	･Satisfaction ･Preferences ･Priorities ･Ownership ･Willingness to pay ･Previous water source ･Reason for having own water source
Data collection method	･Water quality testing ･Sanitary survey	･Household survey ･Focus group discussion	･Inventory survey ･Household survey ･Focus group discussion	･Management records ･Household survey	･Household survey ･Focus group discussion ･Key informant interview

(*Source: Author*)

Chapter 5 DATA PRESENTATION AND ANALYSIS

5.1 Chapter outline

This chapter presents and analyses the data obtained from the main field study in Zambia based on the literature review, and the preliminary field study that identified the five key concepts of: water quality and sanitary condition, accessibility (include collection time/ water quantity), technical and environmental sustainability, cost-effectiveness and acceptability as important to a sustainable rural water supply model. These concepts were investigated to conduct a comparative assessment between communal and Self Supply models. The Self Supply model may bridge the gaps where the communal model has difficulty in providing a sustainable rural water supply especially in sparsely populated rural areas.

A flow chart showing how information was collected in the field work is shown in Fig.5.1 below. It includes quantitative data from the inventory, sanitary and household surveys, and management records. The qualitative data collected over focus group discussions, open-questions in the household surveys and key informant interviews is also presented in this chapter. Fig.5.1 comprehensively shows the key concepts in connection with each data collection method. Data presentation and analysis follows each key concept in this Chapter rather than each data collection method in order to address the research questions with respect to the key concepts.

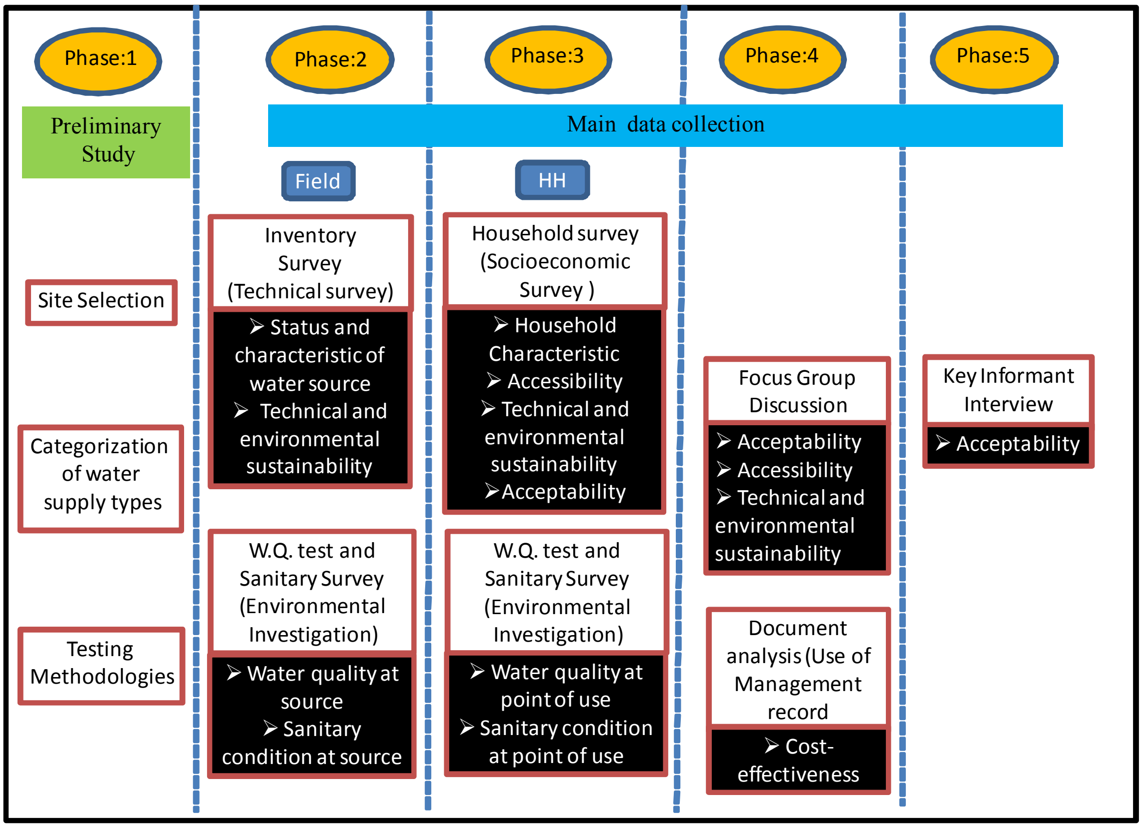


Fig. 5.1: Schematic representation of the data collection procedure
(*Source: Author*)

5.2 Finding of Status of Water Supply

This section looks at the status of water supply data collected from the technical inventory survey. The main field work was conducted in Milenge and Nchelenge Districts for six months in 2010 based on the findings from the preliminary field study done in 2009. Both Districts have various water source types and water supply models. In Milenge District, out of 13 Wards 4 Wards (Chiswishi, Mulumbi, Itemba and Milambo Ward) were selected since both Self Supply and communal water supply models were present in these 4 Wards (see Chapter 2). In Nchelenge District, field work was done in 5 Wards (Nchelenge, Shabo, Mwelu, Kabuta and Kashikishi Wards) using the same criteria for the site selection. However, it is necessary to bear in mind that there were no infrastructure improvements by trained artisans within the Self Supply model in Nchelenge at the time of the visit because priority had been placed on the building capacity of stakeholders and creating community awareness by sensitisation as noted in the Self Supply model in Chapter 2 (see Table 2.1). However a sizable number of hand dug wells (HDW) had started to show a small improvement using local materials.

Technical surveys were conducted to provide an inventory of water sources available to the population that rely on traditional hand dug wells, subsidised communal wells or boreholes. Table 5.1 shows the results of direct water point assessments in two sampled Districts.

Table 5.1: Surveyed water source types in Milenge and Nchelenge

District	Ward	Type of Water Supply				Total
		Not Protected HDW	Partially Protected HDW (include under improvement)	Protected (improved) HDW	Borehole with Handpump	
Milenge	Chiswishi	8	12(6)	4	3	27
	Mulumbi	5	14(2)	7	3	29
	Itemba	10	11	9	6	36
	Milambo	4	6	5	3	18
Sub-total		**27**	**43**	**25**	**15**	**110**
Nchelenge	Nchelenge	16	13	6	11	46
	Kashikishi	8	23	20	3	54
	Shabo	2	13	4	2	21
	Mwelu	8	14	3	2	27
	Kabuta	5	6	1	4	16
Sub-total		**39**	**69**	**34**	**22**	**164**
Total		**66**	**112**	**59**	**37**	**274**

(Source: Author's field work)

An inventory of water supply sources was designed to cover the structural design of the water supply interventions and facility conditions. Although classification of water supply type is predominantly following the JMP definitions (WHO and UNICEF 2006), it is subdivided, especially for the protection level of hand dug well (HDW) based on the scoring of protection (See Appendix A and B) that is commonly used in the studies about Self Supply (Sutton 2010c, Sutton 2010b, Sutton 2010a). A ***Protected*** (improved) HDW would consist of a well with an **apron**, raised **parapet** walls and **top slab** and a **drain**. These would also have a **cover**, which might be lockable, and use a rope pump, windlass or rope and bucket as the lifting device in Zambia. A ***Partially Protected*** (partially improved) HDW would have a **raised ground/platform** around the well mouth (whether or not it was covered by a **layer of cement**) and a **cover**, which might be lockable. This category of *Partially Protected* HDW was typically one that had only one or two aspects missing from the *Protected* condition. A ***Not Protected*** HDW had not reached the protection level of *Partially Protected* status. However, it does **not meant** that ***Not Protected*** HDWs **have no protection features** or actions. It is important to note that some of the ***Not Protected*** HDWs also had a small amount of protection using **at least one improvement** option, especially to the well head parts.

On the other hand, according to the government of Zambia's definition "*A borehole, a tube well, a jetted well, a hand-dug well with drilled-in borehole and a hand-dug well are considered to be Protected when they fulfil the following requirements* (NRWSSP 2007):

a) Is 30 metres away from latrines, refuse pits, or other sources of faecal or other contamination
b) Is lined all the way down
c) Has a platform of concrete or bricks that avoids direct infiltration of dirty water from the surface
d) Is equipped with a handpump, or some other lifting device
e) Has a functioning drainage system for waste water"

To recap, in this thesis, the definition of a protected water source has followed neither the JMP nor the government of Zambia definitions, but rather applied a specific scoring of protection based on the inventory surveys (see Appendix A and B). Table 5.2 presents the portion of work done by Self Supply models or by communal hardware-subsidized government/donor models for HDWs.

Table 5.2: Different water supply models to HDWs

District	Water Supply Model	Protection Level			Total
		Not Protected HDW (at least one protection/improvement)	Partially Protected HDW (include under improvement)	Protected (improved) HDW	
Milenge	Self Supply model (under trained artisans)	0	8	25	33
	Communal subsidized model	0	5	0	5
	Others (owner, neighbours)	27 (13)	30	0	30
Sub-total		**27**	**43**	**25**	**95**
Nchelenge	Self Supply model (under trained artisans)	(3)	0	3	3
	Communal subsidized model	0	6	8	14
	Others (owner, neighbours)	36 (26)	63	23	86
Sub-total		**39**	**69**	**34**	**142**
Total		**66 (39)**	**112**	**59**	**237**

(Source: Author's field work)

Note: *Bracket in Not Protected HDW category refers to the number of water points*

which have at least one protection or improvement;
Underlined figures indicate the number of improvement works done by owner or neighbours

In Milenge District, 33 sampled HDWs had been improved by trained artisans under the Self Supply model including 8 sampled HDWs still under improvement. 5 sampled HDWs had been subsidized by the government in the past in Milenge but recently their condition became *Partially Protected* rather than their original *Protected* status because of abandoned handpumps, missing covers and lack of drains. In Nchelenge District, there were 3 sampled *Protected* HDWs equipped with rope pumps and another 3 were found in a *Not Protected* condition within the Self Supply model in Nchelenge (since 3 rope pumps were abandoned at the time of visit). Out of 14 sampled HDWs constructed by governments or donor institutions in the past, 8 were *Protected* and 6 were *Partially Protected* HDWs in their existing conditions.

Self Supply does not define any specific level of improvement because the learning nature of the project encourages movement up the ladder as far as people feel able by every possible means. In consequence, a number of households (HHs) had expressed willingness to improve their own HDWs and had started making at least one or more improvement themselves. For example, 13 sampled HHs posessing *Not Protected* HDWs took action to make small improvements in Milenge (as did 25 sampled HH in Nchelenge). Also 30 sampled *Partially Protected* HDWs in Milenge had been improved by owners or community members themselves (As had 63 sampled *Partially Protected* HDWs in Nchelenge). The details of protection are discussed in following sections.

5.2.1 Lifting device of HDW

Artisans were trained in metal fabrication to make windlass buckets for a Self Supply model in Milenge so that they could promote them in favour of the non-durable plastic containers commonly used; this resulted in 40 sampled HH (42%) purchasing metal buckets for their HDW. Four sampled HDW owners in Milenge and one sampled HDW owner in Nchelenge purchased windlasses while 5 sampled HDWs in Nchelenge were equipped with windlasses (5%) as giveaway materials under communal models. Although there was no case for having a windlass through a Self Supply model in Nchelenge, 3 HHs purchased and furnished their HDWs with them in the Self Supply model in Milenge. At the onset of the project for the Self Supply model, metal windlasses were promoted but cheaper wooden windlasses have also been encouraged in later stages to fit with households' affordability. On the other hand, DAPP had established the production of rope pumps with a local mechanic in Nchelenge. Four artisans were trained for 14days with the skills to produce low cost rope pumps (see Table 2.1). Seven rope pumps had been sold to the public and 3 rope pumps were operational at the time of visit (one of them was not for drinking water usage). Further details of the rope pump will be discussed in the technical sustainability Section 5. 8.

5.2.2 Lining of HDW

There are two ways for the stabilization of the well shafts although the standard of the Zambian government is to line them all the way down. One is the stabilization of the top part and the other is for below the water table. Materials used for the lining were concrete rings applied to both the top and bottom parts. In many parts of Nchelenge and almost all parts of Milenge, well shafts were prone to collapse at or below the water table (Sutton 2010c). Under the Self Supply model in Milenge, artisans were trained on a practical course on how to cast concrete rings for HDWs and line the top part of HDWs with mud bricks. Using mud bricks for top lining enabled owners to save their budget to improve their water points rather than for purchasing cement. Thereby, apart from the water points in Chiswishi Ward, all *Protected* (improved) sampled HDWs and *Partially Protected* (under improvement) sampled HDWs had a lining for at least the top metre of the shaft; this was one of the improvement requirements in Milenge made by skilled artisans. A further 2 sampled HDWs had a bottom lining below the water table, apart from 5 communal subsidized HDWs in Milenge. It was observed that water points improved by skilled artisans in Chiswishi had no top lining. By contrast, in Nchelenge, 30 sampled HH had already cast well rings for lining the bottom parts of their HDWs themselves and all 14 communal subsidized HDWs had full lining in line with the government standard design.

5.2.3 Wellhead protection

The government of Zambia defines the standard design of a communal *Protected* well as one with apron, drainage, full lining and equipped with handpump, or some other lifting device (NRWSSP 2007). However, the Self Supply project did not adhere to that standard of wellhead design and encouraged traditional low cost improvement to wells on the principle of progressive risk reduction. The technical wellhead protection was broken down in Table 5.3 from collected inventory data. Each condition was graded as 'good' or 'poor depending on whether the condition served a protective function against contamination (e.g. cracks refer 'poor')

Table 5.3: Type of HDW head protection

	Milenge						Nchelenge					
Wellhead protection	Not Protected HDW		Partially Protected HDW (include under improvement)		Protected (improved) HDW		Not Protected HDW		Partially Protected HDW (include under improvement)		Protected (improved) HDW	
Condition	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
Covered by lockable bottomless bucket, drum	2	25	22	19	25	0	14	25	54	15	26	8
Raised wall/casing to protect from inflow	10	17	40	1	25	0	15	24	66	3	28	6
Mounded ground around well mouth	13	14	34	7	25	0	26	13	64	5	28	6
Concrete apron	0	27	12	29	23	2	0	39	20	49	32	2
Top slab	0	27	8	33	25	0	0	39	31	38	34	0
Drainage channel	0	27	4	37	25	0	0	39	13	56	34	0
Grass roof to keep rain out and around the well dry	0	27	0	41	0	25	6	33	14	55	1	33
Fence to keep out animal	0	27	0	41	5	20	0	39	5	64	2	32
Functioning soak away	0	27	1	40	25	0	0	39	7	62	31	3
No water ponded on ground within 5m	8	19	33	8	23	2	18	21	34	35	21	13

(Source: Author's field work)
Note: Figures in table refer to the number of water points

It was found that a raised wall and/or a mound of earth around the well mouth were the most common works for HDW protection/improvement. Some of the sampled HDWs (all *Protected* (improved) HDWs, *Partially Protected* HDWs and even *Not Protected* HDWs) in Milenge had protected their well head with a metal bottomless tin furnished with a lockable metal lid made by trained artisans. It was embedded in the well mouth either within the cement top slab or surrounding mound. Further, it was found that a sizeable number of sampled HDW owners in Milenge prepared or purchased a wooden pole on which to hang the rope and water container tin so that they were not contaminated by being left on the ground (It was also described in the sanitary inspection section 5.5.6). In contrast with Milenge practices, there was a slightly different method of well head protection in Nchelenge. 21 sampled HDWs in Nchelenge had grass roofs to protect the well from rain, keep the well area dry and cool down the water points. A grass roof also provided a place on which to hook the rope and container to dry. In specific communities, one of the interesting features in Kampanpi Ward was that they had placed local colourful clay on the mound around the mouth of the well to reduce water infiltration and also to avoid dust getting into the area. This was also intended to encourage users to respect hygiene control at water points on owners' property. Further in the same Ward, 6 sampled HDW owners had set up a wooden rack at a distance from the HDW to avoid spilling water around the well which could seep back into the well.

5.3 Findings of Socioeconomic Aspects of Water Points

Inventory surveys were used to obtain information regarding technical assessment of the water points from the water point owners or caretakers (see Appendix A). Respondents provided the information on the following water point characteristics: (i) ownership; (ii) year of construction; (iii) number of users; (iv) water source reliability); (v) charge/pay; (vi) restriction; (vii) initial constructor; (viii) lifting device break down; (ix) O&M. Table 5.4 displays a summary of the categorical data obtained on all the above characteristics of water points. It also shows that a sizable number within any protection level of HDWs (100% of *Not Protected*, 84% of Partially, 76% of *Protected* in Milenge and 95%, 91% and 59% in Nchelenge, respectively) were owned either privately or shared. This finding is consistent with the results of a survey by the Ministry of Local Government and Housing (2007) which reported that personal (individual) HDWs are dominant in Luapula Province. A baseline survey with the Zulu Burrow (2008) estimate of more than 10 HH drawing water from HDWs. This number is also consistent with the collected sample results that the number of HDW users (HH) is over 10 HH (average 15HH in *Not Protected*,19HH in Partially and 19HH in *Protected* in Milenge and 23HH, 19HH, and 38HH in Nchelenge, respectively).

The Table further shows that 55% (sum of 9%, 13% and 33%) of the borehole facilities have experiences of handpump break down every 6 months on average in Nchelenge. This result is fairly comparable with a baseline survey of the Self Supply (Zulu Burrow 2008), which found that about 70% of handpumps had broken down in a rainy season every 3 to 6 months. On the other hand, less than 10% of handpumps in Milenge had experienced break down. This discrepancy could be because more than 60% of them in Milenge had been constructed recently (since 2007) combined with the findings that the number of borehole users was relatively small compared with that of borehole users in Nchelenge. Moreover, the results present that a sizable number of water points had rarely charged or had user fees or contributions collected. For example, less than 10% of water points had constant contributions from users apart from *Protected* HDWs in both Milenge and Nchelenge Districts. This finding is supported by the data from surveys with Sutton (2003) and JICA (2008), which found that private water point owners share water sources with community members though rarely charge contributions in Zambia. Nonetheless, the government requires contribution from community members for sustainable handpump O&M.

Table 5.4: Water points characteristics

		Not Protected		Partially Protected		Protected		Borehole	
Characteristics	**Category Description**	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**
Year of construction	Before 1980s	(4, 1)	(17, 3)	(7, 3)	(19, 4)	(4, 2)	(18, 7)	(1, 0)	(7, 0)
	1981-1990	(4, 6)	(17, 15)	(8, 5)	(22, 7)	(2, 2)	(9, 7)	(0, 0)	(0, 0)
	1991-2000	(4, 4)	(17, 10)	(4, 13)	(11, 19)	(3, 5)	(14, 17)	(1, 6)	(7, 30)
	2001-2003	(4, 6)	(17, 15)	(4, 7)	(11, 10)	(3, 3)	(14, 10)	(0, 2)	(7, 10)
	2004-2006	(2, 11)	(8, 28)	(6, 24)	(16, 35)	(1, 6)	(5, 20)	(3, 0)	(21, 0)
	2007-2010	(6, 10)	(25, 25)	(8, 16)	(22, 24)	(9, 12)	(41, 40)	(9, 12)	(64, 60)
Initial construction	Owner	(5, 15)	(19, 38)	(7, 19)	(17, 28)	(3, 2)	(13, 6)	(0, 0)	(0, 0)
	Community with owner paid	(17, 24)	(63, 62)	(19, 41)	(45, 59)	(12, 19)	(50, 59)	(0, 0)	(0, 0)
	Artisans from outside of town	(0, 1)	(0, 3)	(0, 0)	(0, 0)	(1, 0)	(4, 0)	(0, 0)	(0, 0)
	Trained artisans under SS project	(2, 0)	(7, 0)	(2, 0)	(5, 0)	(4, 0)	(17, 0)	(0, 0)	(0, 0)
	NGO/Donor	(0, 0)	(0, 0)	(1, 4)	(2, 6)	(0, 3)	(0, 9)	(13, 13)	(87, 59)
	Government agency	(0, 0)	(0, 0)	(7, 4)	(17, 6)	(2, 8)	(8, 25)	(9, 9)	(60, 41)
Ownership status	Privately (family, not shared)	(0, 1)	(0, 3)	(0, 2)	(0, 3)	(0, 2)	(0, 6)	(0, 0)	(0, 0)
	Privately owned and shared	(27, 37)	(100, 95)	(36, 63)	(84, 91)	(19, 19)	(76, 59)	(0, 0)	(0, 0)
	Community owned	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(3, 0)	(12, 0)	(0, 0)	(0, 0)
	Community owned (Gov' subsidy)	(0, 1)	(0, 3)	(5, 4)	(12, 6)	(0, 9)	(0, 28)	(4, 13)	(27, 59)
	Institution (school, clinic) owned	(0, 0)	(0, 0)	(2, 0)	(5, 0)	(3, 2)	(12, 6)	(11, 9)	(73, 41)
Number of users (HH)	1-10	(19, 15)	(70, 38)	(23, 31)	(53, 47)	(10, 12)	(40, 36)	(0, 0)	(0, 0)
	11-24	(5, 18)	(19, 46)	(11, 18)	(26, 27)	(10, 5)	(40, 15)	(2, 1)	(13, 6)
	25-50	(1, 5)	(4, 13)	(6, 13)	(14, 20)	(3, 11)	(12, 33)	(4, 6)	(27, 33)
	>50	(2, 1)	(7, 3)	(3, 4)	(7, 6)	(2, 5)	(8, 15)	(9, 11)	(60, 61)
	Average	(15, 23)		(19, 19)		(19, 38)		(32, 50)	
Water source reliability	No dry up in last 5 years	(5, 12)	(19, 31)	(5, 31)	(12, 47)	(6, 18)	(25, 55)		(58, 44)
	No dry up this year	(7, 14)	(26, 36)	(11, 37)	(26, 56)	(16, 22)	(67, 67)	(4, 18)	(33, 100)
	Dry up once in last 5 years	(0, 2)	(0, 5)	(2, 5)	(5, 8)	(0, 2)	(0, 6)	(1, 0)	(8, 0)
	Dry up seasonally	(19, 2)	(70, 5)	(31, 3)	(74, 5)	(8, 2)	(33, 6)	(0, 0)	(0, 0)
	Dry up daily	(1, 21)	(4, 54)	(0, 22)	(0, 33)	(0, 7)	(0, 21)	(0, 0)	(0, 0)
Lifting device break down	No break down	(3, 2)	(11, 5)	(4, 4)	(10, 6)	(13, 1)	(54, 3)	(5, 2)	(33, 9)
	Every month	(6, 12)	(22, 31)	(9, 17)	(21, 25)	(1, 10)	(4, 31)	(0, 2)	(0, 9)
	Every 2-3 months	(11, 16)	(41, 41)	(11, 27)	(26, 39)	(3, 10)	(13, 31)	(0, 2)	(0, 13)
	Every 4-6 months	(4, 7)	(15, 18)	(10, 13)	(24, 19)	(2, 6)	(8, 19)	(1, 7)	(7, 33)
	Every 7-12 months	(1, 1)	(4, 3)	(2, 4)	(5, 6)	(4, 4)	(17, 13)	(3, 4)	(20, 18)
	More than a year	(0, 0)	(0, 0)	(2, 0)	(5, 0)	(1, 1)	(4, 3)	(4, 5)	(27, 18)
Restriction	Lock	(1, 11)	(4, 28)	(3, 14)	(7, 20)	(7, 5)	(29, 16)	(6, 11)	(40, 50)
	Lifting device store in house	(0, 2)	(0, 5)	(0, 2)	(0, 3)	(0, 1)	(0, 3)	(0, 0)	(0, 0)
	Prohibit kids use	(10, 6)	(37, 15)	(16, 13)	(38, 29)	(8, 8)	(33, 25)	(3, 1)	(20, 5)
	Limited quantity	(0, 0,)	(0, 0)	(0, 0,)	(0, 0)	(0, 0,)	(0, 0)	(0, 3)	(0, 14)
	Take off shoes	(0, 3)	(0, 8)	(0, 14)	(0, 20)	(1, 5)	(4, 16)	(0, 0)	(0, 0)
	Clean surround	(1, 5)	(4, 13)	(2, 4)	(5, 6)	(2, 2)	(8, 6)	(0, 1)	(0, 5)
	No washing around water point	(3, 0)	(11, 0)	(2, 7)	(5, 10)	(0, 3)	(0, 9)	(1, 2)	(7, 9)
	No pouring water around water point	(2, 4)	(7, 10)	(0, 6)	(0, 9)	(1, 0)	(4, 0)	(0, 0)	(0, 0)
	R&B hang on shelter or in basin	(1, 0)	(4, 0)	(3, 4)	(7, 6)	(8, 1)	(33, 3)	(0, 0)	(0, 0)
	Handwash in advance	(0, 0)	(0, 0)	(0, 1)	(0, 1)	(1, 0)	(4, 0)	(0, 0)	(0, 0)
Charge/pay	No contribution	(26, 25)	(96, 66)	(42, 33)	(100, 53)	(18, 12)	(75, 43)	(11, 3)	(73, 17)
	When need arises	(4, 6)	(1, 16)	(0, 18)	(0, 29)	(4, 5)	(1, 18)	(7, 0)	(1, 0)
	Irregulary	(0, 6)	(0, 16)	(0, 6)	(0, 10)	(2, 7)	(8, 25)	(1, 15)	(7, 83)
	Constantly	(0, 1)	(0, 3)	(0, 5)	(0, 8)	(3, 4)	(13, 14)	(2, 0)	(8, 0)
O&M	Owner (family)	(21, 26)	(78, 67)	(30, 44)	(71, 64)	(12, 19)	(50, 59)	(0, 0)	(0, 0)
	Users	(2, 11)	(7, 28)	(2, 18)	(5, 26)	(5, 10)	(21, 31)	(0, 0)	(0, 0)
	Village head	(0, 1)	(0, 3)	(0, 1)	(0, 1)	(0, 0)	(0, 0)	(0, 0)	(0, 0)
	Artisans	(0, 0)	(0, 0)	(7, 1)	(17, 1)	(7, 1)	(29, 3)	(0, 2)	(0, 9)
	AMPs	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(5, 12)	(33, 50)
	Donor/Government	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(2, 3)	(13, 14)
	Unknown	(2, 0)	(7, 0)	(3, 0)	(7, 0)	(0, 0)	(0, 0)	(6, 5)	(40, 23)

(Source: Author's field work)

In summary, comparisons with other relevant survey data in Luapula Province (NRWSSP 2007, Zulu Burrow 2008) indicate that the samples taken for this study showed fairly consistent water point characteristics. The following section describes the results of environmental surveys.

5.4 Finding of Sampled Household Characteristics

Table 5.5 displays a summary of the data obtained from household surveys (see Appendix F). The results indicate that there were slightly more males (55% in Milenge and 52% in Nchelenge, respectively) than females (45% in Milenge and 48% in Nchelenge).

Table 5.5: Sampled household characteristics

Characteristics	Valid Cases: N (Milenge, Nchelenge)		Frequency (%)
Gender of interviewee	447 (174, 273)		
Male		(96, 142)	(55, 52)
Female		(78, 131)	(45, 48)
Household size	413 (157, 256)		
1-5 people		(51, 87)	(32, 34)
6-10 people		(84, 131)	(53, 51)
Over 10 people		(22, 38)	(14, 15)
Average		(7, 7)	(7, 7)
Occupation of household head	435 (170, 265)		
Farmer		(150, 133)	(88, 50)
Fisher		(0, 48)	(0, 18)
Fisher/Farmer (subsidiary business)		(3, 48)	(2, 18)
Civil servant		(10, 21)	(6, 8)
Self emplyed in business		(4, 11)	(2, 4)
Other (retirement, housewife)		(3, 5)	(1, 2)

(Source: Author's field work)

The gender of respondents for the study sample is fairly consistent with a recent national household survey (CSO Zambia 2006) which found that in the Nchelenge District there was a higher percentage of males, 51.2% against 48.8% for females.

Sample results also reveal that the household size in both Districts averaged 7 members. The figure is fairly consistent with the data from the Central Statistical Office (CSO) in Zambia (2006) which gave an estimate of 6 members in both Districts. The Table further shows that farming is the dominant occupation of the household head especially in

Milenge. This finding is also consistent with the socio-economic survey data from the CSO Zambia (2006) which reported that more than 85% of the rural population earned their living from agriculture. The discrepancy of the data in Nchelenge is because there is huge lake there where people rely on fishing as their livelihood which was not stated in the statistical data.

To sum up, comparisons with the census data from the CSO Zambia (2006) population and housing data confirm that the sample for the study is similar in various aspects to the population from which it was drawn. The obtained data were sufficient to be statistically reliable and collected by different methods to capture different perspectives in order to emphasise their validity and reliability. The researcher took all measures to ensure that the protocol and the documentation were adequate for the data to be trustworthy. The following sections present primary and alternative water sources used by the sampled households based on the data obtained from household surveys (see Appendix F).

5.4.1 Primary water source

The most popular uses for water from the source were drinking, cooking, bathing and washing i.e. for consumption and hygiene purposes. Besides those domestic activities, some community members used water for small-scale gardening or brick making as income generating activities. 'Primary water source' is used in this study as a term to indicate the source used as a drinking water source although 'Primary source' generally refers to the main source of supply. Table 5.6 shows which water supply types have been used by the sampled households as their primary source and for their other water usages.

Table 5.6: Primary water source and other water usages

Primary water source (drinking)	Valid Cases: N (Milenge, Nchelenge)	Cooking: % (Milenge, Nchelenge)	Bathing: % (Milenge, Nchelenge)	Washing: % (Milenge, Nchelenge)	Other activities: % (Milenge, Nchelenge)
Not Protected	76 (28, 48)	(75, 98)	(68, 98)	(68, 98)	(18, 31)
Partially Protected	146 (52, 94)	(83, 98)	(83, 97)	(83, 97)	(17, 25)
Protected	97 (49, 48)	(94, 94)	(88, 92)	(90, 94)	(31, 31)
Borehole	109 (43, 66)	(77, 71)	(58, 67)	(65, 65)	(0, 0)
Tap	4 (0, 4)	(0, 50)	(0, 50)	(0, 50)	(0, 50)
Others (stream, spring)	15 (2, 13)	(100, 29)	(100, 18)	(100, 18)	(0, 0)

(Source: Author's field work)

Table 5.6 shows that over 80% of both *Partially Protected* and *Protected* HDW users

(HH) have also been using their primary water source for cooking, bathing and washing purposes. In contrast, one third of *Not Protected* HDW users in Milenge and Borehole users in both Districts draw water only for drinking usage. It is also important to note that some income generating activities have been observed among individual HDW owners although not all 'other activities' came into this category. To be specific, the most prevailing economic activity using water from the HDW was small-scale gardening. One of the *Partially Protected* HDW owners at Chilongosh village in Nchelenge District, sold plants (citrus, flowers, orange and pine), and then earned a profit of ZMK 1million (about US$222) annually as his side business. Also, one of the Protected HDW owners at Kaseka village in Nchelenge Ward utilized his water source for his goats from which he earned ZMK700,000 (US$156) annual income. Notably, these owners also had a strong interest in improving their HDWs and using their profits for achieving more sustainable and safe water. These types of income activities were never observed among communal HDW or borehole users because of the nature of the shared community commodity.

5.4.2 Alternative water sources

Of the 447 HH responding to the household questions, overall 283 HH used a secondary water source in addition to the primary water source for a variety of reasons. There were broadly two kinds of secondary water source use;

1) Alternative use only when the primary water source was not available
2) Multiple use to complement the primary water source in the same day

Out of that 283HH, 196HH used the secondary water source as an alternative source only when the primary was difficult to access whilst 87HH used the secondary water sources for multiple purposes. Table 5.7 shows the alternative water sources.

Table 5.7: Alternative water source

Alternative water source	Valid Cases: N (Milenge, Nchelenge)	% (Milenge, Nchelenge)
Not Protected HDW	(9, 8)	(12, 7)
Partially Protected HDW	(9, 15)	(12, 12)
Protected HDW	(3, 4)	(4, 3)
Borehole	(3, 28)	(4, 23)
Tap	(0, 12)	(0, 10)
Others (Spring, stream)	(51, 54)	(68, 45)
Total	**(75, 121)**	**(100, 100)**

(Source: Author's field work)

It was found that nearly two thirds of alternative water source users in Milenge relied on unprotected surface water sources while those of Nchelenge had a wider range of different water sources including taps. Poor reliability, which usually means dried up water sources during the dry season, was one of the most frequent reasons given from both Districts (24% in Milenge and 49% in Nchelenge) for using a secondary water source as an alternative water source. 'Bad water quality in terms of smell, colour and taste' was another significant reason for changing their water source in Milenge. As well as these reasons, other factors were; experience of breakdown of the lifting device (8% in Milenge, 21% in Nchelenge), long queues at the primary water source (10% in Milenge, 16% in Nchelenge), expense at the primary source (10% in Nchelenge) and the locking system (12% in Milenge, 4% in Nchelenge).

The above sections have looked at the status of water supply, sampled household characteristics and their water situation in a descriptive manner. The following sections will present data analysis alongside presentation of research findings in line with the research questions and key aspects.

5.5 Water Quality and Sanitary Condition

Quality assessment of water from different water supply models was undertaken to find data on their levels of water safety. The literature review in Chapter 3 explained the significance of water quality, and its key importance for acceptability by the water professionals as well as beneficiaries (communities) of a water supply model based on the protection of public health. The environmental investigations addressed the safety aspects of water points in terms of water quality and sanitary condition while technical surveys investigated the technical options for water supply and their level of protection from risk of contamination (see data collection process Fig.5.1). The environmental investigations comprised data from microbiological water quality tests and sanitary inspections. Thereby, this section looks at whether Self Supply models can achieve safe water for rural dwellers in comparison with communal water supply models. Fig. 5.4 shows the research outlines associated with the principal argument, concepts, research questions and indicators. The concepts of water quality and sanitary condition are associated with the specific research questions:
What impact do the water supply models have on the quality of water? What are the factors likely to affect water quality? What is the status of sanitary condition? What are

the sanitary risks likely to affect the water quality? How does water quality change at source and the point of use, and what are the contributory factors?

The following sections present data collected through water quality testing, sanitary inspections and inventory surveys (see Fig.5.1 and Appendices A, C, D & E) and analyse each variable relating to water quality and sanitary condition which are defined below:

- Water quality and water supply type (section 5.5.1)
- Water quality and water supply model (section 5.5.2)
- Water quality monitoring (section 5.5.3)
- Water quality and lifting device (section 5.5.4)
- Water quality and protection features at water source (section 5.5.5)
- Sanitary condition at source (section 5.5.6)
- Sanitary condition and water quality (section 5.5.7)
- Household water treatment (section 5.5.8)
- Water quality change at the source and the point of use, and HWT (section 5.5.9)
- Sanitary Inspection at household (section 5.5.10)
- Water quality change and distance to source (section 5.5.11)

Principal Argument

Reliance only on a communal water supply model limits the achievement of increased sustainable access to safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.

Concept 1
Water quality and sanitary condition

Concept 2
Accessibility

Concept 3
Technical and Environmental sustainability

Concept 4
Cost-effectiveness

Concept 5
Acceptability

Research Questions

What impact do the water supply models have on the quality of water? What are the factors likely to affect water quality? What is the status of sanitary condition? What are the sanitary risks likely to affect the water quality? How does water quality change at source and the point of use, and what are the contributory factors?

Indicator parameter 1
Water quality at source
Variable 1: Water quality and water supply type
Variable 2: Water quality and water supply model
Variable 3: Water quality monitoring

Indicator parameter 2
Protection feature
Variable 1: Water quality and lifting device
Variable 2: Water quality and level of protection types

Indicator parameter 3
Sanitary condition
Variable 1: Sanitary condition at source
Variable 2: Sanitary inspection at source and water quality

Indicator parameter 4
Water quality at the point of use
Variable 1: Water treatment at point of source and use
Variable 2: Water quality at point of source and use
Variable 3: Sanitary inspection at source and water quality
Variable 4: Water quality change and distance to source

Fig. 5.2: Principal argument, indicator parameter

5.5.1 Water quality

Microbiological water quality testing was done using the membrane filtration method at 269 water points to measure faecal coliforms; these samples included one spring and one tap water source. Two *Partially Protected* HDWs and five borehole sites could not be tested because the water source had dried up and the handpump broken down, respectively. From the preliminary study in 2009, it was observed from the data of the NGOs involved that chemical parameters were not a serious issue apart from the iron content in deep groundwater; therefore this research focused on faecal coliforms as a critical indicator of contamination in order to assess the effectiveness of water supply source interventions for water quality. As expected from the preliminary study in 2009 there was poor monitoring data from the NGOs involved, and therefore the water quality testing was done by the researcher himself. For quality control purpose of water quality analysis, the test results were compared with the results from Mr Festus Mulenga who had trained as a science laboratory technologist. The results of comparisons among 7 random samples between the researcher and the science laboratory technologist showed that there was no significant difference between the test results (greater than significance 0.05).

Fig. 5.3 and Fig. 5.4 show the test results in Milenge and Nchelenge, respectively. The faecal coliforms were selected because the absence of thermotolerant coliforms is one component of the WHO Guidelines for Drinking Water Quality (WHO 2006). The use of <10FC/100ml was justified as this level has been suggested by WHO as an *appropriate relaxation* for small water supplies (WHO 1997), whilst zeroFC/100ml was the Zambian national guideline for untreated water (Zambia Bureau of Standards 1990). Thereby, in this study, an *acceptable level* for a drinking water is less than 10FC/100ml.

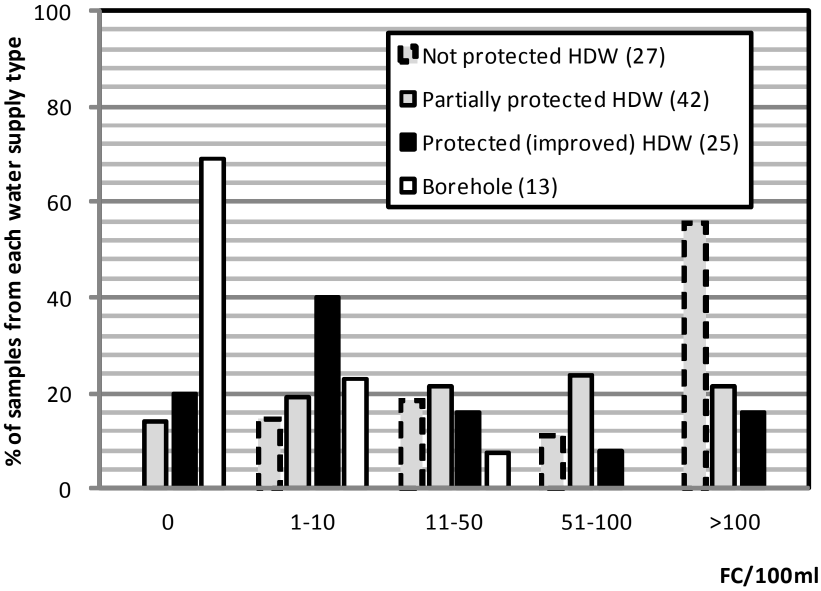


Fig. 5.3: Faecal coliform test results in Milenge

(Source: Author's field work)

Figs. 5.3 and 5.4 show that more than 90% of the water collected from the boreholes was at an acceptable level for drinking water. Also, it appeared from the results of Milenge (see Fig.5.3) that the contamination level in sampled HDWs decreased significantly according to the level of HDW protection. The results showed that 60% (n=15) of *Protected* HDWs prepared by skilled artisans under a Self Supply model were at an acceptable level (*appropriate relaxation*: <10FC/100ml) for a drinking water source whilst only 15% (n=4) of *Not Protected* HDWs fell within the acceptable level of contamination. One third (n=14) of *Partially Protected* HDWs also showed an acceptable level for drinking water, including those under improvement by trained Self Supply artisans (n=5).

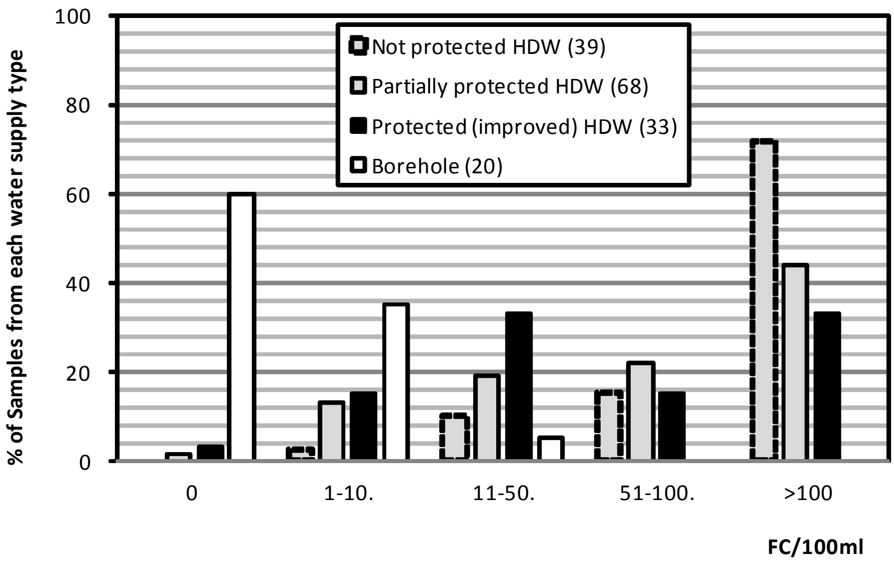


Fig. 5.4: Faecal coliforms test results in Nchelenge

(Source: Author's field work)

Results from microbiological water quality testing in Nchelenge (see Fig.5.4) showed similar inclinations to the Milenge results. The level of faecal contamination increased in accordance with the lack of HDW protection. However, there was a considerable difference between Nchelenge and Milenge with respect to the proportion having an acceptable level for drinking water. For example, less than 20% of *Protected* HDWs in Nchelenge were at an acceptable level for drinking even though the same protection level brought many more into the less than 10FC/100ml category in Milenge (60%). These findings imply that the sanitary condition may affect water quality so this relationship will be analysed and discussed in Section 5.5.7.

5.5.2 Water quality and water supply model

As shown in Figs. 5.3 and 5.4 the water quality was significantly improved in terms of faecal contamination alongside an increased protection level, especially where water points were improved by trained artisans under Self Supply in Milenge. Meanwhile, the government or NGOs/external support agencies provided not only a borehole equipped with a handpump, but they also subsidized a HDW with a windlass as a communal water supply model. The government subsidized communal well was a standard design with apron, drainage, full-lining and originally with windlass. However, the conditions of these wells were categorised either as "*Protected*" or "*Partially Protected*" in this study because some protective parts had broken down or were missing despite the fact that the government regarded them all as "*Protected*". Further, HDWs were closely examined in relation to the Self Supply model, to assess how this approach might affect their water quality; this aspect was excluded in Figs. 5.3 and 5.4. Therefore, Figs. 5.5 and 5.6 show the test results in relation to different water supply models in Milenge and Nchelenge, respectively. The ownership status of HDW is simply categorised below:

- HH (individual household)
- HH under Self Supply
- Communal under subsidy
- Communal under Self Supply

As noted in Section 5.5.1, the faecal contamination level from HDWs decreased significantly with the level of HDW protection especially in Milenge (see Fig. 5.4). There were different water supply models under *Partially Protected* HDWs in Milenge; those were the Self Supply model, the subsidized communal model and the owner model (unsupported). Further, as noted in Section 5.2, the "*Partially Protected* HDW (communal under subsidy) in Fig. 5.5 referred to the water source that was originally subsidized but whose protection had deteriorated (i.e. missing covers and lack of drains). Also, "Protected HDW (Communal under Self Supply)" referred to the water source that was improved by a Self Supply model with **a small group of community members**. It is important to note from Fig. 5.5 that *Partially Protected* HDWs (HH under the Self Supply) were significantly brought into an appropriate relaxation level for drinking water (more than 60% were <10FC/100ml) compared with the same protection level under communal subsidized and individual household (less than 40% of both are <10FC/100ml). These *Partially Protected* HDWs (N=8) were under improvement by trained artisans within Self Supply, and they lacked drainage at the time of visit.

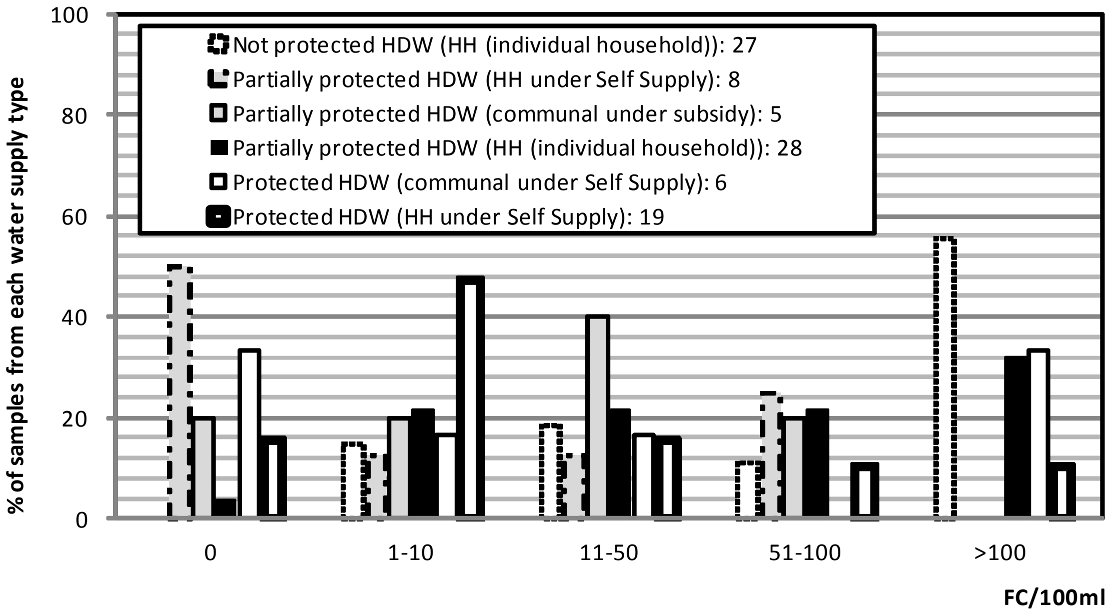


Fig. 5.5: Faecal coliforms tests results by water supply model in Milenge
(Source: Author's field work)

Partially Protected HDWs (communal under subsidy) also had a higher ratio in an appropriate relaxation level for drinking water (<10FC/100ml) than *Partially Protected* HDWs with the ownership of the individual households, but not much higher than Self Supply ones (40% and 25%, respectively: <10FC/100ml). It is also apparent from Fig. 5.5 that the proportion of appropriate relaxation levels for drinking water of *Partially Protected* HDWs (HH under Self Supply) was even comparable to that of *Protected* HDWs (HH under Self Supply) which were also carried out by trained artisans in the Self Supply model. Further, it is found from the comparison of communal wells between *Partially Protected* HDWs (communal under subsidy) (n=5) and *Protected* HDWs (communal under Self Supply) (n=6) that Self Supply resulted in a higher proportion of appropriate relaxation level with nearly 50% in contrast with 40% of that in communal subsidized wells. These findings suggested that the Self Supply model may achieve an appropriate relaxation (acceptable) level for drinking water by way of an improvement ladder.

It is also apparent from Fig. 5.5 that one third (33%) of *Protected* HDWs (communal under Self Supply) compared with 11% of *Protected* HDWs (HH under Self Supply) showed a high level of contamination (>100FC/100ml). In fact, there were no more than 6 *Protected* HDW (communal under Self Supply) at the time of the visit to Milenge. Box

5.1 is an excerpt from the survey with the caretaker of the *Protected* HDW (communal under Self Supply). This HDW was originally constructed and equipped with a handpump by the government as a subsidized project.

<u>Box 5.1: Excerpts from survey with caretaker of *Protected* HDW (communal under Self Supply) at Chipaila village, Mulumbi Ward</u>

We were suffering from having no access to a water source even for drinking water. Our village had a well fitted with a pump but it was abandoned because nobody repaired the broken pump……..We were tired of going to fetch water from a stream quite a way off. So we decided to improve our abandoned water point by collecting contribution from community members, and then asking skilled artisans (Self Supply) to work on it. It was a great achievement to have a water source within our community for a while…… but nowadays we find difficulty in keeping the water source clean because a lot of community members rely on one water source and it is not possible for their behaviour to be controlled by the caretaker.

This indicated that communal water sources are difficult to keep clean by controlling users' hygiene practices no matter how the water source is protected.

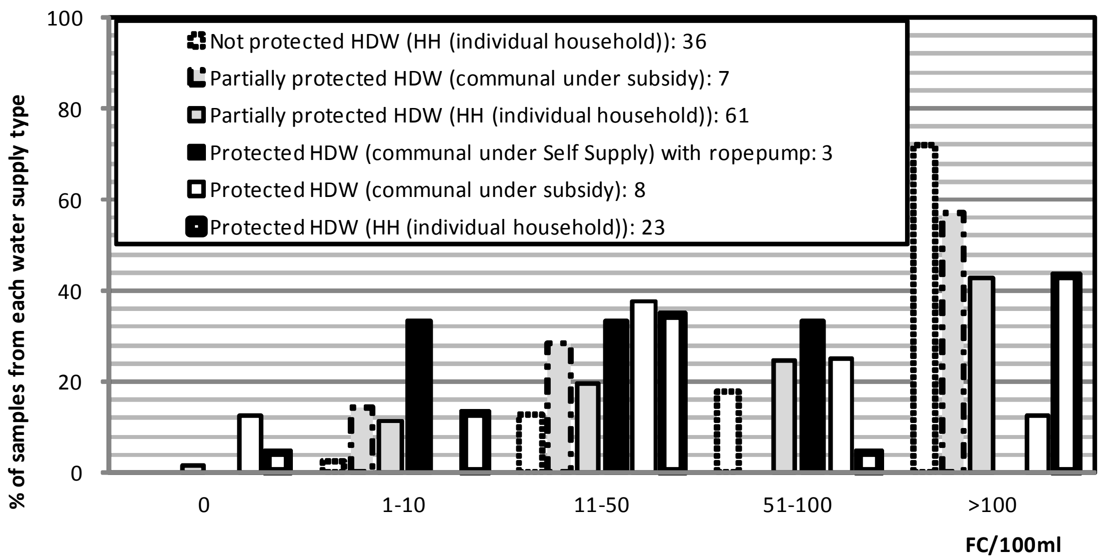


Fig. 5.6: Faecal coliforms test results by water supply model in Nchelenge

(Source: Author's field work)

It is interesting to note for Fig. 5.6 that *Partially Protected* HDWs showed no significant differences between communal under subsidy and individual HH owner initiatives despite the fact that communal wells were subsidized and satisfied the standard design criteria. Further, it was also found that the same proportions of *Protected* HDWs were within the acceptable level for drinking water (<10FC/100ml) for both subsidized communal (13%) and non-subsidized individual HH ones (17%); however a smaller proportion of subsidised communal *Protected* HDWs (13%) had high levels of contamination when compared with 43% of *Protected* HDW owned by individual HH (>100FC/100ml). Although the sampled number was very small (N=3), the results of faecal contamination from *Protected* HDWs under Self Supply equipped with rope pumps in Nchelenge showed a range from an appropriate relaxation level for drinking to a medium level of faecal contamination.

5.5.3 Water quality monitoring

Sections 5.5.1 and 5.5.2 looked at water quality in connection with different water supply models. This section will assess the water quality change based on the monitoring data. Fig. 5.7 is the summary of the microbiological water quality monitoring used to assess what difference was made by improvements to water quality and seasonal change in Milenge. Twenty-nine water points were tested between April and August to compare the results during seasonal change. April was the season just after the wet season and August was the totally dry season. It is apparent from Fig. 5.7 that no differences were found in water quality at *Not Protected* HDWs, but the water from those *Partially Protected* HDWs under owners' initiatives were relatively improved between April and August. On the other hand, there was significant water quality improvement in *Protected* and *Partially Protected* HDWs within the Self Supply model between the two different months. Out of 19 sampled *Protected* HDWs, 17 sampled (90%) showed contamination-free results. This was the same as, or an even better result compared with water from boreholes (see Figs. 5.3 and 5.4). : This could be explained by two factors: 1) seasonal change and 2) The timing of first water sampling (April). As the water quality change could be found even in the water sources where there had been no interventions under Self Supply, the dry season may give less risk of water intrusion from the surface. Another possibility is that the time of first sampling was just after water source improvement under Self Supply so that the water might have remained contaminated from artisanal works. This evidence is supported by the study of Sutton (2004a) where water quality was monitored in more than sixty sources which were improved. The study showed that in all of them water quality improved significantly after time had elapsed following the improvement. However, it can be noted that other factors could have influenced the results, owing to other events that could have taken place at the sites during the time between the sampling intervals.

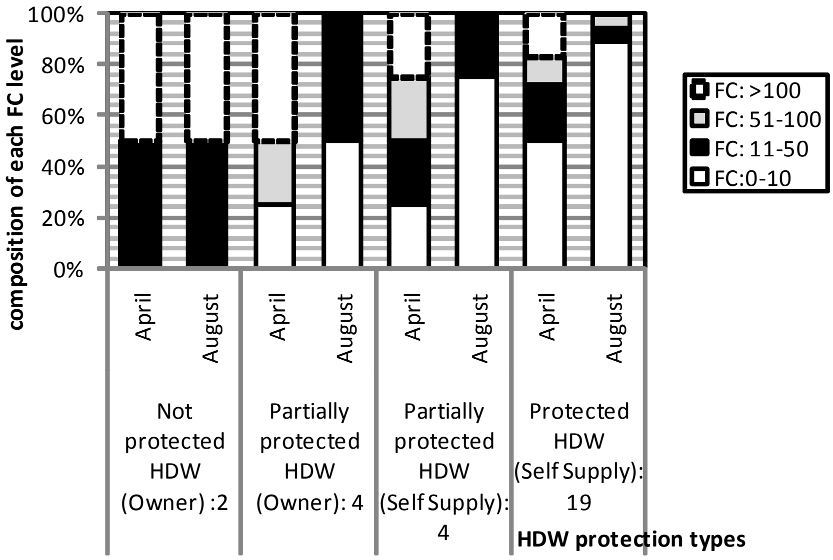


Fig. 5.7: Results of water quality monitoring in Milenge
(Source: Author's field work)

These findings also indicated that HDWs, either *Protected* or *Partially Protected* by trained artisans under the Self Supply model had achieved the level of protection for the required standard for '*Protected*' water points despite the fact that they were not equipped with either windlass and/or full lining which was the original standard design of '*Protected*' (NRWSSP 2007).

5.5.4 Water quality and lifting device

The results from Section 5.5.2 imply that the lifting device may also have been a factor in the level of contamination among the same protection categories of HDW. Therefore, this section examines the water quality associated with different lifting device i.e. between windlass, and rope and bucket. Figs. 5.8 and 5.9 show the test results of water quality associated with lifting devices in Milenge and Nchelenge, respectively.

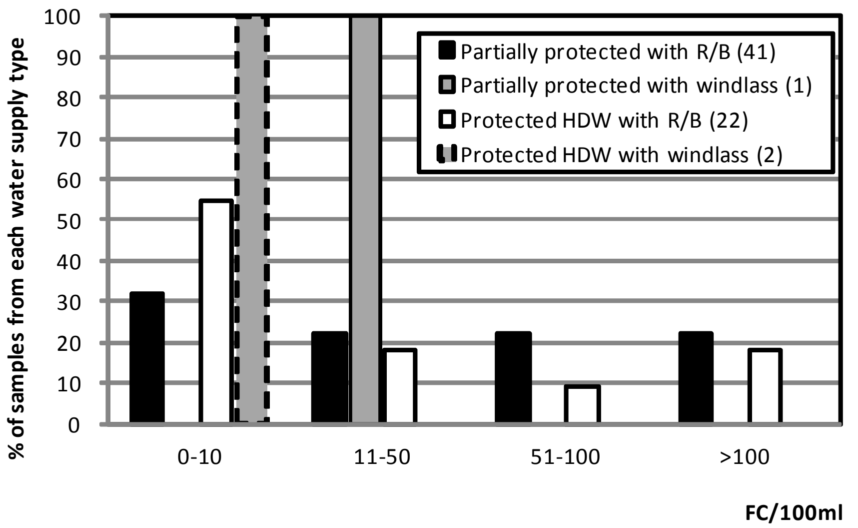


Fig. 5.8: Faecal coliforms test results with lifting device in Milenge
(Source: Author's field work)

Fig. 5.8 shows that water points equipped with windlass had less faecal contamination compared with those using rope and bucket, although the sampled numbers of water points with windlass was very small. In addition, it was also noted that among water points having a windlass, *Protected* HDWs showed better results, with an appropriate relaxation level for drinking (0-10FC/100ml), in contrast with *Partially Protected* HDW equipped with windlass with medium levels of contamination.

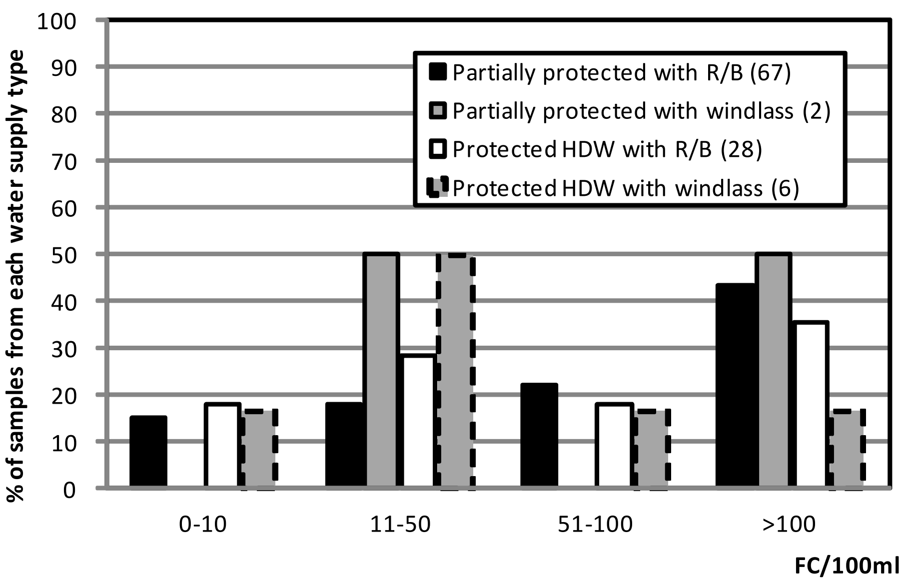


Fig. 5.9: Faecal coliforms test results with lifting device in Nchelenge
(Source: Author's field work)

The findings in Fig. 5.8 of water points with windlass were fairly consistent with the results of those in Nchelenge (see Fig. 5.9). For instance, *Protected* HDWs with windlass had a higher proportion (50%) of medium level of contamination (11-50FC/100ml) than those without windlass (29%), while at the appropriate relaxation level (0-10FC/100m) there was no significant difference. These findings from Figs. 5.8 and 5.9 suggest that water points where a windlass is used to draw water and allowing less direct contact than a rope and bucket could result in faecal contamination reduction; this combined with the findings that *Protected* HDWs could reduce the risk of contamination further than *Partially Protected* HDWs, suggests that combining protection features at the water source and a better lifting device could be important interventions for water source improvement.

5.5.5 Water quality and small improvement

The above findings and discussions also posed the questions of how small improvements can impact on the water quality, and to what extent. There is no solid solution for protecting the water source without not only relying on skilled artisans, but also on individual action for improvement being taken by the HH owner. As one of the examples, 4 sampled HDW owners set up a wooden rack at a distance from their HDWs by themselves (see Section 5.2.3). The results of the microbiological water quality test were that half of them were at the acceptable level for drinking water (<10FC/100ml) and the other two sampled were low (<30FC/100ml) and high levels (>100FC/100ml) of faecal contamination, respectively. Further, 4 sampled *Partially Protected* HDWs had been using the practice of putting local colourful clay on the mound around the mouth of the well (see Section 5.2.3). The test results were that half of them were low level (<30FC/100ml) and the other two had medium (50-100FC/100ml) and high levels (>100FC/100ml) of contamination, respectively.

Despite the fact that these cases were found from a very small number, they implied that these small improvements related to hygiene practice work may reduce the risk of contamination rather than just leaving the water source without any action for protection. Box 5.2 outlines the household survey with one of the *Partially Protected* HDW owners, where she took ownership to set up a wooden rack at a distance from her water source.

<u>Box 5.2: Excerpts from household survey with owner of *Partially Protected* HDW at Chipaye village, Mwelu Ward</u>

My reason for having a container rack at a distance from my well is to prevent dirty water flowing back into the well. This idea was came up from our family on how to keep my water source clean… We do not mind neighbour households using my well without any contribution. But we teach them how to prevent water from contamination, for example, to wash hands before drawing water, wash feet when they come back from bush, avoid rope touching the ground and use that container rack…….You know, we can control neighbour behaviour because this well is my family made.

Furthermore, at least one improvement could be also found in the *Not Protected* HDWs (see Table 5.2 in Section 5.2). Therefore, Fig. 5.10 shows the comparison between *Not Protected* with/without a small degree of protection.

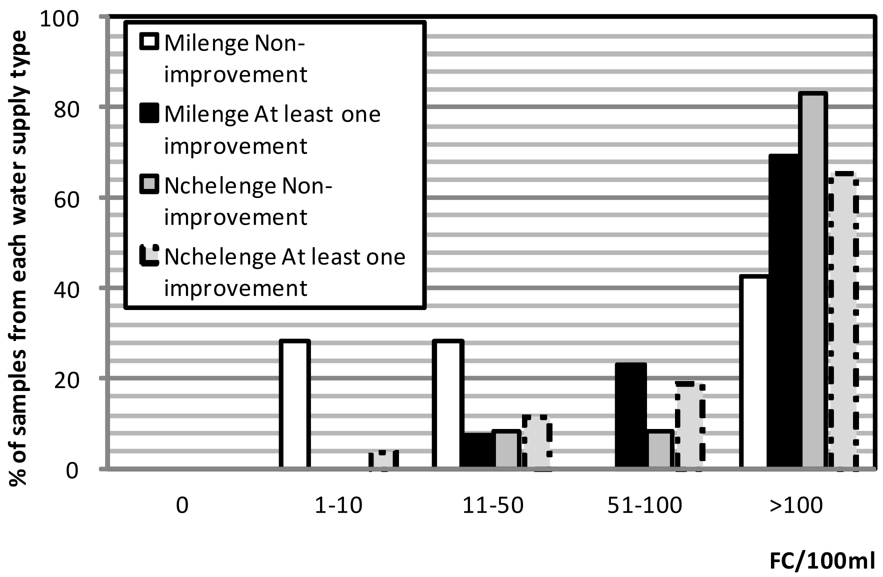


Fig. 5.10: Results of microbiological test among *Not Protected* HDWs
(Source: Author's field work)

'Mounded ground around well mouth' was the most common protection/improvement among the *Not Protected* HDWs. It was found that a small improvement in Nchelenge brought water quality into a slightly better category than *Not Protected* although it did not reach an acceptable level for drinking water. On the other hand, the results from Milenge showed that *Not Protected* HDWs without any improvement had better results than those with at least one improvement, which was 'Mounded ground around well mouth'. Therefore, these results indicated that the results of contamination-free were not derived from a single protection or practice but rather multiple causes among physical protection, environmental conditions and hygiene practices. Subsequently there needs to be further analysis of water quality linked with Sanitary Inspection and how hygiene practice impacts on or connects with water quality in order to gain further insight.

5.5.6 Sanitary conditions at source

Following direct water points assessment, Sanitary Inspection (SI) forms were used at the sources to collect quantitative data on the selected variables as a direct visual survey method (see Section 4.8). SI is a form of risk assessment and is designed to evaluate the water supply sources to see whether there is a likelihood of contamination occurring alongside the microbiological water quality test. SI has a series of questions that all have a YES/NO answer (see Appendices C & D). For every question that has a 'Yes' answer one point is allocated and for every 'No' answer zero points are allocated. The results of the Sanitary Inspection are summarized in Table 5.8.

Table 5.8: Summaries of Sanitary Inspection of HDWs (Average Scores)

SI	Hazard of TWS	Milenge			Nchelenge		
		Not protected	Partially protected	Protected	Not protected	Partially protected	Protected
1	Latrine within 10m of the well	0.00	0.00	0.04	0.20	0.19	0.09
2	Faeces within 10m of the well	0.19	0.14	0.29	0.32	0.26	0.18
3	Any other sources of pollution within 10m of well	0.37	0.17	0.17	0.21	0.21	0.30
4	Fence missing or faulty	1.00	1.00	1.00	0.97	0.94	0.88
5	Cement less than 1m in radius around the top of the well	0.93	0.52	0.00	0.72	0.54	0.30
6	Animal roam around the well	0.26	0.19	0.25	0.77	0.57	0.33
7	Can water flow back into the well	0.85	0.48	0.04	0.64	0.32	0.09
8	Well mouth lower than surrounding ground	0.37	0.12	0.04	0.59	0.13	0.09
9	Rope and bucket leave on the ground	0.67	0.43	0.13	0.69	0.59	0.64
10	Well cover insanitary	0.89	0.64	0.08	0.74	0.50	0.36
Total		**5.53**	**3.69**	**2.04**	**5.85**	**4.25**	**3.26**

(Source: Author's field work)

The figures in Table 5.8 give an average value for each protection level of HDW. There was a clear benefit in the general sanitary conditions for a water point from improvement works, especially in Milenge. Unfortunately even the *Protected* (improved) water points did not get an 'all clear'. The results of the SI are summarized as a 'Total' risk score in the bottom line between 0 and 10 depending on the number of hazards present. Thereby, higher SI scores are negative in that they indicate heightened risk. The risk score showed that where the protection level was higher, fewer hazards were found in both Milenge and Nchelenge Districts.

Table 5.9: Summaries of Sanitary Inspection of boreholes

SI	Hazard of Borehole	Milenge	Nchelenge
1	Latrine within 10m of the well	0.08	0.00
2	Animal faeces within 10m of the well	0.00	0.14
3	Any other sources of pollution within 10m of boreholes	0.42	0.05
4	Drainage faulty allowing ponding within 2m of borehole	0.33	0.18
5	Drainage channel cracked, broken or need cleaning	0.33	0.64
6	Fence missing or faulty	0.75	0.50
7	Apron less than 1m in radius	0.08	0.09
8	Spilit water pond in the apron area	0.17	0.09
9	Apron cracked or damaged	0.25	0.18
10	Handpump loose at the point of attachment to apron	0.25	0.05
Total		**2.66**	**1.92**

(Source: Author's field work)

Table 5.9 shows the results of the SI of borehole sites. The most common hazard of boreholes was 'fence missing or faulty' followed by 'drainage channel cracked, broken or need cleaning'. It was necessary to correlate all features of the SI with the level of feacal contamination in the section below.

5.5.7 Sanitary condition at source and water quality

To elaborate on the correlation between any particular features of the Sanitary Inspection (SI) at water sources with faecal contamination, the Mann-Whitney test was applied to collected data. The Mann-Whitney test is one of the non-parametric tests which compares two independent groups of sampled data and provides an estimate of precision as to whether one of the two samples of independent observations tends to have larger values than the other. The results of the Mann-Whitney test are shown in Tables 5.10 and 5.11. A common hazard for both sampled HDWs (*Not Protected* HDWs at both Districts, *Partially Protected* and *Protected* HDWs in Milenge) and sampled boreholes (in Nchelenge) was found to be associated at 95% level of statistical significance, and that was animal faeces within 10m of the water supply facilities. Although this was not a statistically significant hazard in Nchelenge *Protected* HDWs, a similar hazard, that of 'animals roaming around the well', was statistically significant ($p < .05$) as it was in Milenge *Protected* HDWs.

Table 5.10: Association of any particular feature with FC levels for HDW

SI	Hazard of HDW	Milenge			Nchelenge		
		Not protected	Partially protected	Protected	Not protected	Partially protected	Protected
1	Latrine within 10m of the well	N/A	N/A	0.096	0.102	0.499	0.315
2	Faeces within 10m of the well	0.034*	0.039*	0.016*	0.044*	0.542	0.171
3	Any other sources of pollution within 10m of well	0.706	0.009**	0.260	0.394	0.897	0.316
4	Fence missing or faulty	N/A	N/A	N/A	0.171	0.266	0.366
5	Cement less than 1m in radius around the top of the well	0.105	0.196	N/A	0.803	0.489	0.451
6	Animal roam around the well	0.142	0.255	0.027*	0.075	0.454	0.011*
7	Can water flow back into the well	0.495	0.012*	0.147	0.001**	0.014*	0.451
8	Well mouth lower than surrounding ground	0.145	0.017*	0.828	0.001**	0.369	0.451
9	Rope and bucket leave on the ground	0.625	0.001**	0.204	0.976	0.083	0.081
10	Well cover insanitary	0.247	0.014*	0.373	0.046*	0.064	0.456

(*Source: Author*)

Note: Figure in the table shows statistical significant (p)

*significant at <.05 ** significant at <.01

Table 5.11: Association of any particular features with FC levels for borehole

SI	Hazard of Borehole	Milenge	Nchelenge
1	Latrine within 10m of the well	0.057	0.976
2	Animal faeces within 10m of the well	0.305	0.004**
3	Any other sources of pollution within 10m of boreholes	0.146	0.228
4	Drainage faulty allowing ponding within 2m of borehole	0.362	0.092
5	Drainage channel cracked, broken or need cleaning	0.362	0.381
6	Fence missing or faulty	0.186	0.157
7	Apron less than 1m in radius	0.300	0.324
8	Spilit water pond in the apron area	0.370	0.632
9	Apron cracked or damaged	0.152	0.398
10	Handpump loose at the point of attachment to apron	0.152	0.803

(*Source: Author*)

Note: Figure in the table shows statistical significant (p)

***significant at <.01*

Interestingly, the findings that faecal contamination levels of *Not Protected* HDWs in Nchelenge associated with SI2 (see Table 5.10) and SI7, combined with the findings of SI8 and SI10 are statistically associated hazards with FC contamination levels at 95% levels of significance, suggest that each of **these hazards increases the risk of faecal contamination** at the sampled *Not Protected* HDWs in Nchelenge. Such successive statistically significant hazards are also found at the sampled *Partially Protected* HDWs in Milenge and furthermore 'rope and bucket on the ground' is the most statistically significant hazard threatening faecal contamination.

Even though the distance from water point to latrine in Nchelenge was closer than those located in Milenge, there was found to be no statistically significant association with faecal contamination. Therefore, the location of latrine did not appear to have any effect.

To further address the relationship between FC levels and aggregation of hazards, Spearman's rank order correlation was also applied to determine the strength and direction of the relationships. The results of Sanitary Inspections are summarized as a total risk score between 0 and 10 depending on the number of hazards present. As shown in Fig. 5.11, Spearman uses statistic R that falls between -1 and 1. If R falls between 0 and 0.5, there is a weak positive correlation. If the value of R falls between 0.5 and 1.0, there is a strong positive correlation.

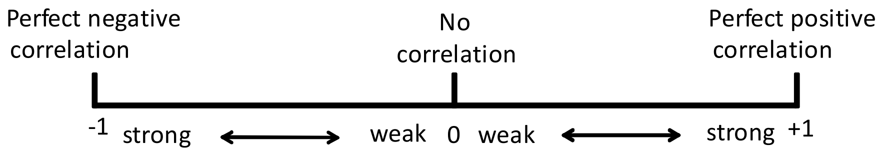


Fig. 5.11: The strength and direction of correlation coefficients
Source: Bryman and Cramer (2009)

The results show that all total risk score of sampled HDWs and boreholes achieved statistical significance in both Districts apart from the sampled boreholes in Milenge. Specifically, sampled *Partially Protected* HDWs in Milenge and *Not Protected* HDWs in Nchelenge showed a strong positive correlation followed by *Protected* HDWs in both Districts, and *Partially Protected* and borehole in Nchelenge.

Table 5.12: Speamans rank correlation between SI risk score of water supply types and FC levels

Rank correlation	Milenge				Nchelenge			
	Not protected	Partially protected	Protected	Borehole	Not protected	Partially protected	Protected	Borehole
Spearmans rho (R)	0.459*	0.690***	0.624**	0.439	0.556***	0.332**	0.559**	0.655**
Sig. (2-tailed) (p)	0.016	0.0005	0.001	0.153	0.0005	0.007	0.006	0.003

(*Source: Author*)

Note: ***Correlation is significant at the p< .001 level
** significant at <.01 *significant at <.05

Notably, *Protected* HDWs in both Districts showed a strong positive correlation between their SI risk score and FC levels. Overall, these results suggested that applied hazards found in Sanitary Inspections captured the risk of faecal contamination in respect of water supply types. In other words, the more effort they put into reducing these hazards, the more safe water they can access.

5.5.8 Water treatment and storage

As for household level water treatment, the prevailing method was chlorination at the point of source and use. Based on the household surveys, it was found that there was rarely the practice of well chlorination in Milenge except for one *Protected* HDW. Therefore, Table 5.13 shows HWTS practice in Nchelenge. On the whole, out of 164 water points among operational among HDWs and boreholes, 94 water points (65%) have had chlorine applied at the point of source. At the borehole facility, caretakers had the responsibility for point of source chlorination. Meanwhile, in the 78HDWs, 14HDW owners (18%) poured chlorine into their well by themselves.

Table 5.13: Water treatment at point of source in Nchelenge

Water source	Valid case: N(%)
Not protected	21 (54)
Partially protected	44 (68)
Improved	13 (57)
Borehole	16 (89)

(Source: Author's field work)

The rest of the cases (82%) were done by either clinic health worker, NHC (Neighbourhood Health Committee), council or NGOs. In Nchelenge District, they organized a NHC under the Rural Health Centre (RHC) which was concerned with health issues, malaria, HIV/AIDS, cholera, water and sanitation issues. Two types of chlorination were found in the field study; one was liquid Klorin and another was Hyperchlorite powder. Below Table 5.14 shows the collected data from household surveys regarding the procedure for well chlorination. It was found that the frequency of using either hyperchlorite powder or liquid klorin varied from place to place.

Table 5.14: Types and ways of well chlorination

Chlorination point	Chlorine type	Frequency	Amount	Who	Where	Idea	Case: N
Well chlorination	Hyperchlorite powder	Only when cholera happened	N/A	Health worker	Clinic	Clinic	51
		3 months	N/A	Health worker	Clinic	Clinic	2
		2 months	5 tea spoons	NHC	Clinic	Clinic	6
		1 months	1 pack	Owner	Kitwe (shop)	Clinic	1
		1 months	1 match box	Owner	Clinic	Owner	1
		2 weeks	1 tea spoon			Owner	1
	Liquid Klorin	Only when cholera happened	10ml	Health worker	Clinic	Clinic	1
		Only when cholera happened	half bottle (125ml)	Owner	Shop	Owner	1
		2 months	1 bottle (250ml)	Health worker	Shop	Clinic	4
		1 months	2 bottle	Owner	Shop	Owner	1
		1 months	1 bottle	Owner	Shop	Clinic	5
		1 week	1 bottle	Owner	Shop	Owner	2
		2 weeks	1 bottle	Owner	Shop	Owner	2

(Source: Author's field work)

Chlorination at point of use (household) meant household water treatment and 65HH (38% in Milenge respondents) and 62HH (22% in Nchlenge) had answered that they constantly used liquid chlorine at their houses. The other households underscored the reasons for not using household chlorine constantly as:

1) Only use during a cholera epidemic period since not manageable all the time (31% in Nchelenge)
2) Cannot manage to purchase (63% in Milenge, 23% in Nchelenge)
3) Water point is well protected so no need (8% in Milenge)
4) Waiting for free distribution (20% in Nchelenge)
5) Well owners pour chlorine in the well so not necessary at house (13% in Milenge)
6) No stock at shop, RHC (3% in Milenge, 4% in Nchelenge)

5.5.9 Water quality change, and HWT

Water could become contaminated during the process from the point of collection through carrying and storing water at the point of use. Extant literature highlights the fact that water quality is contaminated during transport and/or storage (Sutton 2009b, Wright 2004). This section examines water quality at both points in order to test the difference in levels of contamination and to assess the effectiveness of household water treatment. Fig. 5.12 shows the results of water quality tests at points of source and use in Milenge. 40 water points were selected randomly and 44 households were also chosen for testing of the storage water collected from those 40 water points; this included 4 water points duplicated with different households. 11 household owners out of the 44 HH used water treatment at their storage (see Fig. 5.12).

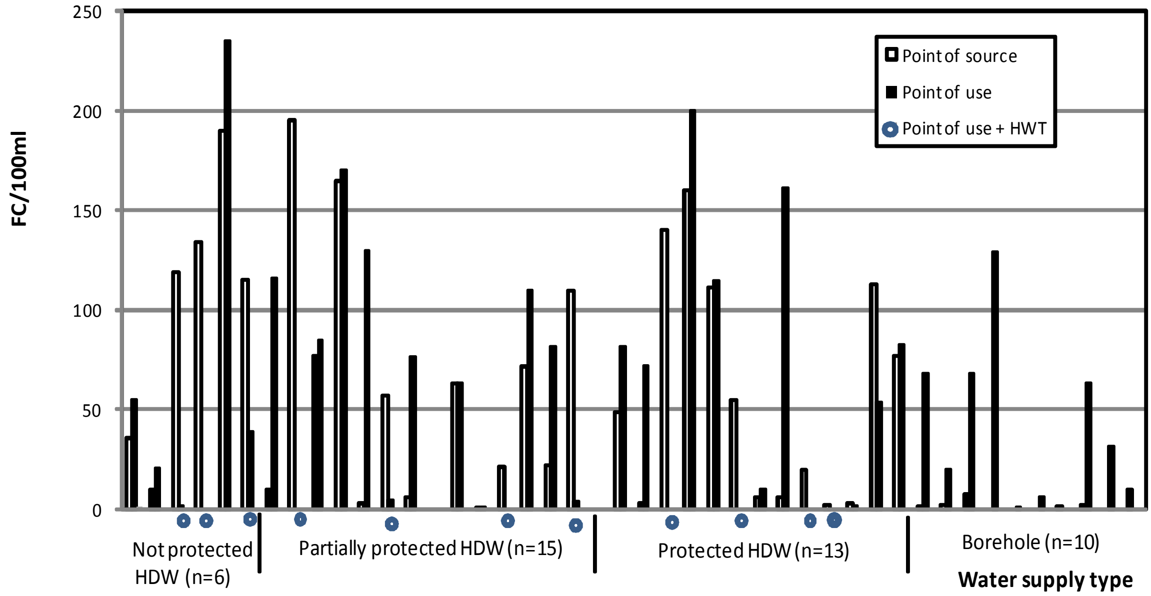


Fig. 5.12: Faecal coliforms test results at point of source and use in Milenge

(Source: Author's field work)

It appears from Fig. 5.12 that out of 33 sampled waters at point of use where they did not apply household water treatment (HWT), 19 samples (58%) had increased levels of faecal contamination. Table 5.15 presents to what extent contamination level increased from point of source to use where no household water treatment was done.

Table 5.15: Level of contamination increase from point of source to use

Faecal Coliforms at point of source to use (FC/100ml)	N	%
Low (<10) to Middle (<50)	3	20
Low (<10) to Middle (<100)	4	27
Low (<10) to High (>100)	3	20
Middle (<50) to Middle (<100)	3	20
Middle (<50) to High (>100)	2	13
Middle (<100) to High (>100)	2	13
High (>150) to High (>200)	2	13
Total	**19**	**100**

(Source: Author's field work)

On the other hand, 11 sampled waters collected from households resulted in very low or contamination free scores where water sources were contamination free. Specifically, 1 HH water sample collected from *Not Protected*, 3 sampled HH water collected from *Partially Protected* HDW, 3 sampled HH water collected from *Protected* and 4 sampled

HH water collected from Borehole sites showed that they kept very low levels of contamination without household water treatment from point of source to use.

Furthermore, out of 11 sampled waters from households where they used liquid chlorine as a household water treatment, 9 had significantly reduced faecal contamination (see Fig. 5.12). 2 sampled waters where they used chlorine at household storage level had reduced the level of contamination to low (<10FC/100ml) whilst the remaining 7 achieved contamination free water. To sum up, the test results implied that the faecal contamination risk increased during the process of transportation and storage at household, but the risk could also be mitigated by using household water treatment. The findings are justified by the extant literature, and Sutton (2009b) highlights the fact that water quality for more than 40 percent of households carrying water from the source becomes contaminated during transport and/or storage. The other 2 sampled waters collected from households showed medium levels of contamination even though liquid chlorine was applied, according to the household surveys. The reason could have been an inappropriate way of using chlorine, such as an inadequate amount of liquid chlorine being applied.

5.5.10 Sanitary conditions at the point of use

The previous section presented the results of water quality tests at points of source and use. Sanitary Inspection (SI) were conducted at point of use in order to look into what factors were likely to affect the water quality at use. Table 5.16 summarises the results of the Sanitary Inspection. SI has a series of questions that all have a YES/NO answer as for the SI at source. For every question that has a 'Yes' answer one point is allocated and for every 'No' answer zero points are allocated (see Appendix E).

Table 5.16: Summaries of Sanitary Inspection at household

SI	Hazard of household storage	Average
1	Drinking water kept in a mixed container	0.00
2	Drinking water container kept floow level	0.26
3	Water contaier have wide mouth/opening	0.37
4	Container have no lid/cover	0.16
5	In place at time of visit	0.09
6	No utensil used to clean inside container	0.11
7	Duty inside of drinking water container	0.21
8	Duty outside of drinking water container	0.23
9	Not clean inside of container everyday	0.05
Total		**1.48**

(*Source: Author's field work*)

It can be seen from Table 5.16 that the most significant hazard of household storage was "water container has wide mouth/opening". This might have increased the risk of contamination compared with a container having a narrow mouth/opening. To examine the correlation between hazards of household storage and faecal contamination levels, the Mann-Whitney test was used. Table 5.17 summarises the results of the statistical tests.

Table 5.17: Correlation any particular hazard of household storage with FC

SI	Hazard of household storage	Significance
1	Drinking water kept in a mixed container	N/A
2	Drinking water container kept floow level	0.091
3	Water contaier have wide mouth/opening	0.045*
4	Container have no lid/cover	0.088
5	In place at time of visit	0.070
6	No utensil used to clean inside container	0.069
7	Duty inside of drinking water container	0.478
8	Duty outside of drinking water container	0.182
9	Not clean inside of container	0.676

(*Source: Author*)

Table 5.17 shows that faecal contamination had a significant correlation with water storage where the container had a wide mouth and opening ($p < .05$). This suggests that the risk of contamination was increased by some intrusion or direct touch by dirty hands when the water container had a wide mouth/opening.

5.5.11 Water quality change and distance to source

Water can be contaminated in the sequence of displacement from where it is stored underground to where rural dwellers consume it at their habitation. The process requires end users to carry water from source to use, unlike a water distribution system. If the water source is far away from their house, this enforces women and children to walk a considerable distance and use energy. Then, water quality change might be attributable to their drinking water directly from the container on the way to home in order to slake their thirst. Therefore, this section examines whether distance to source bears any relationship with the change of water quality from source to use. Table 5.18 summarises the result of the chi-square test which examined the association between water quality change and distance to source. The sampled waters at point of source and use are the same as in Section 5.5.9. Null-hypothesis is that there is no association between distance to water source and change of water quality from source to use.

Table 5.18: Cross-tabulation of distance to water source by water quality change

Milenge		Distance to water source				
Water quality change from source to use		1-20m	21-250m	251-500m	501-1000m	Row total
Constant	Count	6	7	1	0	14
	% (r)	43%	50%	7%	0%	100%
Worse	Count	7	2	6	4	19
	% (r)	37%	11%	32%	21%	100%
χ^2	Value		Df		Significance	
	9.896		3		0.019*	

*(Source: Author's field work) Note: *significant at <.05*

Out of 33 sampled storage waters where they did not apply household water treatment, 19 samples (58%) showed increased levels of faecal contamination compared with the water quality at source (see Section 5.5.9) so that Table 5.18 categorised the water quality as "constant" or "worse" from source to use. A cross-tabulation of distance to water source by change of water quality from source to use showed that the null-hypothesis was rejected by the Pearson Chi-square test at the significance level of 0.019 as shown in Table 5.18. This indicated that there was likely to be an association between distance to water source and water quality change from source to use. The table showed that water quality at use became worse where the distance from house to water source increased. For instance, less than 10% of sampled waters which did not go down in water quality between source and use were transported over 250m while more than 50% of deteriorated water quality was found where the distance exceeded 250m.

Although one third of deteriorated water quality was found from where the distance to source was close (<20m), these findings suggest that the distance to water source could be one of the significant factors increasing the risk of contamination in the process of carrying water from source to use.

This Section has provided a synthesis of the results of the data analysis associated with water quality and sanitary conditions. First, the results of microbiological water quality tests were analysed in connection with water supply type, water supply model and seasonal change. Second, protection features of water supply were examined to investigate what factors were likely to affect water quality such as well head protection or lifting device. Further, sanitary conditions were looked at in association with water supply types and water quality. Finally, water treatment was looked into with respect to water quality improvement in parallel with water quality change at point of source and use. The next section will focus on the other key aspect, accessibility.

5.6 Accessibility

The nature of communal water point ownership is that it belongs to a community rather than to an individual household/family. The location of a communal water source, either borehole or subsidized HDW, takes into consideration hydro-geological conditions, accessibility for construction machines and equity among community households. On the other hand, private HDWs are generally constructed within householders' premises and are shared with neighbours or dominated by the owners' family based on their decisions rather than by obeying community demand. This inevitably generates disparities among different water supply sources and/or different ownerships. The literature review, Chapter 3 outlined the importance of distance to source, ownership and queuing time at the water source. Thereby, this section will examine Accessibility through comparative assessment of communal and Self Supply models in order to look at the viability of Self Supply and the challenges of communal water supply models. Fig. 5.13 showed the research outlines associated with the principal argument, concepts, research questions and indicators. The concept of accessibility is associated with these specific secondary questions;

What is the status of accessibility towards different water supply models? What are the factors likely to affect the accessibility in terms of distance and time? What is the status of per capita water use among different water supply models and how is this likely to be affected by accessibility?

This section presents data obtained from household surveys (see Appendix F), and analyses the key indicators relating to accessibility which is defined below:

- Distance to primary water source (section 5.6.1)
- Distance to alternative water source (section 5.6.2)
- Distance to primary water source and water supply type (section 5.6.3)
- Distance to primary water source and ownership status (section 5.6.4)
- Queuing time (section 5.6.5)
- Queuing time and number of users (section 5.6.6)
- Water collection time (section 5.6.7)
- Per capita water use (single source users) (section 5.6.8)
- Per capita water use (multiple source users) (section 5.6.9)
- Water quantity and water supply types (section 5.6.10)
- Water quantity and distance to primary water source (section 5.6.11)
- Water quantity and distance to each water supply type (section 5.6.12)

Principal Argument

Reliance only on a communal water supply model limits the achievement of increased sustainable access to safe water supply; hence a Self Supply model is needed which does not compete with conventional models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.

Concept 1
Water quality and sanitary condition

Concept 2
Accessibility

Concept 3
Technical and Environmental sustainability

Concept 4
Cost-effectiveness

Concept 5
Acceptability

Research Questions

What is the status of accessibility towards different water supply models? What are the factors likely to affect the accessibility in terms of distance and time? What is the status of per capita water use among different water supply models and how is this likely to be affected by accessibility?

Indicator parameter 1

Distance

Variable 1: Distance to primary water source
Variable 2: Distance to alternative water source
Variable 3: Distance to primary water source and water supply type
Variable 4: Distance to primary water source and ownership status

Indicator parameter 2

Water collection time

Variable 1: Queuing time
Variable 2: Queuing time and number of users
Variable 3: Water collection time

Indicator parameter 3

Per capita water use

Variable 1: Per capita water use (single source users)
Variable 2: Per capita water use (multiple source users)
Variable 3: Water quantity and water supply type
Variable 4: Water quantity and distance to primary water source
Variable 5: Water quantity and distance to each water supply type

Fig. 5.13: Principal argument, indicator parameters

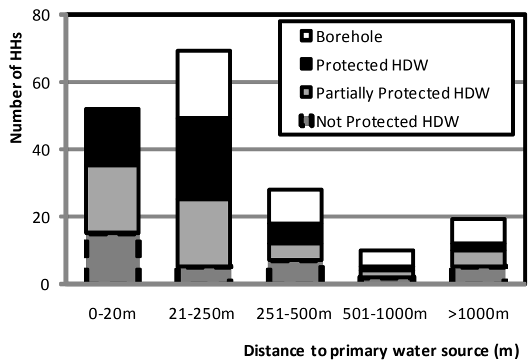
5.6.1 Distance to primary water source

Sections 5.6.1 and 5.6.2 describe the data associated with distance to primary water source and alternative water source. As noted in Section 5.4, in this study 'primary water source' is a term to indicate the water source used for drinking water and 'alternative water source' refers to the water source used when the primary water source is not reliable. Table 5.19 presents the distance from each HH to their primary water source. Further, Figs. 5.14 and 5.15 present the data of Table 5.19 to capture the figures visually. The results shown in Table 5.19 indicate that more than 80% of any types of HDW users could access their primary water source within 500m from their premises. On the other hand, approximately half of borehole users (51% in both Milenge and Nchelenge) had to walk a long way to reach their water points (>250m).

Table 5.19: Distance to primary water source

Water supply types	Valid Cases: N (Milenge, Nchelenge)	0-20m :% (Milenge, Nchelenge)	21-250m :% (Milenge, Nchelenge)	251-500m :% (Milenge, Nchelenge)	501-1000m :% (Milenge, Nchelenge)	>1000m :% (Milenge, Nchelenge)
Not Protected	82 (34, 48)	(46, 56)	(14, 35)	(25, 4)	(4, 0)	(11, 4)
Partially Protected	146 (52, 94)	(38, 53)	(38, 36)	(10, 6)	(4, 4)	(10, 0)
Protected	97 (49, 48)	(33, 46)	(49, 48)	(12, 4)	(2, 2)	(4, 0)
Borehole	109 (43, 66)	(2, 2)	(47, 48)	(23, 17)	(12, 23)	(16, 11)

(Source: Author's field work)



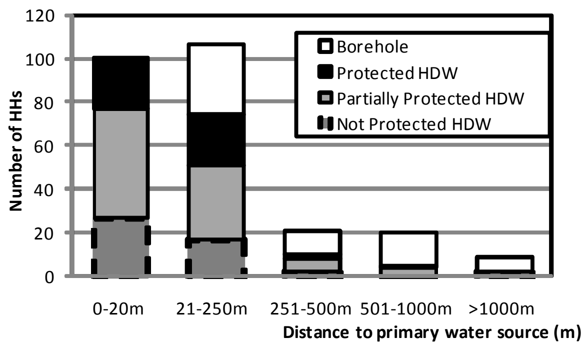


Fig. 5.14: Distance to primary water source in Milenge **Fig. 5.15: Distance to primary water source in Nchelenge**

A communal borehole with handpump was able to serve up to 250 people as a standard coverage number, and this forced the community members to walk a considerable distance in sparsely populated rural areas such as Milenge District (5.9persons/km^2). In contrast, the majority of HDWs were privately owned and shared with surrounding small groups except for those owned by the community or institutions under communal or Self Supply models.

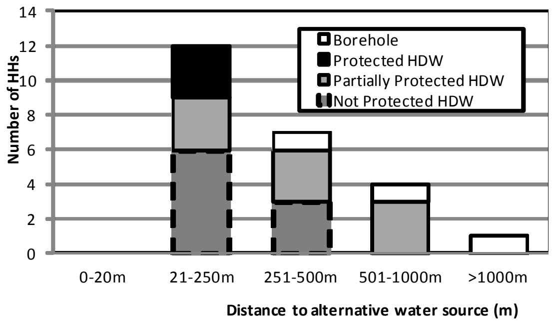
5.6.2 Distance to alternative water source

Table 5.20 shows the alternative water source and the distances from their HH. As mentioned in Section 5.4.2, Of the 447 HH responding to the household questions, overall 283 HH used a second water source either for 1) alternative use only when the primary water source was not reliable (196HH) or 2) multiple uses to complement the primary water source in the same day (87HH). Table 5.21 presents the data of alternative water source users which is equivalent to 196HH. Figs.5.16 and 5.17 present the same data as Table 5.20 as a visual aid to understanding.

Table 5.20: Alternative water source and their accessibility

Alternative water source	Valid Cases: N (Milenge, Nchelenge)	0-20m: % (Milenge, Nchelenge)	21-250m: % (Milenge, Nchelenge)	251-500m: % (Milenge, Nchelenge)	501-1000m: % (Milenge, Nchelenge)	>1000m: % (Milenge, Nchelenge)
Not Protected	20 (9, 8)	(0, 0)	(67, 88)	(33, 0)	(0, 0)	(0, 13)
Partially Protected	24 (9, 15)	(0, 0)	(33, 67)	(33, 27)	(33, 0)	(0, 7)
Protected	7 (3, 4)	(0, 0)	(100, 100)	(0, 0)	(0, 0)	(0, 0)
Borehole	28 (3, 25)	(0, 0)	(0, 8)	(33, 20)	(33, 24)	(33, 48)
Tap	12 (0, 12)	(0, 50)	(0, 50)	(0, 0)	(0, 0)	(0, 0)
Others (Spring, stream)	105 (51, 54)	(0, 0)	(8, 11)	(12, 21)	(20, 33)	(60, 33)

(Source: Author's field work)



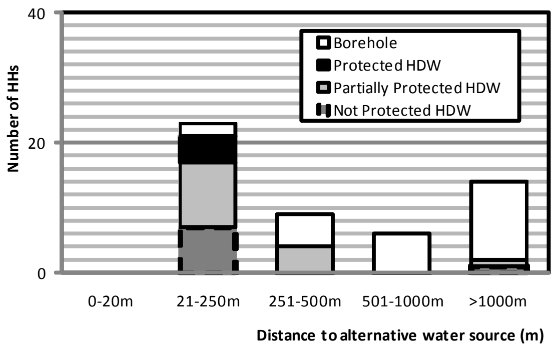


Fig. 5.16: Distance to alternative source in Milenge

Fig. 5.17: Distance to alternative source in Nchelenge

It is apparent from Table 5.20 that it was rare to have alternative water points within premises (0-20m) except for a tap which only has an intermittent supply. It should also be noted that over two thirds of any types of alternative HDW were accessible within 500m whereas a borehole as an alternative water source was far more remote than a primary source (see Tables 5.19 and 5.20). These findings suggest that rural dwellers could find alternative HDWs nearby as the subsidized boreholes were located at a considerable distance.

5.6.3 Distance and water supply type

The distance to the primary water source was presented in the previous section in a descriptive manner. This section further analyses the association between water supply type and distance to those water sources. Table 5.21 shows the cross-tabulation of distance to primary water source by different water supply types. The Chi-squared test can look at the association between two variables (in this case, “water supply type” and “distance to primary water source”) but does not necessarily provide a systematic association. The distance to primary water source is classified in four categories in order to enhance the statistical validity (see questionnaire in Appendix F). Four different water supply types (three from well and one from borehole) are included in the analysis in order to examine the difference of distance to primary water source by different water supply types.

Table 5.21: Cross-tabulation of distance to primary water source by different water supply types

		Distance to primary water source				
Milenge		1-20m	21-250m	251-500m	>500m	Row total
Not protected	Count	13	8	8	5	34
	% within Not protected	38%	24%	24%	15%	100%
Partially protected	Count	20	24	8	7	52
	% within Part' protected	34%	41%	14%	11%	100%
Improved	Count	16	24	6	3	49
	% within Protected	33%	49%	12%	6%	100%
Borehole	Count	1	20	10	12	43
	% within Borehole	2%	47%	23%	28%	100%
χ^2	**Value**		**Df**		**Significance**	
	22.551		9		0.007*	
Nchelenge		1-20m	21-250m	251-500m	> 500m	Row total
Not protected	Count	27	17	2	2	48
	% within Not protected	56%	35%	4%	4%	100%
Partially protected	Count	50	34	7	4	95
	% within Part' protected	53%	36%	7%	4%	100%
Improved	Count	22	23	2	1	48
	% within Protected	46%	48%	4%	2%	100%
Borehole	Count	1	34	10	20	65
	% within Borehole	2%	52%	15%	31%	100%
Others (spring, stream and tap)	Count	2	2	0	13	17
	% within others	12%	12%	0%	76%	100%
χ^2	**Value**		**Df**		**Significance**	
	40.758		9		0.0005***	

(Source: Author’s field work)

*Note *significant at <.05 ***significant at <.001*

The distances to primary water sources are significantly different between different water supply types with a Pearson Chi-square of 0.007 in Milenge and 0.0005 in Nchelenge, respectively. As outlined in Section 5.6.1, about half of borehole users (51% in both Milenge and Nchelenge) had to walk more than 250m to draw water compared with HDW user groups where no more than 20% of them had to cover a distance of more than 250m. Accessibility to HDWs in Nchelenge was better than in Milenge. For instance, over 90% of *Not Protected* HDW users in Nchelenge could access water within 250m compared with 60% of *Not Protected* users in Milenge. This could be explained by their difference in population density where Milenge District was approximately 5.9 (person/m^2) and Nchelenge District was about three times denser with 15.1 (person/km^2).

The higher density in Nchelenge compared with Milenge may have narrowed the distance between neighbouring houses and water points. On the other hand, more than 30% of borehole users in Nchelenge went a distance of more than 500m whereas this was true for less than 30% of borehole users in Milenge. This could be explained by the nature of the borehole construction sites. The borehole construction sites were alongside the paved road since the construction machinery had a limitation for movement into the bush. However, not all the houses of village dwellers in Nchelenge were located on the roadside because of the higher population density than in Milenge. It is important to also note that HDWs had different ownership, not only private individual households, but also public communities. The next section therefore discusses whether their different ownership status could have an impact on their accessibility to primary water sources.

5.6.4 Distance to primary water source and ownership status

Ownership status was divided into 5 categories; privately owned (family only, not shared); privately owned and shared; community owned; community owned (gov't subsidy); and institution (school or clinic) owned (see Table 5.4 in Section 5.3). Table 5.22 shows the results of cross-tabulation of distance by ownership status of each water supply type. The three former categories of the ownership status fall into the Self Supply model whereas the two latter categories become a communal model.

Table 5.22: Cross-tabulation of distance by ownership status of each water supply types

Milenge	Ownership status		Distance to primary water source					Pearson Chi-suqare		
			1-20m	21-250m	251-500m	> 500m	Row total	Value	Df	Sig. (p)
Not protected HDW	Privately owend and shared	Count	13	8	8	5	34	N/A	N/A	N/A
		% (r)	38%	24%	24%	15%	100%			
Partially prote' HDW	Privately owned and shared	Count	19	18	5	5	47			
		% (r)	40%	38%	11%	10%	100%			
	Community owned (Gov't subsidy)	Count	0	2	0	2	4	8.005	6	0.238
		% (r)	0%	50%	0%	50%	100%			
	Institution (school or clinic)	Count	1	0	0	0	1			
		% (r)	100%	0%	0%	0%	100%			
Protected HDW	Privately owned and shared	Count	15	13	4	1	33			
		% (r)	45%	39%	12%	3%	100%			
	Community owned	Count	0	5	0	0	5	12.869	6	0.045*
		% (r)	0%	100%	0%	0%	100%			
	Institution	Count	1	6	2	2	11			
		% (r)	9%	55%	18%	18%	100%			
Borehole	Community owned (Gov't subsidy)	Count	1	8	2	4	15			
		% (r)	7%	53%	13%	26%	100%	4.240	3	0.270
	Institution	Count	0	12	8	8	28			
		% (r)	0%	43%	29%	29%	100%			

Nchelenge	Ownership status		Distance to primary water source					Pearso		
			1-20m	21-250m	251-500m	> 500m	Row total	Value	Df	Sig. (p)
Not protected HDW	Privately (family only, not shared)	Count	1	0	0	0	1			
		% (r)	100%	0%	0%	0%	100%			
	Privately owned and shared	Count	26	17	2	0	45	48.571	6	0.0005***
		% (r)	58%	38%	4%	0%	100%			
	Community owned (Gov't subsidy)	Count	0	0	0	2	2			
		% (r)	0%	0%	0%	100%	100%			
Partially prote' HDW	Privately (family only, not shared)	Count	1	2	0	0	3			
		% (r)	33%	66%	0%	0%	100%			
	Privately owned and shared	Count	49	30	7	4	90	5.187	6	0.520
		% (r)	54%	33%	8%	7%	100%			
	Community owned (Gov't subsidy)	Count	0	2	0	0	2			
		% (r)	0%	100%	0%	0%	100%			
Protected HDW	Privately (family only, not shared)	Count	1	0	0	0	1			
		% (r)	100%	0%	0%	0%	100%			
	Privately owned and shared	Count	20	19	0	0	39			
		% (r)	51%	49%	0%	0%	100%	23.401	9	0.005**
	Community owned (Gov't subsidy)		0	4	2	1	7			
		Count	0%	57%	29%	14%	100%			
	Institution (school or clinic)	% (r)	1	0	0	0	1			
		Count	100%	0%	0%	0%	100%			
Borehole	Community owned (Gov't subsidy)	% (r)	1	25	6	7	39			
		Count	3%	64%	15%	18%	100%	8.468	3	0.037
	Institution (school or clinic)	% (r)	0	9	4	13	26			
			0%	35%	15%	50%	100%			

(Source: Author's field work)

*Note: *significant at <.05 **significant at <.01 ***significant at <.001*

It is apparent from the results shown in Table 5.22 that distance from the sampled HH to *Protected* HDWs point by ownership status had a significant relationship with a Pearson Chi-square of 0.045 in Milenge and 0.005 in Nchelenge, respectively. The table shows that access to a *Protected* HDW decreased the distance where owned privately, while access to a *Protected* HDW owned by community/institution increased the distance. This could be explained by the fact that private HDWs were generally shared with extended families and/or neighbouring households although *Protected* HDWs owned by communities/institutions covered the total community members in as wide a sphere as for the similar design of communal borehole models.

5.6.5 Queuing time

Table 5.23 shows the average waiting time at different water sources.

Table 5.23: Waiting time at water points

Water supply types	Milenge	Nchelenge	Average
Not Protected	14.11	15.57	14.84
Partially Protected	9.21	10.76	9.99
Protected	16.58	13.22	14.90
HDW	**13.30**	**14.64**	**13.97**
Borehole	31.59	56.41	44.00
Average	**22.45**	**23.41**	**22.93**

(Source: Author's field work)

Note: figures in the table present minutes

Waiting time varied significantly depending on the primary water source that households used. The government standard is 250 people to a borehole facility whilst 25HH (equivalent to about 150 people) for a *Protected* HDW. On the whole, community members queued on average 23 minutes a day at water points. The borehole users queued for an average of 40 minutes or more than 2.5 times as long as the HDW users, who waited an average 14 minutes.

5.6.6 Queuing time and number of users

This section discusses the relationship between queuing time and number of users. Table 5.24 shows the result of cross-tabulation of queuing time by number of users. From a cross-tabulation of two variables 'number of users' and 'queuing time', it was found that the hypothesis 'There is likely to be a relationship between queuing time and number of users' was accepted by the Pearson Chi-square at *Not Protected*, *Partially Protected* and *Protected* HDWs in Milenge had significance levels of 0.026, 0.030 and 0.006, respectively. Further, there is likely to be a relationship between the queuing time and the number of HH for *Partially Protected* HDWs in Nchelenge with a significance value of 0.001 (less than <0.01). This result suggests that they needed to queue for a long time to draw water from places where a number of people rely on the same water source.

Table 5.24: Cross-tabulation of queuing time by number of users

Milenge	Number of users (HH)		Queuing time (min.) 0-30	31-90	>90	Row total	Pearson Chi-suqare Value	Df	Sig. (p)
Not protected HDW	1-10	Count	15			15			
		% (r)	100%			100%			
	11-24	Count	6			6	7.304	2	0.026*
		% (r)	100%			100%			
	> 25	Count	2	1		3			
		% (r)	66%	33%		100%			
Partially prote' HDW	1-10	Count	30			30			
		% (r)	100%			100%			
	11-24	Count	11			11	6.982	2	0.030*
		% (r)	100%			100%			
	> 25	Count	5	1		6			
		% (r)	83%	17%		100%			
Protected HDW	1-10	Count	12			12			
		% (r)	100%			100%			
	11-24	Count	21	1		22	14.532	4	0.006**
		% (r)	95%	5%		100%			
	25-50	Count	5		3	8			
		% (r)	63%		36%	100%			
Borehole	11-24	Count	5			5			
		% (r)	100%			100%	1.256	2	0.534
	25-50	Count	23	3	3	29			
		% (r)	79%	10%	10%	100%			

Nchelenge	Number of users (HH)		Queuing time (min.) 0-30	31-90	> 90	Row total	Pearson Chi-suqare Value	Df	Sig. (p)
Not protected HDW	1-10	Count	15			15			
		% (r)	100%			100%			
	11-24	Count	18	5		23	5.135	2	0.077
		% (r)	78%	22%		100%			
	> 25	Count	6	3		9			
		% (r)	67%	33%		100%			
Partially prote' HDW	1-10	Count	27			27			
		% (r)	100%			100%			
	11-24	Count	20	1		21	17.159	4	0.001*
		% (r)	95%	5%		100%			
	> 25	Count	18		2	20			
		% (r)	90%		10%	100%			
Protected HDW	1-10	Count	14	4		18			
		% (r)	78%	22%		100%			
	11-24	Count	2			2	0.556	2	0.757
		% (r)	100%			100%			
	25-50	Count	12	3		15			
		% (r)	80%	20%		100%			
Borehole	25-50	Count	7	5		12			
		% (r)	58%	42%		100%	1.962	3	0.580
	>50	Count	12	16	2	30			
		% (r)	40%	53%	7%	100%			

(*Source: Author's field work*)

Note: *significant at <.05 **significant at <.01

5.6.7 Water collection time

Accessibilities contain not only 'distance', but also 'time' as their different dimensions for evaluating their value. This section therefore combines distance to primary water source and queuing time in one set as 'collection time'. This collection time comprised of two stages, time for the round trip from their house to water points and time for queuing at water points in a day. Table 5.25 shows the summary of average water collection time. Each water source type is further categorised to specifically compare privately owned and community owned because distance and queuing time may not be consistent within the same water supply types if the ownership status is different i.e. water supply models between Communal and Self Supply.

Table 5.25: Water collection time at different water supply types by ownership status

Water supply types	Ownership status	Count (Milenge, Nchelenge)	% within each water supply (Milenge, Nchelenge)	Waiting time [Average min.] (Milenge, Nchelenge)	Water collection time [Average min.] (Milenge, Nchelenge)
Not protected HDW	Privately (family only, not shared)	(0, 1)	(0, 2)	(N/A, 0)	(N/A, 35)
	Privately owend and shared	(17, 43)	(100, 93)	(14, 16)	(62, 51)
	Community owned (Gov't subsidy)	(0, 2)	(0, 4)	(N/A, 0)	(N/A, 200)
Partially protec' HDW	Privately (family only, not shared)	(0, 1)	(0, 1)	(N/A, 0)	(N/A, 20)
	Privately owend and shared	(40, 75)	(95, 96)	(9, 6)	(84, 55)
	Community owned (Gov't subsidy)	(2, 2)	(5, 3)	(15, 180)	(85, 210)
Protected HDW	Privately (family only, not shared)	(0, 1)	(0, 3)	(N/A, 0)	(N/A, 20)
	Privately owend and shared	(30, 29)	(70, 91)	(7, 17)	(70, 60)
	Community owned	(5, 0)	(12, 0)	(84, N/A)	(196, N/A)
	Community owned (Gov't subsidy)	(0, 2)	(0, 6)	(N/A, 75)	(N/A, 143)
	Institution (school or clinic)	(8, 0)	(19, 0)	(8, N/A)	(118, N/A)
Borehole	Community owned (Gov't subsidy)	(5, 22)	(20, 69)	(6, 47)	(44, 144)
	Institution (school or clinic)	(20, 10)	(80, 31)	(37, 70)	(205, 151)
Average	Privately (family only, not shared)	(0, 3)	(0, 2)	(N/A, 0)	(N/A, 25)
	Privately owend and shared	(87, 147)	(69, 78)	(10, 13)	(72, 55)
	Community owned	(5, 0)	(4, 0)	(84, N/A)	(196, N/A)
	Community owned (Gov't subsidy)	(7, 28)	(6, 15)	(15, 76)	(65, 174)
	Institution (school or clinic)	(28, 10)	(22, 5)	(23, 70)	(162, 151)

(Source: Author's field work)

Note: N/A= not applicable

As noted in Section 5.4.1 and 5.4.2, there were three types of households in terms of water usage.

1) Single water source users
2) Single water source users but using alternative water sources when the primary source is unreliable
3) Multiple water source users on a daily basis

Table 5.25 reflected the results only from single source HHs (those are 1) and 2) in the above categories), and the next section discusses the water collection time of multiple source users. The trend of it being time-consuming to draw water at borehole sites compared with HDWs users was presented in Section 5.6.5. Further, Table 5.25 indicated that the reason for it being time-absorbing was the result of the aggregation not only of the distance to the source, but also queuing time at the water source. Privately owned (family member, not shared) water points were, needless to say, the most time saving for water collection. The water collection time from community owned borehole (government subsidy) in Milenge took the relatively short time of 44min compared with 144min. in Nchelenge. This could be explained by the fact that the number of HH sharing a communal borehole in Milenge was 32HH which was smaller than the average of 50HH in Nchelenge (see Table 5.4 in Section 5.3). Also, the water collection time difference between community owned and institution borehole users could be assumed by the fact that the number of community owned borehole users (two sampled) was between 11-24 (two sampled) compared with over 25HH users in the institution borehole (see Table 5.4).

It was found from Table 5.25 that water collection time was considerably dependent on the ownership status of the water source. For example, water collection time from *Protected* HDWs owned privately and shared in Milenge was half of that from *Protected* HDWs owned by the community or institution which was over 2 hours. It was also apparent from the bottom column of the table which combined the results of the different water supply types by ownership status, that privately owned water source users took less time than communal source users regardless of their different types of water supply sources.

These findings that drawing water from borehole water points took an age because of considerable distance and queuing time, combined with the results that communal HDW water point users also took a long time to collect water, suggested that privately owned water points were able to provide more opportunity to access water with relatively less distraction of distance and/or time.

5.6.8 Per capita water use (single source users)

To understand what quantity of water was used for a household, per capita water use was investigated. Subsequently as noted in Section 5.4, 87 HH relied on more than one water source whilst 360 HH used only one water source unless their primary water source was unavailable. Therefore, this section looks at per capita water source usage of single source users.

Table 5.26: Per capita water use

District	Milenge		Nchelenge		Average
Water supply types	(N)	(lcd)	(N)	(lcd)	(lcd)
Not Protected HDW	19	29.59	42	23.09	26.34
Partially Protected HDW	42	31.85	92	22.20	27.03
Protected HDW	43	38.44	46	25.80	32.12
Total HDW	104	**33.29**	180	**23.70**	**28.50**
Borehole	25	20.48	43	14.89	17.69
Average		**26.89**		**21.50**	24.20

(Source: Author's field work)

Note: figures in the table represent litres per capita per day (lcd)

For the aggregate sample, it was found that the average value of per capita water use among HDW users was 28.50 lcd whilst the average value for borehole users was 17.69lcd. Per capita water use by Milenge HDW users was about 10lcd greater than that of HDW users in Nchelenge. It is interesting to note, however, that the more the HDW was protected, the greater was the increase in per capita water use. In other words, *Protected* HDWs produced the highest per capita water use amongst the different water supply types. This could imply that *Protected* HDWs were able to deliver sufficient water for the users and/or that *Protected* HDW users found benefit from the *Protected* HDW.

These results were compared with relevant studies to ensure the credibility of collected data, particularly because the water-use levels were self-reported by households, rather than measured by a surveyor or a meter (see Household survey process in Section4.8.4 and the questionnaire in Appendix F). IWMI studied per capita water use linked with gender roles in India and examined two categories of villages in 2004; one was where people needed to walk more than 1km to fetch water and the other was where they had private or partnership wells (Upadhyay 2004). Based on information collected from household surveys, IWMI reported that average rural water use where they had private wells in India was 36.1lcd-and where people needed to walk more than 1km to draw water it was 18.6lcd. Although the figures obtained in this study were somewhat lower than in the IWMI study, the tendency for private HDWs to provide a larger amount of water to users than communal water sources was fairly consistent.

Further comparison with other neighbouring countries revealed the following. In the study by Drawers of Water Ⅱ (DOWⅡ), they collected per capita water use in urban sites at several Eastern Africa sites between 1967 and 1997 (Thompson, Porras et al. 2000). They categorised areas into non-piped and piped areas, and they stated that unpiped areas corresponded roughly to rural locations. The study presented that per capita water use in unpiped site in Kenya, Tanzania and Uganda was 27.7, 25.1 and 23.5lcd, respectively so that the average became 24.3lcd. Despite minor differences in the results, this study and DOWⅡ have provided strong evidence that the average per capita water use in rural households in Eastern Africa is 20-30lcd.

5.6.9 Per capita water use and water collection time (multiple water source users)

As noted in the above section, 87HH used multiple water sources to complement their primary water source. Table 5.27 below, presents a combination of primary and complementary water sources and their per capita water use. Out of 173HH sampled in Milenge, 45HH (26%) used another water source to supplement their primary drinking water source while 42HH (15%) in Nchelenge relied on multiple water sources. It is apparent from Table 5.27 that nearly half of the multiple water source users used boreholes to complement their other water sources (41% in Milenge, 52% in Nchelenge). It is also important to note that overall 36HH used another water source despite having their own HDWs.

Table 5.27: Per capita water use and water collection time of multiple water sources

Primary water source	Valid case: N (Milenge, Nchelenge)	Complement water source	Frequency :% (Milenge, Nchelenge)	Per capita water use (Milenge, Nchelenge)	Water collection time (Milenge, Nchelenge)
Borehole	13 (3, 10)	O-HDW	(8, 24)	(40.21, 23.00)	(312.5, 159.66)
	16 (5, 11)	N-HDW	(11, 26)	(51.03, 31.50)	(173.33, 191.81)
	11 (10, 1)	Others (stream, spring)	(22, 2)	(27.18, 28.75)	(200.83, 150.00)
N-HDW	19 (15, 4)	O-HDW	(33, 10)	(40.01, 17.87)	(141.78, 125.44)
	7 (7, 0)	N-HDW	(16, 0)	(48.84, N/A)	(261.33, N/A)
	5 (3, 2)	Others (stream, tap)	(8, 5)	(38.72, 20.00)	(202.5, 84.00)
Others	4 (0,4)	O-HDW	(0, 10)	(N/A, 29.54)	(N/A, 175.63)
(stream, spring and tap)	10 (2, 8)	N-HDW	(4, 33)	(18.00, 20.14)	(150.00, 180.67)

(Source: Author's field work)

Abbreviation: O-: Owned, N-: Neighbour's

According to their response as to why they were not only using their own HDWs especially for drinking usage, the reasons were;

1) Inadequate level of protection for the prevention of contamination (initially used for drinking usage but stopped since frogs and insects dropping inside led to a bad smell) (60% in Milenge, 72% in Nchelenge)
2) Under improvement (30% in Milenge, 12% in Nchelenge)
3) Not yet water quality tested (6% in both Districts)

Further, it is evident from Table 5.27 that water collection times from multiple water source became two to three hours except for tap water users. The findings clearly show that extra time is required for multiple water source users to collect water when compared with the single source users (see Table 5.25).

5.6.10 Water quantity and water supply types

The quantity of water delivered and used for households is an important aspect of domestic water supplies, which influences hygiene and therefore public health (Howard 2003). Water quantity refers to the litre per capita per day accessed by households. This section looks at the relationship of the per capita per day of single source users by water supply types, and the result of cross-tabulation is shown in Table 5.28. Although the average per capita water use of HDW exceeds 25 lcd, the analysis below integrated all the sampled over 25 lcd into ">25 lcd" because the standard set by the Zambian government for definition of access to a safe water supply is a minimum of 25lcd of water from a *Protected* water source (NRWSSP 2007).

Per capita per day of single source users was significantly different between water supply types with a Pearson Chi-square of 0.006 in Milenge and 0.007 in Nchelenge, respectively. It is apparent from the table that per capita per use increased in accordance with the protection level of HDWs, especially in Milenge. The less per capita water use in Nchelenge compared with Milenge could be explained by the fact that average number of users (both HDW and borehole) in Nchelenge is higher than that of Milenge (see Table 5.4 in Section 5.3). However, over 40% of both *Not Protected* and *Partially Protected* HDW users accounted for less than 25lcd compared with those of less than 30% of *Protected* HDW users in Milenge. In fact, it was found from Table 5.26 in Chapter 5.6.8, that the average litres per capita per day of *Protected* HDW users was 6 lcd greater than those of *Not Protected* and *Partially Protected* HDW users. The difference between *Protected* HDWs and Not/Partially Portected HDWs could also be explained by the fact that the reliability of *Protected* HDWs was higher than *Not Protected* and *Partially Protected* (see Section 5.7); also *Not Protected* and *Partially Protected* HDWs had no significant difference in terms of water source reliability. On the other hand, notwithstanding the high water source reliability at boreholes (see Section 5.7.3), the per capita use per day of borehole users was less than that of HDW users. The next section, therefore, looks at the relationship between per capita use per day and the distance to the water source.

Table 5.28: Cross-tabulation of per capita use per day by water supply types

Per capita per day (lcd)					
Milenge		0-10	11-24	>25	Row total
Not protected HDW	Count	2	6	10	18
	% (r)	11%	33%	55%	100%
Partially protec HDW	Count	2	15	23	40
	% (r)	5%	38%	58%	100%
Protected HDW	Count	0	10	24	34
	% (r)	0%	29%	71%	100%
Borehole	Count	5	8	4	17
	% (r)	29%	47%	24%	100%
χ^2	**Value**	**Df**		**Significance**	
	18.278	6		0.006**	

Per capita per day (lcd)					
Nchelenge		0-10	11-24	>25	Row total
Not protected HDW	Count	3	26	13	42
	% (r)	7%	62%	31%	100%
Partially protec HDW	Count	12	40	31	83
	% (r)	14%	48%	37%	100%
Protected HDW	Count	2	19	9	30
	% (r)	7%	63%	30%	100%
Borehole	Count	9	27	2	38
	% (r)	24%	71%	5%	100%
χ^2	**Value**	**Df**		**Significance**	
	17.624	6		0.007**	

(*Source: Author's field work*)

Note: ***significant at <.01*

5.6.11 Water quantity and distance to primary water source

This section analyses the relationship between water quantity and distance to the primary water source. Water quantity refers to the litres per capita per day of single source users. The test result of cross tabulation is shown in Table 5.29.

Table 5.29: Cross-tabulation of distance to primary water source by water quantity

Milenge		**Distance to primary water source**				
Per capita per day [lcd]		1-20m	21-250m	251-500m	>500m	Row total
0-10	Count	1	8	1	6	16
	% (r)	6%	50%	6%	38%	100%
11-24	Count	15	18	4	2	39
	% (r)	38%	46%	10%	6%	100%
> 25	Count	31	26	6	3	66
	% (r)	47%	39%	9%	5%	100%
χ^2		**Value**	**Df**		**Significance**	
		22.550	6		0.001**	

Nchelenge		**Distance to primary water source**				
Per capita per day [lcd]		1-20m	21-250m	251-500m	> 500m	Row total
0-10	Count	9	12	0	7	28
	% (r)	32%	43%	0%	25%	100%
11-24	Count	48	52	7	5	112
	% (r)	43%	46%	6%	5%	100%
25-50	Count	28	25	2	1	56
	% (r)	50%	45%	4%	2%	100%
χ^2		**Value**	**Df**		**Significance**	
		20.564	6		0.002**	

(*Source: Author's field work*)
*Note: **significant at <.001*

The likelihood of a relationship between distance to primary water source and litres per capita per day was accepted by the Pearson Chi-square at Milenge and Nchelenge at significant levels of 0.001 and 0.002, respectively (Table 5.29). The table indicated that the further they walked to fetch their water, the less the amount they used for their daily consumption and hygiene purposes. In other words, litres per capita per day were increased where the distance to water source decreased.

Table 5.30 further investigates the association between distance to primary water source and litres per capita water use by combining the collected data from Milenge and Nchelenge.

Table 5.30: Cross-tabulation of distance to primary water source by per capita water use

Milenge + Nchelenge		**Distance to primary water source**				
Per capita per day [lcd]		1-20m	21-250m	251-500m	>500m	Row total
0-10	Count	10	20	1	13	44
	% (r)	23%	45%	2%	30%	100%
11-24	Count	63	70	11	7	151
	% (r)	42%	46%	7%	5%	100%
> 25	Count	59	51	8	4	122
	% (r)	48%	42%	7%	3%	100%
χ^2		**Value**	**Df**		**Significance**	
		39.555	6		0.0001***	

(*Source: Author's field work*)
Note: *** significant at <.0001

It is apparent from Table 5.30 that there was significant association between litres per capita water use and distance to primary water source. Thereby, it could imply that the amount of water use was apt to decrease if people needed to collect water in rural areas along way away from their settlement.

5.6.12 Water quantity and distance to each water supply type

It can be seen from Section 5.6.11 that the amount for daily consumption and hygiene purposes was related to the distance to the primary water source. This section further discusses how this relationship was different between water supply types. Table 5.31 shows the results of a cross-tabulation test of distance to primary water source by water quantity accessed at different water supply sources. Table 5.31 showed that the Pearson Chi-square test gave significance levels of 0.045, 0.011 (which is less than 0.05) for boreholes in Milenge and Nchelenge, respectively, with the majority of respondents who had to travel a considerable distance (more than 500m) using smaller amounts of water.

On the other hand, there was no statistical significance between the distance to HDWs and the amount of fetched water from HDWs (larger than 0.05 in all types of HDWs). In fact, more than 80% of any protected types of HDW users could access their primary water source within 250m from their premises (see Table 5.19 in Section 5.6.1). This implied that there was no significant difference in the amount of fetched water for consumption and hygiene purposes where the primary water source was within 250m.

Table 5.31: Cross-tabulation of distance by water quantity among water supply types

Milenge	Per capita		Distance to primary water source					Pearson Chi-suqare		
			1-20m	21-250m	251-500m	> 500m	Row total	Value	Df	Sig. (p)
Not protected HDW	0-10	Count	1	1	0	0	2			
		% (r)	50%	50%	0%	0%	100%			
	11-24	Count	6	0	0	0	6	4.999	4	0.287
		% (r)	100%	0%	0%	0%	100%			
	> 25	Count	6	3	2	0	11			
		% (r)	55%	27%	18%	0%	100%			
Partially prote' HDW	0-10	Count	0	2	0	0	2			
		% (r)	0%	100%	0%	0%	100%			
	11-24	Count	7	4	3	1	15	8.797	6	0.185
		% (r)	47%	27%	20%	7%	100%			
	>25	Count	12	10	0	1	23			
		% (r)	52%	43%	0%	4%	100%			
Protected HDW	11-24	Count	2	7	1	0	10			
		% (r)	20%	70%	10%	0%	100%	4.148	3	0.246
	> 25	Count	12	8	3	1	24			
		% (r)	50%	33%	13%	4%	100%			
Borehole	0-10	Count	0	3	1	6	10			
		% (r)	0%	30%	10%	60%	100%			
	11-24	Count	0	7	0	1	8	12.586	6	0.045*
		% (r)	0%	88%	0%	13%	100%			
	> 25	Count	1	4	1	0	6			
		% (r)	17%	67%	17%	0%	100%			

Nchelenge	Per capita		Distance to primary water source					Pearson Chi-suqare		
			1-20m	21-250m	251-500m	> 500m	Row total	Value	Df	Sig. (p)
Not protected HDW	0-10	Count	1	2	0	0	3			
		% (r)	33%	67%	0%	0%	100%			
	11-24	Count	16	7	1	2	26	4.063	6	0.668
		% (r)	62%	27%	4%	8%	100%			
	> 25	Count	6	6	1	0	13			
		% (r)	46%	46%	8%	0%	100%			
Partially prote' HDW	0-10	Count	7	5	0	0	12			
		% (r)	58%	42%	0%	0%	100%			
	11-24	Count	22	14	3	1	40	2.048	6	0.915
		% (r)	55%	35%	8%	3%	100%			
	> 25	Count	16	13	1	1	31			
		% (r)	52%	42%	3%	3%	100%			
Protected HDW	0-10	Count	1	1	0	0	2			
		% (r)	50%	50%	0%	0%	100%			
	11-24	Count	9	10	0	0	19	0.923	2	0.630
		% (r)	47%	53%	0%	0%	100%			
	25-50	Count	6	3	0	0	9			
		% (r)	67%	33%	0%	0%	100%			
Borehole	0-10	Count	0	4	0	7	11			
		% (r)	0%	36%	0%	63%	100%			
	11-24	Count	1	21	3	2	27	16.481	6	0.011*
		% (r)	4%	78%	11%	7%	100%			
	> 25	Count	0	3	0	0	3			
		% (r)	0%	100%	0%	0%	100%			

(*Source: Author's field work*)

*Note: *significant at <.05*

To sum up, this Section 5.6 has presented and examined one of the key aspects, accessibility. First, distances to primary and alternative water source were analysed in connection with water supply types and ownership status. Second, accessibility was investigated under the dimension of time by combining the queuing time and travelling time as a water collection time. Then, water collection time was looked at in association with the water supply type, number of users and water supply model. Further, the study extended accessibility to water quantity consumed and used. Per capita water use of single source users and multiple source users were presented and analysed in association with water supply type and distance to water source. The following section will look into reliability in terms of technical and environmental sustainability.

5.7 Technical and Environmental Sustainability

Poor construction of the water supply source has the potential to allow direct intrusion of contaminants to the groundwater and also leads to difficulties in accessing groundwater. The literature review Chapter 3 outlined the importance of initial construction practices and post construction support for O&M to emphasise the sustainability aspects of both technology and environment. Thereby, this section looks at how a Self Supply model is sustainable with respect to Technology and Environment through comparison with communal water supply models. Fig. 5.18 shows the research outlines associated with the principal argument, concepts, research questions and indicators. The concept of technological and environmental sustainability is associated with specific secondary questions;

What is the status of the technical sustainability of different water supply models? What is the status of water reliability from different water supply models? What are the factors likely to affect technical sustainability and water reliability? In what way are water supply models delivering operation and maintenance systems to the households/communities?

The next sections present data obtained by inventory and household surveys (see Appendices A & F), and analyse each variable relating to technical and environmental sustainability which are defined below:

- Technical sustainability of lifting device (section 5.7.1)
- Water supply down time (section 5.7.2)
- Water source reliability (section 5.7.3)

- Water source dry up and bottom lining (section 5.7.4)
- Frequency of water source dry up and number of users (section 5.7.5)
- O&M and their post construction support models (section 5.7.6)

Principal Argument

Reliance only on a communal water supply model limits the achievement of increased sustainable access to safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.

Concept 1
Water quality and sanitary condition

Concept 2
Accessibility

Concept 3
Technical and Environmental sustainability

Concept 4
Cost-effectiveness

Concept 5
Acceptability

Research Questions

What is the status of the technical sustainability of different water supply models? What is the status of water reliability from different water supply models? What are the factors likely to affect technical sustainability and water reliability? In what way are water supply models delivering operation and maintenance systems to the households/communities?

Indicator parameter 1

Technical sustainability

Variable 1: Technical sustainability of lifting device
Variable 2: Water supply down time

Indicator parameter 2

Environmental sustainability

Variable 1: Water source reliability
Variable 2: Water source dry up and bottom lining
Variable 3: Frequency of dry up and number of users

Indicator parameter 3

O&M model

Variable 1: O&M and their post construction support models

Fig. 5.18: Principal argument, indicator parameters

5.7.1 Technical sustainability of lifting device

A performance assessment of the water supply systems in the case study sites was undertaken to find information on their technical sustainability. The definition of 'technical sustainability' refers to the durability of lifting devices in this study. Technical sustainability is important for reliability because reliability can be threatened where a lifting device is non-functioning which makes water inaccessible even when it is there. Table 5.32 presents the data on lifting device break down. Rope and bucket were the most prevalent devices in the Self Supply model and are represented in the table under *Not Protected*, *Partially Protected* and *Protected* HDWs. Meanwhile, the handpump was the dominant lifting device at communal borehole models.

Table 5.32: Frequency of lifting device break down

Category Description	Not Protected		Partially Protected		Protected		Borehole	
Lifting device type	Rope and bucket		Rope and bucket		Rope and bucket		Handpump	
Lifting device break down	**Cases:N** (Milenge, Nchelenge)	**Frequency (%)**	**Cases:N** (Milenge, Nchelenge)	**Frequency (%)**	**Cases:N** (Milenge, Nchelenge)	**Frequency (%)**	**Cases:N** (Milenge, Nchelenge)	**Frequency (%)**
No break down	(3, 2)	(11, 5)	(4, 4)	(10, 6)	(13, 1)	(54, 3)	(5, 2)	(33, 9)
Within a month	(6, 12)	(22, 31)	(9, 17)	(21, 25)	(1, 10)	(4, 31)	(0, 2)	(0, 9)
2-3 months	(11, 16)	(41, 41)	(11, 27)	(26, 39)	(3, 10)	(13, 31)	(0, 2)	(0, 13)
4-6 months	(4, 7)	(15, 18)	(10, 13)	(24, 19)	(2, 6)	(8, 19)	(1, 7)	(7, 33)
7-12 months	(1, 1)	(4, 3)	(2, 4)	(5, 6)	(4, 4)	(17, 13)	(3, 4)	(20, 18)
More than a year	(0, 0)	(0, 0)	(2, 0)	(5, 0)	(1, 1)	(4, 3)	(4, 5)	(27, 18)

(Source: Author's field work)

It can be seen from Table 5.32 that frequency of 'rope and bucket' breakdown was higher at *Not Protected* and *Partially Protected* HDWs than at *Protected* HDWs. For instance, more than half of the 'rope and bucket' at *Protected* HDWs in Milenge had no experience of breakdown though only about 10% of both of *Not Protected* and *Partially Protected* HDW sites with rope and bucket had no breakdown. Further, the frequency of handpump breakdown at boreholes was different from Milenge to Nchelenge. For example, more than 50% of handpumps at Nchelenge had experiences of breakdown every six months on average compared with less than 10% in Milenge. The following sections further examine the association of each lifting device type between frequency of lifting device break down and water supply type, number of users and construction year.

i. Rope and bucket

The Pearson Chi-square statistic (χ^2) test was done to measure the relationships between frequency of device breakdown where they used rope and bucket, and the results are shown in Table 5.33. The null-hypothesis is that the frequency of break down would show no difference between the different types of HDWs. The frequency of breakdown was classified in four categories in order to enhance statistical validity.

Table 5.33: Cross-tabulation of HDW types by frequency of rope and bucket break down

		Frequency of break down				
Milenge		< 1 month	2-6 months	> 7 months	No break down	Row total
Not protected	Count	6	14	1	2	23
	% within Not protected	26%	60%	4%	9%	100%
Partially protected	Count	9	13	4	5	31
	% within Part' protected	29%	42%	12%	16%	100%
Protected (improved)	Count	1	5	3	11	20
	% within Protected	5%	25%	15%	55%	100%
χ^2	**Value**		**Df**		**Significance**	
	19.001		6		0.004**	
Nchelnege		< 1 month	2-6 months	> 7 months	No break down	Row total
Not protected	Count	8	16	2	2	28
	% within Not protected	29%	57%	8%	7%	100%
Partially protected	Count	6	20	4	0	30
	% within Part' protected	20%	67%	13%	0%	100%
Protected (improved)	Count	7	6	1	0	14
	% within Protected	50%	43%	7%	0%	100%
χ^2	**Value**		**Df**		**Significance**	
	7.722		6		0.259	

(Source: Author's field work)
*Note: **significant at <.001*

A cross tabulation of HDW types by frequency of lifting device break down showed that the null-hypothesis was rejected by the Pearson Chi-square at the significance level of 0.004 in Milenge as shown in Table 5.33. This indicated that there is likely to be a difference between different HDW types as to the frequency of break down. The table showed increased levels of protection of HDW also providing more durable lifting devices in Milenge. However, there was not found to be any statistical significance (0.259 which is greater than 0.05) in Nchelenge. This could be explained by the fact that the Milenge Self Supply model promoted the use of a durable metal bucket and rope rather than plastic containers which were predominant even in *Protected* HDWs in Nchelenge. In fact, all *Protected* HDW owners purchased the metal bucket as a lifting container in Milenge.

Meanwhile, the frequency of lifting device breakdown may have differed between places where a small number of HH use, and where a large number of users were involved. Therefore, their relationship was analysed and Table 5.34 shows the results of whether or not the frequency of breakdown correlated with the number of users.

Table 5.34: Correlation of frequency of breakdown with number of users

	Frequency of break down		
Milenge		Spearmans rho	Sig. (p)
Not protected			
	Number of users	0.211	0.322
Partially protected			
	Number of users	0.24	0.194
Improved			
	Number of users	-0.341	0.141
Borehole			
	Number of users	0.272	0.447
Nchelenge		Spearmans rho	Sig. (p)
Not protected			
	Number of users	-0.126	0.523
Partially protected			
	Number of users	0.069	0.715
Improved			
	Number of users	-0.367	0.197
Borehole			
	Number of users	-0.049	0.862

(*Source: Author*)

Note: (see Fig. 5.11 in Section 5.5.7 for the explanation of the Spearman's rank order correlation)

The test results show in Table 5.34 that there was no statistically significant relationship between the frequency of breakdown and the number of users. This indicated that the number of users was unlikely to be attributable to the frequency of lifting device break down.

ⅱ. Handpump

The frequency of handpump breakdown was from every month to more than once a year on average. The results of the statistical test showed that there was no significant statistical relationship between year of installation and frequency of breakdown. Table 5.35 outlines the results of cross-tabulation for the frequency of breakdown by installation. The table presented the installation year of the handpump chronologically even when the handpumps were not installed, but the statistical test was done excluding these columns (e.g. 1991-2003 in Milenge). The results implied that there was no association between frequency of handpump break down and year of installation (significance p greater than 0.05).

Table 5.35: Cross-tabulation of frequency of handpump breakdown by installation year

		Installation year					
Milenge Borehole		Before 1980	1991-2000	2001-2003	2004-2006	2007-2010	Row total
7-12 months	Count	1			1	2	4
	% within 7-12 months	25%			25%	50%	100%
> 12 months	Count				1		1
	% within > year				100%		100%
No break down	Count					5	5
	% within No break					100%	100%
χ^2	**Value**		**Df**			**Significance**	
	7.321		4			0.120	
Nchelenge Borehole		Before 1980	1991-2000	2001-2003	2004-2006	2007-2010	Row total
< 1 month	Count		2				2
	% within < 1 month		100%				100%
2-3 months	Count			2		2	4
	% within 2-3 months			50%		50%	100%
7-12 months	Count		4	1		5	10
	% within > 7 months		40%	10%		50%	100%
No break down	Count					3	3
	% within No break					100%	100%
χ^2	**Value**		**Df**			**Significance**	
	13.581		4			0.093	

(*Source: Author's field work*)

It was noted however, that break down of handpumps occurred frequently during a specific period, which was September and October. The findings that handpumps broke down frequently during the dry season combined with the finding that more than one-third of HDWs had experienced water drying up, suggested that they could have been overloaded by extra users moving from unreliable water sources during the dry season which resulted in the non-functioning of the handpumps. Further, the demands from communities were increasing in terms of replacement of the riser pipe from galvanized steel to PVC. Box 5.3 outlines an excerpt from the focus group discussion with the Area Pump Mender (APM) in Nchelenge.

Box 5.3: Excerpts from focus group discussion with APM at Kaseka village, Nchelenge Ward

As one of the member of APMs, my work is to repair the handpump facilities and supervise the caretaker to maintain the facility well. As you know, we are faced with problems of the Iron content around this area………. In addition, the government has been constructing borehole facilities with handpumps, and the India Mark Ⅱ is the most popular. But the problem is that the riser pipe is made of galvanized steel so becomes corroded or gives the water a rusty taste because of acidic groundwater……
Community members complain about such a taste and the brownish yellow colour of the water they obtain from handpump facilities……We suggested to the caretakers that they should replace the riser from galvanized steel with a PVC one, but it seems too challenging for them to collect the money from community members……….because community members were even unhappy to contribute monthly for O&M purpose.

The statement of Box 5.3 shows that the community was not happy about the facility constructed by the government and demanded that it be replaced it without contribution. These findings imply that community acceptability may have affected their water source selection (see detail in Section 5.9.5).

ⅲ. Windlass

There were 4 HDWs furnished with a windlass in Milenge and 6 HDWs with them in Nchelenge but no reliable information was available regarding frequency of break down. Three windlasses had been purchased within the Self Supply model in Milenge since Nov. 2009 and no break down had happened before the time of the visit in May 2010. The other windlass had been used at a *Partially Protected* water point Scheme village in Mulumbi Ward, and the duration of the windlass was about 3 years based on the information from household survey. 6 windlasses were operational in Nchelenge at the time of the visit and no breakdown had happened since construction in 1998. The ownerships of these windlasses were 3 individual HDW owners and the other 3 were community owned commodities. Notably, another 11 HDWs had used their windlasses for their subsidized communal HDWs in line with the government standard, but they were abandoned after a few years of operation. According to the surveys with caretakers of communal water points, after 1 to 2 years windlass had broken down and there was nobody to support repair or purchase of replacements which resulted in the use of rope and bucket to fetch the water from communal water points. Box 5.4 is the excerpts from the survey with the caretaker of a communal well.

<u>Box 5.4: Excerpts from survey with a caretaker communal HDW at Chabilikila village, Shabo Ward</u>

Our communal well was constructed in 1972 by Water Affair. It was equipped with a windlass and worked well for a few years…Once we had an experience of windlass break down, which we tried to fix but could not…..So I talked with the community to about gathering a little money from community members in order to ask someone to come and repair it. But most of the community members refused to contribute money although some of the households understood the need to cooperate together…..We just abandoned the windlass and now we are using a rope and bucket as an alternative lifting device because very little money was eventually collected.

<u>*ⅳ. Rope pump*</u>

Sustainability of a rope pump was also difficult to evaluate for durability. Three rope pumps were functional at the time of the visit whilst another 4 rope pumps were dysfunctional. All rope pumps were set out in mid- or late 2009. Since then 4 rope pumps had been abandoned for different reasons within a year. According to the survey with a caretaker of a communal HDW at Kaseka village in Nchelenge Ward, one of the beneficiaries had broken the rope pump intentionally because he was furious about an apparent increase in the amount of contribution for using the communal water point from ZMK1,000 (US$0.25) to ZMK3,000, which was later revealed to be just a rumour. This incident was a police case so that person had promised to repair it but so far no action had been taken since Nov. 2009. The other two rope pumps had already been removed from their HDWs because of their break down and the last one was for an unknown reason. Box 5.5 tells the story of one of the failed rope pump facilities.

<u>Box 5.5: Excerpts from survey with caretaker of HDW equipped with ropepump at Mumba village, Kambwali Ward</u>

We received a rope pump facility from somewhere in February 2009……..The facility was used by the patients of our clinic……After a few months, water was not coming from the rope pump and we had no idea how to repair it……..Nobody came to repair the facility and at that time we also applied for a handpump facility from the government…Our application was accepted by the government so we removed the rope pump facility from the well……..We do not know where the rope pump equipment is now.

This failure (Box 5.5) could be explained by the fact that this rope pump production was in a piloting stage under DAPP so a very limited number of people were trained to operate and maintain the facility.

5.7.2 Water supply down time

The previous section assessed the frequency of lifting device breakdown. These results showed that handpumps were generally more durable from a technical point of view than the simple rope and bucket as lifting devices. However, it must be borne in mind that down time is an important factor when considering reliability. Because reliability can be threatened where a lifting device is dysfunctional that makes water inaccessible even when there is water. For instance, a rope and bucket can be more reliable if a handpump is broken once a year but down time is over six months, while a rope and bucket is worn out every three months but can be replaced on the day after the break down.

In fact, it was found from the household survey that HDW owners could replace a rope and bucket on the same day or the next day when a breakdown happened, especially where the local shop kept suitable stock under the private sector involvement of the Self Supply model. On the other hand, according to the surveys with borehole caretakers, the downtime of handpump at borehole sites was from a few days to over six months depending on the availability of a pump mender, spare parts and amount of collected contribution. Box 5.6 shows one of the examples of a long downtime issue at a borehole site equipped with handpump.

Box 5.6: Excerpts from survey with caretaker of communal well at Mulumbi Rural Health Centre, Mulumbi Ward

We have a handpump facility just in front of our clinic. Clinic patients and neighbours have used the facility to draw water from here for over two years. But now the handpump is broken down and dysfunctional for over 4 months. We have not asked patients to pay for the use so there is no money from the community. But we are planning to apply for government support as a part of medical facility. And we have a trained pump mender in this village to repair the dysfunctional handpump. So we expected it could be repaired very quickly but not.........Because the pump mender does not have a repair kit so has no way to use his skill. We asked the Milenge District council to distribute repair kits but no response so far...

Box 5.6 implies the importance of successive functionality of lifting device. No matter how the water supply facility supplied water for over 2 years, people would suffer from not having water because of such a long period of inaccessibility. The operating life of a rope and bucket is much longer than a handpump because of their simplicity and affordability. The following section is going to look at a different dimension of reliability, which is environmental sustainability.

5.7.3 Water source reliability

Following the assessment of technical sustainability, environmental sustainability was investigated in relation to water source. Environmental sustainability refers in this study to water source reliability. To access safe water every day of the year is one of the criteria for water supply coverage (NRWSSP 2007). Adaptability with respect to the fluctuation of groundwater is an important factor as well as sustainable O&M technology. Therefore, reliability can be broken down into two components; one is depletion of water source, and the other is a non-functional water lifting device as mentioned in Section5.7.1. It does not matter that Luapula Province has the highest availability of groundwater at a shallow depth (Zulu Burrow 2008), when water fluctuation may lead to the drying up of the water source with an inadequate depth of well during the dry season and/or the well may collapse from the bottom with inadequate protection. Table 5.36 presents the frequency of water source dry up.

Table 5.36: Frequency of water source dry up

Category Description	Not Protected		Partially Protected		Protected		Borehole	
Water source reliability	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**	**Cases:N (Milenge, Nchelenge)**	**Frequency (%)**
No dry up in last 5 years	(5, 12)	(19, 31)	(5, 31)	(12, 47)	(6, 18)	(25, 55)	(7, 8)	(58, 44)
No dry up this year	(7, 14)	(26, 36)	(11, 37)	(26, 56)	(16, 22)	(67, 67)	(4, 18)	(33, 100)
Dry up once in last 5 years	(0, 2)	(0, 5)	(2, 5)	(5, 8)	(0, 2)	(0, 6)	(1, 0)	(8, 0)
Dry up seasonally	(19, 2)	(70, 5)	(31, 3)	(74, 5)	(8, 2)	(33, 6)	(0, 0)	(0, 0)
Dry up daily	(1, 21)	(4, 54)	(0, 22)	(0, 33)	(0, 7)	(0, 21)	(0, 0)	(0, 0)

(Source: Author's field work)

It was found from household/caretaker surveys that only one borehole site (out of 37 sampled boreholes) had the experience of inaccessibility to water during the dry season because of an inadequate depth of borehole and not because of a non-functional handpump. But on the other hand, the frequency of dry up was a challenging issue for HDWs. The depth of sampled HDWs was relatively shallow (10-20m from surface) compared with over 20m at borehole, thus groundwater may have gone down during dry season.

5.7.4 Water source dry up and bottom lining

The previous section presented the water source dry up with respect to different water supply types in a descriptive manner. This section will examine the association of water source reliability in connection with one protection feature of HDWs, that of bottom lining. As noted in Section 5.2.2, lining can be one of two types; one is the stabilization of the top part and the other is for below the water table. Bottom lining is important to prevent collapse from soil erosion at the bottom part of the well wall when the groundwater level is up. Table 5.37 shows the statistical test results of whether frequency of water source dry up is different between bottom lined HDWs and non-bottom lined HDWs in Nchelenge (see Section 5.2.2).

Table 5.37: Frequency of water source dry up

Nchelenge		No dry up in last 5 years	Dry up once in last 5 years	Dry up twice in last 5 years	Dry up seasonary	Row total
Bottom lining HDW	Count	29	2	0	12	43
	% within bottom lining HDW	67%	5%	0%	28%	100%
No bottom lining HDW	Count	34	6	5	38	83
	% within no bottom lining HDW	41%	7%	6%	46%	100%
χ^2	**Value**	**Df**		**Significance**		
	9.140	3		0.027*		

(Source: Author's field work)
*Note: *significant at <.05*

Since well head protection itself is not relevant to the reliability of a water source, bottom lining was taken into account in relation to the frequency of dry up. In Nchelenge, there were 43 bottom lined HDWs (partially or fully) with 4 *Not Protected* HDWs (10% of *Not Protected* HDWs) followed by 20 *Partially Protected* HDWs (29% of *Partially Protected* HDWs) and 19 *Protected* HDWs (56% of *Protected* HDWs). Where they had no bottom lining, nearly half (46%) of these HDWs had dried up during the dry season every year compared with less than a third of the bottom lined HDWs (28%). The study found that frequency of water source dry up was related to the bottom lining ($p<.05$, statistically significant)

These findings suggest that bottom lined HDWs provided a sufficient water source every day of the year in contrast to those HDWs without linings. Where there is no lining at the bottom part of the wells, they may collapse from soil erosion in the bottom part of the well wall when the groundwater level is up. It was notable that the improvement work in bottom lining in Nchelenge was done not only for the subsidised communal well, but also for individual HDWs without any subsidy prior to the Self Supply project being launched. This was also linked to the lesson learned from the Self Supply model in Milenge that they could not cast the rings for bottom lining in addition to re-deepening despite the fact that they initially planned to do it prior to having completed the well-head protection (They could have done a lining at least for the top metre of the shaft to improve water quality by reducing the seepage back of dirty water from the surface into the well, and for reducing the risk of the shaft collapse by using skilled artisans in Milenge).

5.7.5 Frequency of water source dry up and number of users

The frequency of water source dry up may link not only with the protection of the well shaft from collapse, but also with the number of the users of the water source. Table 5.38 presents the results of the Spearman's correlation test between frequency of dry up and number of users. There was a significant relationship between the number of *Partially Protected* HDW users and frequency of dry up with a Pearson Chi-square of 0.025 in Nchelenge. Interestingly, 4 sampled HDWs were found from household surveys to have restricted the number of users to prevent water source dry up and all of those 4 HDWs were *Partially Protected* HDWs.

Table 5.38: Pearson Chi-square of frequency of dry up by number of users

Frequency of dry up		
Milenge	Spearmans rho	Sig. (p)
Not protected		
Number of users	3.659	0.723
Partially protected		
Number of users	1.949	0.924
Improved		
Number of users	2.567	0.463
Nchelenge	Spearmans rho	Sig. (p)
Not protected		
Number of users	14.053	0.120
Partially protected		
Number of users	19.078	0.025*
Improved		
Number of users	7.051	0.316

(*Source: Author*)

*Note *significant at <.05*

Box 5.7 shows the excerpt from the survey with a *Partially Protected* HDW owner.

Box 5.7: Excerpts from survey with *Partially Protected* HDW owner at Eliabu village, Kashikishi Ward

We had constructed my water point in 2004, and in the past about 30 neighbours' HH shared my well without any contributions…… In 2006, we had only a small rainfall compared with previously. Then my water source also sometimes dried up during the dry season. That is because my family decided to restrict the number of shared neighbours and now we allow no more than 10HH to draw water from my well. As a result, we could access water the whole the year without concerning ourselves about a dried up water source……………..What is more, one more good things from reducing the shared households was that we can control their hygiene practice easily because it is easy to teach a small number.

5.7.6 O&M and their post construction support models

As outlined in literature review Chapter 3, one of the most prevalent water supply models is community based management where operation and minor maintenance (O&M) are the responsibility of WASH committees. Meanwhile, a lack of long-term sustainability is due to an emphasis on construction with inadequate post-construction support. Thus, in the post construction period, they started looking at what needs to be done to support and maintain water models addressing not only technical tasks, but also administrative, legal, training and other 'software' needs (Lockwood *et al.* 2010).

In one of the core components of the software programme in the study sites in Zambia, JICA has trained Area Pump Menders (APMs) to have the skills to instruct on the operation and maintenance of non-functional handpumps. Their approach is to enable APMs to become one of the options for the maintenance of a water supply model as a mechanism to support community-led maintenance systems in remote areas where handpump distributors and construction companies are reluctant to go into the market. In fact, currently there were 12 APMs who were already trained under JICA Luapula Province groundwater development project in Nchelenge District (4 APMs in Milenge) and a further 12 members were newly trained under the Nchelenge District Council. Box 5.8 outlines an excerpt from a survey with a caretaker of a communal well.

Box 5.8: Excerpts from survey with caretaker of communal well at Kafwalo village, Matishi Ward

Our well was constructed by JICA in 2007 under their pilot project. We found a dysfunction of the handpump and could not pump water properly. At that we asked the council to repair our handpump but it took a long time…I do not remember exactly but it was over 6 months….So we were forced to go back to fetch water from spring or lake…which as you know are contaminated………We had another experience of break down but after asking the council to repair it, skilled people came and repaired it within a very short period - within a week. It was very helpful and we realized that they were called APMs for repairing handpump facilities.

Interestingly, those 12 APMs in Nchelenge were also trained and involved in the piloting project of the Self Supply model by DAPP to mobilize the community and improve/construct HDWs in Nchelenge. This was a different modality from Milenge where JICA (conventional communal approach) trained APMs and WaterAid built up the capacity of local artisans under Self Supply.

In conjunction with APM development in Zambia, as a new initiative, the Sustainable Operation and Maintenance Approach (SOMAP) for rural water supply has been tested in some Districts and has now started expanding into areas including Luapula Province. To ensure the sustainability in O&M of rural water supply and sanitation, the following principles should be applied (NRWSSP 2007);

1. Cost sharing by communities
2. Sustainable supply chains
3. O&M mechanisms
4. Choice of appropriate technology
5. Capacity building

The first principle, 'Cost sharing by communities', is going to be discussed in the later section on lifecycle costs. 'Sustainable supply chains' applies to spare parts for rural water supply facilities. These SOMAP guidelines are supported and funded by JICA, and therefore they are trying to set up spare parts for handpumps alongside their rural water supply projects to be available at outlets at all times with an emphasis on affordable 'sustainable supply chains'. 'O&M mechanism' is intended to be taken care of at the lowest appropriate level. Further, they are trying to develop or reactivate V-WASHE committees to encourage and promote their ownership (see Section 2.2.2).

'Choice of appropriate technology' is to satisfy hydro-geological conditions and to consider affordability in terms of capital and recurrent costs. The SOMAP especially encourages standardizing the handpumps and narrowing down the type of handpump to maximum of 2 types from the viewpoint of maintenance. The India Mark Ⅱ type handpump is most prevalent in Zambia, but there is a growing case for adopting the Afridev from the viewpoint of the durability of the riser pipes to low pH (acidity) and for ease of maintenance (JICA 2007). An iron removal plant, using the sand filtration method, was added to a borehole with handpump facility where the Iron content of the water exceeded the standards. The installation of an Iron removal plant was done as a free giveaway by JICA but caretakers/community members were given the responsibility for the operation and maintenance of the equipment. In particular, community members have to clean the inside of the equipment by removing and washing the sand when it becomes stained by the Iron colour which may be problematic in terms of sanitary aspects. Although they received training as to how to clean the plants, current sanitary conditions have the space to allow contamination by the intrusion of unhealthy material. Box 5.9 shows an example of the comments from a focus group discussion with a villager.

Box 5.9: Excerpts from focus group discussion with village dweller at Springa village, Itemba Ward

I know that our village has a borehole facility, and it was constructed last year in 2009…... But I have rarely used that facility because the taste and colour is very bad for drinking water even though access to the facility is about 100m……So I usually go to a different water source which is bit distant from my house but the taste is really good (*Partially Protected* HDW)……I use the borehole only when I am busy at work and cannot go to fetch water from the distance place….. I also know that recently the borehole facility installed something with a handpump to clean water….But still I am still reluctant to use it because it is not well maintained and sometimes cockroachs are present.

It is necessary to monitor their O&M activity because the installation of the Iron removal plant is relatively new (since 2010). 'Capacity building' is the part of APMs training providing supportive policies and a regulatory framework.

On the other hand, the Self Supply model has the following components as the base for enabling a sustainable environment (Sutton 2009a);

1) Technology/technical advice

2) Financial mechanisms/markets
3) Enabling policy and
4) Private sector capacity

'Technology/technical advice' is important for O&M in the Self Supply model in that ownerships of water points is crucially weighted towards private (individual) households so that they select technology for their water point from their preferences and affordability. Production of the rope pump in Nchelenge was one of the examples of providing a variety of options for rural dwellers. 'Financial mechanisms/markets' were also encouraged to provide and accelerate the Self Supply model especially in the period before harvest, when the cash flow is likely to be sluggish. A revolving loan fund was established in the piloting Self Supply model in Milenge, and the fund is available for not only the individual households who intend to improve/construct water points, but also to traders who stock materials and spare parts for the Self Supply model. The detail of financial mechanisms is discussed in the later section on lifecycle costs. 'Enabling policy' is also important for the Self Supply model in order to strengthen government recognition and support towards the Self Supply model in terms of the above components without threatening competition with the prevailing conventional communal water supply model. In fact, this Self Supply model is at the pilot stage and is not yet included in Zambian government policy. These pilot projects would be the evidence as to whether Self Supply has a role to play in the NRWSSP.

'Private sector capacity' is crucial as a building block for sustainable O&M as well as the Self Supply model itself. One of the core parts of 'Private sector capacity' is the encouragement to set up local shop outlets and to engage traders and suppliers in creating a sustainable environment in term of supply chains. This has created an environment in which materials and/or spare parts for water point construction/protection can be accessed where there are challenges and difficulties such as even finding cement locally. As an example of this, Box 5.10 shows an excerpt from a focus group discussion with village dwellers.

Box 5.10: Excerpts from focus group discussion with village dwellers at Chamalawa village, Itemba Ward

Before this Self Supply project came, we had to go to town in Mansa (70km away from Milenge) when the rope was cut off or the container broken……..Our village market is very very small and there is no way to find good material or to buy them….. it was tough to go Mansa by bicycle, as you know, it is very far…. But nowadays we can find such material at the local shop or we can ask for such material from skilled artisans….This is very nice for us.

This example illustrates the importance of setting up an environment which enables rural dwellers to access materials especially in sparsely populated rural areas. Further, the availability of skilled labour was an integral part of the Self Supply model, together with the materials supply chain and financing. The trained artisans in this Milenge case provided the much required trained labour to facilitate improvements of water points. The artisans reported having attended at least two major trainings sessions under the Self Supply model in both theoretical and practical aspects of water source protection and upgrading techniques.

One of the lessons learned from piloting the Self Supply model in Milenge was the significance of a systematic strategy. Loan repayment by households or communities who borrowed money for water point construction/protection from the revolving loan fund had gloomy prospects since any dissatisfaction toward workmanship resulted in them being reluctant to repay the loan. Box 5.11 shows the excerpt from the survey with two *Protected* HDW owners.

This was because the delay of access to the loan system in this pilot Self Supply project delayed the onset of improvement work in the rainy season so that incomplete work led to unsatisfactory levels in the next dry season with the result that water sources dried up. In particular, they had constructed/*Protected* well-head parts but put off casting rings in the well bottom until they could re-deepen them during the dry season. In other words, this experience suggested that any future Self Supply model would need systematic loan disbursement to alleviate this barrier.

Box 5.11: Excerpts from surveys with *Protected* HDW owners at Eliabu village, Kashikishi Ward
I am the owner of this well and the well was improved by trained artisans under the Self Supply project. The reason for improvement is that water is life so that anytime we can draw water even in the night or when my family member urgently gets sick...................However, the quality of improvement work is very poor because there are already cracks on the concrete top slab, and it is too expensive to pay for the amount of total improvement costs. We have never discussed the detail costs with the artisans before the work. ********************************** My well was constructed in early 2010 by skilled artisans..........It is already dried up now (Aug.) so we cannot draw water from my well. In spite of this the loan committee come to ask paying back of the loan? How come I have to pay for the work when water source is not reliable within a year?

In summary, this Section 5.7 has looked into reliability from the viewpoints of both technical sustainability and environmental sustainability. Technical sustainability was presented and analysed in association with water supply types, number of users and construction years. In addition, environmental sustainability was investigated especially for water source dry up in connection with bottom lining of HDWs. Further, the operation and maintenance systems were assessed to see how different water supply models could contribute to building a sustainable environment in the context of a sparsely populated rural setting. The next section is going to investigate cost-effectiveness with respect to lifecycle cost.

5.8 Cost-Effectiveness

Where there are limited financial resources in households or governments, analysis of cost effectiveness is crucial to support water supply models and needs to look at several options for efficiently improving their water supply sources or for achieving defined goals at the lowest possible cost. The literature review Chapter 3 underscored the importance of evaluating the impacts of a product or process from 'cradle' to 'grave'. Thereby lifecycle cost analysis has been applied in this study to consider all construction costs and maintenance of systems in the short and long term, taking into account the need for hardware and software, operation and maintenance, capital maintenance, the cost of capital, source protection, and the need for direct and indirect support, including training, planning and institutional pro-poor support (Fonseca *et al.* 2010). This section will examine the most appropriate rural water supply model by comparative assessment of the communal and Self Supply models. Fig. 5.19 shows the research outlines associated with the principal argument, concepts, research questions and indicators. The concept of cost-effectiveness is associated with the specific secondary questions;

What costs constitute lifecycle cost for the different water supply models? How do lifecycle costs impact on project costs and household/community costs? When are the costs incurred?

The next sections discuss with analysis the key indicator parameters for cost effectiveness which are defined below:

- Total capital costs (section 5.8.1)
- Lifecycle project costs (section 5.8.2)
- Lifecycle household/community costs (section 5.8.3)
- Chronological lifecycle costs (section 5.8.4)

Although the costs can only be compared and properly assessed when they are related to particular levels of model (Fonseca *et al.* 2010), this cost analysis looks into how much and what are the cost components for fulfilling the minimum requirement for achieving sustainable access to safe water.

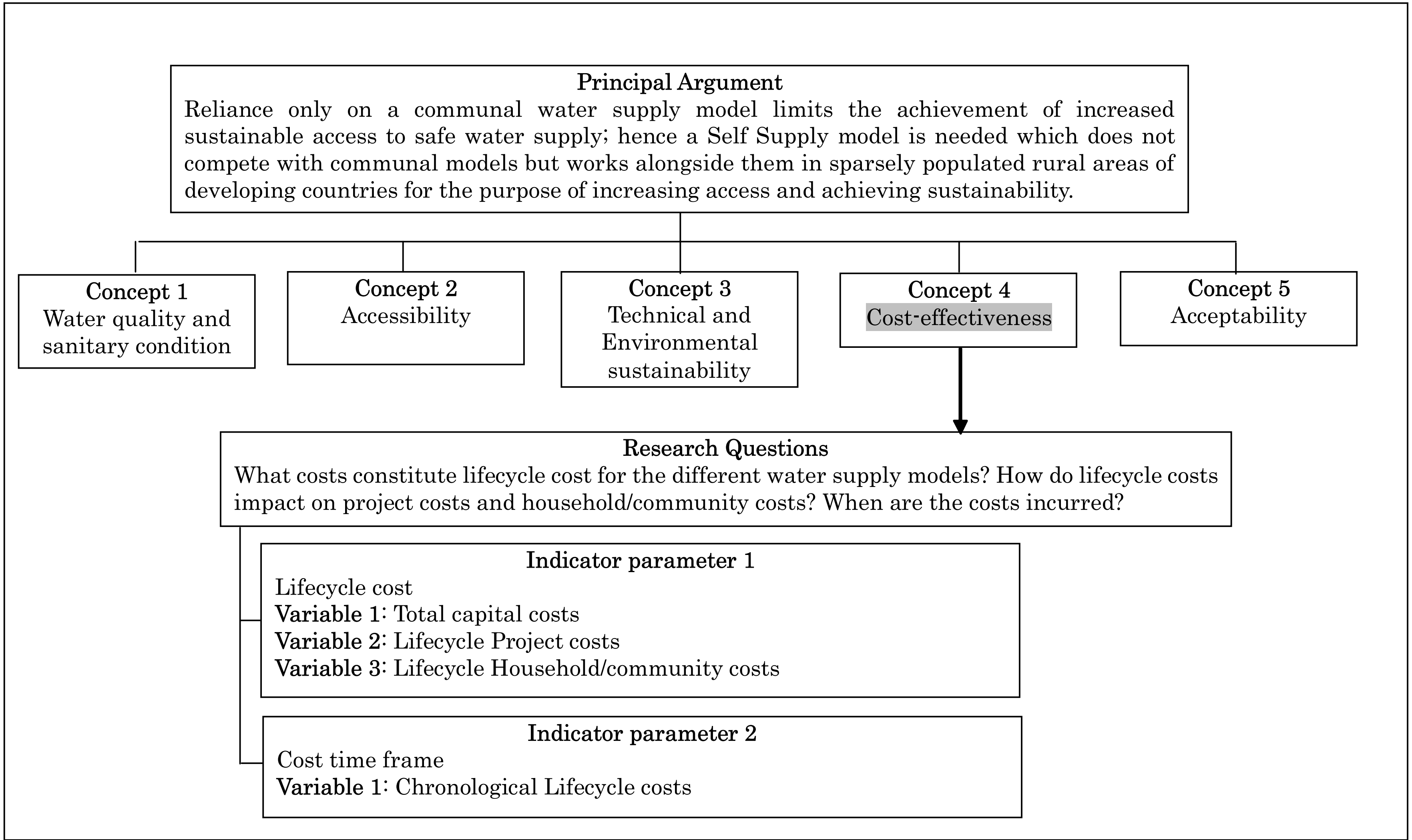


Fig. 5.19: Principal argument, indicator parameters

5.8.1 Total capital costs

Financial data associated with water supply projects was collected from both a communal water supply project and a pilot Self Supply project in order to analyse the lifecycle costs. The former water supply model was the project done by JICA while the latter one was done by WaterAid in Milenge. The analytical work takes three steps to determine the lifecycle costs from different spectra; i.e. *what*, *who*, and *when*. Table 5.39 presents a summary of overall capital cost in each project. The table includes all project capital costs, but recurrent and replacement costs are not reflected. The information was obtained from a combination of published information (JICA 2007), WaterAid and household/caretaker interviews. Cost analysis will be based on lifecycle costs which are presented in the following sections (5.8.2 and 5.8.3) that cover the whole process from 'cradle' to 'grave' rather than hardware cost exclusively.

In this cost analysis, a borehole with handpump represented the subsidised communal water supply model although a subsidised communal HDW with full lining also comes into the category of communal water supply model. The costs of a communal model may vary considerably, even for the same technology, and depend on the local environment. Further, the costs of Self Supply are also different from one approach to another, and depend on the rural setting. Therefore, this study mainly looks at how the hard and soft components are made up within the communal and Self Supply models, and to what extent the costs are incurred by the government or household, rather than simply by examining the effectiveness of the costs. The number of communal water supply boreholes constructed and equipped with handpumps was 200 whereas that of the Self Supply model was 40 HDWs which had been improved by trained artisans at the time of the visit.

It is apparent from Table 5.39 that the breakdown of total capital costs with respect to the conventional communal model is accounted for largely by hardware, while software aspects constitute a large portion of the costs of the Self Supply model. Technology for HDW is generally simple and it is easy to operate and maintain the facility. According to the obtained data from household surveys, the average replacement cost of rope and bucket was about US$4 to US$8 and repair cost for a handpump was about US$150. O&M cost will be combined with lifespan and applied to the lifecycle cost in the following sections.

Table 5.39: Total capital costs of communal (borehole) and Self Supply models

Conventional communal model (200 boreholes)		Self Supply model (40 HDWs)	
Activities	Cost (US$)	Activities	Cost (US$)
Borehole construction (200)	4,386,324	Project selection	1,682
Pumping test		Water situation analysis	1,272
Water quality analysis		Promote low cost technical options	80
handpump installation		Awareness to local suppliers	645
Apron construction		Water point improvemnet demo	3,210
Installation of Iron Removal Plant		Develop loan scheme	875
Tools for Area Pump Mender (APM)		Training of loan committee	2,407
Detail design, construction supervision	1,366,666	Social marketing	1,375
Software component programme activities	451,282	Water treatment & handling	1,437
Personnel expense during siting work in the detailed design study	3,810	Water quality monitoring	1,762
Personnel expenses during supervision work	6,189	Artisans training in water point improvement	2,982
Personnel expenses during inspection for handover of facilities	10,400	Short course for Artisans	5,480
Personnel expenses for the software component under the responsibility of Zambia side	70,900	Team building training-Artisans	2,165
Advising Commission for Authorization to Pay (A/P)	84	Skills devemlopment for VAGs/WASHEs/ADCs	3,300
Payment commission to bank	3,086	Monitoring activity	3,946
Monitoring activity for O&M	55,605	Project coordination	1,891
		TWS improvement	2,027
		Water quality testing	2,815
		Hygiene promotion	5,668
		Learning-exchange visit	19,232
		Capacity building	18,196
		Monitoring, coordination & reporting	13,707
		Revolving Loan Fund	15,000
		Project management team	87,078
		Capital items	16,875
		Administration cost	4,650
		Local travel	5,940
		Orientation	1,227
Total	**6,354,351**	**Total**	**226,931**
Average cost per water point	31772	Average cost per water point	5673
Average cost per borehole per head	127	Average cost per HDW per head	38

Source: JICA (2007) *and WaterAid*

As noted in Table 5.39, WaterAid is using the financial strategy of a revolving loan fund in the piloting Self Supply project in Milenge in the period before harvest, when cash is very hard to come by. The nature of this loan system is revolving so that the recovered loan would circulate to the next person who applied for a loan to improve their water points or even construct new wells. ZMK15million (≒US$3,750) has been distributed to each of the 4 Wards so that a total US$15,000 has been managed by the trained loan committee since November 2009. Committee members are made up from Artisans and CBOs (Community based organizations [ADC, NHC and V-WASHE]). They have received training from experts under the Self Supply project and attended workshops for fund management. Loan repayments were made over either 6 months or 12 months depending on the amount borrowed. ZMK1-500,000 (about US$110) was to be repaid in 6 months and amounts over this value in 12 months. Either cash or in-kind was acceptable as a loan repayment method. For those that defaulted on their payments, the signed contracts provided fall back steps. These steps included going to court, or confiscation of items pledged. The following sections will discuss how the lifecycle costs are calculated.

5.8.2 Lifecycle project costs

This section looks into the project costs in the context of lifecycle cost. Lifecycle Project costs refer to the cost which the Government or NGOs/external support agencies have incurred, while Household/community costs are defined in this study as literally the costs which the end users pay or contribute in order to use the water supplies on an ongoing basis. This section and the following Section 5.8.3, thereby calculate the lifecycle costs based on the total capital costs in Table 5.39 (see Section 5.8.1) and data obtained from the household survey and WaterAid for O&M, replacement and rehabilitation costs.

Project selection and water situation analysis for needs assessment and community mobilization are generally funded by the government institution or donor organization prior to water supply model delivery. Both a conventional communal water supply model and Self (household) Supply model require this phase. The cost of implementing this phase for a communal borehole with a handpump model is significantly different from that in the Self Supply model. The communal model consists mainly of technical hardware models for facility provision mostly subsidized by the government, NGOs or donor organizations. The Self (household) Supply model is much focused on building blocks of an enabling sustainable environment through software subsidy. The components of the enabling environment are; 1) Creating awareness, 2) Technology/Technical Advice, 3) Financial mechanisms markets, 4) Private sector capacity and 5) Enabling policy. The cost of implementing a water supply project comprises the need for hardware and software, the cost of capital, source protection and the training of stakeholders. The cost of technical and institutional support for O&M is essential for the post construction phase of the water supply as well as the monitoring, coordination and regulation for long term sustainable water supply. The components of lifecycle costs are explained in Table 5.40.

Table 5.40: Lifecycle cost components for water supply model

Lifecycle cost components	Resources, Infrastructure and demand/access
Capital expenditure-hardware	Capital investment in fixed assets
Capital expenditure- software	One-off work with stakeholders prior to or during construction or implementation
Operating and minor maintenance expenditure	Expenditure on labour, fuel, chemicals, materials, regular purchases of any bulk water
Capital maintenance expenditure	Expenditure on assets renewal, replacement and rehabilitation costs
Cost of capital	Costs of raising for capital investment
Expenditure on Direct Support	Post-construction support activities direct to local level stakeholders, users or user group
Expenditure on Indirect Support	Macro-level support, planning and policy making

Source: Fonseca et al. (2010)

Although Fonseca *et al.* (2010) breaks down their WASHCost lifecycle costs into the seven components, this study has included the components of "expenditure on direct support" and "expenditure on indirect support" into the other five components because obtained data could not be separated into one category or another. The information used in the analysis was collected from a combination of published information (JICA 2007), site visits and data from WaterAid Zambia.

The results of the analysis show the unit cost based on the number of water supply facilities (communal boreholes: N=200 and HDWs done by trained artisans under Self Supply: N=40 at the time of the visit) from overall costs in Table 5.39. In addition, the unit costs were calculated per head based on both the Zambian government standard served number and actual served number obtained from household surveys. Table 5.41 shows the figures used for the calculation.

The lifespan of the technology itself should be included in lifecycle costing but it was not possible to collect reliable data from a borehole facility in this field work because more than 90% of them were constructed within the past 10 years in Milenge and had not yet been newly replaced. Therefore, it was calculated by using '20' years as the expected life span of a borehole with a handpump facility in this study.

Table 5.41: Figures used in the lifecycle cost analysis

Water service model	Communal supply	Self Supply
Number of water points	200	40
Estimated number of years before rehabilitation (years)	20	20
Estimated number of years before handpump replacement (years)	5	n/a
Standard served number (persons)	250	150
Actual served number (persons)	190	110

(*Source: Author's field work*)
Note: n/a (not applicable)

The life span of HDW and O&M periods of both borehole and HDW were calculated from obtained data in management records of APMs and from household surveys. By using these figures, the lifecycle costs were then expressed as the unit cost per capita per year of safe water provision. Table 5.42 shows the results of lifecycle project costs of both models.

The lifecycle cost for Self Supply depended on their choice of improvement level or choice of technology. Therefore, an existing HDW improved by trained artisans, which was the most common in Milenge, was taken as an example. It consisted of a 2m-redeepened, top lining, concrete apron, drainage, top slab with lockable lid and rope and metal container (* see Capital cost-hardware and software on Self Supply in the table). As for 'Cost of capital', at the time of survey, about 40 hand dug wells had been improved through the Self Supply model and about 10 people were on the waiting list for improvement or new construction using the revolving loan in each Ward. Subsequently the calculation of revolving loan in lifecycle cost was divided by 80 (40 already improved + 40 newly improved). This was within the coverage of the total amount of loan if these 80 improved wells simply cost the same amount each i.e. US$172×80= US$13,670< US$15,000. However, the revolving loan fund is supposed to be paid back to the implementer (government or external support agency). Also, the result of the lifecycle project cost of the communal water supply model was multiplied by 95% taking account of community contributions (see detail in next Section 5.8.3)

Further, the current rehabilitation and replacement costs in the Capital maintenance cost of the communal water supply model were calculated by taking account of the expected lifespan of the water supply facilities in years and the interest rate. One method of incorporating the current replacement cost and future asset replacement costs is amortization whereby equal amounts are set aside every year, taking into account interest rates (Harvey 2007). The detail of calculation is explained in the *Note* following Table 5.42. The rehabilitation cost was not included in addition to the capital hardware costs in order to avoid double counting in the annual lifecycle costs. Operating and minor maintenance costs of both water supply models are explained in the following section 5.8.3.

Table 5.42: Summary of lifecycle project costs (to government or external support agency) on annual basis

Lifecycle cost components	Communal water supply model	Assumed life span (year)	Unit cost (US$/person/year) [standard served number]	Unit cost (US$/person/year) [actual served number]	Piloting Self (household) Supply model	Assumed life span (year)	Unit cost (US$/person/year) [standard served number]	Unit cost (US$/person/year) [actual served number]
Capital cost-hardware and software	Borehole construction	20	6.61	8.70	Project selection	20	0.02	0.03
	Pumping test				Water situation analysis		0.02	0.02
	Water quality analysis				Promote low cost technical options		0.00	0.00
	Apron construction				Awareness to local suppliers		0.01	0.01
	Installation of Iron Removal Plant				Water point improvement demonstration		0.07	0.10
	Tools for Area Pump Mender (APM)				Training of loan committee		0.04	0.06
	Detailed design, construction supervision		2.08	2.74	Social marketing		0.02	0.03
	Personnel expense during siting work in the detailed design study		0.01	0.01	Water treatment & handling		0.02	0.03
	Personnel expenses during supervision work		0.01	0.01	Artisans training		0.14	0.19
	Personnel expenses for the software component under the responsibility of Zambia side		0.11	0.14	Water quality testing		0.06	0.08
	Payment commission to bank		0.00	0.01	Hygiene promotion		0.08	0.10
	Software component programme activities		0.69	0.91	Project management team		1.16	1.59
	Personnel expenses during inspection for handover of facilities		0.02	0.02	Capital items/Admin. Cost/local travel		0.37	0.50
	Monitoring activity for O&M		0.08	0.11	Skills development for VAGs/WASHEs/ADCs/LA		0.30	0.41
	Handpump installation	5	0.22	0.29	Monitoring, coordination & reporting		0.26	0.36
Subtotal (Capital cost-hardware and software)*			**9.83**	**12.94**	**		**2.58**	**3.52**
Capital maintenance cost	Current rehabilitation cost (Total original cost of water system)	20	Annual rehabilitation cost is covered in the Capital cost above		Annual rehabilitation cost is covered in the Captal cost (refer Lifecycle household/community costs)			
	Current replacement cost	5	Annual replacement cost is covered in the Capital cost above					
Subtotal (Capital maintenance cost)			**n/a**	**n/a**			**n/a**	**n/a**
Cost of capital	N/A				Revolving Loan Fund***		0.10	0.14
Subtotal (Cost of capital)			**0.00**	**0.00**			**0.10**	**0.14**
Grand Total			9.83	12.94			2.68	3.66

n/a (not applicable)

Source: Author's field work, JICA (2007) and WaterAid

Note:

** estimating capital cost of communal water supply model: C= US$4,335,525 assumed interest rate:r=5%, estimated years of number of years before rehabilitation: n=20years, annuity factor: $AF_{r,n}$=12.4622 (Harvey and Reed 2006), Capital cost: A_c=C/A $F_{r,n}$=347,894*

Also, unit replacement cost of handpump: R=US$254, assumed interest rate: r=5%, function of the expected lifespan of the handpump: n=5 years, annuity factor A $F_{r,n}$=4.3295, Replacement cost: A= R/A $F_{r,n}$=58.67

Thereby, total Capital unit cost is 347,894/200+58.67=1798.14

*This can then be divided by 250 to convert to a unit cost per capita per year of US$7.19. Finally, this can be multiplied by 95% taking account community contributions. 7.19*0.05= US$6.83*

*** estimating capital cost of Self Supply model: C= US$193,200 assumed interest rate:r=5%, estimated years of number of years before rehabilitation: n=20years, annuity factor: $AF_{r,n}$=12.4622, Capital cost: A_c=C/A $F_{r,n}$=15,502.88*

Thereby, Capital unit cost is 15,502.88/40 = 387.572

This can then be divided by 150 to convert to a unit cost per capita per year of US$2.58

**** total amount of loan is US$15,000, and the amount is divided 80 (already improved well (40)+number of waiting list for well improvement (40)). Same annuity factor of 12.4622 (see **) was applied to the figure of revolving loan fund*

It was apparent from Table 5.42 that the communal supply model was costing hardware components more predominantly than 'software component programme activities' in contrast with the Self Supply model where costs are made up exclusively from software components unless the revolving loan funds are recovered. This could be explained by the fact that the nature of the Self Supply model was to encourage households/communities in building blocks towards an enabling environment through software components. On the other hand, the software component programme in the communal model was subsidiary to the provision of capital subsidized hardware, which was a borehole with handpump.

It was also found that the software component costs of the Self Supply model were about three times higher than for the conventional model. Despite that fact, the results of the total lifecycle project costs of the communal model including hard/software were about three times greater than those for the Self Supply model. This indicates that the hardware component costs of the communal model using a borehole equipped with a handpump exceeded the costs of software activities of the Self Supply model. These findings suggest that the Self Supply model is more cost-effective than the communal model looked at from the viewpoint of lifecycle project costs because considerable hardware subsidies towards the communal model are incurred by government or NGO/external support agencies.

5.8.3 Lifecycle household/community costs

The previous section discussed lifecycle project costs which were met by the government and the NGO/external support agency side. Overall lifecycle costs did not only cover project costs, but also accounted for the household/community expenditure. Community contribution is undoubtedly necessary for sustainable access to water supply unless the government meets all the lifecycle costs from cradle to grave. This section thereby looks at the lifecycle costs from the viewpoint of household/community costs. Fig. 5.20 shows the flow model of the communal water supply model.

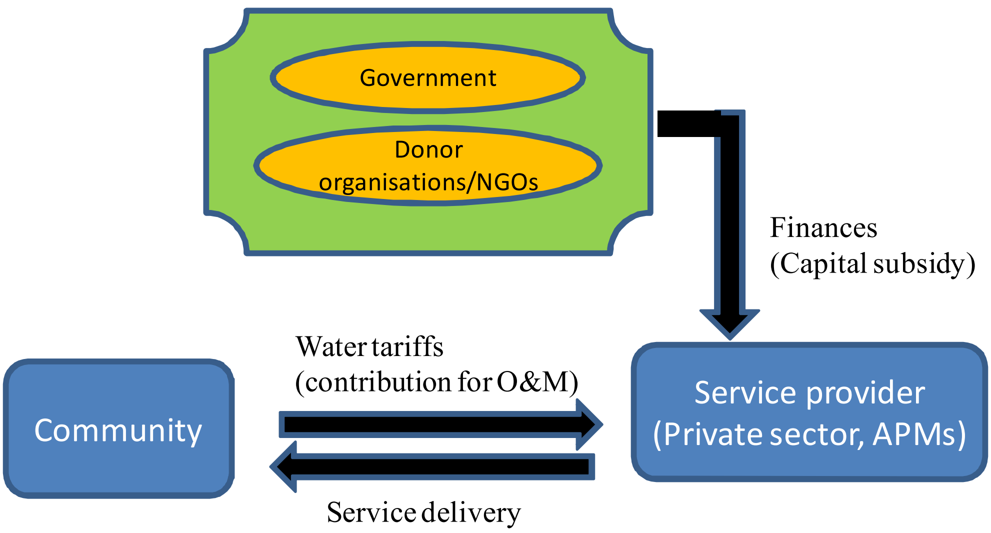


Fig. 5.20: Communal water supply model
(*Source: Author*)

To date almost the entire communal water supply model has been a capital subsidised approach so that the community side was not paying for the capital cost. In Zambia, as a new initiative, the Sustainable Operation and Maintenance Approach (SOMAP) for

Rural Water Supply has been tested in some Districts and has now started to expand into the area including Luapula Province. One of the principles was that of cost sharing by communities: Communities were expected to contribute 5% capital costs and 5% of rehabilitation and replacement costs and 100% cost for O&M. In this sense, capital, rehabilitation and replacement costs were predominantly subsidised by government or donor organisations, and the community had total responsibility for O&M costs while funders may also have provided community cross subsidies for poorer households. On the other hand, the pilot Self Supply model had a different financial flow mechanism which is shown in Fig. 5.21. There was no financial flow to capital hardware cost for the community/household but there was to capital software costs for the service provider and loan committee (see Fig. 5.21). Loan finance flowed to traders to encourage private sector involvement and to enable an environment associated with sustainable supply chains for hardware materials and spare parts where there was unlikely to be easy access to those materials. Instead of providing a loan directly from the donor organisation or government to individual HDW owners for hardware provision, a loan scheme was developed by an organising loan-committee to give revolving loan sustainability so that people were able to copy from improved HDW owners within their own affordability.

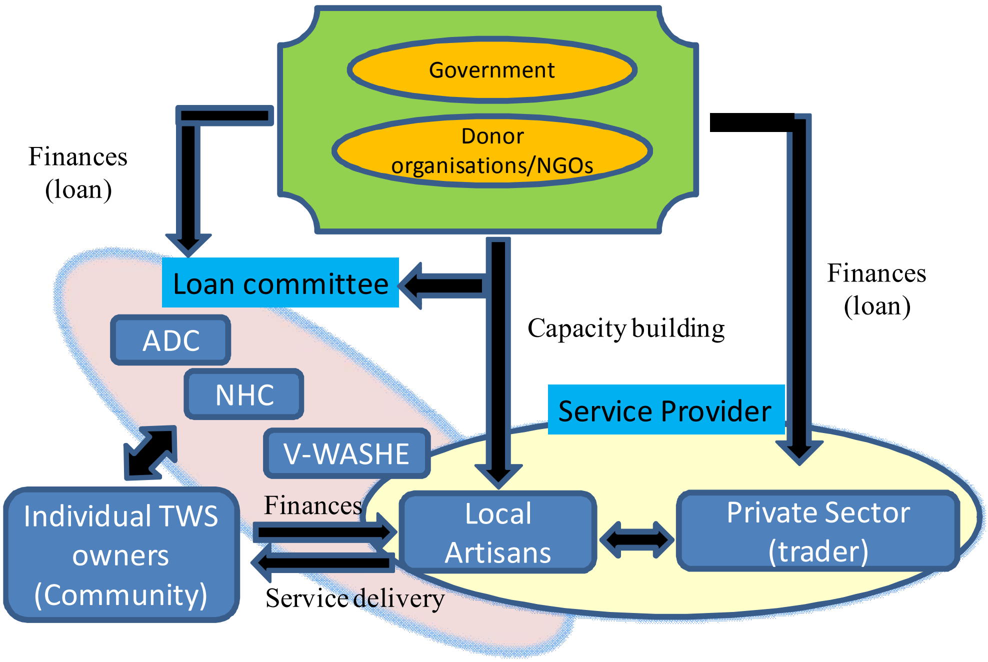


Fig. 5.21: Piloting Self Supply model in Zambia

(*Source: Author*)

However, this point was totally different from the communal water models in terms of cost sharing. According to the SOMAP principle, 95% of capital costs of a communal water supply model was provided by the government side, and 5% of them was from the community side (during field study, even this rarely happened but sand and stone were provided by the community). On the other hand, individual HDW owners (community) were paying most of the costs themselves including capital hardware and O&M costs within the Self Supply model. In fact, apart from improved HDWs owned by school or clinic, most of the HDW owners were planning to pay back the loan by themselves or co-operate with their extended families. Further investigation of the loan recovery rate is needed to explore the affordability of the capital hardware cost and potential of stepwise improvement towards top water supply levels.

Table 5.43 shows the results of the lifecycle household/community costs of different models. The unit cost is *US$ per head per year*. The figures, such as the estimated number of years before rehabilitation) applied in Table 5.43 are the same as Table 5.41. As noted in the previous section, it was necessary for 'time value' to be considered in the costs for the capital, replacement and operating and minor maintenance. Amortization was again used whereby equal amounts were set aside every year by considering the interest rate. The details of the calculation are explained in the *Note* following Table 5.43. The replacement and rehabilitation costs were not included in addition to the capital hardware costs in order to avoid double counting in the annual lifecycle costs. It was found from Table 5.43 that the conventional communal model user incurred about four times greater operating and minor O&M costs than those users of the Self Supply model. Also, capital costs to household/community showed a significant difference between the two models. In fact, according to the data collected through a key informant interview with Ms Miku Okada, whilst 5% of the capital cost is supposed to be contributed by the community in the SOMAP principle for the community water supply model, ZMK1.5 million (about US$333) has also been proposed in practice as an alternative capital contribution per unit from the community (less than 5% of the capital cost) when considering affordability. The bracket in the "*UNIT*" cost under the category of "*Capital cost*" for the communal water supply model refers to the cost based on the calculation using US$375 as the community contribution to the capital cost.

Table 5.43: Lifecycle household/community costs on annual basis

Household/community costs								
Cost components	Communal water supply model	Assumed life span (year)	UNIT (US$/person/year) [standard]	UNIT (US$/person/year) [actual]	Self (household) Supply model	Assumed life span (year)	UNIT (US$/person/year) [standard]	UNIT (US$/person/year) [actual]
Capital cost	5% contribution to capital cost	20	0.52 (0.11)	0.68 (0.14)	Improved existing Hand Dug Well **	20	0.06	0.08
Subtotal (Capital cost)			**0.52 (0.11)**	**0.68 (0.14)**			**0.06**	**0.08**
Rehabilitation and replacement cost	5% contribution to rehabilitation cost	20	Annual rehabilitation cost is covered in the Capital cost above		Rehabilitation cost	20	Annual rehabilitation cost is covered in the Capital cost above	
	5% contribution to replacement cost	5	Annual replacement cost is covered in the Capital cost above					
Subtotal (Capital maintenance cost)			**n/a**	**n/a**			**n/a**	**n/a**
Operating and minor maintenance cost	Grease	1	0.01	0.02	Rope	1	0.03	0.03
	Spare parts (O-ring seal, cup leather, nut, leather rubber, chain, handle axle, secondhand		0.30	0.39	Bucket	0.3	0.06	0.08
	Transport and labour		0.30	0.39	Dredge out collapsed sand/mud and debris ***	1	0.05	0.07
Subtotal (Operating and minor maintenance cost)*			**0.64**	**0.85**			**0.14**	**0.19**
Grand Total			**1.16 (0.75)**	**1.53 (0.99)**			**0.20**	**0.27**

n/a (not applicable)

Source: Author's field work, JICA (2007) and WaterAid

Note: * *estimated operating and minor maintenance cost of borehole and with handpump OM=US$150, assumed interest rate r=5%, annuity factor* $AF_{r,n}$*=0.9524, Operating and minor maintenance cost* A_{OM}*= US$160.65/year*

** *Improved existing hand dug well with 2m re-deepening, top lining, concrete apron, drainage, reservoir, top slab, wire, labour, 3bag cement, lockable cover, rope and bucket =US$180*

*** *estimated operating and minor maintenance cost of hand dug well with rope/bucket OM=US$21, assumed interest rate r=5%, annuity factor* $AF_{r,n}$*=0.9524, Operating and minor maintenance cost* A_{OM}*= US$22.04/year*

The grand total of the Table indicated that the communal supply user HH paid off about US$1.16-1.53 (or US$0.75-0.99)/person/year compared with about US$0.20-0.27/person/year for the Self Supply user HH despite the number of cost sharers being higher than for Self Supply. This could be explained by the difference in technologies used for water source protection. The types of technology which were applied in this study significantly contributed to the capital hardware cost and capital maintenance cost. The improved HDW hardware cost of capital, capital maintenance and minor maintenance costs were much cheaper than the borehole with handpump facility in the case of the examples in Table 5.43. This is reasonable since a higher level of technology with respect to protection was used, which was more expensive to install as well as to operate and maintain.

It must be remembered that the amount of total Self Supply costs at US$0.20-0.27 per head per year was the case only if the costs could be shared with users. However, 85% (out of those improved by Self Supply trained artisans) of water point owners were paying most of the cost themselves including the capital hardware and O&M costs in the Self Supply model in Milenge while the remaining 15% were owned by schools, clinics and churches. According to the data collected through household surveys, the unit cost for the most prevalent improved option in Milenge, including a few metres of re-deepening, top lining, concrete apron, drainage, reservoir, top slab, wire, labour, 3 bags of cement, lockable cover, rope and bucket was about US$150-170. Despite such a large amount of costs being incurred by them, water point owners who had improved their HDWs expressed a high level of satisfaction with respect to their improvements and considered them to be value for money. Some of the *Protected* (improved) HDW owners explained the motivations for improving their water points (Box 5.12 and Box 5.13).

Box 5.12: Excerpts from survey with well owner at Chamalawa village, Itemba Ward

It has not been very cheap for me to improve my well since I am not rich compared with neighbours. However, I am a proud man because even if I died today, I know I would have left a very precious asset not only for my children but even for my grandchildren. This family asset is a pride of my life.

The indications from Boxes 5.12 and 5.13 are that they found benefits in putting what little money they had into improving or having their own water source, adding to their original value, and this may be overlooked when a water supply model is decided from a macro-economic viewpoint.

Box 5.13: Excerpts from focus group discussion with well owner at Daison village, Kashikishi Ward

I used to go to a neighbour's well to draw water paying k200 (≒US$0.04) per container every day. It was hard work for us to carry plenty of water from the neighbour's well to my home and it was difficult to pay every time……….. In my mind, it was better to have my well rather than paying k200 per container everyday to someone else's water source. So I decided in 2000 and spent k1.5million (≒ US$333) in constructing my well and purchasing a windlass…………………Having my well was also costly at the time of construction, but since then I have no need to pay money to someone else to fetch water…………. In addition, I earn money by making and selling bricks for about k3.5million (≒US$700) annually. You know, water is necessary for making bricks to mix with local soil, so once we got our well we are able to use this water not only for drinking but for our livelihood.

5.8.4 Chronological lifecycle cost

This section is the step inputting the lifecycle costs chronologically into a table as a visual aid to understand when these lifecycle costs (Sections 5.8.2 and 5.8.3) are necessary for payment by the government and community. This section, thereby, simply sheds light on when these costs take place whereas previous sections 5.8.2 and 5.8.3 have analysed the lifecycle costs by focusing on the contents and who meets the costs i.e. government or community.

Tables 5.44 and 5.45 present the over time lifecycle costs for both the communal and Self Supply models. The figures, such as estimated number of years before rehabilitation applied in Table 5.44 and 5.45 are the same as Table 5.41. It is apparent from Tables 5.44 and 5.45 that the greater proportion of costs were incurred in the first year of project implementation, especially by government or external support agencies in both water supply models. However, the government will not meet the cost for routine minor maintenance of the water supply facilities in either model so the community/household needs to meet the operation and maintenance costs. Further, these tables imply that the community is clearly required to make a contribution annually for sustainable O&M, and should consider the need for saving beyond the annual operation and minor maintenance costs to prepare for future replacement/rehabilitation costs.

Table 5.44: Chronological lifecycle conventional communal cost by year incurred

COSTS (per unit) [US$]	Costs	Expected life in years	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Total grant for capital costs			31493.3																				
Monitoring activity for O&M	300	3	92.68	92.68	92.68																		
Routine maintenance cost for handpump	153	1	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153
Current replacement cost for handpump	254	5	254	0	0	0	0	254	0	0	0	0	254	0	0	0	0	254	0	0	0	0	254
Current rehabilitation cost	5000	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5000
Total costs			31585.98	245.68	245.68	153.00	153.00	407.00	153.00	153.00	153.00	153.00	407.00	153.00	153.00	153.00	153.00	407.00	153.00	153.00	153.00	153.00	407.00
Costs incurred by government/donor			30011.31	92.68	92.68	0.00	0.00	241.30	0.00	0.00	0.00	0.00	241.30	0.00	0.00	0.00	0.00	241.30	0.00	0.00	0.00	0.00	4991.30
Costs incurred by community			1574.67	153.00	153.00	153.00	153.00	165.70	153.00	153.00	153.00	153.00	165.70	153.00	153.00	153.00	153.00	165.70	153.00	153.00	153.00	153.00	415.70

(*Source: Author's field work, JICA* (2007) and WaterAid)

Table 5.45: Chronological lifecycle Self Supply cost by year incurred

COSTS (per unit) [US$]	Costs	Expected life in years	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Total grant for capital costs			4717.5																				
Monitoring activity for O&M	480	3	160	160	160																		
HDW improvement			180																				
Routine maintenance cost	24	1	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Current rehabilitation cost	265	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	265
Total costs			5081.50	184.00	184.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	289.00
Costs incurred by government			4877.50	160.00	160.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Costs incurred by household/community			204.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	4.00	24.00	24.00	289.00

(*Source: Author's field work, JICA* (2007) and WaterAid)

In conclusion, this Section 5.8 has provided a synthesis of the data presentation and analysis of cost-effectiveness. First, overall capital costs related to water supply projects were presented for both communal and Self Supply models. Further, the overall capital costs were incorporated into lifecycle costs, and then separated into project costs and household costs in order to clarify who was going to meet the costs related to the water supply. Chronological lifecycle costs were also analysed to understand when the costs would take place. This section demonstrated how the lifecycle costs comprised of hardware and software costs in different water supply models, and to what extent the government and household incurred the costs. The following Section is going to examine the acceptability.

5.9 Acceptability

User acceptability and preference/demand for different water supply models are important variables in understanding water supply sustainability from the different dimensions associated with ownership of the water supply types. The literature review in Chapter 3 outlined the fact that communities were reluctant to operate and maintain the communal sources due to the top-down form of the communal water supply model while the Self Supply model might develop ownership by the households or small groups when improving water sources as a result of their own decisions. Thereby, this section will examine the viability of the Self Supply model compared with the communal one through assessment of user satisfaction and transition of community water supply dynamics. Fig. 5.22 shows the research outlines associated with the principal argument, concepts, research questions and indicators. The concept of user acceptability is associated with these specific secondary questions;

What is the status of acceptability towards water supply models for end users in terms of water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability? What are the factors likely to affect user satisfaction? How are user preferences/satisfactions in selecting water supply model likely to affect the community water supply dynamics?

The next sections present and discuss data obtained from household surveys (see Appendix F), with analysis of the key indicator parameters relating to user acceptability as defined below:

- User satisfaction (section 5.9.1)
- User satisfaction and water supply types (section 5.9.2)
- User satisfaction and ownership (section 5.9.3)
- Previous water source (section 5.9.4)
- Community water supply dynamics (section 5.9.5)

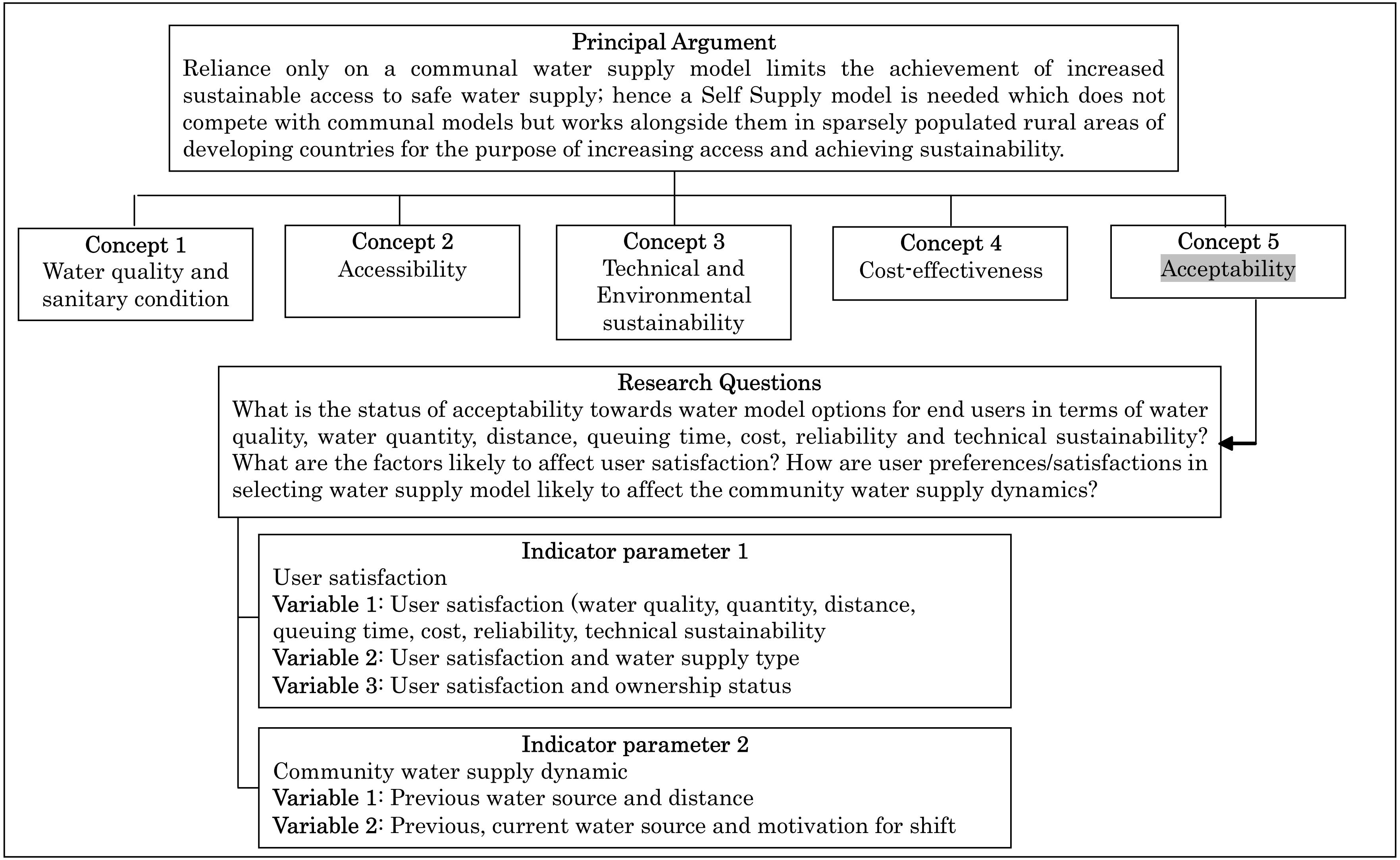


Fig. 5.22: Principal argument, indicator parameters

5.9.1 User satisfaction

To elucidate end users perceptions of current water supply sources, user satisfaction with respect to a variety of aspects (water quality, water quantity, distance, waiting time, cost, reliability and technical sustainability) was investigated under questionnaire based household surveys. In order to assess their satisfaction level, outcome evaluations were measured using sets of items that asked respondents to rate how satisfied or dissatisfied the various outcomes would be for them (+2: very satisfied, +1: Satisfied, 0: Neither, -1: Not satisfied; and -2: Not very satisfied). For descriptive purposes, mean scores on each of the 5-point scales are classified into six categories as shown in Table 5.46.

Table 5.46: Mean score classification on 5-point scale

Score on bi-polar scale (Sb)	Score classification/description
Sb > 1.5	Very high
0.5 < Sb ≤ 1.5	High
0 < Sb ≤ 0.5	Fairly high
-0.5 < Sb ≤ 0	Fairly low
-1.5 < Sb ≤ -0.5	Low
Sb < -1.5	Very low

(*Source: Author*)

Table 5.47 shows their satisfaction level with different water supply types associated with a variety of variables. 'Cost of water' means 'the amount of contribution/payment' to water points. In this sense, sampled respondents were limited to the people who used water points with a charging system. Reliability refers in this study to environmental sustainability and whether it was available at any time whilst the definition of 'technical sustainability' refers to durability of lifting devices in this study. The majority of lifting devices were rope and bucket but 13 HDWs were equipped with a windlass or rope pump so that it was necessary to look at their satisfaction level in the later data analysis chapter. Overall, it is apparent from Table 5.47 that responding households using HDWs were satisfied with their current primary water sources whilst borehole users expressed a fairly low level of satisfaction in terms of water quantity, distance, waiting time and cost of water.

Table 5.47: Descriptive statistics for user satisfaction

Variables	Valid cases: N (Milenge, Nchelenge)	Category description	Frequency: % (Milenge, Nchelenge)	Max score (Milenge, Nchelenge)	Min score (Milenge, Nchelenge)	Mean score (Milenge, Nchelenge)	Standar deviation (Milenge, Nchelenge)
Water quality	(173, 268)	Not Protected	(16, 21)	(2, 2)	(-2, -2)	(0.32, 0.77)	(1.19, 1.11)
		Partially Protected	(30, 37)	(2, 2)	(-2, -1)	(0.79, 1.35)	(1.18, 1.07)
		Protected	(28, 16)	(2, 2)	(-1, -1)	(1.29, 1.60)	(1.18, 1.07)
		Borehole	(25, 26)	(2, 2)	(-1, -1)	(0.35, 0.88)	(1.17, 1.09)
Water quantity	(173, 265)	Not Protected	(16, 22)	(2, 2)	(-2, -2)	(0.89, 1.25)	(1.19, 1.29)
		Partially Protected	(30, 38)	(2, 2)	(-2, -1)	(1.38, 1.44)	(1.18, 1.27)
		Protected	(28, 16)	(2, 2)	(-1, -1)	(1.57, 1.48)	(1.18, 1.24)
		Borehole	(25, 25)	(2, 2)	(-2, -2)	(0.77, -0.27)	(1.20, 1.27)
Distance	(173, 268)	Not Protected	(16, 21)	(2, 2)	(-2, -2)	(0.93, 1.23)	(1.47, 1.34)
		Partially Protected	(30, 37)	(2, 2)	(-2, -2)	(0.75, 1.19)	(1.46, 1.40)
		Protected	(28, 16)	(2, 2)	(-2, -1)	(1.2, 1.30)	(1.47, 1.36)
		Borehole	(25, 26)	(2, 2)	(-2, -2)	(0.49, -0.15)	(1.46, 1.40)
Waiting time	(173, 268)	Not Protected	(16, 21)	(2, 2)	(-2, -2)	(0.75, 0.73)	(1.61, 1.42)
		Partially Protected	(30, 37)	(2, 2)	(-2, -2)	(0.87, 1.04)	(1.60, 1.42)
		Protected	(28, 16)	(2, 2)	(-2, -1)	(0.90, 1.12)	(1.60, 1.40)
		Borehole	(25, 26)	(2, 2)	(-2, -2)	(0.3, -0.21)	(1.60, 1.42)
Cost of water	(19, 142)	Not Protected	(5, 15)	(2, 2)	(NA, -1)	(2.00, 1.09)	(N/A, 1.28)
		Partially Protected	(0, 33)	(2, 2)	(NA, -1)	(N/A, 1.38)	(N/A, 1.27)
		Protected	(47, 19)	(2, 2)	(0, -2)	(1.78, 0.55)	(1.02, 1.25)
		Borehole	(47, 32)	(2, 2)	(-2, -2)	(0.22, -0.21)	(1.36, 1.28)
Reliability	(172, 267)	Not Protected	(16, 21)	(2, 2)	(-2, -2)	(0.39, -0.02)	(1.24, 1.13)
		Partially Protected	(30, 37)	(2, 2)	(-2, -2)	(0.73, 0.85)	(1.22, 1.12)
		Protected	(28, 16)	(2, 2)	(-2, -1)	(1.51, 1.37)	(1.24, 1.09)
		Borehole	(15, 25)	(2, 2)	(-2, -2)	(1.49, 1.76)	(1.23, 1.13)
Technical sustainability	(169, 263)	Not Protected	(16, 21)	(2, 2)	(-2, -2)	(0.32, 0.28)	(1.26, 1.18)
		Partially Protected	(30, 38)	(2, 2)	(-2, -2)	(0.80, 0.60)	(1.25, 1.17)
		Protected	(28, 16)	(2, 2)	(-2, -2)	(1.58, 0.85)	(1.26, 1.18)
		Borehole	(15, 25)	(2, 2)	(-2, -2)	(1.49, 1.27)	(1.26, 1.18)
Summary		Not Protected				**(0.80, 0.76)**	
		Partially Protected				**(0.89, 1.12)**	
		Protected				**(1.40, 1.18)**	
		Borehole				**(0.73, 0.44)**	

(Source: Author's field work)

Further, the level of satisfaction increased in incremental steps relative to the protection level of HDWs except for boreholes. For instance, the summary integrating all aspects (see bottom column of Table 5.47) shows that *Protected* HDW users reached the highest satisfaction level among the different water supply models while lowest satisfaction level was found in the borehole users. The following section looks in further detail at each aspect of satisfaction.

5.9.2 User satisfaction and water supply types

In order to assess their satisfaction level with respect to a variety of aspects (water quality, water quantity, distance, waiting time, cost, reliability and technical sustainability), outcome evaluations were measured using sets of items that asked respondents to rate how satisfied or dissatisfied the various outcomes would be for them. The level of user satisfaction was categorised from five to three (see Table 5.48) by combining 'not very satisfied' and 'not satisfied', 'very satisfied' and satisfied' in order to enhance the statistical validity and to examine the difference in user satisfaction towards different water supply models rather than look into the small differences in levels of user satisfaction. The next section looks at the associations between user satisfactions and indicator variables.

Table 5.48: Classification of user satisfaction

Classification	Five	Three
User Satisfaction	Very Satisfied	Satisfied
	Satisfied	
	Neither	Neither
	Not Satisfied	Not Satisfied
	Not Very Satisfied	

(*Source: Author*)

<u>Water quality</u>

Table 5.49 shows the results of cross-tabulation of user satisfaction for water quality by water supply types.

Table 5.49: Cross-tabulation of user satisfaction by water supply type with water quality

District	Indicator variables	Water supply types		User satisfaction (Water quality) Not Satisfied	Neither	Satisfied	Row total	Pearson Chi-suqare Value	Df	Sig. (p)
Milenge	Water quality	Not protected HDW	Count	8	9	11	28	18.986	6	0.004**
			% (r)	28%	32%	40%	100%			
		Partially protected HDW	Count	5	18	29	52			
			% (r)	10%	35%	56%	100%			
		Protected HDW	Count	2	10	37	49			
			% (r)	4%	20%	75%	100%			
		Borehole	Count	7	18	18	43			
			% (r)	16%	42%	42%	100%			
Nchelenge		Not protected HDW	Count	11	10	27	48	15.811	6	0.015*
			% (r)	23%	21%	56%	100%			
		Partially protected HDW	Count	4	16	71	91			
			% (r)	4%	18%	78%	100%			
		Protected HDW	Count	3	7	36	46			
			% (r)	7%	15%	78%	100%			
		Borehole	Count	9	15	39	63			
			% (r)	14%	24%	62%	100%			

(Source: Author's field work)
*Note: *significant at <.05　　　**significant at <.001*

From the cross-tabulation (Table 5.49) of the user satisfaction for water quality by water supply types, it was found that the null-hypothesis where 'User satisfaction for water quality has no association with the different types of water supply' was rejected by the Pearson Chi-square test with a significance value of 0.004 in Milenge and 0.015 in Nchelenge. This indicated that not all users were satisfied with their water sources despite the fact that they were using them as their primary water sources. For instance, the level of user satisfaction for water quality increased in accordance with the level of protection of HDWs with the exception of boreholes. This could be explained by the fact that the level of faecal contamination led to a level of dissatisfaction among HDW users whilst other factors, such as an iron smell or colour, might have had an impact on the satisfaction level among borehole users. Whatever the reason for dissatisfaction, in the mean time, the level of user satisfaction for water quality from both *Partially Protected* and *Protected* users was notably higher than for borehole users'. Box 5.14 shows one of the opinions from household survey for water quality.

Box 5.14: Excerpts from survey with one of the beneficiaries from *Not Protected* HDWs at Robi compound, Nchelenge Ward

We used to go to the stream to collect water for my domestic usage, of course it included water for drinking purposes…………A couple of years ago, a handpump water supply facility was constructed which was much closer than the stream….But the quality of water from the handpump was very bad…..It tasted like salty or rusty…..The constructors told us that it was not harmful for our health but you know, we were used to drinking water drawing it from the stream so we had no experiences of such taste…..That is why I am now using a neighbour's well which is much closer and the taste is good.

Water quantity

Table 5.50 presents the results of the Pearson Chi-square test of user satisfaction by water supply type with water quantity. It shows that water quantity had a significant association between user satisfaction and water supply types with the significance value of 0.010 in Milenge and 0.0005 in Nchelenge, respectively.

Table 5.50: Cross-tabulation of user satisfaction by water supply type with water quantity

District	Indicator variables	Water supply types		User satisfaction (Water quantity)				Pearson Chi-suqare		
				Not satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Water quantity	Not protected HDW	Count	7	3	18	28	16.788	6	0.010*
			% (r)	25%	11%	64%	100%			
		Partially protected HDW	Count	4	7	41	52			
			% (r)	8%	13%	79%	100%			
		Protected HDW	Count	1	4	44	49			
			% (r)	2%	8%	90%	100%			
		Borehole	Count	11	4	28	43			
			% (r)	26%	9%	65%	100%			
Nchelenge		Not protected HDW	Count	5	4	39	48	68.121	6	0.0005***
			% (r)	10%	8%	81%	100%			
		Partially protected HDW	Count	6	7	78	91			
			% (r)	7%	8%	86%	100%			
		Protected HDW	Count	4	2	40	46			
			% (r)	9%	4%	87%	100%			
		Borehole	Count	34	6	22	62			
			% (r)	55%	10%	35%	100%			

(Source: Author's field work)

Note: *significant at <.005 ***significant at <.0001

This could be explained from Section 5.6.8 where there was a significant relationship between the amount of drawn water (lcd) and water supply types, and thereby user satisfaction was dependent upon the amount of water they could draw from their primary water source.

Distance

Table 5.51 shows the results of cross-tabulation of user satisfaction by water supply type with distance. It was found from the table that the hypothesis was accepted in Nchelenge that 'there is association between user satisfactions as for distance and water supply types' with a significance value of 0.0005 while the hypothesis was rejected in Milenge. This could be attributed to the difference between HDW users and borehole users. For instance, over 75% of any type of HDW users in Nchelenge (77% in Not protect, 78% in Part Protect and 80% in *Protected* HDW users, respectively) scored 'Satisfied' while less than 40% of borehole users indicated 'Satisfied'. Furthermore, 45% of borehole users expressed 'Not satisfied' regarding distance, but less than 15% of HDW users marked 'Not satisfied'. On the other hand, over 50% of the borehole users in Milenge did mark 'Satisfied' and 28% were 'Not satisfied' and these results showed no significant difference from other water supply types.

Table 5.51: Cross-tabulation of user satisfaction by water supply type with distance

District	Indicator variables	Water supply types		User satisfaction (Distance)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Distance	Not protected HDW	Count	5	4	19	28	12.659	6	0.049
			% (r)	18%	14%	68%	100%			
		Partially protected HDW	Count	16	4	32	52			
			% (r)	30%	8%	62%	100%			
		Protected HDW	Count	4	11	34	49			
			% (r)	8%	22%	69%	100%			
		Borehole	Count	12	9	22	43			
			% (r)	28%	21%	51%	100%			
Nchelenge		Not protected HDW	Count	7	4	37	48	42.859	6	0.0005***
			% (r)	14%	8%	77%	100%			
		Partially protected HDW	Count	10	10	71	91			
			% (r)	11%	11%	78%	100%			
		Protected HDW	Count	3	6	37	46			
			% (r)	7%	13%	80%	100%			
		Borehole	Count	28	11	23	62			
			% (r)	45%	18%	37%	100%			

(Source: Author's field work)

*Note: *** significance<.0001*

A possible explanation for this can be traced to the findings from Table 5.19 in Section 5.6.1 that more than 30% of borehole users in Nchelenge went a distance of more than 500m while less than 20% of borehole users in Milenge had a similar distance. These findings suggest that when the distance to the water source was over 500m, users' satisfaction decreased dramatically.

Queuing time

Table 5.52 shows the results of a statistical test to assess the association between user satisfaction regarding queuing time and water supply type. There was a significant association between user satisfaction for queuing time and water supply type in Nchelenge as the Pearson Chi-square significance was less than 0.0001.

Table 5.52: Cross-tabulation of user satisfaction by water supply type with queuing time

District	Indicator variables	Water supply types		User satisfaction (Queuing time) Not Satisfied	Neither	Satisfied	Row total	Pearson Chi-suqare Value	Df	Sig. (p)
Milenge	Queuing time	Not protected HDW	Count	7	4	17	28	4.019	6	0.674
			% (r)	25%	14%	61%	100%			
		Partially protected HDW	Count	14	5	33	52			
			% (r)	27%	10%	64%	100%			
		Protected HDW	Count	11	5	33	49			
			% (r)	22%	10%	67%	100%			
		Borehole	Count	16	6	21	43			
			% (r)	37%	14%	49%	100%			
Nchelenge		Not protected HDW	Count	14	4	30	48	44.203	6	0.0005***
			% (r)	29%	8%	63%	100%			
		Partially protected HDW	Count	11	12	68	91			
			% (r)	12%	13%	75%	100%			
		Protected HDW	Count	10	2	34	46			
			% (r)	22%	4%	74%	100%			
		Borehole	Count	33	9	20	62			
			% (r)	53%	15%	33%	100%			

(Source: Author's field work)
*Note: *** significance<.0001*

The table shows that over 60% of HDW users in Nchelenge marked 'Satisfied' (63% for *Not Protected*, 75% for Part *Protected* and 74% for *Protected*, respectively) although only 33% of borehole users in Nchelenge expressed 'Satisfied' with their queuing time. This indicated that user satisfaction had no significant difference among HDW users (*Not Protected*, *Partially Protected* and *Protected*), but had a significant difference when compared with that of borehole users. Table 5.23 in Section 5.6.5 was also consistent with the point that average queuing time at the borehole was more than 2.5 times as long as that of HDW users.

Contribution

A small number of water points had a contribution system for O&M. Table 5.53 shows how their satisfaction regarding contribution was different for water supply types. The amount of the contribution was within the same range, between k1,000/HH/m (≒US$0.2) and k3,000/HH/m (≒US$0.6), among all types of water supply sources. It was found from the table that user contribution in Milenge showed no significant difference between user satisfaction and water supply types, but user contribution in Nchelenge had a significant association between the two variables with a significance value of 0.0005 (Smaller than 0.001).

Table 5.53: Cross-tabulation of user satisfaction by water supply type with contribution

District	Indicator variables	Water supply types		User satisfaction (Contribution)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Contribution	Not protected HDW	Count	0	0	1	1	6.009	4	0.199
			% (r)	0%	0%	100%	100%			
		Protected HDW	Count	0	1	8	9			
			% (r)	0%	11%	89%	100%			
		Borehole	Count	4	1	4	9			
			% (r)	44%	11%	44%	100%			
Nchelenge		Not protected HDW	Count	4	2	16	22	28.065	6	0.0005***
			% (r)	18%	9%	73%	100%			
		Partially protected HDW	Count	1	6	37	44			
			% (r)	2%	14%	84%	100%			
		Protected HDW	Count	7	2	18	27			
			% (r)	26%	7%	67%	100%			
		Borehole	Count	22	4	18	44			
			% (r)	50%	9%	41%	100%			

(Source: Author's field work)
*Note: *** significance<.0001*

Interestingly, in Milenge the distribution of user satisfaction was similar for *Protected* HDW users and borehole users whilst *Not Protected* and *Partially Protected* users had a similar distribution of satisfaction in Nchelenge. Therefore, the ownership statuses of the water sources were separated and the associations were tested again between user satisfaction and ownership status in Section 5.9.3.

Reliability

Table 5.54 presents a cross-tabulation test of user satisfaction regarding water source reliability by water supply types. A null hypothesis (there is likely to be no differences between user satisfaction for reliability and water supply types) was rejected by the Pearson Chi-square tests at both Milenge and Nchelenge as the significance levels were both 0.0005. Therefore, there are likely to be differences between user satisfaction for reliability and water supply types. The level of satisfaction increased consistent with the level of protection types.

In fact, from Section 5.7 of environmental sustainability, frequency of water source dry up had a significant association with the level of water source protection not only for HDWs but also for boreholes. This indicated that end users expressed their level of dissatisfaction towards frequent experiences of primary water source drying up.

Table 5.54: Cross-tabulation of user satisfaction by water supply type with reliability

District	Indicator variables	Water supply types		User satisfaction (Reliability)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Reliability	Not protected HDW	Count	9	5	14	28	29.773	6	0.0005***
			% (r)	32%	18%	50%	100%			
		Partially protected HDW	Count	7	16	28	51			
			% (r)	14%	31%	55%	100%			
		Protected HDW	Count	4	2	43	49			
			% (r)	8%	4%	88%	100%			
		Borehole	Count	4	3	36	43			
			% (r)	10%	7%	84%	100%			
Nchelenge		Not protected HDW	Count	21	8	19	48	54.887	6	0.0005***
			% (r)	44%	17%	40%	100%			
		Partially protected HDW	Count	10	16	65	91			
			% (r)	11%	18%	71%	100%			
		Protected HDW	Count	4	6	36	46			
			% (r)	9%	13%	78%	100%			
		Borehole	Count	1	2	58	61			
			% (r)	2%	3%	95%	100%			

(Source: Author's field work)

*Note: *** significance<.0001*

Technical sustainability

Technical sustainability as referred to in this study is the 'operational time of the lifting device'. In another cross-tabulation of the variables user satisfaction regarding technical sustainability with water supply type, the hypothesis that (there is likely to be an association between the two variables) was accepted by the Pearson Chi-square test at both Milenge and Nchelenge Districts with a significance value of 0.0005 for them (see Table 5.55). It is apparent from the table in Milenge, for example, that 46% of *Not Protected* and 61% of *Partially Protected* HDW users marked 'Satisfied' while over 85% of both *Protected* HDW and borehole users scored 'Satisfied'. A possible explanation for this can be traced to the fact that *Protected* HDW users in Milenge used a durable rope and bucket (See Section 5.7.1) compared with plastic containers which were used at *Not Protected* and *Partially Protected* HDWs. Further, Section 5.7.1 outlined the durability of the lifting device, and there was a significant association between 'rope and bucket' and 'HDW types' in Milenge. These findings indicated that the level of HDW user satisfaction increased with the level of HDW protection, which was the improvement in the durability of the lifting device.

Table 5.55: Cross-tabulation of user satisfaction by water supply type with technical sustainability

District	Indicator variables	Water supply types		User satisfaction (Technical sustainability)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Technical sustainabilit	Not protected HDW	Count	11	4	13	28	36.631	6	0.0005***
			% (r)	40%	14%	46%	100%			
		Partially protected HDW	Count	5	15	31	51			
			% (r)	10%	29%	61%	100%			
		Protected HDW	Count	2	4	42	48			
			% (r)	4%	8%	88%	100%			
		Borehole	Count	3	3	37	43			
			% (r)	7%	7%	86%	100%			
Nchelenge		Not protected HDW	Count	18	6	24	48	24.954	6	0.0005***
			% (r)	37%	13%	50%	100%			
		Partially protected HDW	Count	16	21	54	91			
			% (r)	17%	23%	59%	100%			
		Protected HDW	Count	9	5	32	46			
			% (r)	20%	11%	69%	100%			
		Borehole	Count	3	8	51	62			
			% (r)	5%	13%	82%	100%			

(Source: Author's field work)
*Note: *** significance<.0001*

5.9.3 User satisfaction and their ownership

It is important to understand how ownership status impacts on satisfaction levels because the different water supply models of communal and Self Supply create different ownership status, especially at HDWs. Table 5.56 presents descriptive statistics of user satisfaction by ownership status.

It is apparent from Table 5.56 that privately owned HDW owned by one family expressed the highest overall satisfaction followed by privately owned and shared HDW users. On the other hand, community or institution owned water source users had low levels of user satisfaction in when contrasted with those privately owned water source users. These findings imply that ownership status impacts on user satisfaction. In order to explore the factors affecting user satisfaction related to ownership status, the next sections examine the association with different indicators. The cross-tabulations of user satisfaction by ownership status among water supply types with different indicators (water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability) are presented from Table 5.57 to Table 5.63.

Table 5.56: User satisfaction by ownership status

District	Water source types	Ownership status	Water quality	Water quantity	Distance	Waiting time	Cost of water	Reliability	Technical Sustainablity	Total Average
Mielenge	Partially prote' HDW	Privately owned and shared	0.87	1.38	0.74	0.85	1.46	0.74	0.80	0.98
		Community owned (Gov't)	-0.25	1.75	0.50	0.75	2.00	0.75	1.00	0.92
		Institution (school or clinic)	1.00	0.00	2.00	2.00	2.00	0.00	0.00	1.00
	Protected HDW	Privately owned and shared	1.36	1.76	1.24	1.33	1.39	1.30	1.56	1.42
		Community owned	2.00	2.00	2.00	-2.00	2.00	2.00	2.00	1.42
		Institution (school or clinic)	0.72	0.81	0.72	0.90	1.60	1.90	1.45	1.16
	Borehole	Community owned (Gov't)	0.80	1.47	0.67	0.73	0.87	1.60	1.60	1.10
		Institution (school or clinic)	0.11	0.39	0.39	0.07	1.39	1.43	1.43	0.74
Nchelenge	Not protected HDW	Privately (family only)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
		Privately owned and shared	0.82	1.33	1.33	0.76	0.96	-0.02	0.27	0.78
		Community owned (Gov't)	-1.00	-1.00	-1.50	-0.50	2.00	-0.50	-0.50	-0.43
	Partially prote' HDW	Privately (family only)	1.00	1.67	1.67	0.67	1.33	0.33	-0.33	0.90
		Privately owned and shared	1.41	1.50	1.24	1.14	1.34	0.86	0.60	1.16
		Community owned (Gov't)	0.00	-1.00	-1.00	-2.00	1.00	2.00	1.00	0.00
	Protected HDW	Privately (family only)	2.00	2.00	1.00	2.00	2.00	2.00	2.00	1.86
		Privately owned and shared	1.42	1.37	1.34	1.03	0.84	1.11	0.71	1.12
		Community owned (Gov't)	1.00	1.83	0.83	0.83	1.00	0.83	0.50	0.97
		Institution (school or clinic)	2.00	2.00	1.00	-1.00	1.00	2.00	1.00	1.14
	Borehole	Community owned (Gov't)	0.78	-0.08	-0.14	-0.36	0.17	1.64	1.08	0.44
		Institution (school or clinic)	1.19	-0.35	-0.19	-0.15	0.15	1.96	1.50	0.59
	Summary	Privately (family only)								**1.59**
		Privately owned and shared								**1.09**
		Community owned (Gov't)								**0.63**
		Institution (school or clinic)								**0.82**

(*Source: Author's field work*)

<u>Water quality</u>

The ownership status shows no significant association with user satisfaction in terms of water quality in any of the water supply types (greater than significance 0.05) except *Partially Protected* HDW in Nchelenge as the significance level of 0.003. Although the sampled number of Privately (family) and Community Owned (with government subsidy) are too small to validate the result, it implied that ownership status of water supply source might contribute user satisfaction level for water quality (see Table 5.57).

Table 5.57: Cross-tabulation of user satisfaction regarding water quality by ownership status

District	Water source types	Ownership status		User satisfaction (Water quality)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Mielenge	Partially prote' HDW	Privately owned and shared	Count	4	15	28	47			
			% (r)	8%	32%	59%	100%			
		Community owned (Gov't)	Count	1	3	0	4	6.174	4	0.187
			% (r)	25%	75%	0%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
	Protected HDW	Privately owned and shared	Count	1	6	26	33			
			% (r)	3%	18%	79%	100%			
		Community owned	Count	0	0	5	5	4.527	4	0.339
			% (r)	0%	0%	100%	100%			
		Institution (school or clinic)	Count	1	4	6	11			
			% (r)	9%	36%	54%	100%			
	Borehole	Community owned (Gov't)	Count	2	4	9	15			
			% (r)	13%	27%	60%	100%	3.204	2	0.202
		Institution (school or clinic)	Count	5	14	9	28			
			% (r)	18%	50%	32%	100%			
Nchelenge	Not protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	0%	100%			
		Privately owned and shared	Count	9	10	26	45	7.732	4	0.102
			% (r)	20%	22%	58%	100%			
		Community owned (Gov't)	Count	2	0	0	2			
			% (r)	100%	0%	0%	100%			
	Partially prote' HDW	Privately (family only)	Count	1	0	2	3			
			% (r)	33%	0%	67%	100%			
		Privately owned and shared	Count	3	14	69	90	15.965	4	0.003**
			% (r)	3%	16%	77%	100%			
		Community owned (Gov't)	Count	0	1	1	2			
			% (r)	0%	50%	50%	100%			
	Protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	3	5	30	38			
			% (r)	8%	13%	79%	100%	2.562	6	0.861
		Community owned (Gov't)	Count	0	2	4	6			
			% (r)	0%	33%	66%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
	Borehole	Community owned (Gov't)	Count	7	10	20	37			
			% (r)	19%	27%	54%	100%	2.630	2	0.269
		Institution (school or clinic)	Count	2	5	19	26			
			% (r)	8%	19%	73%	100%			

(Source: Author's field work)

Water quantity

In another cross-tabulation (see Table 5.58) of the two variables 'user satisfaction for water quantity' with 'ownership status', which identified a null hypothesis (there is likely to be no association between ownership status and user satisfaction for water quantity), this was rejected by the Pearson Chi-square test at *Protected* HDWs in Milenge and *Not Protected* and *Partially Protected* HDWs in Nchelenge as the significance levels were 0.027, 0.001 and 0.0005, respectively (smaller than 0.05). The cross-tabulation of user satisfaction by ownership status of *Protected* HDWs in Milenge shows that about 97% of privately owned *Protected* HDW users marked a 'Satisfied' level whilst less than 70% of institution owned *Protected* HDW users scored a 'Satisfied' level.

Table 5.58: Cross-tabulation of user satisfaction regarding water quantity by ownership status

District	Water source types	Ownership status		User satisfaction (Water quantity)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Partially prote' HDW	Privately owned and shared	Count	4	6	37	47	7.560	4	0.109
			% (r)	8%	13%	79%	100%			
		Community owned (Gov't)	Count	0	0	4	4			
			% (r)	0%	0%	100%	100%			
		Institution (school or clinic)	Count	0	1	0	1			
			% (r)	0%	100%	0%	100%			
	Protected HDW	Privately owned and shared	Count	0	1	32	33	10.934	4	0.027*
			% (r)	0%	3%	97%	100%			
		Community owned	Count	0	0	5	5			
			% (r)	0%	0%	100%	100%			
		Institution (school or clinic)	Count	1	3	7	11			
			% (r)	9%	27%	64%	100%			
	Borehole	Community owned (Gov't)	Count	2	0	13	15	8.128	4	0.087
			% (r)	13%	0	87%	100%			
		Institution (school or clinic)	Count	9	4	15	28			
			% (r)	32%	14%	54%	100%			
Nchelenge	Not protected HDW	Privately (family only)	Count	0	0	1	1	18.111	4	0.001**
			% (r)	0	0	100%	100%			
		Privately owned and shared	Count	3	4	38	45			
			% (r)	6%	9%	84%	100%			
		Community owned (Gov't)	Count	2	0	0	2			
			% (r)	100%	0%	0%	100%			
	Partially prote HDW	Privately (family only)	Count	0	0	3	3	29.37	4	0.0005***
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	4	7	75	86			
			% (r)	5%	8%	87%	100%			
		Community owned (Gov't)	Count	2	0	0	2			
			% (r)	100%	0%	0%	100%			
	Protected HDW	Privately (family only)	Count	0	0	1	1	1.453	6	0.963
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	4	2	32	38			
			% (r)	11%	5%	84%	100%			
		Community owned (Gov't)	Count	0	0	6	6			
			% (r)	0%	0%	100%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
	Borehole	Community owned (Gov't)	Count	18	6	12	36	4.812	2	0.090
			% (r)	50%	17%	33%	100%			
		Institution (school or clinic)	Count	16	0	10	26			
			% (r)	62%	0%	38%	100%			

(Source: Author's field work)

*Note: * significance<.05 *** significance<.0001*

There were similar results in that users of *Not Protected* private HDWs and *Partially Protected* private HDWs in Nchelenge showed a 'Satisfied' level for water quantity with 87% and 84%, although nobody marked the 'Satisfied' level among users of community/institution owned, either *Not Protected* or *Partially Protected* HDWs. These findings indicate that where the water supply source was owned by communities/institution it resulted in complaints from end users in contrast with privately owned water supply sources which fulfilled fringe user satisfaction.

Distance

The Pearson Chi-square tests also showed that 'user satisfaction for distance' had a significant association with ownership status at *Not Protected* and *Partially Protected* HDWs in Nchelenge with significance levels of 0.043 and 0.002, respectively (see Table 5.59).

Table 5.59: Cross-tabulation of user satisfaction regarding distance with ownership status

District	Water source types	Ownership status		User satisfaction (Distnace)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Partially prote' HDW	Privately owned and shared	Count	15	3	29	47			
			% (r)	32%	6%	61%	100%			
		Community owned (Gov't)	Count	1	1	2	4	2.438	4	0.656
			% (r)	25%	25%	50%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
	Protected HDW	Privately owned and shared	Count	3	6	24	33			
			% (r)	9%	18%	73%	100%			
		Community owned	Count	2	1	2	5	6.074	4	0.194
			% (r)	40%	20%	40%	100%			
		Institution (school or clinic)	Count	1	5	5	11			
			% (r)	9%	45%	45%	100%			
	Borehole	Community owned (Gov't)	Count	4	2	9	15			
			% (r)	27%	13%	60%	100%	1.000	2	0.607
		Institution (school or clinic)	Count	8	7	13	28			
			% (r)	28%	25%	47%	100%			
Nchelenge	Not protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	5	4	36	45	12.487	6	0.043*
			% (r)	11%	9%	80%	100%			
		Community owned (Gov't)	Count	2	0	0	2			
			% (r)	100%	0%	0%	100%			
	Partially protected HDW	Privately (family only)	Count	0	0	3	3			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	8	10	68	86	17.312	4	0.002**
			% (r)	9%	12%	79%	100%			
		Community owned (Gov't)	Count	2	0	0	2			
			% (r)	100%	0%	0%	100%			
	Protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	2	5	31	38			
			% (r)	5%	13%	82%	100%	1.734	6	0.942
		Community owned (Gov't)	Count	1	1	4	6			
			% (r)	17%	17%	67%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
	Borehole	Community owned (Gov't)	Count	15	7	14	36			
			% (r)	42%	19%	38%	100%	0.447	2	0.880
		Institution (school or clinic)	Count	13	4	9	26			
			% (r)	50%	15%	35%	100%			

(Source: Author's field work)

Note: **significant at <.05*

For example in Nchelenge, less than 10% of users who drew water from privately owned *Partially Protected* HDWs scored 'Not Satisfied' whilst all respondents who used community owned *Partially Protected* HDWs (N=2) complained about the distance from their house to the water source, resulting in a 'Not satisfied' level. Although the number of respondents was very small, it was likely to result in their satisfaction when the water source was owned by individual neighbours rather than communal water sources where fringe users had to travel some distances.

Queuing time

It can be seen from Table 5.60 that there were significant associations between user satisfaction in terms of queuing time and ownership status. *Partially Protected* HDWs users in Nchelenge and *Protected* HDWs users in Milenge presented significant differences between their satisfaction level as for water quantity and ownership status with the Pearson Chi-square level of 0.0005 and 0.0005, respectively (smaller than 0.001).

Table 5.60: Cross-tabulation of user satisfaction regarding queuing time by ownership status

District	Water source types	Ownership status		User satisfaction (Queuing time) Not Satisfied	Neither	Satisfied	Row	Pearson Chi-suqare Value	Df	Sig. (p)
Milenge	Partially prote' HDW	Privately owned and shared	Count	13	5	29	47			
			% (r)	28%	11%	62%	100%	1.133	4	0.889
		Community owned (Gov't)	Count	1	0	3	4			
			% (r)	25%	0%	75%	100%			
	Protected HDW	Privately owned and shared	Count	4	3	26	33			
			% (r)	12%	9%	79%	100%			
		Community owned	Count	5	0	0	5	20.320	4	0.0005***
			% (r)	100%	0%	0%	100%			
		Institution (school or clinic)	Count	2	2	7	11			
			% (r)	18%	18%	64%	100%			
	Borehole	Community owned (Gov't)	Count	4	2	9	15			
			% (r)	26%	13%	60%	100%	1.282	2	0.527
		Institution (school or clinic)	Count	12	4	12	28			
			% (r)	43%	14%	43%	100%			
Nchelenge	Not protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	13	3	29	45	6.630	6	0.356
			% (r)	29%	7%	64%	100%			
		Community owned (Gov't)	Count	1	1	0	2			
			% (r)	50%	50%	0%	100%			
	Partially protected HDW	Privately (family only)	Count	0	2	1	3			
			% (r)	0%	67%	33%	100%			
		Privately owned and shared	Count	9	10	67	86	22.565	4	0.0005***
			% (r)	10%	12%	78%	100%			
		Community owned (Gov't)	Count	2	0	0	2			
			% (r)	100%	0%	0%	100%			
	Protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	9	1	28	38			
			% (r)	24%	3%	74%	100%	3.238	6	0.778
		Community owned (Gov't)	Count	1	1	4	6			
			% (r)	17%	17%	67%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	0%	100%			
	Borehole	Community owned (Gov't)	Count	21	5	10	39			
			% (r)	54%	13%	26%	100%	0.978	2	0.613
		Institution (school or clinic)	Count	12	4	10	26			
			% (r)	46%	15%	38%	100%			

(Source: Author's field work)
*Note: ***significant at <.0001*

For instance, all community owned *Partially Protected* HDWs respondents (N=2) in Nchelenge scored 'Not Satisfied' whereas only 9 (10%) out of the 86 Privately owned and shared *Partially Protected* HDW users indicated a 'Not Satisfied' level of satisfaction. This suggests that community owned water sources might lead to the dissatisfaction of the end users toward the queuing time at water source although the sample number is very small.

Contribution

In another cross-tabulation (see Table 5.61) of the two variables 'user satisfaction for contribution' with 'ownership status' which identified as a null hypothesis (there is likely to be no association between ownership status and user satisfaction for contribution), this was rejected by the Pearson Chi-square test at *Protected* HDWs in both Milenge and Nchelenge as the significance levels were 0.011 and 0.0005, respectively (smaller than 0.05). The Pearson Chi-square tests indicated that more than 70% (N=18 out of 25) of respondent users who relied on *Protected* HDWs owned by individuals in Nchelenge scored 'Satisfied' for their costs in paying a contribution while all respondents (N=4) using community owned *Protected* HDWs expressed their satisfaction level as 'Neither' or 'Not satisfied'.

Table 5.61: Cross-tabulation of user satisfaction regarding contribution by ownership status

District	Water source types	Ownership status		User satisfaction (Contribution)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Protected HDW	Privately owned and shared	Count	0	0	3	3	9.000	2	0.011*
			% (r)	0%	0%	100%	100%			
		Community owned	Count	0	0	5	5			
			% (r)	0%	0%	100%	100			
		Institution (school or clinic)	Count	3	0	0	3			
			% (r)	100%	0%	0%	100%			
Nchelenge	Partially protected HDW	Privately owned and shared	Count	1	6	37	44	1.187	2	0.520
			% (r)	2%	14%	84%	100%			
		Community owned (Gov't)	Count	0	0	5	5			
			% (r)	0%	0%	100%	100%			
	Protected HDW	Privately owned and shared	Count	7	0	18	25	27.000	2	0.0005***
			% (r)	20%	0%	72%	100%			
		Community owned (Gov't)	Count	2	2	0	4			
			% (r)	50%	50%	0%	100			
	Borehole	Community owned (Gov't)	Count	16	4	11	31	2.487	2	0.288
			% (r)	52%	13%	35%	100			
		Institution (school or clinic)	Count	6	0	7	13			
			% (r)	46%	0%	54%	100%			

(Source: Author's field work)

Note **significant at<.05* ****significant at <.0001*

This implies that communities tend to be satisfied with contributing to private water sources rather than to public water sources. On the other hand, it is interesting to note from Table 5.61 that users of both privately owned and community owned *Protected* HDWs marked the 'Satisfied' level in terms of their contribution.

On the other hand, the 'Not satisfied' level was scored by institution owned *Protected* users (N=3) in Milenge. Notably, the 5 respondent users drew water not from subsidized communal *Protected* HDWs, but from non-subsidized communal *Protected* HDWs. This means that the non-subsidized communal *Protected* HDWs were improved by the budgets from community members under the Self Supply project. Box 5.15 shows one of the examples from a household survey.

Box 5.15: Excerpts from household survey with one of the household headwoman at Chapabuku village, Milambo Ward

I heard that my neighbour is about to improve his well in order to protect the well from contamination. And maybe the government will also construct a new borehole in our village in next year. I know that a borehole is better protected than a non-protected well.............But I am not going to contribute to the borehole facility but I am willing to contribute to that friend's well since I know my friend needs support for maintenance, but the government has money so why do I need to pay for the borehole?

These findings suggest that no matter whether water sources are privately or publicly owned, community members are likely to be satisfied with their contribution towards water sources where individual/community members have invested their money rather than where subsidized water was sourced as a giveaway.

Reliability

Table 5.62 below illustrates that ownership status made no significant differences to user satisfaction in terms of 'Reliability' for any of the water supply types (greater than significance 0.05) i.e. the null hypothesis was accepted. This implied that their satisfaction level for reliability had no association to their ownership status.

Table 5.62: Cross-tabulation of user satisfaction regarding reliability by ownership status

District	Water source types	Ownership status		User satisfaction (Reliability)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Partially prote' HDW HDW	Privately owned and shared	Count	7	13	26	46			
			% (r)	15%	28%	57%	100%			
		Community owned (Gov't)	Count	0	2	2	4	3.435	4	0.488
			% (r)	0%	50%	50%	100%			
		Institution (school or clinic)	Count	0	1	0	1			
			% (r)	0%	100%	0%	100%			
	Protected HDW	Privately owned and shared	Count	4	2	27	33			
			% (r)	12%	6%	87%	100%			
		Community owned	Count	0	0	5	5	3.315	4	0.507
			% (r)	0%	0%	100%	100%			
		Institution (school or clinic)	Count	0	0	11	11			
			% (r)	0%	0%	100%	100%			
	Borehole	Community owned (Gov't)	Count	1	1	13	15			
			% (r)	7%	7%	87%	100%	0.199	2	0.905
		Institution (school or clinic)	Count	3	2	23	28			
			% (r)	11%	7%	83%	100%			
Nchelenge	Not protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	20	7	18	45	3.709	4	0.447
			% (r)	32%	16%	40%	100%			
		Community owned (Gov't)	Count	1	1	0	2			
			% (r)	50%	50%	0%	100%			
	Partially prote' HDW HDW	Privately (family only)	Count	1	1	1	3			
			% (r)	33%	33%	33%	100%			
		Privately owned and shared	Count	9	15	62	86	3.224	4	0.521
			% (r)	10%	17%	72%	100%			
		Community owned (Gov't)	Count	0	0	2	2			
			% (r)	0%	0%	100%	100%			
	Protected HDW	Privately (family only)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	4	3	31	38			
			% (r)	11%	8%	82%	100%	8.944	6	0.177
		Community owned (Gov't)	Count	0	3	3	6			
			% (r)	0%	67%	50%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
	Borehole	Community owned (Gov't)	Count	1	2	33	36			
			% (r)	3%	6%	92%	100%	2.191	2	0.334
		Institution (school or clinic)	Count	0	0	25	25			
			% (r)	0%	0%	100%	100%			

(Source: Author's field work)

Technical sustainability

Table 5.63 shows the results of cross-tabulation of ownership status by user satisfaction for technical sustainability (i.e. the lifting device). The results indicated that there was no significant association found between the two variables in any type of water supply source (significance is greater than 0.05, respectively). This indicated that user satisfaction regarding technical sustainability was unlikely to be related to the ownership status of the water supply sources.

Table 5.63: Cross-tabulation of user satisfaction regarding technical sustainability by ownership status

District	Water source types	Ownership status		User satisfaction (Technical sustainability)				Pearson Chi-suqare		
				Not Satisfied	Neither	Satisfied	Row total	Value	Df	Sig. (p)
Milenge	Partially prote' HDW HDW	Privately owned and shared	Count	5	13	28	46	3.026	4	0.554
			% (r)	11%	28%	61%	100%			
		Community owned (Gov't)	Count	0	1	3	4			
			% (r)	0%	25%	75%	100%			
		Institution (school or clinic)	Count	0	1	0	1			
			% (r)	0%	100%	0%	100%			
	Protected HDW	Privately owned and shared	Count	1	3	28	32	1.528	4	0.822
			% (r)	3%	9%	88%	100%			
		Community owned	Count	0	0	5	5			
			% (r)	0%	0%	100%	100%			
		Institution (school or clinic)	Count	1	1	9	11			
			% (r)	9%	9%	82%	100%			
	Borehole	Community owned (Gov't)	Count	0	2	13	15	2.942	2	0.230
			% (r)	0%	13%	87%	100%			
		Institution (school or clinic)	Count	3	1	24	28			
			% (r)	11%	4%	86%	100%			
Nchelenge	Not protected HDW	Privately (family only)	Count	0	0	1	1	4.415	4	0.353
			% (r)	0%	0%	100%	100%			
		Privately owned and shared	Count	17	5	23	45			
			% (r)	38%	11%	51%	100%			
		Community owned (Gov't)	Count	1	1	0	2			
			% (r)	50%	50%	0%	100%			
	Partially protected HDW	Privately (family only)	Count	2	0	1	3	6.666	4	0.155
			% (r)	66%	0%	33%	100%			
		Privately owned and shared	Count	14	21	61	86			
			% (r)	17%	24%	71%	100%			
		Community owned (Gov't)	Count	0	0	2	2			
			% (r)	0%	0%	100%	100%			
	Protected HDW	Privately (family only)	Count	0	0	1	1	11.720	6	0.069
			% (r)	0	0	100%	100%			
		Privately owned and shared	Count	8	2	28	38			
			% (r)	22%	5%	74%	100%			
		Community owned (Gov't)	Count	1	3	2	6			
			% (r)	17%	50%	33%	100%			
		Institution (school or clinic)	Count	0	0	1	1			
			% (r)	0%	0%	100%	100%			
	Borehole	Community owned (Gov't)	Count	3	6	27	36	3.659	2	0.161
			% (r)	9%	17%	75%	100%			
		Institution (school or clinic)	Count	0	2	24	26			
			% (r)	0%	8%	92%	100%			

(*Source: Author's field work*)

5.9.4 Previous water source

Community water supply selection is not the result of static behaviour as there exists a community dynamic alongside a change of water situation in the community. To capture the community dynamic regarding their water point, the use of a previous water source before using the current primary water source was investigated. Table 5.64 shows the previous water source which was used prior to the current primary water sources and the distance from their house.

The table shows that unprotected surface water, river, stream and lake were the water sources that they had relied on for their primary water source in the past in both Districts (60% in Milenge and 44% in Nchelenge, respectively) followed by neighbours'

HDWs (17% in Milenge, 21% in Nchelenge). Further, apart from the water points of HDWs, more than 80% of borehole and unprotected surface water users fetched their water from more than 500m from their premises.

Table 5.64: Previous water source and the distance

District	Previous water source		1-20m	21-250m	251-500m	500-1000m	>1000m	Total	% (c) in District	Current water source	Own TWS	Neigh. TWS	Borehole
Milenge	Own TWS	Count	1	0	0	0	0	1			0	1	0
		% (r)	100%	0%	0%	0%	0%	100%	1%		0%	100%	0%
	Neigh. TWS	Count	0	13	5	2	4	24			10	11	3
		% (r)	0%	54%	21%	8%	17%	100%	17%		42%	46%	13%
	Borehole	Count	0	1	1	3	7	12			4	7	1
		% (r)	0%	8%	8%	25%	58%	100%	9%		33%	58%	8%
	Spring	Count	0	1	2	5	11	19			7	7	5
		% (r)	0%	5%	11%	26%	58%	100%	13%		37%	37%	26%
	River, Stream, Scoophole	Count	0	6	6	12	61	85			27	34	24
		% (r)	0%	70%	70%	14%	72%	100%	60%		32%	40%	28%
Nchelenge	Own TWS	Count	2	0	0	0	0	2			0	1	1
		% (r)	100%	0%	0%	0%	0%	100%	1%		0%	50%	50%
	Neigh. TWS	Count	0	21	6	5	4	39			28	9	2
		% (r)	0%	58%	17%	14%	11%	100%	21%		72%	23%	5%
	Borehole	Count	0	0	1	3	15	24			12	8	4
		% (r)	0%	0%	5%	16%	79%	100%	13%		50%	33%	17%
	Spring	Count	0	0	3	2	4	9			0	3	6
		% (r)	0%	0%	33%	22%	44%	100%	5%		0%	33%	67%
	Tap	Count	20	11	0	0	0	31			8	11	12
		% (r)	65%	35%	0%	0%	0%	100%	16%		26%	35%	39%
	Stream, Lake, Scoophole	Count	0	3	5	18	58	84			24	28	32
		% (r)	0%	4%	6%	21%	69%	100%	44%		29%	33%	38%

(Source: Author's field work)

For instance, 58% of previous borehole users in Milenge had more than 1km to the water source and 79% of previous borehole beneficiaries in Nchelenge used to walk more than 1km distance. Compared with the findings from the current primary water source (Table 5.19 in Section 5.6.1), about three to five times more of the borehole users were forced to walk more than 1km to access their water sources. In fact, those previous borehole water source beneficiaries shifted to having their own water sources i.e. 33% of previous borehole users in Milenge and 50% in Nchelenge (see Table 5.64).

5.9.5 Community water supply dynamics

It is also important to elaborate on the community dynamic visually with respect to water source selection to understand users' preferences and/or acceptability. Figs. 5.23 and 5.24 thereby show the transition of community water supply selection in Milenge and Nchelenge, respectively. Arrows refer to the change of community water source selection from previous water source to current water source. All the directions of arrows are either to boreholes or HDWs (own or neighbours) because respondent households were using those water sources at the time of visit. The Numbers in the

Figure indicate the number of households counted in each transition from their previous to current water sources. For instance, 33 current borehole users had come from neighbours HDWs (n=3), streams (n=24), springs (n=5) and other boreholes (n=1) (see Fig. 5.23). From Fig. 5.23 it can also be seen that out of 48 current HDW owners in Milenge, about 30% of them shifted from other groundwater sources (n=10 from neighbours HDWs and n=4 from boreholes, respectively). The reasons for their shift from other groundwater sources to their own water source were derived from the fact that they found multiple benefits such as water quality, distance and hygiene purpose etc. rather than from a single reason.

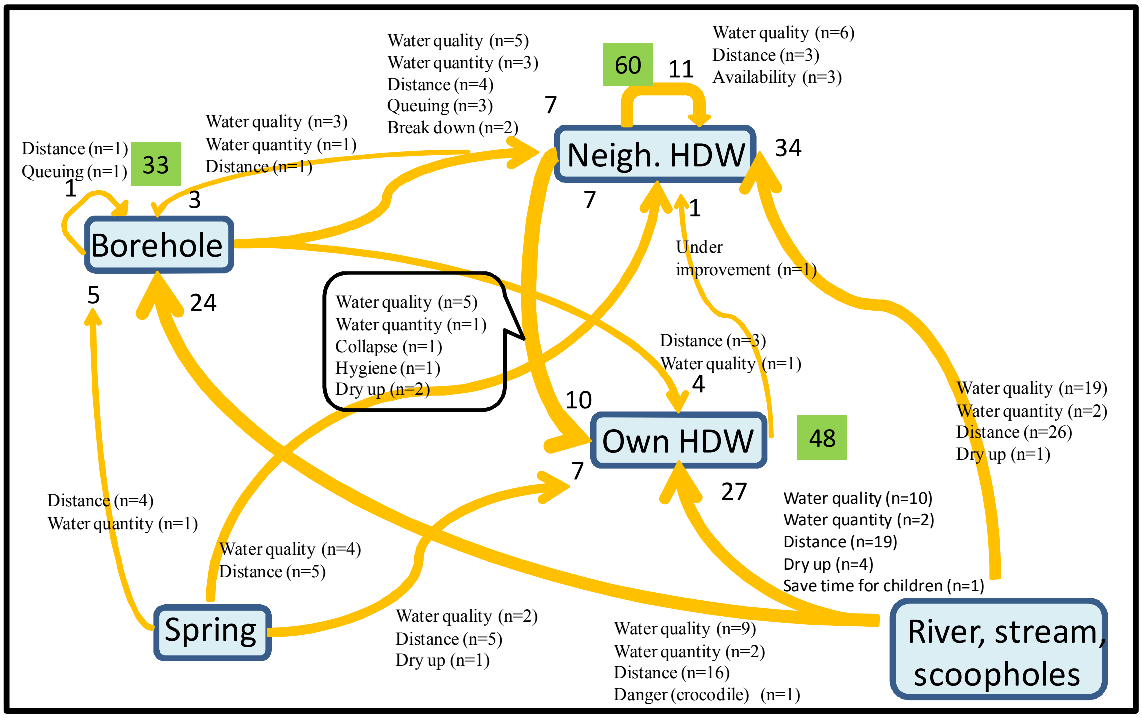


Fig. 5.23: Diagram of community water supply dynamic in Milenge

(Source: Author's field work)

On the other hand, it is also apparent from Fig. 5.23 that out of 33 current borehole users, about 90% of them relied on unprotected surface water rather than on another groundwater source (less than 10% (n=3) of them from neighbours' HDWs). It could be assumed that surface water was not the only available water source near borehole facilities, but rather they put a value on having their own water source based on their preference for water source selection. Box 5.16 shows one of the examples from a focus group discussion.

Box 5.16: Excerpts from focus group discussion with one of the *Not Protected* HDWs owner at Kakasu village, Itemba Ward

I have a well, and it was constructed a long time ago………I cannot purchase cement to protect my well from collapse but it has still been working well since 1960……….We were told that next year someone will come to construct a well furnished with a handpump in our village….I know it is easy to draw water using a handpump, but I will never leave my well. You know, my well is very near to my house and I can use water anytime even when my family members get sick……. I know that community wells have constraints like locking, queuing and expensive costs when break down happened…. So what is the point in me abandoning my well?

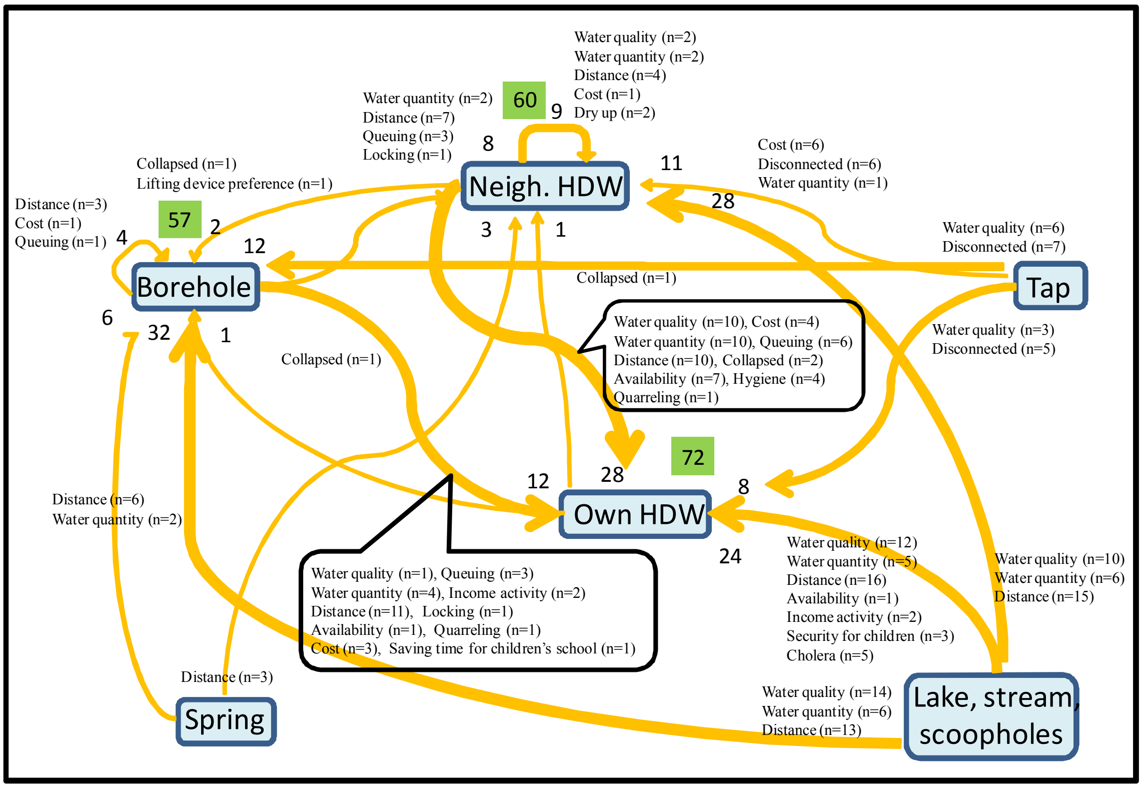


Fig. 5.24: Diagram of community water supply dynamic in Nchelenge

(Source: Author's field work)

Fig. 5.24 also illustrates that out of 72 current HDW owners, users had decided to construct their own wells rather than rely on boreholes (17%, n=12) or neighbours HDW (39%, n=28). Notably, it can be seen that over half of current HDW owners had moved from other groundwater sources. Their preferences for having a well combined a variety of perspectives. For example, the most powerful reason for a shift from borehole to having their own well was the distance (n=11) followed by water quantity (n=4), cost (n=3), queuing (n=3) and income activities (n=2) etc. This was supported by the finding in respect of the distance to the previous water source where less than 5% of previous borehole users could access a borehole facility within 500m of their premises (see Table 5.64). Meanwhile, the reasons for a shift from a neighbour's HDW to their own water source may provide further insight into their preferences for having their own water source. Interestingly, despite the fact that 75% of previous neighbouring HDW users could access their neighbours' water points within 500m (see Table 5.64), they cited 'distance' as one of the motivation for constructing their own well (n=10). This may be related to other reasons, such as water quantity (n=10) in that the shorter the distance to the water source, the greater the amount of water used (Table 5.30 in Section 5.6.11). They also put their value on water quality (n=10) and hygiene purposes (n=4). Box 5.17 shows an excerpt from a household survey.

Box 5.17: Excerpts from household survey with one of the *Not Protected* HDWs owner at Polen village, Itemba Ward

We used to go to the well which my friend has at her house to collect water. We had to use that water for all drinking, cooking, washing and bathing. I have 8 children in my home and water is never enough for such uses……especially, water for bathing was very limited so my kids could only bath every three days…I was kind of ashamed to use water from her well so many times…...That is why we made a decision to dig our well in 2007……..since then, we have not suffered any more from a shortage of water for daily usage and my kids can bath every evening.

Box 5.17 indicates how they gave importance to having water nearby with respect not only to securing their water availability but also to improving hygiene practice.

It was also noticeable that their motivation for moving from other water sources to their own water source was derived from concern about their children. For an example of this, one of the reasons for changing their water source from fetching water from a borehole (n=1 in Nchelenge) and stream (n=1 in Milenge) to constructing their own well was that of saving time for children commuting to school. Children were undertaking the role of drawing and carrying water from the source to their house to help their families. Box 5.18 shows an excerpt from a focus group discussion in Milenge.

Box 5.18: Excerpts from focus group discussion with one of the *Partially Protected* HDW owners at Npinduka Village, Chiswishi Ward

My family constructed the well in 2003. Until we had our well, we went to the stream to collect water but the place was very very far away from our house…………My daughter and my grand kids were forced to go to there which meant that the kids could not go to school on time or even could not attend the classes at all………..Now we can draw water from just there (her well) and even I can do it without asking my family members to help. So my grand kids are happy to be able to go to school every day.

Further, a significant difference between previous water sources and current water sources was that well owners could extend their water usage not only for consumption and/or hygiene purpose, but also for productive use. As in the excerpt in Box 5.13 at Section 5.8.3, they optimized use of their water source in order to earn some income. To be specific, one of the *Partially Protected* HDW owners in Chilongosh village, Nchelenge Ward sold plants (citrus, flowers, oranges and pines) then earned an annual profit of k1million (about US$222) as his subsidiary business. The other HDW owner at Kaseka village, Nchelenge Ward, utilized water from his well for his goats from which he earned about US$156 per year. Notably, these owners also had a strong interest in improving their wells to achieve more sustainable and safe water by using the profits that they made. This point should be highlighted in the Self Supply model as an alternative way of improving their water points rather than having total reliance on available loans or community funds.

To sum up, this Section 5.9 has looked into the key aspect of sustainable water supply, which is acceptability. Firstly, data of user satisfactions toward water quality, quantity, distance, queuing time, cost, reliability and technical sustainability were presented in a descriptive manner. Secondly, the association between user acceptability and water supply type was analysed by chi-square test. In addition, ownership status of water supply source was examined to see whether it could be a factor affecting user satisfaction. Further, data from previous water source and distance were presented in connection with the community water supply dynamics.

5.10 Chapter summary

This chapter has presented data collected over field work in Zambia for 6 months in

2010. The obtained data were enough to be statistically reliable and was collected by different methods in order to capture different perspectives and emphasise their validity and reliability. The researcher took all measures to assure the protocol and the documentation was enough for the trustworthiness of the data. Based on the data collected through technical survey, environmental investigation, household survey and key informant interview, analyses were carried out in connection with key research concepts and research questions, namely water quality and sanitary condition, accessibility, technical and environmental sustainability, cost-effectiveness and acceptability. In summary, the following key points emerged from the analyses presented below.

<u>Water quality and sanitary condition</u>

- The faecal contamination level from sampled HDWs decreased significantly with the level of HDW protection
- There was significant water quality improvement in *Protected* and *Partially Protected* HDWs done by trained artisans through the Self Supply model between April and August.
- Significant relationships between faecal contamination level and Sanitary risks were
    - Faeces within 10m of the well (*Not Protected* HDW in both Districts, *Partially Protected* and *Protected* HDW in Milenge)
    - Animals roaming around the well (*Protected* HDW in both Districts)
    - Where water can flow back into the well (*Not Protected* in Nchelenge, *Partially Protected* in both Districts)
    - Well cover insanitary (*Partially Protected* in Milenge, *Not Protected* in Nchelenge)

<u>Accessibility</u>

- The distance to water source was significantly different between private and public water sources rather than between HDWs and boreholes.
- Private HDWs were generally shared with extended families and/or neighbouring households although *Protected* HDWs owned by communities/institutions covered entire communities in as wide a sphere as the similar design of communal borehole facilities.
- Public water source users (conventional HDWs and boreholes) took considerably more time for water collection than private water source users in that queuing time

at the communal source and distance to the communal source were longer than for the private water source.

Technical and environmental sustainability

- Durability of lifting device (rope and bucket) was increased by using a metal bucket which was promoted in the Self Supply in Milenge rather than plastic container
- The frequency of handpump break down was from every month to more than once a year on average.
- Breakdown of handpump occurred frequently during the specific period of September and October, when HDWs users shifted because of water source dry up
- More than one-third of HDWs had experienced water drying up
- Bottom lined HDWs provided a sufficient water source for the whole year unlike the HDWs without linings

Cost-effectiveness

- The Self Supply model was more cost-effective than the communal model looked at from the view point of lifecycle project costs; this was because considerable hardware subsidies towards the conventional communal model are incurred by government or NGO/external support agencies.
- Lifecycle household costs of the communal model were much higher than that of the Self Supply model. However, the most common payment method for Self Supply is made exclusively by the owner's family members rather than by sharing the costs with neighbours.

Acceptability

- The level of user satisfaction for water quality increased in accordance with the protection level of HDWs with the exception of boreholes.
- Water supply source owned by communities/institution (both subsidised communal HDWs and boreholes) resulted in end user dissatisfaction in contrast with privately owned water supply sources (HDWs) which fulfilled fringe user satisfaction.
- No matter whether water sources were owned privately or publicly, community members were likely to be satisfied with their contribution towards the water source where individual/community members had invested their money rather than where subsidized water was provided as a giveaway communal model.
- Over half the current HDW owners changed their water source from other groundwater sources (neighbour's HDWs and/or boreholes), and their reasons for

that movement were underpinned by the fact that they put a value on having their own water source based on their preference for water source selection.

Chapter 6 DISCUSSION AND IMPLICATIONS OF FINDINGS

6.1 Chapter Outline

This chapter of the thesis discusses the key findings that emerged from the analyses carried out in the previous chapter. These findings are discussed in the context of this research and the reviewed literature in Chapter 3. In this chapter, the principal argument is discussed by addressing the research questions. The discussion covers the status of water safety (water quality and sanitary condition), accessibility, technical and environmental sustainability, cost-effectiveness and acceptability with respect to the types of water supply model that village dwellers use. An integrated water supply model for a sparsely populated rural area is proposed in Section 6.8. This model is based on the research findings, insights obtained during the field studies and the extant literature. The rural water supply model was looked into not only from the viewpoint of the micro-level (households demand and water supply model design), but also from the macro-interest of government and donor for policy development.

To recap, the aim of the research was to *determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective and acceptable water supplies for households in sparsely populated rural areas of Zambia*. The communal water supply model may not be likely to fulfil community demand, especially in sparsely populated rural areas, because the nature of the approach is communal so that they require higher delivery costs or significant amounts of energy on the end user sides. In contrast with such a communal model, the Self Supply model may be a viable approach to complement and bridge the gap left behind or from inadequate support by government or external support agency in rural areas by private water source improvement through households' investment. Thereby, the principal argument of the research was:

Reliance only on a communal water supply model limits the achievement of increased sustainable access to a safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in sparsely populated rural areas of developing countries for the purposes of increasing access and achieving sustainability.

The principal argument was examined by five key concepts in connection with the rural water supply models:

- Water quality and sanitary condition
- Accessibility
- Technical and environmental sustainability
- Cost-effectiveness
- Acceptability

The key concepts were broken down into the following supplementary research questions:

1) What impact do the water supply models have on the quality of water? What are the factors likely to affect water quality? What is the status of the sanitary conditions? What are the sanitary risks likely to affect the water quality? How does water quality change at the source and the point of use, and what are the contributory factors? (section 6.2)
2) What is the status of accessibility towards different water supply models? What are the factors likely to affect the accessibility in terms of distance and time? What is the status of per capita water use among different water supply models and how is this likely to be affected by accessibility? (section 6.3)
3) What is the status of the technical sustainability of different water supply models? What is the status of the water reliability of different water supply models? What are the factors likely to affect technical sustainability and water reliability? In what way are water supply models delivering operation and maintenance systems to the households/communities? (section 6.4)
4) What costs constitute lifecycle costs for different water supply models? How do lifecycle costs impact on project costs and household/community costs? When are the costs incurred? (section 6.5)
5) What is the status of acceptability towards water supply models for end users in terms of water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability? What are the factors likely to affect user satisfaction? How are user preferences/satisfactions in selecting a water supply model likely to affect the community water supply dynamics? (section 6.6)

The following sections address these research questions in accordance with the indicated sections. A wide variety of issues including technical, financial and social aspects are discussed. The focus is to critically assess the pros and cons of water supply model types by comparison between communal and Self Supply models.

6.2 Water Quality and Sanitary Conditions

This 'water quality and sanitary conditions' concept was described in Chapter 5.5 and was guided by the four underlying indicators:

- Water quality at source
- Protection features
- Sanitary condition and water quality
- Water quality at the point of use

The corresponding research questions are:
What impact do the water supply models have on the quality of water? What are the factors likely to affect water quality? What is the status of the sanitary conditions? What are the sanitary risks likely to affect the water quality? How does water quality change at the source and the point of use, and what are the contributory factors?

Water quality at source

Water quality as used in this study refers to drinking water. As explained in Chapter 4, surface water is not covered in this study. It was found from the study that a higher level of protection of a water source reduced the risk of microbiological contamination. More than 90% of the water collected from the boreholes was an acceptable level (<10FC/100ml) for drinking water. Also, water collected from *Protected* (improved) HDWs by trained artisans under the Self Supply model in Milenge showed significant water quality improvement compared with that of the *Not Protected* and *Partially Protected* HDWs (see Fig. 5.3). On the other hand, the results of water quality tests from the same kind of *Protected* HDWs in Nchelenge done by unskilled individual HH and from the subsidised communal model showed significantly less water quality improvement in comparison with Milenge (see Figs. 5.4 and Fig. 5.6). To sum up, the rank order among the different water supply models was as below if consideration is given only to the proportion having an acceptable level for drinking water quality in terms of microbiological water quality;

Communal *Boreholes*≧***Self Supply*** *HDWs*≧***Communal*** *HDWs* ≧***Owner*** *(Non-support) HDWs*

These findings from Milenge and Nchelenge suggest that the trained artisans under the

Self Supply model could provide a high level of protection from faecal contamination because there were no differences in water quality, (or sometimes even better results) than from the subsidized communal boreholes/HDWs which are counted as *Protected* water sources by the JMP definition (see Figs. 5.3, 5.4 and 5.7). According to the JMP definition (WHO and UNICEF 2006); a ***Protected* dug well** is a dug well that is protected from runoff water by a well lining or casing that is raised above ground level and a platform that diverts spilled water away from the well. A *Protected* dug well is also covered, so that bird droppings and animals cannot fall into the well. Also, the Zambian government defined a ***Protected water source*** as a borehole, a tube well, a jetted well and a hand dug well which met the following requirements; 30m distance from latrines, full lining, platform of concrete, drainage and handpump, or some other lifting device (NRWSSP 2007).

In comparison with those features of *Protected* water source, in this study, the "***Protected***" HDW under the Self Supply model in Zambia consisted of a well with an apron, raised parapet walls and top slab and drain. These also had a cover, which might be lockable, and used a rope pump, windlass or rope and bucket as the lifting device. *Protected* (improved) HDWs done by skilled artisans in the Self Supply model consist of bottom lining (although only two water points in Milenge) and top lining, rather than full lining whereas a *Protected* water source defined in the JMP and NRWSSP is one with lining all the way down. A bottom lining functions to prevent collapse from soil erosion when the groundwater level is up while top lining improves water quality by reducing the seepage back of dirty water from the surface into the well, and for reducing shaft collapse.

Further, the partial lining (top and/or bottom) helps well owners to save their money for spending extra costs of well lining in the middle part of the well. In addition, the widely used lifting device for *Protected* (improved) HDWs under Self Supply was still rope and bucket while subsidised communal water points were equipped with either a windlass or handpump. Nonetheless, quality of water from those *Protected* (improved) HDWs was comparable with the conventional communal boreholes/HDWs. It is important to highlight from the findings here that access to sustainable safe water could be achieved on the stepladder of improvement without waiting for the named protection features of JMP or NRWSSP. This finding was consistent with the other literature that discussed water quality of upgraded traditional water sources in Zimbabwe, Uganda and Zambia (Sutton 2004b, Morgan and Chimbunde 1996, WSP 2002, Tillet 2007).

It can be concluded that a Self Supply model where skilled artisans improve the access to water sources, would deliver safe water at a household level at a quality comparable to the subsidised communal water supply model, which is a borehole equipped with a handpump or subsidised full lining HDW with a windlass.

Protection feature

The above section discussed water quality and its relation to the water supply model. However, there is still the argument regarding the improvement level for HDWs. As outlined in Chapter 2, the Self Supply model was slightly different from one NGO to another. WaterAid had put their emphasis on the capacity development of local artisans in Milenge so that the most popular physical improvement of HDW was done by skilled artisans. Meanwhile, the approach of DAPP was to encourage rural dwellers to improve their own water sources by simple improvement, using local materials in parallel with behaviour change, rather than improvement by skilled artisans (although DAPP also trained local artisans and their work was about to start at the end of the researcher's field study). Therefore, this section looks at the significance of the improvement by rural dwellers in connection with the research question. ***"What are the factors likely to affect water quality?"***

In the latest JMP report (WHO and UNICEF 2010, p.34), an 'Improved drinking water source' includes sources that "by nature of their construction and or through active intervention, are *Protected* from outside contamination, particularly faecal matter. It means that there is no one generic solution for protecting water source from faecal contamination. It was found from the study that there have been water sources which were improved not only by skilled artisans, but also by individual households themselves (see Table 5.3 and Section 5.5.5). One of the types of protection work done by householders' initiatives was that they set up a wooden rack at a distance from their HDWs by themselves to avoid spilling water around and seeping back into the well. 50% of water collected from the wells equipped with the above rack showed as contamination-free and 25% had a low level of contamination (<30FC/100ml).

Another example of minor protection was the practice of putting local colourful clay on the mound around the mouth of the well to reduce water infiltration and also to avoid dust remaining around, as well as encouraging users to respect water points as owners' property for hygiene control. The test results showed that 50% of them were low level

(<30FC/100ml), 25% were medium level (50-100FC/100ml) and the other 25% had a high level (>100FC/100ml) of contamination. These findings implied that these small improvements related to hygiene practice work may reduce the risk of contamination rather than just being left without any action towards protection. However, most observed simple improvement work 'mounded ground around well mouth' was less effective in terms of microbiological water quality. Thus, it suggests that the results of being contamination-free were not derived from a single protection or practice but rather from multiple causes within physical protection, environmental conditions and hygiene practices. Further, it could be important to have intervention by skilled artisans in order to enhance the protection level and increase water source sustainability following the owner's improvement. Similar water quality improvements have been reported in many rural water supplies of developing countries (Sutton 2009b, Sutton 2006) though details of minor protections have been scantily discussed in the literature.

Sanitary condition and water quality

Results of water quality tests were examined in the above sections in conjunction with water supply type and physical protection features. This section will discuss the research questions "***What is the status of sanitary conditions? What are the sanitary risks likely to affect the water quality?".*** Although the hazards of HDWs and boreholes are different, the total risk score of a borehole was smaller than the one of a HDW (see Table 5.9). Further, the total risk score of HDWs presented that where the protection level was higher, there was a lower hazard score found in both Milenge and Nchelenge Districts (see Table 5.10). In Section 5.5.7, it was statistically proven that the higher total risk score of HDWs leads to a higher level of faecal contamination (see Table 5.12). The research found that 'animal faeces within 10m of the water supply facilities' led to a higher rate of microbiologically contaminated water in *Not Protected* HDWs in both Milenge and Nchelenge Districts, and *Partially Protected* and *Protected* HDWs in Milenge ($p<.05$, statistically significant*) (see Table 5.10).

Further, the findings that faecal contamination levels of *Not Protected* HDWs in Nchelenge correlated with 'animal faeces within 10m of the well' and 'can water flow back into the well', combined with findings that 'well mouth lower than surrounding ground' and 'well cover insanitary' were statistically correlated hazards with FC contamination levels at 95% levels of significance; this suggested that these hazards increased the risk of faecal contamination. In fact, these characteristics are typical factor of water contamination in rural water supply in many developing countries (Howard 2002). In other words, the sensitisation of households/communities to understanding the importance of sanitary conditions is a crucial precaution with respect to the mitigation of contamination risk since these hazards resulted from not only the inadequate protection features, but also from the lack of awareness among rural dwellers on how to prevent water contamination.

The sanitary inspections of the three types of HDWs (*Not Protected*, *Partially Protected* and *Protected*) in Nchelenge marked higher total risk scores than those of Milenge. These results suggest that they had an inadequate practice for creating awareness of what is safe water and how to achieve safe water by community sensitisation. A typical example of the difference in sensitisation activities in Milenge and Nchelenge was found from the studies as to whether they had clear roles and responsibilities for community members. In Milenge, WaterAid Zambia promoted Self Supply not only from grass-roots level (households), but also from the various stakeholders (political leaders, traditional leaders, civil servants and community based organizations).

By creating awareness of their roles and responsibilities with respect to the concept of Self Supply, they sensitised community members down to the grass-roots level without depending on subsidised external help. Although the approach to the Self Supply model in Nchelenge also involved trying to cooperate with other stakeholders such as Environmental Health Technicians (EHTs), Area Community Organisations (ACOs) and Village Action Groups (VAGs), unfortunately their roles and responsibilities were obscure which resulted in weak linkages beween them. Similar challenges have been reported in many developing countries around the world (Adejunmobi 1990, Bah 1992).

In fact, the household/community perception of the Self Supply model in Nchelenge was different from that in Milenge. Community members in Milenge recognized that Self Supply was an opportunity for anyone interested in achieving safe water to access such a supply by improving the environment of the water source based on their decisions and investment. On the other hand, some of the rural dwellers in Nchelenge had expected to receive cement for their water source protection through the Self Supply model. In Nchelenge, coverage of access to sustainable safe water might have been accelerated significantly if they could have reduced the sanitary risk by knowledge sharing through sensitisation because they had already invested their own money at the grass-roots level customarily to physically construct and protect their water sources.

In fact, small improvements initiated by householders themselves (see Section 5.5.5) were mostly done in Nchelenge so they already have motivation towards accessing safe water at the grass-roots level. This point was also underpinned by the NGOs side through the key informant interview where it has been said

"*Self Supply is not just the improvement of water points but it has other surrounding features or the whole package of Self Supply should include of course water, health and hygiene and how they need to treat the water and the connections between water points and livelihoods, health and other things.*"

(Mr Mubyana Munyangwa, Africare)

Water quality at the point of use

This section discusses water quality at household storage level and the practice of household water treatment in order to look into any change of water quality. The research found that over half (58%) of water sampled from household storage resulted in worse water quality in comparison with that sampled at source (see Fig. 5.12). The reasons for water quality deterioration can be considered in two phases: one is in the process of carrying water from source to house, and the other is the storage condition of water at the house. Some authors have also raised concerns about the contamination risk from source to point of use (Wright 2004, Clasen *et al.* 2009). Women and children were the dominant people for drawing and carrying water for their family usage and they carried the water by putting the water container on top of their head from source to house. While it was just nearby from their house for water point owners, some non-water point households needed to walk to fetch water, especially those relying on the communal water point. In fact, in Section 5.5.11, it was statistically proven that water quality at the point of use became worse as the distance from house to water source increased (see Table 5.18).

One of the explanations for the relationship between distance and water quality change from source to point of use is that rural dwellers might store water for a long time if their house is not close to the water source. The researcher has faced the situation that one of the respondents of the household survey asked us to draw water instead of her because she had had no water since the day before. The distance to the nearest water source was 1km away from her house so that she was used to asking any passing strangers to help her every three days. This case implied that people might store water for a long time if the location of the water source was inconvenient to access, and it could result in an increased risk of deterioration of water quality. Although in general storing water for a while is effective in reducing the risk of gastrointestinal diseases caused by bacteria which are attached to suspended solids, through natural sedimentation (Skinner 2003, WHO 2006), rural dwellers might scoop water from the bottom of the storage if the water is limited. Also, the storage condition of water at the house was an important factor to consider in the change of water quality from source to use. One of the risk hazards of household storage, "water container has wide mouth/opening" had a statistical association with the level of faecal contamination (see Section 5.5.10). This suggested that there might be an increased risk of contamination by some intrusion or direct touch by dirty hands if the water container had a wide mouth/opening.

Furthermore, 80% of the sampled water had significantly reduced faecal contamination at household level where they used liquid chlorine as household water treatment. 20% of the sampled water where they used chlorine at household storage mitigated the level of contamination to low (<10FC/100ml) whilst 60% of sampled water applying chlorine at household achieved contamination free water. Similar water quality results have been reported where rural dwellers have done water chlorination at household storage in Ethiopia (Sutton and Hailu 2011). To sum up, the test results imply that the faecal contamination risk increased during the process of transportation and storage at the households, but the risk could also be mitigated by using household water treatment. Although the HWT cannot reduce the distance to the water source, change the ownership status of the water source or increase water use per capita per day physically, the use of the HWT can support any types of water supply models (communal and Self Supply) in terms of water quality at the point of use.

Section 6.2 has examined water quality and sanitary condition with respect to two different water supply models, those of communal water supply and Self Supply. These results imply that the Self Supply model in Nchelenge had a limitation for access safe water where DAPP encouraged rural dwellers to improve their own water sources by simple improvement using local materials in parallel with behaviour change, rather than by improvement by skilled artisans. On the other hand, the Self Supply model in Milenge by WaterAid could support the acceleration of access to safe water where trained artisans improved the traditional private water sources in addition to sanitary practices carried out by water source users themselves. The findings imply that water collected from boreholes had a good water quality for drinking water, but also had the risk of contamination at the point of use.

6.3 Accessibility

This 'accessibility' concept was discussed in Chapter 5.6 and was guided by the three underlying indicators:

- Distance to primary water source
- Water collection time and
- Per capita water use

The corresponding research questions are:

What is the status of accessibility towards different water supply models? What are the factors likely to affect the accessibility in terms of distance and time? What is the status of per capita water use among different water supply models and how is this likely to be affected by accessibility?

<u>Distance to primary water source</u>

In this study, water sources were categorized as 'primary water source' and 'secondary water source'. Primary water source means that users go there to draw water for drinking and other water usage (cooking, bathing and washing etc.), and 'secondary water source' was defined as the one that they use when the primary water source is not reliable and/or is used to complement the primary water source in the same day. "Access to safe water supply" means that people can access water **within a distance of 500m from the point of use** (NRWSSP 2007). In Section 5.6.1, it was found that a fifth or a third of HHs collecting water from boreholes (18% in Milenge and 34% in Nchelenge, respectively) had to walk more than 500m to draw water compared with no more than 15% of HHs using water from any type of HDWs (see Table 5.19 and table 5. 20).

Further, accessibility to HDWs in Nchelenge was better than that in Milenge. For instance, over 90% of *Not Protected* HDW users in Nchelenge were able to access water within 250m compared with 60% of *Not Protected* users in Milenge. The higher population density in Nchelenge (15.1 persons/km^2) in contrast to Milenge (5.9 persons/km^2) may have reduced the distances to neighbouring houses and water points. On the other hand, more than 30% of borehole users in Nchelenge had a distance of more than 500m compared with about half those users (18%) in Milenge. This may be explained by the nature of borehole construction sites. The borehole construction sites were alongside the paved road because the construction machine had a limitation on movement into the bush. However, not all the houses of village dwellers in Nchelenge were located on the roadside because of the higher population density than that of Milenge.

Moreover, their distance to a primary water source was clearly affected by the ownership status of the HDWs. In Section 5.6.4, it was statistically proven that access to a private HDW was a shorter distance than to public (communal) HDWs (see Table 5.22). It clearly showed that accessibility in terms of distance to private HDWs for end users living in a sparsely populated rural area was more convenient than that of boreholes and HDWs owned as a community commodity. By contrast, a communal water supply model contradicts the Zambian government standard of serving 250 people (≒ 40HH) within a distance of 500m from the point of use because actual rural settlements have such low population density i.e. (1HH/km^2 in Milenge and 3HH/km^2 in Nchelenge) that the standard cannot apply.

<u>Water collection time</u>

Accessibility includes not only 'distance', but also 'time' as different dimensions for evaluating its value. A water collection time comprises two stages in this study: time for the round trip from their house to the water points and time spent in queuing at water points in a day. It was apparent from the study that the borehole users were queuing for an average of 40minutes, or more than 2.5 times as long as the HDW users who wait an average of 14minutes (see Table 5.23). These findings that drawing water from borehole water points took a long time because of considerable distances and queuing times, combined with the results that communal HDW water point users also took a long time to fetch water, suggested that privately owned water points could provide more opportunity to access water with relatively less distraction of distance and/or time in contrast to the conventional water supply models. This finding was consistent with what has been noted in the latest JMP report (WHO and UNICEF 2010) and studies by Cairncross (1987). Similar lessons emerging from Drawers of Water Ⅱ presented that in practice, households members in rural East Africa were forced to choose between bearing costs in terms of potential ill-health (unprotected water source) or through large expenditures of time and effort (Thompson *et al.* 2001).

<u>Per capita water use</u>

The quantity of water delivered and used for households is an important aspect of domestic water supplies, which influences hygiene and therefore public health (Howard

2003). This study revealed that the average value of per capita water use among HDW users was 28.50 lcd whilst the average value for borehole users was 17.69 lcd (see Table 5.26). Although it is acknowledged that they may also consume water at school, work in the field, the sampled borehole users had not reached the Zambian standard level at home, whilst HDW users could access more than the minimum amount of per capita water use under the definition of water supply coverage in NRWSSP (2007) that access to safe water supply should cover a **minimum of 25lcd** of water from a *Protected* source. In fact, out of 109 borehole users (HH), 41 HH used another water source to complement an inadequate supply of water collected from a borehole every day which led to considerable energy and time in collecting water from multiple water sources (see Table 5.27). Also, the volume of per capita water used ties in well with the water usage. As captured by Table 5.6 in Section 5.4.1, HDW users took up sufficient amounts of water for other activities, such as small gardening, animal watering or brick making as productive uses. In fact, recently greater attention has been paid to multiple water use by individual households in rural water supplies (Rivera 2010, Koppen *et al.* 2009).

Further, accessibility significantly impacts on per capita water use. In Section 5.6.11, it was statistically proven that the distance they walked to draw their water led to a lower amount of water used for their daily consumption and hygiene purposes (See Table 5.29). In other words, water use per capita per day was increased as the distance to water source decreased. This is indicative of the fact that rural households compromised in terms of water quantity and accessibility. This viewpoint has been well documented in the literature. Howard and Bartram (2003) highlighted that the level of health concern is very high if total water collection time is more than 30min or 1000m.

Section 6.3 has examined accessibility through comparison between communal water supply (borehole equipped with handpump and subsidised communal HDW) and Self Supply (several protection types of HDW). These results imply that communal models faced fundamental issues in sparsely populated rural areas because a sizable number of rural dwellers were forced to walk beyond the Zambian government standard of serving 250 people within a distance of 500m from point of use. On the other hand, traditional private HDWs, on which the Self Supply model has focused, were generally located within their premises, and such closeness benefited the community in terms of increased per capita water use and saved water collection time.

6.4 Technical and Environmental Sustainability

This 'technical and environmental sustainability' aspect was analysed in Chapter 5.7 and was guided by three underlying indicators:

- Technical sustainability
- Environmental sustainability
- O&M system

The secondary research questions are:

What is the status of the technical sustainability of different water supply models? What is the status of the water reliability of different water supply models? What are the factors likely to affect technical sustainability and water reliability? In what way are water supply models delivering operation and maintenance systems to the households/communities?

Technical sustainability

The definition of 'technical sustainability' refers to the functionality of lifting devices in this study. Types of lifting device found in the study sites were rope and bucket, windlass, rope pump and handpump. The most prevailing lifting device fitting with the HDWs was simply a rope and bucket. The study found that the longevity of rope and bucket depended on the material used for the container rather than on the number of users. For example, it was statistically proven that the plastic containers mostly used at *Not Protected* HDWs led to a lower lifespan when compared with the metal buckets mostly used at *Protected* HDWs or *Partially Protected* HDWs where owners had purchased them from artisans through the Self Supply model (see Table 5.33). Although the number of water points using windlasses was small, their durability was better than that of the rope and bucket because of the structure. Simple use of the rope and bucket resulted in more wearing away of the edge of the well when compared with rolling up by windlass. On the other hand, once a windlass was broken, it was prone to be abandoned without repair when considered as a community commodity.

The Self Supply model in Nchelenge established the production of rope pumps by a local mechanic and 7 rope pumps had been sold to the public since 2009, whilst 3 of them were operational at the time of the visit. The lifespan of rope pumps may be related to the number of users. Where only 2 school staff had permits for using the rope pump fitted at a school well, the well had no experience of breakdown. Meanwhile, one of the HDWs equipped with a rope pump serving two entire villages experienced a breakdown every week. This indicated that a rope pump may not be suitable for a communal well but is better when being managed by a small number of households. In fact, some authors have also raised concerns about the scale of community using the Rope Pump for lifting water (Holtslag and Mgina 2009, Sutton and Hailu 2011). The high rate of rope pump abandonment (57%) was indicative of the fact that this rope pump production was in a pilot stage under DAPP so a very limited number of people were trained to operate and maintain the facility.

The frequency of handpump breakdown was from every month to more than a year, and the frequency was related neither to the number of borehole users nor to the number of years in operation. It was noted, however, that break down of handpumps occurred frequently in the dry season. The findings that handpumps broke down frequently during the dry season combined with the finding that more than one-third of HDWs had experienced water drying up, suggested that they had been overloaded by extra users moving from unreliable water sources during the dry season resulting in non-functioning handpumps. Apart from the frequency of breakdown, selection of material for a handpump was also an important factor when fulfilling the community preference. In Zambia, the most prevalent handpump type was the India Mark II using galvanized steel riser pipes (JICA 2007), which became corroded or left the water with a rusty taste because of the acidic groundwater. Thus, community members complained about the taste and brownish yellow colour of the water collected from a borehole equipped with an India Mark II type of handpump. This statement ties in well with the level of borehole user satisfaction.

Furthermore, although borehole sites experienced less water source dry up, the downtime of the lifting device (handpump), was also a crucial issue for access to water. Reliability could be threatened where the lifting device was non-functional, which made water inaccessible even when there was water in the borehole. According to the surveys with borehole caretakers, the handpump downtime at borehole sites was from a few days to over six months depending on the availability of pump mender, spare parts and amount of collected contribution. Similar reliability issues have been reported in Ethiopia and Tanzania that water is in the borehole but inaccessible for a long period because the boreholes are equipped with non-functioning handpumps (Sutton and Hailu 2011, Berg *et al.* 2009). On the other hand, it was found from HDW owners' survey that they could replace the rope or bucket on the same day or day after when the break down happened, especially where a local shop held those in stock under the private sector involvement in the Self Supply model (see Box 5.10 in Section 5.7.6).

Environmental sustainability

Environmental sustainability refers in this study to water source reliability. To access safe water **every day of the year** is one of the criteria for water supply coverage (NRWSSP 2007), and adaptability with respect to the fluctuation of groundwater is an important factor as well as sustainable water supply technology with O&M. It was found from household/caretaker surveys that only one borehole site (out of 37 sampled boreholes) had the experience of inaccessibility to water during the dry season because of an inadequate depth of borehole and not because of a non-functioning handpump. But on the other hand, the frequency of drying up was a challenging issue among HDWs. For instance, more than two thirds of *Not Protected* HDWs had dried up during the dry season (80% in Milenge and 59% in Nchelenge) (see Table 5.36). With protection, HDWs can generally be constructed to higher depth, which will in turn contribute to the environmental sustainability of the water source.

The study looked into the association between frequencies of water source dry up and bottom lining, because where there is no lining at the bottom part of the wells, they may collapse by soil erosion from the bottom part of the well wall when the groundwater level is up. In Nchelenge, there were 43 bottom lined HDWs (partially or fully) with 4 *Not Protected* HDWs (10% of *Not Protected* HDWs) followed by 20 *Partially Protected* HDWs (29% of *Partially Protected* HDWs) and 19 *Protected* HDWs (56% of *Protected* HDWs). Where they had no bottom lining, nearly half (46%) of the HDWs dried up during the dry season every year compared with less than a third of the HDWs with bottom lining (28%). In section 5.7.4, the study found that frequency of water source dry up had an association with the bottom lining ($p<.05$, statistically significant) (see Table 5.37). These findings suggested that bottom lined HDWs were able to provide a sufficient water source every day of the year whilst those HDWs without linings could not.

O&M system

As highlighted in Section 5.7.6, there are similar approaches existing between communal water supply and Self Supply model delivery models regarding post construction support. In the communal model, the principle of the Sustainable Operation and Maintenance Project (SOMAP) is that of cost sharing by communities, sustainable supply chains, O&M mechanisms, choice of appropriate technology and capacity building. Meanwhile, the following components are the core of a Self Supply model (Sutton 2009a): technology/technical advice, financial mechanisms/markets, enabling policy and private sector capacity. The concept of Self Supply is to support a water supply at household/community level to enable them to fulfil their demand incrementally by building blocks for a sustainable environment. Hereby, the Self Supply model originally embedded the O&M by providing software model components. These models for the post construction period are crucial for a rural water supply strategy, and the case of Nchelenge could be a potential future model in that they have integrated human resources (i.e. local artisans and pump menders) in both communal water supply and Self Supply models.

Section 6.4 examined the technical and environmental sustainability to look at overall reliability. The communal model using handpump had little experience of water source dry up although downtime of the handpump was a serious issue because the community could be inaccessible even if water was there. This situation might be improved by skilled labour training and/or supply chains of spare parts, but fundamentally almost nowhere had the practice of contribution from the community for operation and maintenance. By contrast, materials or devices used in traditional water source improvement were simple and locally available, and the practice of bottom lining showed that dry up of water source could be preventable.

6.5 Cost-Effectiveness

This 'cost-effectiveness' aspect was discussed in Chapter 5.8 and was guided by the two underlying indicators:

- Lifecycle cost
- Cost time frame

The secondary research questions are:

What costs constitute lifecycle cost for different water supply models? How do lifecycle costs impact on project costs and household/community costs? When are the costs incurred?

Lifecycle cost

Although a sustainable financial mechanism is one of the key factors for achieving the MDG water target, current rural water models in developing countries are almost donor dependent, and this might mean slow progress towards the MDG target unless it is understood that the true costs include not only capital hardware and software costs but also O&M, and post construction costs. The lifecycle costs can be broken down into two dimensions: those with 'project costs' which are generally met by the government or an NGO/external support agency and 'household/community costs'. Various studies have highlighted the fact that analysis of the costs, especially O&M, rehabilitation and replacement costs, provides some useful insights into the lifecycle costs (Berg *et al.* 2009, Sutton and Muluneh 2009). It is apparent from this study that the communal water supply (borehole) model was costing hardware components in the lifecycle project costs rather than including any software component programme activities in contrast with the Self Supply model which was made up exclusively of software components in the lifecycle project costs (see Table 5.39). This could be explained by the fact that the nature of the water supply model was that the Self Supply encouraged households/communities by building blocks for an enabling environment as a priority over hardware. On the other hand, the software component programme in the communal model was subsidiary to the provision of capital subsidized hardware, which was a borehole with handpump.

It was also found that the software component costs of the Self Supply model were about three times greater than those of the communal model (see Table 5.42). Despite this fact, the results of the total lifecycle costs of the conventional communal model including hard/software were about three times those of the Self Supply model. This indicates that the hardware component costs of the communal model using a borehole equipped with a handpump were more than the costs of the software activities of the Self Supply model. If the costs are simply compared, aside from the levels of water supply model, these findings suggest that the Self Supply model was more cost-effective than the communal borehole model from the viewpoint of lifecycle project costs because considerable hardware subsidies towards the communal model were met by government or NGO/external support agencies.

The 'household/community costs' were considered for the communal water supply model including O&M and some portion of a contribution towards the capital cost. For example, in Zambia, as a new initiative, the Sustainable Operation and Maintenance Project (SOMAP) for a rural water supply has been piloted and adopted into the policy alongside the conventional communal model. One of the principles is that of cost sharing by communities: communities are expected to contribute 5% of the capital costs and 5% of rehabilitation and replacement costs and 100% costs for O&M (NRWSSP

2007). On the other hand, the pilot Self Supply in Zambia delivered a support to beneficiaries (households/communities), and beneficiaries used their own investment to improve their traditional water sources. In other words, households/communities paid towards capital and O&M hardware costs in contrast to the communal model. As an example of the sharing of capital costs by communities under the subsidised communal model, one way of the calculating per capita cost was simply to multiply 5% of the capital cost. In this case, the lifecycle community/household cost was about US$1.16-1.53/person/year. Alternatively, about US$375 was also proposed as a contribution from the communities. In this case, the community cost became about US$0.75-0.99/person/year (see Table 5.43)

Meanwhile, the average cost of attaining an improved status (well with an apron, raised parapet walls and top slab, top lining, drain, lockable cover and windlass) under the Self Supply model was about US$160, and furthermore they had already invested their money in order to construct a water source by using about US$50. Notably, these capital and improvement costs were rarely shared by beneficiaries although the lifecycle community/household cost analysis became US$0.20-0.27/person/year in the case of the Self Supply model. But rather, they were invested in by individual owners or their families despite the fact that they shared their water source with neighbouring households. These findings pose the question as to whether a Self Supply model is likely to be rejected by households/communities because of the need for a higher amount of investment towards water access? In fact, baseline survey in Milenge (Zulu Burrow 2008) indicated that 97% of the people in the surveyed areas earn annually less than ZMK5,000,000 (≒US$1,250) while 67.8% earn less than ZMK1,000,000 (≒US$250). It implies that they use a significant portion of their income for having their water source. With regard to community contribution, for instance, the Self Supply pilot in Uganda brought about a cost effective upgrading of water supply models at 41 water sources with community contribution amounting to approximately 40% per water source (Joel 2009). It was necessary to monitor this alongside the financial mechanism in Zambia, which was an on-going revolving loan fund in the pilot Self Supply project by WaterAid in Milenge during the period before harvest, when cash was very hard to come by. Over 40 traditional water sources were already improved or even newly constructed by trained artisans within the Self Supply system at the time of the visit and those were financed by the households/communities using loans (fully or partially).

Cost time frame

The first year cost of project implementation is required to be met by government or external support agencies because the capital cost is the greatest proportion of the lifecycle costs for both communal water supply and Self Supply models. However, the government will not meet the cost for minor maintenance costs in both models so communities/households need to meet the operation and maintenance costs. Further, these tables imply that the community is clearly required to contribute annually for sustainable O&M, and should also consider the need for saving beyond the annual operation and minor maintenance costs to prepare for future replacement/rehabilitation costs. However, most of the visited communities had hardly saved money for future repair costs, but rather expected future subsidies from donors. Similar cases have been reported by Whittngton *et al.* (2009) that the community management model for rural water supply in Ghana, which is almost entirely a donor funded capital financing model, has faced difficulty in collecting tariffs for O&M since the rural community may well be justified in believing that future capital and repair subsidies will be forthcoming from donors, NGOs and higher levels of government.

Section 6.5 has examined the cost-effectiveness between communal and Self Supply models using lifecycle cost analysis. The results imply that the Self Supply model was more cost-effective than the communal (borehole) one for government or external support agency because the major project costs of the Self Supply model were for software components and these costs were significantly less than the hardware costs which were the major part of communal model. In addition, cost per head for the community/household of the Self Supply model was more cost-effective than the communal model if the calculation was based on the assumption that the community shared the costs. However, private water source owners practically met all the cost themselves and there was very little practice of community contribution on the ground.

6.6 Acceptability

This 'acceptability' aspect was described in Chapter 5.9 and was guided by the two underlying indicators:

- User satisfaction
- Community water supply dynamics

The secondary research questions are:

What is the status of acceptability towards water model options for end users in terms

of water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability? What are the factors likely to affect user satisfaction? How are user preferences/satisfactions in selecting a water supply model likely to affect the community water supply dynamics?

User satisfaction

The viewpoint of the user is very little understood and decisions are prone to be based on the macro-interest of the government or donor. According to informal discussion with Dr Sally Sutton, that is why in parts of India the government thinks that they provide almost full water coverage but less than 50% are using it in actuality. Some authors have also raised concerns about the possible impact of user satisfaction on the sustainability of rural water supply (Breslin 2003, Sutton 2002, Thompson *et al.* 2001). As captured by Table 5.47, a variety of concepts (water quality, water quantity, distance, waiting time, cost, reliability and technical sustainability) were measured for satisfaction levels with respect to water supply models. The level of user satisfaction for water quality increased in accordance with the protection level of HDWs with the exception of boreholes. The differences between user satisfactions regarding water quality among the different protection types of HDWs were evident in that many people were unlikely to be happy about the appearance of well-head protection and were likely to be suspicious about the quality of water from *Not Protected* HDWs.

Meanwhile, in spite of the highly protected structure of boreholes with handpumps, user satisfaction with the water quality from boreholes was dismal. This phenomenon was depicted in the Box5.14 in Section 5.9.2, showing that user satisfaction for water quality was influenced not only by the level of faecal contamination but also by preferences such as dislikes of an iron taste or colouring, no matter whether or not they were harmful to health. This finding was consistent with what has been reported in the literature. WHO (2006) and Howard (2002) noted that user preferences in water quality were important in sustaining water supply models.

In Section 5.9.2, user satisfaction about the amount of water available showed that user satisfaction for water quantity was likely to be related to water supply models in both Milenge and Nchelenge Districts. Underpinning it was a significant relationship between per capita water use (lcd) and the water supply types, and thereby user satisfaction was dependent upon the amount of water that they could draw from their primary water source. Hence, about 20% of responding households (87HH) relied on a second water source to complement the inadequate amount of water available from their primary water source (see Table 5.27 in Section 5.6.9). This forced households to use additional effort and time in drawing water from multiple water sources compared with the single source users where they could rely on one water source to fulfil their demand.

User satisfaction about the distance to a primary water source showed that when the distance to the water source was over 500m, user satisfaction decreased dramatically (see Table 5.51). This was also related to the ownership status of the water source. In comparison with the private water points that were generally located within their owners' premises or neighbours' water points, a public water source might be a considerable distance away because of the nature of a community commodity. This indicated that user satisfaction about the distance to the water source was influenced not by water supply type but rather whether the water supply source was private or public i.e. Self Supply or Communal model. This phenomenon was found in user satisfaction about queuing time at a water source. It was statistically proven that where water sources were owned by a community, there was a lower level of satisfaction in contrast to that of the private water sources (see Table 5.56). This was evident from Table 5.25 in Section 5.6.7 that, for instance, the water collection time from *Protected* HDWs owned privately and shared in Milenge was half of that from *Protected* HDWs owned by the community or institution where it took over 2 hours to collect water.

User satisfaction in terms of contribution cost indicated that user satisfaction regarding contribution was likely to relate to water supply models in Nchelenge (see Table 5.53). As discussed in Table 5.59 at Section 5.9.3, no matter whether water sources were owned privately or publicly, community members were likely to be satisfied with their contribution towards water sources where individual/community members had invested their money rather than where subsidized water was sourced as a giveaway. User satisfaction as for reliability with both technical sustainability and environmental sustainability was likely to inversely relate to the frequency of lifting device breakdown and the frequency of water source dry up.

<u>Community water supply dynamics</u>

Water source selection by a community is not a static behaviour as there exists a community dynamic alongside any change of the water situation in the community. It was found from Fig. 5.23 and Fig. 5.24 (see Section 5.9.5) that about 20-50% of current private HDW owners had shifted from other groundwater sources in both Milenge and Nchelenge. Their preference for having their own well came from a variety of perspectives. For example, the most powerful reason for shifting from a borehole to their own well was distance (n=11) followed by water quantity (n=4), cost (n=3), queuing (n=3) and income activities (n=2) etc. Similar behaviour patterns have been reported in many rural water supplies of developing countries (Addo-Yobo 2005, Jong 2010). Meanwhile, the reasons for a shift from reliance on a neighbour HDW to having their own water source may provide further insight into their preferences for, or value in having their own water source.

Interestingly, despite the fact that 75% of previous users of neighbours' HDWs could access their neighbours' water points within 500m, they cited 'distance' as one of the motivations for constructing their own well (n=10). This factor of 'distance' may be related to other reasons, such as water quantity (n=10) in that the nearer they were to the water source, the more their per capita water use increased ($p<.05$, statistically significant) (see Table 5.29). Further, they put their value on water quality (n=10) and hygiene purposes (n=4). It was also noticeable that their motivation for moving from another water source to their own water source was derived from saving time and/or productive uses which were unlikely to be achieved by using the conventional communal water sources. Regardless of the placing of the formal handpump sources and/or taps, these movements towards using informal water sources are typical behaviour in many developing countries (Jong 2010, Kasrils 2001). The findings highlight the value householders attach to ownership status of the water point, even if it required their own private investments, which is in line with the concept of the 'tragedy of the commons' (Hardin,1968,).

This indicated how individual households put their value on having their own water source and using their investment voluntarily without a subsidy from the government. In other words, supporting these demands from the community members by the Self Supply model fostered cross-cutting issues of MDGs as well as NRWSSP. For instance, having or accessing a water source closer than the communal water source would help to ease the burden of carrying heavy water containers on their heads every day, especially for women and children. This would even apply to the people who are suffering illness such as HIV/AIDS in that the Self Supply may provide options to save their time and energy, and further to generate income activities by using water for small scale gardening, livestock watering and brick making. This HIV/AIDS issue is one of the most concerning in that heightened illness and deaths arising from HIV/AIDS have dire consequences on household income and enormous consequences for the Zambian economy (NRWSSP 2007).

This section 6.6 has examined user acceptability by comparative assessment of communal and Self Supply models. These findings imply that households had relatively higher satisfaction for traditional water sources than communal water sources apart from issues of technical sustainability and reliability. This tendency could be explained by the ownership status that where a private family owned a water source with sharing neighbours they put their value into the source and recognised it as property. This could not be seen in the communal water supply models, but rather that communal water sources led to constraints such as queuing, distance and restriction (contribution, locking etc.). In fact, the community dynamics for water source selection proved that the households found value in having their own water source.

6.7 Principal Argument

The previous sections discussed the various aspects of water model by responding to the research questions in order to test the principal argument. The principal argument that directed this study is:

Reliance only on a communal water supply model limits the achievement of increased sustainable access to a safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.

The principal argument directed the thesis towards addressing the research aim which is *to determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective, and acceptable rural water supply model for households in sparsely populated rural areas.* It is important, therefore, to integrate the research findings in order to confirm or reject the principal argument. Thereby this section looks into the water supply models by incorporating the various key concepts.

It was found from the data analyses that different water supply models contributed to the key concepts (water quality and sanitary conditions, accessibility, sustainability, cost-effectiveness and acceptability) in varying degrees. The degree of water supply level was dependent on the extent to which the water supply model met a set of key indicators or norms.

In the extant literature, the topic of a water service ladder and a scoring system for a water supply model was discussed (see Fig. 6.1 and Fig. 6.2). The ladders of water services indicate the differences in the quality of the water supply model. In the WASHCost water service delivery ladder, they proposed a service ladder of five tiers from non-service to high-service based on five indicators, namely quality, quantity, accessibility, reliability and status (see Fig. 6.1). Meanwhile, Carter (2006) designed a scoring system for water supply models based on the five characteristics (quality, access, reliability, cost and management), and the scores for a given water supply model were then added up to give an overall score, which could range from 0 to 10 with equal weights for each characteristic.

These tables have been drawn up using assumptions linked to technology types. For instance, a high level service in Fig. 6.1 is essentially piped water into people's houses which is equivalent to a score of nearly 10 in Fig. 6.2. On the other hand, a totally unimproved 'traditional' distant, surface water supply source (with no protection) should score close to zero in Fig. 6.2 which is comparable to 'no-service' in Fig. 6.1.

In the context of a sparsely populated rural area, the water supply models where this study was conducted in Milenge and Nchelenge Districts of Luapula Province would be subject to the water supply model of sub-standard to standard levels on the WASHCost ladder. In fact, the studies of Carter (2006) when investigating options for the Self Supply model in Uganda noted that the overall scores of both a communal water supply and a Self Supply would be 3 to 6 in a scoring system of 0 to 10.

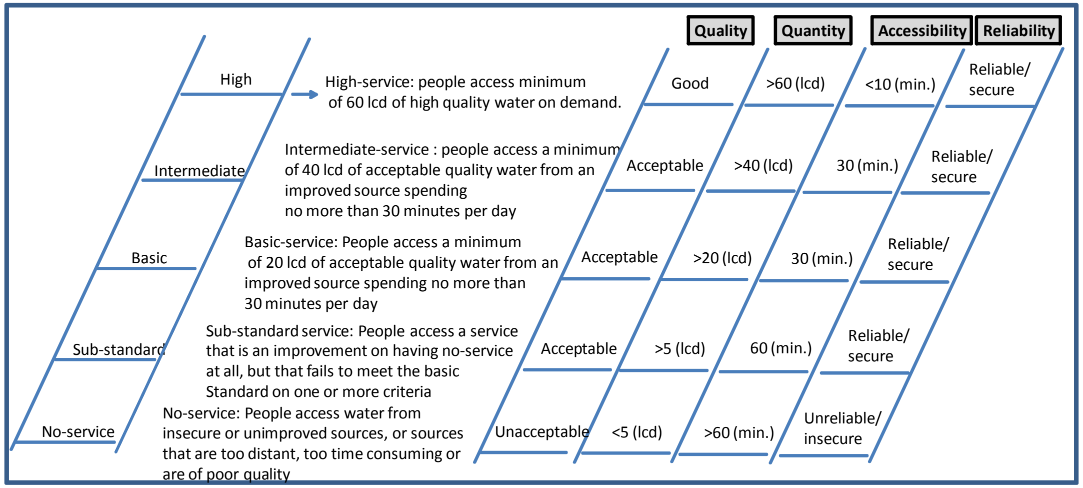


Fig. 6.1: WASHCost water service delivery ladder

Source:Moriarty et al. (2010)

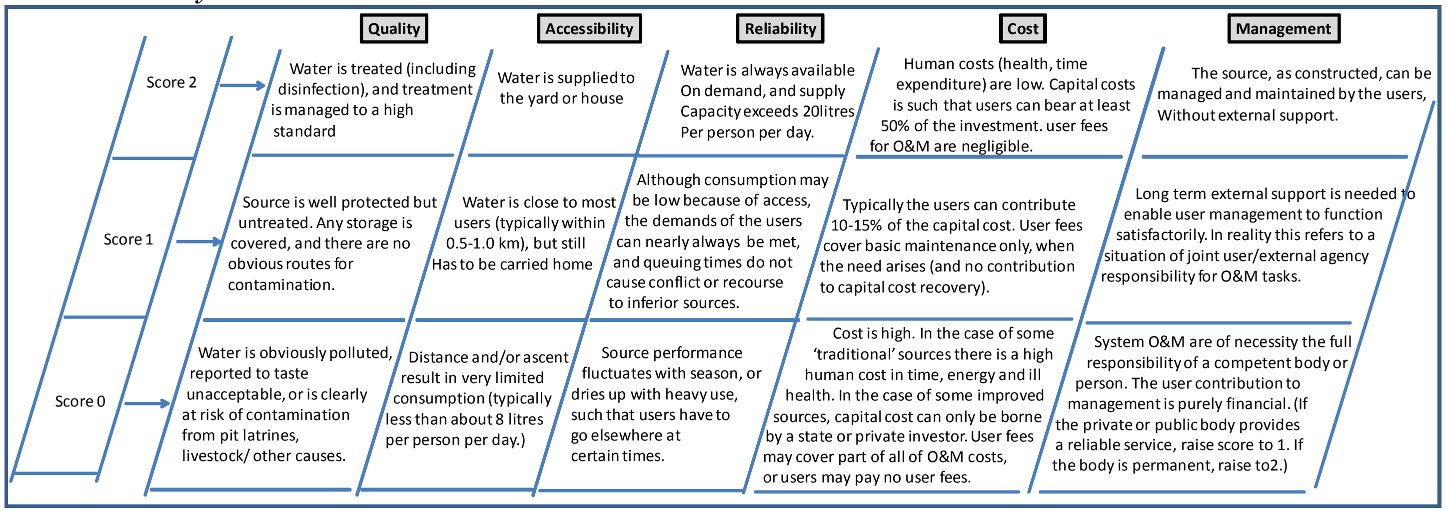


Fig. 6.2: Scoring system for water supply model

Source: Carter (2006)

Fig. 6.3 shows the proportion which met the criteria of the water coverage definition under NRWSSP (2007) based on the data collected from these field studies in Milenge. Nchelenge was excluded in Fig. 6.3 in that they had no *Protected* HDWs improved by skilled artisans under the Self Supply model at the time of the visit. To recap, the definition of access to a **safe water supply** in Zambia is the percentage or proportion of the number of people accessing a **minimum of 25lcd of water** from a *Protected* source **every day of the year** within a **distance of 500m** from point of use (NRWSSP 2007). The quality of safe water refers in this study to less than 10FC/100ml as an appropriate relaxation for rural water supplies (WHO 1997) though physical and chemical parameters are also considered in the NRWSSP. Further, the term 'water collection time' is also included in Fig. 6.3 to consider a different dimension of accessibility although it was not referred to in the NRWSSP definition. '30min' is used due to the fact that the latest JMP report (WHO and UNICEF 2010) states that a reduced amount of water will be collected if the water collection time spent more than 30minutes. Fig. 6.3 shows the proportion that fulfilled the norm of NRWSSP (above the line of 'Norm of NRWSSP') and the proportion at substandard level (below the 'Norm of NRWSSP line).

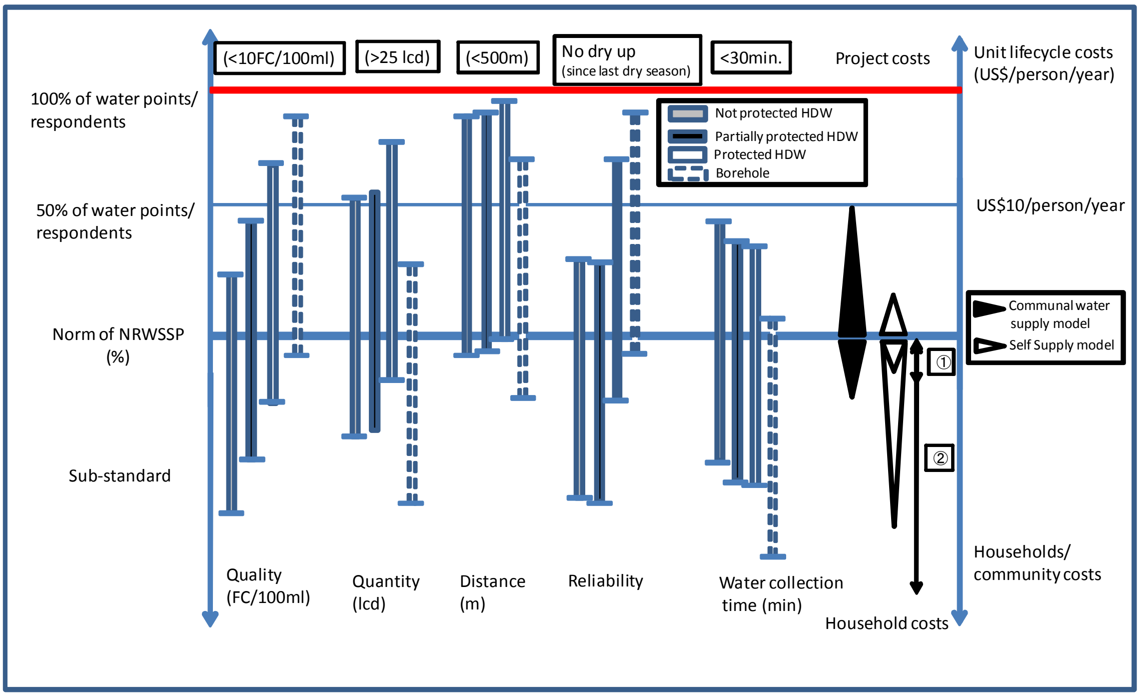


Fig. 6.3: Summary of general findings from the field studies in the light of water coverage in Milenge

(*Source: Author's field work*)

Note: ①: costs incurred by water point owner

②: costs incurred by both owner and sharing neighbours

Not surprisingly, it is found from Fig. 6.3 that none of the key indicators reached the norms of NRWSSP for all water points or respondents. In terms of water supply types, boreholes provided a high proportion of safe water (92%) and reliability (89%) in terms of water quality and water source reliability. After the boreholes, *Protected* HDWs delivered safe water and reliability which met the criteria of over 60% followed by *Partially Protected* HDWs and *Not Protected* HDWs. On the other hand, the results were significantly different when the viewpoint was changed from water sources to the end users. It meant that, for instance, a small number of borehole users achieved the norm for quantity (=per capita water use) (28%), distance (72%) and water collection time (4%) while a higher proportion of the *Protected* HDW users met the criteria of per capita water use (74%), distance (96%) and water collection time (30%). Even the *Partially Protected* HDWs users and the *Not Protected* HDWs users fulfilled these criteria at a higher ratio than that of borehole users.

These findings indicated that access to sustainable safe water was consistent with the higher level of water supply models (Borehole> *Protected* HDW> *Partially Protected* HDW> *Not Protected* HDW) with respect to technical protection. However, it was nonsensical when other criteria were considered: those of per capita water use, distance and water collection time. Compliance with these criteria was met in the following order of water models (*Protected* HDW> *Partially Protected* HDW> *Not Protected* HDW> Borehole). This means that the borehole was the best water supply model of the four water supply models from the aspects of water quality and reliability, but it became the worst water supply model by considering the aspects of per capita water use, distance and water collection time in the context of a sparsely populated rural study area. Also, it should be highlighted that the reliability in Fig. 6.3 did not take into account the downtime of the lifting devices. As noted in Section 5.7.2, reliability could be threatened where the lifting device is non-functioning which makes the water inaccessible even when there is water. The study found that the downtime of handpumps at borehole sites was from a few days to over six months after a breakdown because of the lack of skilled labour, spare parts and contributions compared with that of within a day at HDW sites using rope and bucket.

These results could also be explained by the ownership status of water supply models. Where the ownership status is public (communal) including both communities and institutions, it is unlikely to meet all the criteria for all users for a communal water supply model unless a high number of communal water sources are constructed so that they can get a borehole or a subsidised HDW on their doorstep. This is because the low population density makes it more difficult to meet all required aspects for all end users by a communal water supply model. A sparsely populated rural area suffers from an endemic problem of accessing services not only water supply, but also electricity, transportation, education and medical services when compared with denser rural and urban areas because of the high level of network systems (Tacoli 2008). In fact, according to the IWRM report in Zambia (Republic of Zambia 2008), rural remote areas showed the lowest rates of education, health and water services in Zambia. Therefore no matter whether the water source is newly constructed, it is unlikely to give equivalence for all village dwellers if the water source is a point source and not a line of sources such as small networks, fed by ground or surface water.

This issue is reflected in the water service ladder in the WASHCost (See Fig. 6.1). The 'Sub-standard service' corresponds most closely with the services that are suffering from endemic problems or where context specific issues, such as low population density, make it difficult to meet all the criteria, such as distance, per capita water use etc (Moriarty *et al.* 2010). They also highlighted the fact that it is typical of the sort of service accessed by people living on the fringes of better-service areas, but can be applied to anyone whose service fails to meet one or more of the key indicators.

Does it mean, however, that no water supply model is likely to cover the gap in order to meet the required norms for accessing safe water by fringe users living in a sparsely populated rural area? It is noteworthy, however, that private (individual) water points, on which the Self Supply model has focused, could deliver water to users within much shorter distances and taking less time (distance & water collection time) because the existing high number of HDWs have contributed to the dispersal of water users from limited communal water points to neighbours' water points. At least, this has allowed an increase of per capita water use (see the Section 5.6.11 water quantity and distance). Further, the parameters of 'water quality' and 'reliability' could also be improved by a Self Supply model. For a concrete example of this, water quality was significantly improved at *Protected* HDWs over a four month period which was even comparable with the results of boreholes when water quality settlement and seasonal factors were taken into account (see Section 5.5.3 water quality monitoring results). Although one of the lessons learned from the Self Supply model in Milenge was the failure to re-deepen and cast bottom linings during the dry season, it was statistically proven from the studies in

Nchelenge that reliability could be significantly improved when the HDWs were lined at the bottom (see Section 5.7.4 environmental sustainability). These two parameters (water quality and reliability) depended on the water source protection and lifting device sustainability while distance, quantity and water collection time were contingent on the relationship between the users and the ownership status of the water source. No matter whether the water source was a HDW or a borehole, it resulted in considerable distance, time and inadequate quantity if the water source was communal model.

The last parameter, but not the least, cost-effectiveness is also described in Fig. 6.3. The upward direction of the deltoid group means project costs and the downward direction of the deltoid group refers to household/community cost. As noted in the data analysis Chapter 5.8, the project costs were incurred by government or NGOs/external support agencies while household costs were the ones to which the end users contributed or paid in order to use the water supply sustainably. The communal water supply model was less cost-effective than the Self Supply model in terms of both project costs and households/communities costs in the case of the cost sharing. Although NGOs and donors were reluctant to support individual water sources because of the difficulty of funding individual water source (see Section, 3.7.3), the Self Supply model offered an environment for individual households to improve their water sources without direct funding. Although the household costs were incurred by water point owners exclusively (the most prevalent approach at the time of the visit) rather than shared with beneficiaries, the well owners found benefits in putting what little money they had into improving or having their own water source, adding to their original value, and this may be overlooked when a water supply model is decided from a macro-economic viewpoint.

To sum up, integrating research findings reveals that reliance only on a communal water supply models limited the achievement of increased sustainable access to a safe water supply. Further, the Self Supply model could increase access and achieve a sustainable environment for rural water supply, especially in sparsely populated rural areas where the communal model was unlikely to fulfil all the key concepts of water quality, accessibility, reliability, cost-effectiveness and acceptability. Therefore, the principal argument that "*Reliance only on a communal water supply model limits the achievement of increased sustainable access to a safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of* *increasing access and achieving sustainability*" is clearly proven by the findings that emerged from the study.

6.8 Further findings on a rural water supply model

The previous section discussed how the communal and Self Supply models contributed to or constrained the water supply in a sparsely populated rural area with respect to the safe, accessible, sustainable, cost-effectiveness and acceptability concepts. At the micro level, the communal water supply model has not been appreciated by the end users in that the nature of a public source leads to unacceptable water consumption levels, accessibility and water collection time (see Section 5.9). Such dissatisfactions are underpinned by collected practical data and by the criteria of access to safe water from NRWSSP. The Self Supply model can overcome such barriers with a vibrant community dynamic towards private water supply. In this section, a further analytical step is taken by evaluating the practices of rural water supply models in Zambia in order to determine the most appropriate water supply model for households in sparsely populated rural areas. The research findings for improving the water supply models in a sparsely populated rural area are presented in this section both from a micro viewpoint and a macro point of view in the following section.

6.8.1 Rural water supply model –Micro level–

The aim of this research was to determine the most appropriate water supply model for safe, accessible, sustainable, cost-effective and acceptable water supply for households in sparsely populated rural areas of Zambia. The research findings show that Self Supply is a crucial approach to complement the communal water supply model in sparsely populated rural areas. This section thereby reflects on how the rural water supply models could scale up their approach for water sector professionals to implement water supply projects by shedding light on the findings of both the Self Supply and communal water supply models.

Self Supply model

It is acknowledged that the Self Supply model has limitations and uncertain aspects such as environmental reliability and financial viability for households as well as not being a panacea in all rural contexts. One of the challenges to the sustainability of the Self Supply model was the financial viability in that households/communities incurred all the hardware costs of the lifecycle costs in contrast with highly subsidized hardware project costs in the communal water supply models. In Milenge, WaterAid Zambia established and applied revolving loans for Self Supply on behalf of grants to accelerate improvement work when cash was not available prior to harvest season, but the loan repayment outlook was gloomy since some dissatisfaction towards the workmanship has resulted in the reluctance of the well owner to repay the loan (see Box 5.11 in Section 5.7.6).

To that end, systematic loan disbursement would alleviate this barrier in future work since the delay in access to the loan system in this Self Supply pilot project in Milenge pushed the onset of improvement work into the rainy season so that incomplete work done by artisans led to unsatisfactory levels in the next dry season with the result that water sources dried up. The revolving loan fund was established in Oct. /Nov. 2009 which resulted in an overload both in setting up the loan system in the community and for improvement work within the limited dry season for 2009. Further, it may be useful to consider the linkage between the loan committee and the local authority.

The loan committee in Milenge was made up of artisans and CBOs (community based organizations [ADC, NHC and V-WASHE]) from each of the targeted four Wards within the Self Supply model, and they had been trained in fund management. Although some of the Wards had organized management records of the loan fund, there was no consolidated data until it was requested by WaterAid and Milenge DC. In order to have a sustainable and transparent financial management system, opening the loan committee bank account with the support of the local authority could be one of the financial management options which is in line with the communal bank account management of community O&M funds (contribution) within the communal water supply model.

Moreover, it is important to highlight that the motivation of individual households should not be killed at the outset of access to water supplies. The option of a loan should be the last choice for households where they were already prepared or were ready to invest cash or in-kind prior to the loan option. It should be set up with at least with the deposit even if the loan is the last option. Otherwise, ownership status might become immaterial once water sources are subsidized. This was also underpinned from the government/NGOs side through the key informant interviews where it has been said

"*Whatever you explain from the start of the concept of Self Supply, once you mention money to community members, they then forget everything. So they just eat the loan"* (Mr Mubyana Munyangwa, Africare).

"*I would say the current situation makes it very difficult for people to learn a culture of paying back the loan because they feel that all money should come from the government, donors or cooperating partners, so if they say loan, it won't matter if you don't pay"*
(Mr Danny B Chibinda, Nchelenge District Planning Officer).

It is noteworthy, for instance, that the fixed improvement options using a loan has impeded the efforts of owners who have prepared cement for well rings, by both causing damage and not allowing their use for improvements in Milenge. This is due to the local artisans paid little attention to the households' preparation. Further, it was found from the studies in Nchelenge that the establishment of a loan system for Self Supply also did not take into account the need for either a down payment or material preparation (sand, bricks were prepared in advance though) by the owner sides despite the fact there were owners who had unfortunately already prepared material by themselves. These findings indicated that the NGOs and donors should look closely into a situation analysis for future work to determine exactly what water supply model needs are required by households, such as money, material or skilled labourers.

In conjunction with the above, it is acknowledged that domestic consumption account for 10 percent of water use compared to 20% industrial use and 70% agricultural use (Kasrils 2001, UN World Water Assessment Programme 2009). However, environmental reliability has to be monitored in future work with respect to climate change because current affordable technologies for Self Supply depend on very shallow groundwater which is most likely to be vulnerable to water depletion. In fact, it is predicted that shallow groundwater in sub-Saharan Africa would not be affected very much by climate change (Macdonald *et al.* 2009). But this discussion centres around a 50m degree of groundwater for a handpump facility and not to very shallow groundwater (less than 20m) which is significantly used for the traditional water sources. In the case of the Republic of Yemen, improved tubewell technology have resulted in the extracts of over 150% percent of the country's renewable water resources by rapid consumption of water for irrigation (Independent Evaluation Group World Bank 2010). Also, this concern was acknowledged by Sutton and Hailu (2011) in the study of the Rope Pump in Ethiopia. If the well owners extend the usage of water for more productive use, it may cause over-exploitation of groundwater which would result in the need for counter measure such as regulation, rainwater harvesting and/or artificial groundwater recharge in line with integrated water resource management (IWRM).

Further, monitoring water safety with respect to water quality is also a crucial component for any water supply model. Where there is little or no hardware subsidy for a private supply, although shallow groundwater is the most reliable water source for a private water supply apart from rainwater and surface water, it is also vulnerable to contamination. However, the results of incremental improvement works for shallow wells in the Self Supply model provided an acceptable water quality for drinking water even though not all water points reached the standardized protection level of "*Protected* well" in the country's standard. That being the case, water safety would be easily threatened by insanitary conditions without the sensitisation of the rural dwellers with respect to hygiene practices and sustainable O&M works (see Section 5.5.6 sanitary conditions at source).

In this regard, household water treatment and Storage (HWTS) have to be promoted alongside any type of water supply models. No matter whether water is clean at the point of source delivered by either a communal or a Self Supply model, it means nothing if the water becomes contaminated on the way to the point of use (household) during transport and storage (Heierli 2008). The communal water sources multiply this risk by the nature of a communal commodity which entails more distant transport than water points on their premises (see Section 5.5.11). By including the promotion of HWTS which is the most cost-effective approach among the water quality interventions (Clasen *et al.* 2009, Clasen and Haller 2008) ,the Self Supply model enables rural dwellers to access a sufficient amount of safe water for hygiene practice and further water related activities such as other productive uses.

Further, private sector capacity development is cardinal for long term sustainable access to safe water. As described in Table 2.1 (see Chapter 2), the Self Supply model differed slightly between WaterAid (in Milenge District) and DAPP (in Nchelenge). While WaterAid put their emphasis on the capacity development of local artisans, DAPP addressed capacity development of Area Community Organisers (ACOs) for community mobilization. Not surprisingly, community members are interested in private traditional water source improvement and willing to invest although they had no concrete idea in terms of techniques, skilled persons and materials for improvement

(Zulu Bullow 2008). Strengthening local artisan participation has enabled rural dwellers to access sufficient information and skills towards water source improvement. Thereby, even if an external support agency leaves the project site, rural dwellers can sustain and act on their desire to improve their water sources where local private sectors are strongly involved in rural water supply.

Both capacity development and involvement of ACOs, Neighbourhood Health Committee or any other local committee are essential for community mobilization and sensitisation. However, such effects could be significantly accelerated if the local private sector capacity is built up concurrently.

Last, but not least, is the importance of Self Supply marketing. In comparison with the communal water supply model, the concept of Self Supply regards community members as customers rather than just beneficiaries. No matter whether the private sector is developed or a variety of technologies are available, the Self Supply model would be terminated if the households/communities did not find any advantages and/or right information regarding a Self Supply model. Heierli (2008) describes the marketing strategy and has categorised the consumer segment in the studies of marketing safe water systems (Table 6.1).

Table 6.1: Consumer segments

Cunsumer segment	Group of people	Media
Early adopters	Innovative people, better educated, usually with a higher disposable income, mostly found in town rather than in village	TV, promotional flyers, a product video
Early majority	Usually do not buy something new they have never seen at least at their neighbors' house	Not through TV, rather that hear of the product through a person they trust
Late majority and laggards	Older people	By word of mouth and not through educational or promotional mass media

Source: Heierli (2008)

The way for social marketing of the Self Supply by WaterAid in Milenge was that they promoted a demonstration plot, had talking walls, identified champions of Self Supply, and distributed materials to advertise availability of skilled labourers, technological options and models (see Table 2.1 in Chapter 2). The demonstration plot could be seen as targeted towards the early adopters who were interested in the Self Supply model from the onset of the project. Talking walls have been the result of painting walls at schools and clinics, with emphases on the importance of access to safe water and sanitation and the ways of improving their water source. The school children and patients could be the crucial driving force for spreading the messages of Self Supply.

To overcome the dilemma of social marketing where targeted communities are scattered communities (5.9person/km^2) with no public transportation, electricity or mobile networks, WaterAid and the District Council of Milenge organized an event about Self Supply in line with World Water Day on 22nd March 2010. In the event, they promoted the concept and the details of the Self Supply model by distributing advertisement handbills while they honoured early adopters of the Self Supply model, from the owners who took initiatives to improve their water sources by themselves to the artisans involved in Self Supply from the initial stage. These social marketing activities may have generated and accelerated recognition of the concept of Self Supply as well as providing dignity to the people who were already involved in Self Supply in any way. Surprisingly, the Self Supply social marketing in Milenge had repercussions beyond the project target areas, which resulted in having generated demand from outside the target areas and yielded new *Protected* water points and job creation. These findings showed how social marketing is important for the Self Supply model and how individual households are able to be a driving force for the community dynamics of behaviour change casting off from government/donor dependency.

Some of the specific lessons learned were found through studies regarding social marketing below:

- ✓ *Options of demonstration*: Both the Self Supply models in Milenge and Nchelenge had demonstration plots. However, the demonstrated options were exclusively one option in the early stages. For instance, the protected conditions of HDW (with a concrete apron, raised parapet walls and top slab, drain and use of metal bucket with rope or windlass) in Milenge and rope pump installation in Nchelenge. It gave the impression that the Self Supply model could only provide one specific model for protection and discouraged improvements with high cost options. To that end, the Self Supply concept could be made clearer for village dwellers if they could see demonstration of improvement options in line with a step by step approach.
- ✓ *Identification of demonstrator*: It was found from the study that one of the big farmers could not access the information about Self Supply but who later showed great interest in having a new well equipped with a high level of lifting device such as the rope pump in Milenge once he accessed the information. If they had discovered such people in the early stages of the project, it might have broadened

the options for demonstration and technology. To that end, more frequent meetings with village leaders may help to spread information all the way around because that big farmer could have got to know the information from the village headman much earlier than 2 years from the onset of the project.

- ✓ *Dissemination tool*: As noted in section 6.2, perceptions of the concept of Self Supply became distorted by inadequate sensitisation in Nchelenge. One of the difficulties in the context of Nchelenge was that each area leader covered each Ward, which meant that more than 18 villages were covered by each of them. No matter whether they cooperated with other stakeholders such as artisans, EHT and V-WASHE, they may have overlooked some of the people interested in Self Supply. To that end, the radio network may support and accelerate the dissemination of the information more widely because a high number used a radio in Nchlenge in comparison with the context of Milenge. In fact, one of the respondents of the household survey was a radio personality from the local network, and he suggested that a variety of people listen to the radio and it is an easier way of passing on the information in a short time than by visiting houses one-by-one.
- ✓ *Older people*: Although older people are categorised in the late majority in Table 6.1, it was observed from the studies that older people value the dignity of initiating an activity which they knew had to be important. Apart from the level of the improvement, significant numbers of water point owners improved their water source not only for themselves, but also for their family, surrounding neighbours and even for offspring. Therefore, it may not be a better option to put older people in the later stage but rather to allow them to become a status symbol by putting them first, showing how admirable it is to improve a water source.
- ✓ *Neighbours*: It is important to monitor the change of community dynamic not only for following up the water points which they have already improved in order to monitor their hygiene practices, but also for capturing how neighbours perceive the Self Supply models. For example, one of the water point owners who took the initiative for his own water source improvement copied it from what neighbouring water point owners had done for improvement under the Self Supply model. Since they did not have a good enough relationship to share the idea, the neighbours tried to copy visually without asking the available human resources (local artisans). This indicated that the idea can be spread by neighbours even where there is an inability to communicate with each other, by using modern networks such as mobile phones or e-mail, and such emerging demands from individual households should not be overlooked.

- ✓ *Co-operation with traditional leaders*: Although WaterAid had a meeting with the senior chief of Milenge to introduce the project and seek permission to operate in the chiefdom, they also invited the chief for the World Water Day event, which may have given support to the Self Supply concept or even the overall water supply and sanitation programme. One of the interesting points was found from the studies in Nchelenge where, as noted in Section 5.2.3, interesting improvement works had been done in Kampanpi Ward using local material. It was found from the surveys with households at Kampanpi Ward that originally there were some principles from the chief Kasembe (who ruled the areas) about what kind of water sources they had. These practices of water point improvement offered ways to comply with the rules; otherwise, they would be punished by the chief who took away their livestock. Therefore, it is crucial to establish a rural water supply strategy combining and balancing the national policy development with the empowerment of traditional leaders in the country context.

<u>Communal water supply model</u>

It should not be assumed that once water supply facilities are delivered to a community by means of a communal model, every household in a sparsely populated rural area has access to them. It is acknowledged that the communal water supply model has delivered significant amounts of safe water to community members and corresponding SOMAP principles were addressed by the sustainability of the water supply model itself. However, as noted in one of the SOMAP principles, cost sharing by communities is the crucial driving force for sustaining the communal water supply model. No matter how the blocks leading to a sustainable environment for water supply are built, it is likely to be desk theory based only, on the macro-interest of the government or donor if user satisfaction and preference are disregarded. The community dynamics with respect to water source selection gave evidence of how community members put value on their private water source (see Section 5.9.5).

It was found from the field studies and extant literature that challenges to community contribution are derived from; community interpretation, roles and responsibilities, acceptability, payment options, fund management and the surrounding water environment (Kleemeier 2010a, Whittington *et al.* 2009, Doe and Khan 2004). It was found from the studies in Milenge and Nchelenge, in fact, that a contribution system seldom works out because of the above combined factors. Therefore, software programmes address these issues in the pre-, ongoing and post-implementation of communal models. For example, according to the JICA report (2007), project orientation is held in advance where the candidate site for the construction of a water supply facility is at village level. Meanwhile, they promote a foundation or a reorganization of V-WASHE, where confirmation of agreement has to be signed regarding the responsibility of the village side for project implementation including O&M roles and responsibilities. These software components are crucial for sharing the policy, knowledge, method, and making clear their roles and responsibilities for sensitisation from the grass-roots level upwards.

These software components are the approach to transcending rural water supply models from "build-infrastructure-and-walk-away" to "build-capacity-and-infrastructure". By sensitising community members to the importance of contribution towards sustainable access to safe water, it may be possible to gradually overcome this factor. However, it would be difficult to sensitise community members regarding a contribution mechanism when they can access a free water source near to their premises compared with a place where a borehole and handpump facility is the only water source they can access. Box 6.1 showed one example of this case.

Despite the fact that there was an agreement among community members regarding a contribution system, Box 6.1 indicated that it is likely to be influenced by the surrounding water environment. Community members may be dedicated to a contribution system if a reliable water source is exclusively a communal water supply model. In contrast, it may be impeded by the surrounding water environment if they have other reliable water sources especially if they are free of charge. A similar issue was found from the studies in Kachenge village in Milenge District where only 5 households were using the borehole facility although the total number of households in the village was over 200. The initiation of a contribution system in June 2010 resulted in the number of users dramatically decreasing from 72HH in May to 5HH in August 2010. There were two factors stated by community members for withdrawing their use of the borehole: those who disagreed with the payment option which was k10,000 (≒ US$2) payment annually, and the surrounding water environment.

Box 6.1: One of the examples of a dysfunctional contribution mechanism at Munpundu village Kashikishi Ward

Munpundu village comprises about 600 households, and they rely on their water source for their consumption and hygiene purposes from a communal borehole, 6 to 8 individual hand dug wells and a stream.

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I am one of the caretakers of this borehole. This water supply facility was constructed in the middle of 2008 by JICA. My responsibility as a caretaker is to open and lock the facility every day to allow community members to pump water during specific times. The village people had initially agreed to a locking and contribution system for sustainable operation and maintenance purpose. However, it turned out that it was like an empty promise since almost nobody contributed…….In November 2009, we called APMs from Nchelenge Ward because our handpump had broken down. They repaired our handpump without payment at that time, and we agreed to pay for repair work as soon as we collected money from community members………The total amount we have collected since Nov. 2009 is ZMK70,500 (≒US$15) over five months. The repair cost was ZMK150,000 so we have not yet achieved this….The number of users of this borehole is now five households because these five households are the only ones paying the contribution ZMK1,500 (≒US$0.3) every month. The rest of them, returned to a stream or just using water from the neighbours well……….I do not want to continue this work anymore because community members might come and burn my house because of the strict contribution system. Such a case has happened in my village before………

The community members highlighted the fact that the single annual payment made it difficult for people relying on seasonal income, and the decision was primarily made by a small number of people surrounding the village head without asking the community members. This issue implied the importance of flexible payment options and a V-WASHE was set up (see Section 5.7.6). On the other hand, the second factor, which means that another free water source is around, cannot be overcome unless the other surrounding water sources have other inadequate aspects such as water quality, reliability or accessibility. This indicated that the current site selection might have overlooked the user acceptability/preference for their water source selection, and the actualities of a communal water supply model might not fulfil the standard design to serve 250 persons per communal facility.

6.8.2 Rural water supply model –Macro level–

At the macro level, while the above barriers or challenges provide an important insight for water sector professionals to implement water supply projects, policymakers are likely to be interested in knowing what is the actuality of the different water supply models and how they could be adapted into the predominant communal water supply models. In fact, an evaluation of the overall rural water supply policy framework was generally sound, especially the statements on the community based project in Zambia (NRWSSP 2007). This section presents further implications for a sustainable rural water supply strategy from a macro viewpoint by applying the findings and insights from the studies.

In the NRWSSP (2007), they outlined the current organization of the water supply and sanitation sub-sector and their roles and responsibilities, but their structures only took into account a subsidised communal water supply model. The previous section discussed the strengths and weaknesses of the communal and the Self Supply models, and those findings indicated that while software components in a communal model were required, the site selection of the communal model should be reformed to some extent in consideration of the current community dynamics with respect to water source selection. Fig. 6.4 shows, thereby, the proposed rural water supply strategy incorporating the findings and insights of this study into the current organization of the water supply sub-sector and their roles and responsibilities described in the NRWSSP (2007).

In the NRWSSP, they separated the water users into three categories: those from urban communities, peri-urban communities and rural communities. Rural communities had been receiving support for water supply from a department of water affairs, a department of infrastructure and support services and a community based scheme. These water supply models were achieved through individual communal water supply models under these three institutions at national and district levels cooperating with the external support agencies, such as UNICEF, JICA, African Development Bank. In fact, more than 90% of the investment costs for the rural water supply and sanitation in Zambia came from the cooperating partners (NRWSSP 2007).

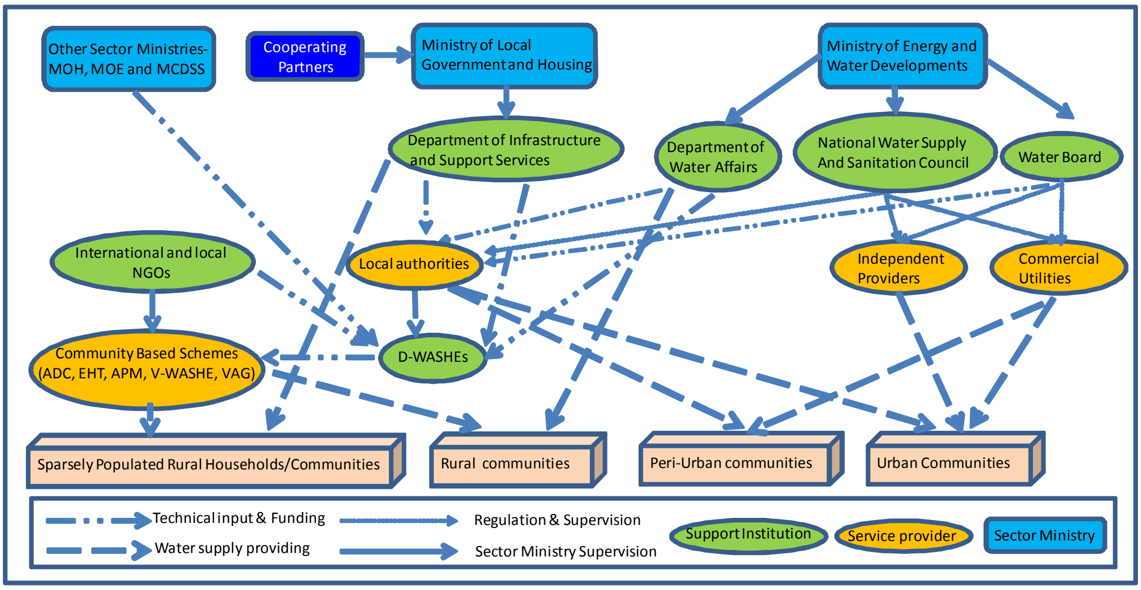

Fig. 6.4: Schematic diagram of proposed water supply sector structure in Zambia

Source: Developed by author from NRWSSP (2007)

In the proposed water sector structure (see Fig. 6.4), 'Sparsely populated rural households/communities' are differentiated and incorporated into the water users as a fourth new category. The current communal water supply model may have overestimated that once communal water supply facilities are delivered to the communities, every household among the rural areas would have access to them. It may have covered the standard design number (e.g. 250 persons by communal borehole or 150 persons by communal HDW) within the populated rural area, but the studies showed that it was unlikely to fulfil the norms of key indicators and demands from the community members towards accessing safe water where village dwellers lived in sparsely populated rural areas. Therefore, differentiation of the sparsely populated rural setting from the current rural communities would be important in considering appropriate water supply models for rural end users.

Information Management System (IMS), which is one of the NRWSSP components, would be useful to sort out the category of the sparsely populated rural households/communities and rural communities based on the database of their population density, existing water supply models and water sources. Moreover, the Self Supply model may also be suitable for the areas where people face inadequate aspects of existing communal water supply model such as distance, ownership, queues and quantity. These areas include peri-urban and poor urban communities in Fig. 6.4. In fact, Gronwall *et al.* (2010) found in their studies in India and Zambia that a sizeable number of poor urban dwellers rely on the water from a backyard well rather than piped water because of inconvenience, settlement status and/or payment to public water sources. Further research would be necessary to look at these areas in the light of the peri-/urban context such as policy, regulation and population density. Also, recent study in Nigeria (Oluwasanya *et al.* 2011) showed that nearly half of the urban population was found to have access to either a restricted or free access hand dug well.

This study showed that the Self Supply model may bridge the gap between a household demand and a communal water supply especially in a sparsely populated rural area. As noted in Section 6.7, a Self Supply model can overcome the barriers of the communal water model by a stepwise improvement of private water sources. This pilot Self Supply project in Luapula Province has been funded by UNICEF, and implemented by the NGOs (WaterAid Zambia and DAPP) acting in partnership with the District councils (DCs). It was found from the study that the District capacity has not been established well in line with decentralization.

For instance, WaterAid implemented the Self Supply project in Milenge with the Milenge DC, but one field staff member from the DC was assigned in Aug. 2009 although the activities on Self Supply model had already started around July 2008 by WaterAid. Further, the assigned field staff member from the Milenge DC had a responsibility not only for the Self Supply but also for other water supply and sanitation programmes in Milenge west, and this made it difficult to dedicate all his efforts to Self Supply. Although it was acknowledged that Self Supply was a pilot project, the role of the council in the project of the Self Supply model was not clear compared with that of the WaterAid staff. Future rural water supply strategies, requires clear roles and responsibilities defined between the DC and NGOs in a limited capacity in order to forge long term sustainability.

One of the options for this, is that the DC may undertake the role of forging strong links with private sectors including both the loan committee and artisans (perhaps Artisan Associations). As noted in the previous section 6.8.1, an integrated system between the loan committee and the DC would enable the financial management system to be transparent and sustainable. Further, as noted in Section 5.2.2 (Lining of HDW), it was difficult to assess whether there was slipshod work or not in, for example, top lining or re-deepening. Therefore, it is important for the DC to work with artisans so that they can audit and assess the workmanship to achieve fairness for water point owners, especially when they work on well shaft improvement. This assessment of the water point would enable the DC to record water point information for the Information Management System (IMS). These roles and responsibilities were not followed up in the pilot project but coordination between local authority and private sector would become essential in order to achieve long term sustainability rather than simply depending on NGOs which may only be present for short period.

Subsequently, building up the capacity of the various stakeholders is also crucial for promoting a Self Supply model. Community based schemes are encompassed in ADC, EHT, APM at a sub-district level and V-WASHE and VAG at a community level (see Fig. 6.4). The V-WASHE and VAG are key stakeholders for providing advice and sensitisation for rural dwellers at the grassroots level while the capacity development in the private sectors is essential for long term sustainability for the rural water model. In Milenge, trained artisans under the Self Supply model were different from APMs trained under the JICA communal model. On the other hand, 12 skilled APMs were also involved in the Self Supply programme in Nchelenge on the recommendation of their communities.

The integrated manpower showed both the strengths of, and barriers to a rural water supply model. The strength was that they could become a catalyst for incorporating water supply models of either the communal and Self Supply models if they have the knowledge and techniques of both private household and public community level water supply models. In fact, there was a demand from the community and artisans in Milenge for manpower able to work on the various water supply models; this was because the limited number of APMs in Milenge resulted in the delay of the handpump repair although they had a number of trained artisans for the Self Supply project exclusively without the skills for handpump repair.

Meanwhile, one of the challenges found in the studies was that the trained artisans in Milenge implied that their motivation for the work was derived from altruistic values towards the community members rather than from high income generation. In fact, they were earning their living not from the artisan's job exclusively but combined with subsidiary small farming. Therefore, it is important for artisans and APMs to foster their motivations and to learn and sell their multiple skills for income generation. Further, it may encourage the private sector such as small traders to stock the necessary materials both for Self Supply as well as the communal water supply spare parts in order to enable a sustainable supply chain in line with the SOMAP.

A barrier was found from the studies in that current numbers of integrated skilled persons (APMs and artisans) in Nchelenge were already overstretched which resulted in the delay of work for either handpump repair as an APM or HDW improvement under Self Supply. As noted in Chapter 5.7.1, handpump breakdown occurred during the dry season when extra users moved in from other unreliable water sources. Meanwhile, it was a good time for artisans to implement improvement work for Self Supply when the groundwater level has become lower during the dry period. This means that there is a requirement for adequate skilled labour to correspond to the tremendous demands for water supply during the dry period in a cross-sectional manner.

To overcome this barrier, incorporating the technical human resources into Artisan Associations might have mitigated the overload on limited human resources, and then enable the rural water supply model to take a step towards scaling up. The Artisans Associations (AA) are formal associations of masons and APMs whose primary role is WASHE model provision at a local level in their catchment area (UNICEF 2008). By establishing the AA, it would accelerate the overall sustainability of rural water supply in that they could assure the quality of workmanship. In fact, one of community members in Milenge complained of the poor workmanship and inequality of artisan selection from the community. This point was acknowledged by the Self Supply project officer from WaterAid who had left all the selection of artisans to community members, but found that some artisans were selected from their friends and relatives in Chiswishi Ward (where they did not obey the standards of improvement work, such as lack of top lining) (see Section 5.2.2). To be assured of both quality of artisans and workmanship, it is important to have an assessment from a third party (AA, DC or NGOs) especially at the outset of the water supply model.

Also, as noted in section 6.8.1, the site selection is the crucial factor for the government in reforming their rural water supply strategy. The current communal water supply models tended to disregard the traditional water source such as HDWs or spring as unsafe despite the fact that rural dwellers put value on having their own wells, and the Self Supply model could achieve access to safe water. However, not everyone can attain a high cost water supply facility such as a borehole with a handpump for their own water source because the Self Supply model in Zambia depends on households' investment for HDW improvement i.e. affordability. In other words, a shallow groundwater level is an ideal condition for Self Supply if households/communities intend to construct or improve their water sources with current low cost technologies.

Having a water source using deep groundwater is generally expensive where the hydro-geological condition does not allow shallow groundwater. Thereby, the subsidised communal water supply model should utilize the strengths that high cost technology can provide. In the communal water supply model done by JICA, the highest priority was given to the schools, rural health centres and sites (villages) **where safe water is not yet secured**, and secondarily to the most populated sites (JICA 2007). It is acknowledged that these criteria were critical indicators for the site selection of the borehole construction. However, it is essential that new site selection for securing safe water should take into account the current local water situation and not ignore household demands or sacrifice other criteria i.e. accessibility, per capita water use, water collection time. To optimize the strengths of a communal model and find a symbiosis with a Self Supply model, therefore, the communal model should concentrate their efforts into **where** it is **unlikely to achieve sustainable safe water by any other water supply models (i.e. Self Supply)** for sparsely populated rural communities and even populated rural communities.

Herein, it may happen that one village is receiving a communal water supply model and the next village delivers their water supply model by Self Supply. Or it may occur even happen that both communal and Self Supply models are required to fulfil the water demand in one village because it is unlikely that one water supply model will be fit for all the village dwellers. Though much of the emphasis was on avoiding duplication in a site by using different water supply models or organizations in Zambia, some target areas in the project of the Self Supply model have been faced with an overlap with a communal project as noted in Chapter 2.

According to the key informant interviews in the field studies, one of the biggest concerns of the government and the donor organizations was that competition might happen between a communal water supply and a Self Supply model because of the different concepts and approaches. The communal model delivers predominantly hardware components to the end users while the Self Supply model provides non-hardware components to the fringe users rather than supporting them, in cases where private sector capacity, availability of credit systems and new technologies are delivered through donor support. To adapt the concept of the Self Supply model into the national policy, is it only likely to cause competition or confusion among the stakeholders? If so, is it better to separate the Self Supply model from the communal model? This point was also one of the concerns from the policymaker side through the key informant interviews where it has been said

"*When we are trying to shift from a previous to a new approach to initiate new policy, there will be conflicts. Some of the water sector players just come and say that "we are going to implement the communal approach without any community contribution". Maybe another player says that "no, we are trying to do a Self Supply approach". So the community might be confused as to what the government is trying to do regarding water supply.*"

(Mr Sinkala Steave, Water Engineer at Provincial Water Affairs Office)

Box 6.2 might show one of the implications of this question. Box 6.2 outlines one of the small case studies where they had both a communal water supply model and a Self Supply model in a village. Further, Box 5.18 also illustrates one of the village dwellers at this Chilongoshi village (see Section 5.9.5) who was using water for productive use. He found economic benefit in using water from his well and was also about to start improvement work by trained artisans under Self Supply at the time of the visit. These findings showed that there is likely to be symbiosis between communal and Self Supply models. Although Sutton (2009c) pointed out that where people believe that communal solutions will be provided they will be de-motivated from self help, this small case study showed that community members may select their water source without becoming demotivated.

Box 6.2: One of the examples of symbiotic water supply models at Chilongoshi village, Nchelenge Ward

Chilongoshi village has 815 persons in their population. Existing water sources are 34 individual HDWs and 1 borehole equipped with a handpump facility. They have a huge Lake Mweru that is located 1km away from the village. The population in the village is increasing, and now it is over 1,000 persons according to the village head though not yet an official record. The year of the borehole construction was 2007 done by JICA and those individual wells were mostly constructed after 2000.

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I am one of the caretakers of a handpump facility. I have taken care of this borehole since 2009, and we are managing this facility all the time. Three caretakers are in charge of this position and our responsibilities are for the locking system, collection of contribution from registered community members, supervision at the water point and weekly maintenance activity. As a maintenance activity, we apply grease to the top part of the handpump weekly and check the stroke everyday and record it in the book. The amount of contribution is ZMK2,000 (≒US$0.4)/HH/month, and then only households who have paid and are recorded in the book can use the handpump facility. The average number of borehole users is about 75 households. We managed to collect contribution from users so far because I think they know the importance of getting safe water from a handpump rather than going to fetch contaminated water from the lake.

(Caretaker)

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I am usually drawing water from this handpump facility. Actually my neighbour has his well but the water from there is not as good as the water from the handpump and sometimes it is dried up. So I mostly use water from this handpump……I am paying ZMK3,000 (≒US$0.6) for the handpump and also need to pay ZMK2,000 (≒US$0.4) for the neighbours well. There is no safe water we can collect which is free of charge.

(Village woman)

<u>Box 6.2 (Continued)</u>

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My house is located near the handpump facility and the neighbour's well is a bit far from my home. I pay both water sources ZMK2,000 (≒US$0.4) for the neighbour's well and ZMK3,000 (≒0.6) for the borehole. I use the neighbours well sometimes because the handpump is sometimes locked and there is a long queue. The water quality is just the same from the neighbours well and the handpump. There isn't any way to find a water source that we can get for free. The contribution is not cheap for my family but it is much better than using dirty water from the lake or constructing our own well that is not affordable for me.

(Village man 1)

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I am using my well (Not Protected HDW) since 2009 at my house, and I paid about ZMK300,000 (≒US$66) to community members to construct this well. I used to draw water from the Lake Mweru but my family suffered lots of sickness and we knew that the water from the lake was contaminated. We also tried to find water from the neighbours well and the communal handpump facility but everywhere we needed to pay to access safe water. That is why my family decided to have a well at my house.

(Village man 2)

Having said that, the crucial point in this village was that they understood the importance of access to safe water and paid for sustainable access to water supply. In either case of access to communal/neighbours water source or improve/have their own water source, sustainable access to safe water cannot be justified as free of charge. It was not a common tradition for village dwellers in Milenge to pay for water itself. However, it is important to recognise for them that there was no way to access water sustainably without O&M that required some costs both for communal and Self Supply models.

There was also a challenging case of the symbiosis between communal and Self Supply models. As noted in the previous section 6.8.1, Kachenge village had a borehole facility equipped with a handpump which was used by only 5 households. Apart from the setting up of a contribution system (see Section 6.8.1), one of the other reasons for the small number of borehole users was that there was another water source that they were able to use without charge. Surprisingly, one such water source was where one of the villagers had constructed his well under the Self Supply model as a *Protected* HDW. Box

6.3 outlines the excerpt from a survey with this HDW owner.

Box 6.3: Excerpt from a survey with one of the *Protected* HDW owners at Kachenge village, Mulumbi Ward

I constructed my well in November 2009. We used to draw water from a neighbours well and a stream. But we realized that the water quality was bad because they (neighbours) did not care about hygiene conditions. So we decided to dig a well by the Self Supply project in my yard. We knew that our village would get a handpump facility but I was sure that the high Iron content would discourage us from using the water from the handpump……The handpump facility was constructed just within 100m from my house at the same time (Nov. 2009)….There is no point in drawing water from the borehole because now I have my own water. We allow neighbours to collect water from my well just free of charge because now the handpump facility is also a giveaway for use…… My plan is that I would ask them for a small contribution for using my well when they stop using the communal facility for any reason.

(Interview date: 30th March 2010, Protected HDW owner)

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As you know, now village people have stopped using the borehole because of the high contribution cost (ZMK10,000), and then some of them came to draw water from my well. I expected to get small contribution from them but they refused to pay it. I even provided options for contribution either ZMK5,000(≒US$1) per year or ZMK500 (US$0.1) per month, but they again refused and started criticising my behavior.

(Interview date: 25th June 2010, Same Protected HDW owner)

Box 6.3 indicates the challenges of symbiotic use between the communal and the Self Supply models. Where people find a reliable water source that they can use for free, it is unlikely that a contribution mechanism will be achieved for the communal model. Although the small number of borehole users may contribute to the water source sustainability with fewer burdens in the short term, O&M costs must be covered by community members to run the facility for long term sustainability. Further, it is a challenge to initiate a contribution mechanism where fewer people understand the importance of contribution for long term sustainability no matter whether the water source is a communal or Self Supply model. From the other point of view, this case was one prior to the stage of Chilongoshi village (see Box 6.2) where they accepted a symbiosis between Self Supply and communal water supply models. Once users recognize how to achieve sustainable safe water for the long term from either public or private water source, the different water supply models may fit with their individual affordability and preference. In fact, as noted in Box. 6.3, one of the village dwellers accepted and utilized the Self Supply model despite the existence of a communal water supply model within 100m of his premises.

Overall, these findings implied that it is important to build blocks for a sustainable environment to access safe water in a **symbiotic way** between the communal and Self Supply models on the condition that the government and NGOs/external support agencies overcome the temptation to regard water supply provision to rural dwellers as a giveaway social service.

6.9 Chapter summary

This chapter has focused on responding to the research questions in connection with the key research aspects. Implications for practice have been developed from the results of the data analysis, ideas from the extant literature and insights obtained during the field studies. The following key points can be highlighted from this chapter:

- The findings from the studies indicated that the access to sustainable safe water was consistent with the higher level of water supply models (Borehole > *Protected* HDW> *Partially Protected* HDW> *Not Protected* HDW) with respect to technical protection. However, it was nonsensical when we considered other criteria: those with per capita water use, distance and water collection time. Compliance with these criteria was met by the following order of water supply models (*Protected* HDW> *Partially Protected* HDW> *Not Protected* HDW> Borehole). It was evident that private (individual) water points could deliver water to users with much shorter distance and time (distance & water collection time) in that the existing high number of HDWs contributed to the dispersal of water users from limited communal water points to neighbours water points in sparsely populated rural areas.
- Further, the parameters of 'water quality' and 'reliability' could be improved by a Self Supply model. For a concrete example of this, water quality was significantly improved at *Protected* HDWs over a four month period which gave comparable results with water from a borehole. Although it is one of the lessons learned from the Self Supply model in Milenge that failure to re-deepen and cast bottom linings during the dry season led to the water source drying up, it was statistically proven

from the studies in Nchelenge that reliability could be significantly improved when the HDWs are lined at the bottom levels.

- The communal water supply model was less cost-effective than the Self Supply model in terms of project costs but more cost-effective for households/communities if the household costs were incurred by water point owners exclusively (the most prevalent approach at the time of the visit) rather than shared with beneficiaries. Despite the fact that Self Supply model is less cost-effective for households, rural dwellers found benefits in putting what little money they had into improving or having their own water source, adding to their original value (e.g. accessibility, acceptability or income generation activities etc.), and this may be overlooked when a water supply model is decided from a macro-economic viewpoint i.e. policy makers.
- The current communal water supply model may have assumed that once communal water supply facilities are delivered to the communities, every household in rural areas has access to them. The Self Supply model may bridge the gap between a household demand and a communal water supply especially in the sparsely populated rural area. Therefore, differentiation of the sparsely populated rural setting from rural communities is important when considering an appropriate water supply strategy for rural end users.
- Private sector capacity development is cardinal for long term sustainable access to safe water. Even if an external support agency leaves a project site, rural dwellers can sustain and act on their desire to improve their water sources where local private sectors are strongly involved in the rural water supply. Further, it is important to note that capacity development and involvement of ACOs, Neighbourhood Health Committee or any other local committee are necessary in order to mobilise and sensitise communities. However, such effects could be significantly accelerated if local private sector capacity is build up concurrently by means of a systematic approach.
- The data collected from the field studies showed that these different models should be incorporated into national or international strategies for rural water supply improvement together rather than by working separately to bridge the gap between the weak points among the different approaches.

Chapter 7 CONCLUSION

7.1 Chapter Outline

This chapter concludes the thesis by recapping the crucial points that have emerged from the study. It illustrates that the research has successfully addressed the research questions and principal argument by measuring and analysing the different types of rural water supply models within the communal and Self Supply models, and underscoring their implications for a sustainable water supply strategy in sparsely populated rural areas of Zambia. Contribution to the body of knowledge and limitations of the research are also highlighted in this chapter.

7.2 Research Questions and Principal Argument

Research questions are embedded into key research concepts, namely, those of water quality and sanitary conditions, accessibility, technical and environmental sustainability, cost-effectiveness and acceptability. This section examines all the research questions in order to prove the principal argument. Below is a summary of the conclusions drawn for each research question:

Water quality and Sanitary Conditions

Research question 1: *What impact do the water supply models have on the quality of water?*

The findings from this research showed that more than 90% of the water collected from the boreholes was an acceptable level (<10FC/100ml) for drinking water. In addition, Protected HDWs used for the Self Supply model could reduce the risk of faecal contamination much more than *Partially Protected* and *Not Protected* HDWs. In particular, a Self Supply model would deliver skilled artisans to improve water sources for access to safe water at a household level at a quality comparable to the subsidized communal HDW and communal borehole water supply model.

Research question 2: *What are the factors likely to affect water quality?*

The findings from this study showed that contamination-free results were not derived from a single protection or practice but rather from multiple causes within physical protection, environmental conditions and hygiene practices. Further, it could be important to have intervention by skilled artisans in order to enhance the protection level and increase water source sustainability following the owner's initial improvements or hygiene practices.

Research question 3: *What is the status of sanitary condition? What are the sanitary risks likely to affect the water quality?*

The findings of the research suggested that animal faeces within 10m of the water supply facilities led to a higher rate of microbiologically contaminated water in *Not Protected* HDWs in both Milenge and Nchelenge Districts, and *Partially Protected* and *Protected* HDWs in Milenge. Faecal contamination levels of *Not Protected* HDWs in Nchelenge correlated with 'animal faeces within 10m of the well' and 'can water flow back into the well'; these factors combined with findings of 'well mouth lower than surrounding ground' and 'well cover insanitary' were statistically correlated hazards with FC contamination levels at 95% levels of significance, suggesting that each of these hazards increased the risk of faecal contamination at the sampled *Not Protected* HDWs in Nchelenge.

Research question 4: *How does water quality change at source and the point of use, and what are the contributory factors?*

The research findings showed that over half (58%) of the water sampled from household storage resulted in a worse water quality in comparison with that sampled at source and that the risk of quality reduction might have occurred from two phases: one was in the process of carrying water from source to house, and the other was in the storage condition of water at the house. The study statistically proved that water quality at the point of use became worse as the distance from house to water source increased. Further, the storage condition of water at the house was an important factor in considering the change of water quality between source and use. One of the risk hazards of household storage, "water containers have wide or singular mouth/opening" was the highest risk found in the study, and it was also statistically proven that whether the mouth/opening of water container was wide or narrow it had an association with the level of faecal contamination. To sum up, the test results implied that the faecal contamination risk increased during the process of transportation and storage at the household, but the risk could also be mitigated by using household water treatment.

Accessibility

Research question 1: *What is the status of accessibility towards different water supply models?*

The findings of the research indicated that a fifth or a third of HHs collecting water from boreholes (18% in Milenge and 34% in Nchelenge, respectively) had to walk more than 500m to draw water compared with HHs using water from any protection type of HDW where no more than 15% of them had a distance to a water source of more than 500m. However "access to safe water supply" as defined in the Zambian government standard requires people to be able to access water **within a distance of 500m from point of use**. So HDWs, in particular privately owned, met this access criterion better than boreholes.

Research question 2: *What are the factors likely to affect the accessibility in terms of distance and time?*

The findings of the study suggested that accessibility in terms of distance to private HDWs for end users living in a sparsely populated rural area was more convenient than that for boreholes or HDWs owned as a community commodity. By contrast, the communal water supply model contradicts the Zambian government standard of serving 250 people (≒40HH) within a distance of 500m from point of use because the actual rural settlements have such a low population density i.e. (1HH/km^2 in Milenge and 3HH/km^2 in Nchelenge) that the standard cannot apply. Further, it was apparent from the study that the borehole users were queuing for an average of 40minutes, or more than 2.5 times as long as the HDW users who waited on average for 14minutes. These findings that drawing water from borehole water points takes a long time because of considerable distances and queuing times, combined with the results that communal HDW water point users also take a long time to fetch water, suggested that privately owned water points, on which the Self Supply model has focused, could provide more opportunity to access water with relatively less of the distractions of distance and/or time in contrast to the conventional communal water models.

Research question 3: *What is the status of per capita water use among different water supply models and how is this likely to be affected by accessibility?*

The findings of the research revealed that, for single water source users, the average value of per capita water use among HDW users was 28.50 lcd whilst the average value of borehole users was 17.69 lcd. Although it is acknowledged that they may also have consumed water at school or work in the field, the sampled borehole users had not reached the Zambian standard level at home, whilst HDW users could access more than the minimum amount of per capita water use under the definition of water supply coverage in NRWSSP (2007) i.e. that access to safe water supply should cover a **minimum of 25lcd** of water from a *Protected* source. In fact, out of 109 borehole users (HH), 41 HH used another water source every day to complement an inadequate supply of water collected from a borehole, which led to extra energy and time in collecting water from multiple water sources rather than being able to rely on a single water source although the average per capita water use of multiple source users could exceed 25 lcd. Further, the study showed that the distance they walked to draw their water led to a lower amount of water being used for their daily consumption and hygiene purposes. In other words, per capita per day increased where the distance to water source decreased. This is indicative of the fact that rural households compromised in terms of water quantity and accessibility.

Technical and Environmental Sustainability

Research question 1: *What is the status of the technical sustainability of different water supply models and what are the factors likely to affect technical sustainability?*

The findings of the study suggested that the longevity of a rope and bucket depended on the material they used for the container rather than on the number of users. For instance, the metal buckets mostly used at *Protected* HDWs or *Partially Protected* HDWs, where owners purchased them from artisans through the Self Supply model, had a significantly longer life span than plastic containers. The frequency of breakdown of windlass and ropepump varied from every few months to over a year, but significant reasons for breakdown were not found due to the limited data collected. Further, the study also suggested that the reliability of a borehole equipped with a handpump could be threatened where the lifting device was non-functioning with downtime ranging from a few days to over six months, which made the water inaccessible even when there was water in the borehole.

Research question 2: *What is the status of water reliability of different water supply models and what are the factors likely to affect environmental sustainability?*

The findings of the research showed that more than two thirds of *Not Protected* HDWs had dried up during the dry season (80% in Milenge and 59% in Nchelenge) while water sources seldom dried up at borehole facilities. The findings of the study revealed that the frequency of HDW dry up had an association with the bottom lining of the well. The bottom lined HDWs provided a sufficient water source every day of the year by preventing collapse from soil erosion in the bottom part of the well wall when the groundwater level was up in contrast with those HDWs without linings. An inadequate depth of the well might also lead collapse from the bottom with inadequate protection. In fact, the depth of sampled HDWs was relatively shallow (10-20m from surface) compared with over 20m at borehole.

Research question 3: *In what way are water supply models delivering operation and maintenance systems to the households/communities?*

The findings of the study showed that, in the communal water supply model in Zambia, JICA has attempted to enhance the water supply sustainability by building blocks, such as cost sharing by communities, sustainable supply chains, O&M mechanisms, choice of appropriate technology and capacity building through SOMAP projects. Meanwhile, the Self Supply model has tried to enable a sustainable environment through technology advice, financial mechanism, policy change and private sector development. By incorporating and integrating human resources, such as in the case of Nchelenge where handpump menders for conventional communal sources also implemented artisanal works under Self Supply, the operation and maintenance system of both communal and Self Supply models could be strengthened.

Cost-Effectiveness

Research question 1: *What costs constitute lifecycle cost for the different water supply models?*

The findings of the study showed that the communal water supply model included mostly hardware components in the lifecycle project costs rather than any software components; this was in contrast with the Self Supply model lifecycle project costs which were made up exclusively of software components. It was also found that the software component costs of the Self Supply model were about three times greater than those of the communal borehole model in the lifecycle project costs. Despite this fact, the results of the total lifecycle project costs of the conventional communal model including hard/software were about thrice those of the Self Supply model. This indicates that the hardware component costs of the communal model using a borehole equipped with a handpump were more than the costs of the software activities of the Self Supply model.

Research question 2: *How do lifecycle costs impact on project costs and household/community costs?*

The findings of the research suggested that the Self Supply model was more cost-effective than the communal model based on the lifecycle project costs because considerable hardware subsidies towards the communal model were incurred by government or NGO/external support agencies; This was the case if the costs were simply compared in isolation from the levels of the water supply model. On the other hand, the costs incurred by households/communities were erratic. The communal model involved the household/community contributing a more than for the amount of the Self Supply model if the calculation was based on the assumption that the community shared the costs. However, the study found that capital and improvement costs for individual water points were rarely shared by beneficiaries despite the fact that owners shared their water sources with neighbouring households. It was more usual for water point owners or their families to invest for themselves. In addition, very few communal water points had systems of contribution in practice.

Research question 3: *When are the costs incurred?*

The findings of the study showed that the greater proportions of costs were incurred in the first year of project implementation, especially by government or external support agencies in both water supply models. However, the government will not meet the cost for minor maintenance costs in either model so communities/households need to meet the future operation and maintenance costs themselves. Further, the study also implied that that community should consider the need for saving beyond the annual operation and minor maintenance costs to prepare for future replacement/rehabilitation costs.

Acceptability

Research question 1: *What is the status of acceptability towards water supply models for end users in terms of water quality, water quantity, distance, queuing time, cost, reliability and technical sustainability?*

The findings of the study identified that overall community members using HDWs showed higher satisfaction levels than borehole users in terms of water quality, quantity, distance, queuing time and contribution but lower from the point of view of technical and environmental sustainability. The satisfaction level also increased in parallel with the protection level of HDWs.

Research question 2: *What are the factors likely to affect user satisfaction?*

The findings of the study showed that ownership status was likely to affect user satisfaction with respect to per capita water use, distance and queuing time. Private (household) water source users presented higher satisfaction levels than communal HDWs and borehole users. This was justified by the fact that where the ownership status was the community, the water source required users to spend considerable time and distance for access to water. Further, no matter whether the water sources were owned privately or publicly, community members were more likely to be satisfied with their contribution towards the water sources where individual/community members had invested their money rather than where subsidized water was sourced as a giveaway.

Research question 3: *How are user preferences/satisfactions in selecting a water supply model likely to affect the community water supply dynamics?*

The findings of the study showed that water source selection by a community was not a static behaviour as a community dynamic was created alongside a change of water situation in the community. The study found that customarily there had been a high demand for a private water sources, and communities had already started taking steps to access water. The findings of the research suggested that even if they could access neighbours water points or communal sources, water point owners put their value on having their own water source and making their investment gradually without a subsidy from the government.

Principal Argument

The thesis was directed by the principal argument that:

Reliance only on a communal water supply model limits the achievement of increased sustainable access to a safe water supply; hence a Self Supply model is needed which does not compete with communal models but works alongside them in sparsely populated rural areas of developing countries for the purpose of increasing access and achieving sustainability.

The principal argument directed the thesis towards determining the most appropriate water supply model in sparsely populated rural areas of Zambia. In order to examine the principal argument, five key concepts (water quality and sanitary conditions, accessibility, technical and environmental sustainability, cost-effectiveness and acceptability) were addressed in the thesis through comparative assessment between communal and Self Supply models. The principal argument was strongly defended from the overall findings below:

- The findings related to the Water Quality and Sanitary Conditions showed that the Self Supply model could support the acceleration of access to safe water where trained artisans improved traditional private water sources where sanitary practices had been started by water source users themselves. The quality of water from *Protected* HDWs under the Self Supply model was shown to be comparable with that of the subsidised communal model and the sanitary conditions have proved that hygiene practices through community sensitisation within Self Supply reduced the risk of water contamination.
- In addition, the findings from the Accessibility concept implied that communal models faced fundamental issues in sparsely populated rural areas because a sizable number of rural dwellers were forced to walk beyond the Zambian government standard of serving 250 people within a distance of 500m from point of use. On the other hand, traditional private HDWs were generally located within their premises, and such closeness significantly benefited the community in terms of increased per capita water use and saved water collection time.
- Further, the findings related to the Technical and Environmental Sustainability indicated that the communal model using a handpump showed little evidence of

water source dry up although the downtime of the handpump was a serious issue because the community source could sometimes be inaccessible even if water was there. This situation might be improved by skilled labour training and/or a supply chain of spare parts, but fundamentally almost nowhere had the practice of community contribution towards operation and maintenance. In the meantime, materials or devices used in traditional water source improvement were simple and locally available, and the practice of bottom lining showed that dry up of the water source could be preventable.

- The findings related to the Cost-effectiveness implied that the Self Supply model was more cost-effective than the communal borehole model for the government or external support agency because the major project costs of the Self Supply model were for software components and these costs were significantly less than hardware costs which were major parts of the communal model costs. In addition, cost per head for the community/household of the communal model was also greater than that the amount per capita for the Self Supply model, as practically all the private water source owners met all the costs by themselves and there was very little practice of community contribution on the ground.
- And last but not least, the findings of the Acceptability concept indicated that the community/household had relatively higher satisfaction with private traditional water sources than with communal water sources except for the concepts of technical sustainability and reliability. This tendency could be explained by the ownership status that where a private family owned a water source and shared it with neighbours, they put their value into the source and recognized it as property. This could not be seen in the communal water sources, but rather a communal water source led to constraints such as queuing, distance and restriction (contribution, locking etc.). In fact, the community dynamics for water source selection proved that individual household found value in having their own water source.

7.3 Implications for Policy and Practice

The overall research findings emerging from the study provided empirical evidence that the Self Supply model could significantly reduce the faecal contamination risk in water quality and deliver greater per capita water use and better convenience of access than communal water supply models; however, its reliability with regard to water source dry up requires to be monitored. Meanwhile, the communal model constrained the end users' access to water because of the nature of the community property, which resulted in substandard levels for distance, per capita water use and water collection time. A Self Supply model may fit with people living in sparsely populated rural areas where a communal model may have limitations for delivering water close enough to fulfil a household's demand. However, this does not mean that the communal model is not sustainable anywhere, rather that it is important to build blocks for a sustainable environment allowing access to safe water in a **symbiotic way** between the communal and Self Supply models but with the condition that the government and NGOs/external support agencies overcome the temptation to provide water supply to rural dwellers as a giveaway social service. This study led to the following implications for policy and practice.

- The current communal water supply model may have assumed that once communal water supply facilities are delivered to the communities, every household in rural areas has access to them. The Self Supply model may bridge the gap between a household demand and a communal water supply especially in the sparsely populated rural area. Therefore, differentiation of the sparsely populated rural setting from rural communities is important when considering an appropriate water supply strategy for rural end users.

- Incorporating the technical human resources into Artisan Associations might mitigate overload on limited human resources in the rural areas. , Skilled artisans could become driving forces for rural water supply strategy to take a step towards scaling up both communal water supply and Self Supply models. Further, it is also important to note that capacity development and involvement of ACOs, Neighbourhood Health Committee or any other local committee are necessary in order to mobilise and sensitise communities. However, such effects could be significantly accelerated if local private sector capacity is build up concurrently by means of a systematic approach.

- The findings of this research highlight the need for different models to be incorporated into national or international strategies for rural water supply improvement together rather than by working separately to bridge the gap between the weak points among the different approaches.

7.4 Contribution to the Body of Knowledge

The previous section presented the conclusions of the research findings in connection with five key concepts following the related research questions, and it has proved the principal argument that a Self Supply model is of significant importance for a rural water supply strategy in not competing with a communal model but rather by working in harmony with it. The significant contribution to the body of knowledge is presented in this section.

- Extant literature and analysis reported among water sectors show that a sizeable number of researchers have examined the sustainability of rural water supply. However, very little research has focused on household level water supply, as more emphasis has been on communal water supply. This study is one of the few studies that have examined the suitability and sustainability of household level water supply.

- This is one of the few documented studies to monitor and evaluate the Self Supply model in a holistic way including technical, financial and social aspects associated with key indicators for a sustainable safe water supply in comparison with the communal water supply model.

- This is one of the few studies that has monitored and analysed microbiological water quality systematically alongside water source improvements under the Self Supply model. Also, this is one of the few studies to illustrate that the level of faecal contamination could be reduced by the degree of HDW protection from *Not Protected* to *Partially Protected* to *Protected* condition.

- This is one of the few studies to examine the impact of different water supply models by comparing communal water supply with Self Supply in order to identify the competition or symbiosis. It also proposes a symbiotic rural water supply strategy incorporating both communal and Self Supply models based on geographical and settlement conditions.

- The viewpoint of the user is very little understood in the extant studies and decisions tend to be based on the macro-interest of the government or donor. This is one of the few studies that looked into user acceptability and preference towards selection of which water source to use.

- This is one of the few studies to identify the community dynamics with respect to water supply selection. This study contributes to knowledge by using community dynamic mapping to show how community members take a decision to have their own water source or to select a water source.

7.5 Limitation of the Research

The study has identified significant findings and contributed to the body of knowledge about sustainable safe rural water supply. Meanwhile, it is also acknowledged that the study has a number of limitations in its research findings. Firstly, this research looked into the area where people live in a sparsely populated rural area with low water coverage, rather than by income level or ethnic group, and these factors might have influenced the data collected in study. Nonetheless, comparison with the data from the Country Statistic Office of Zambia and relevant literature showed that the ethnic groups and income levels of the settlement are fairly similar to those characteristics in this study area.

Secondly, this study was supported by research assistants in terms of translation in order to help rural dwellers to express their opinion openly using native language. This transition from local language to English might lead to inaccurate interpretation. This limitation was minimized by training of the research assistants to assure the quality of work.

Thirdly, all the data was collected by the researcher in order to endorse the process of data collection and quality. However, the presence of the researcher in household surveys and key informant interviews might have affected the respondent's answers because they might perhaps expect something from outside people. To avoid any misunderstanding by the respondents, a self introduction and purpose of the study was given/ explained to respondents and interviewees prior to all data collection methods.

Fourthly, low frequencies for some of the categories are a limitation for robustness of statistical analysis especially dividing samples into small groups in the user satisfaction analysis. To enhance the validity of the results, different methods such as focus group discussion and open-ended questionnaire in household survey were used as triangulation design.

Finally, this study looked into the comparison between communal water supply and Self Supply models in Luapula Province of Zambia exclusively. Thus, the findings are not likely to be applicable to all rural areas in other developing countries. However, by taking all measures to assure the protocol for both qualitative and quantitative data and obtaining data to be quantitatively statistically reliable, the study enables the research findings to be applied to some extent in other rural areas of other developing countries where they have similar environmental, social and geographical background.

To sum up, although some limitations of this study were noted above, they seldom spoilt the quality of the work, but rather provided further research recommendations.

7.6 Suggestions for Further Research

This thesis has conducted a comparative assessment of communal water supply and Self Supply models to determine the most appropriate water supply model for sparsely populated rural areas. The findings of the study have significantly contributed to the body of knowledge on sustainable rural water supply strategy. This is the last section of the thesis which suggests further research areas related to the study.

- This study focused on the areas where rural dwellers settle in sparsely populated areas. However, household level water supply customarily exists not in only scattered communities, but also peri-urban and poor urban communities. The people living in the latter areas might face inadequate water supply in terms of distance, quantity or queuing time. Or perhaps they are also challenged by the affordability of public/private utility use. By shedding light on these areas where they have originally used traditional water sources, the study would be beneficial for both end users and policy makers in re-examining the suitability and sustainability of both the communal and Self Supply models (e.g. willingness to pay, sustainability of water supply facility, user acceptability/preference or community water supply dynamics).

- The research focused on the comparison between the communal water supply and Self Supply models in Zambia exclusively. However, the approaches are not a panacea for everywhere. For instance, the Self Supply model in Zambia involved zero-hardware subsidy for the households, but in the case of Uganda they might subsidise some portions of the hardware costs. It is important to know from future studies how the subsidies impact on HDW owners' motivation to improve their water source or discourage their ownership status.

- This study focused on the area where people live in dispersed regions, and excluded the factors of income level, ethnic group or occupation of sampled households. Replication of this study to areas where people live with a variety of income levels, tribes or work will contribute to an understanding of the similarities or differences from one to another.

- This study excluded the detailed impact of the revolving loan, the sustainability of the loan itself and loan committee. Further research into the financial mechanisms in connection with the Self Supply model would contribute to the body of knowledge regarding financial sustainability.

- This study examined inadequate sample numbers for rope pump facilities. Although extant literature discussed its structure, it seldom examined the sustainability of the technology. It is important to understand how and to what extent the low cost technology is sustainable in order to extend the options of the Self Supply model.

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APPENDICES

APPENDIX [A]

Inventory Survey Form

Water Source No.____________________

Name of Water Source _______________ District _________________________

Ward _____________________ Village __________________________

GPS Reading (South)________________ (East)_____________________

Interviewee's name _______________________Date _______________

1. What is the water source:

	Good	Poor
1) Borehole		
2) Hand dug well		
3) Rooftop rainwater catchment		
4) Pond/stream/swamp/lake		
5) Other (Specify__________________)		

1. What type of **lifting devices**:

	Good	Poor
1) Bucket and rope	1	6
2) Handpump	2	7
3) Windlass/Pulley	3	8
4) Rope pump	4	9
5) Other (Specify_________________)	5	10

2. What type of **Protection**:

(Multiple)

	Good	Poor
(a) Cover		
(b) Raised wall/casing to protect from inflow		
(c) Raised ground around well mouth		
(d) No apparent route for surface water to seep in		
(e) Concrete apron		
(f) Apron but in poor condition		
(g) Top slab		
(h) Drainage channel		
(i) Functioning soak away		
(j) No water ponded on ground within 5m		
(k) Lining at least for top meter of shaft		

3. Where **latrine** locates

1) No latrine within 50m ☐
2) Latrine within 30m ☐
3) Latrine within 10m ☐

4. What is the depth of water source at time of visit ___________

5. What depth of lining ___________

7. What material used for **lining**

1) Brick lining ☐
2) Concrete lining ☐
3) Corrugated steel/Culvert lining ☐
4) Other (Specify) ______________________

8. What type of **well cover**

1) Steel cover ☐
2) Concrete cover ☐
3) Polythene cover ☐
4) Other (Specify) ______________________

Section for Private Well Owner/ Committee for Communal source

1. Who **owns** the water source in use

1) Privately (individual family, not shared) owned ☐
2) Privately owned and shared ☐
3) Community owned ☐
4) Government owned ☐
5) Other (Specify_________________) ☐
6) No one ☐

2. When was it constructed __________________

3. Number of users **Number** of **households** ________

4. Can water source supply **sufficient** water for all users all year?
    1) Yes, this year
    2) Yes, in last 5 years
    3) No, dry up seasonally (specific ______________)
    4) No, dry up monthly ______________
    5) No, Dry up daily ______________

5. Is there any **charge/pay** for use of the facility
    1) Yes, constantly
    2) Yes, but irregularly (Specify________________)
    3) Only when the need arises
    4) Only in the past
    5) No

6. **How often** and **how much** is the charge
    1) Per bucket/jerry cans
    2) Per household/week
    3) Per household/month
    4) Per household/ year
    Amount ZMK ______________
    5) In-kind ____________________

7. What are the funds collected used for
    1) To meet household requirements
    2) For maintenance of the source
    3) Income
    4) For improvement of water source
    5) Other (Specify ________________)

8. How was the amount for user fees decided
    1) By owner
    2) Agreed with users
    3) By Gov. agency
    4) By NGO/Donor
    5) Other (Specify ________________)

9. Is there **difference** between **now** and **past** toward **contribution** from users

1) Increase contribution (Reason ______________) ☐
2) Decrease contribution(______________________) ☐
3) No change ☐

10. Why there is **no charging** for user fees

1) No need ☐
2) Asked, but refused (Reason______________) ☐
3) Need, but not asked (______________________) ☐

11. Is there any **restrictions** to draw water

1) Yes, open hour restriction by lock ☐
2) Yes, lifting device is stored at home ☐
3) No ☐

12. **Why** is there a **restriction** (Multiple)

1) Source has low flow ☐
2) Too many people use source ☐
3) Limited time for caretaker ☐
4) Non-domestic uses of water ☐
5) Stranger use without permission ☐
6) Other (specific _____________) ☐

13. How **initial construction** was conducted in terms of work and cost

Initial construction	WASHE	NGO/Donor ___________	Gov. agency _____________	Owner	User	Other ______
Actual Work						
Cost(capital/ contribution/material)						

14. How many times **lifting device broken down** since installation

____

15. How long did it stay **out of use** each time ________________________

16. Who is the **responsibility** for **repair** work and cost for lifting device

Repair	WASHE	NGO/Donor ______	Gov. agency ______	Owner	User	Other ______
Actual Work						
Cost (cash/material)						

17. Who is **responsible** for **daily maintenance** (sweeping, cleaning out, dredging out etc.) of the source

Maintenance	WASHE	NGO ______	Gov. agency ______	Owner	User	Other ______	No body
Actual Work (1) ______ (2) ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______
Running Cost(cash/material) (1) ______ (2) ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______

Section for Private Well Owner

18. Has any **improvement** work has been carried out on the water supply (Multiple)

1) Re-deepening ☐
2) Full-Lining ☐
3) Partially-Lining ☐
4) Drainage channel construction ☐
5) Apron/top slab construction ☐
6) Soak-away ☐
7) Lifting device change (__________) ☐
8) Raised walls around well mouth ☐
9) Well cover replacement ☐
10) Other (Specify________________) ☐

19. If done **re-deepening**, what depth change from initial

Initial depth ________ m
Re-deepening ________ m

20. **Why** did you **improve** the water source

1)	Water quality	☐
2)	Water quantity	☐
3)	Availability	☐
4)	Other (specify ______________)	☐

	V-WASHE	NGO/Donor ______	Gov. Agency ______	Owner	Users	Other ______
Improvement (1) ______ (2) ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______
When (1) ______ (2) ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______
Work (1) ______ (2) ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______
Idea (1) ______ (2) ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______
Cost (1) ______ (2) ______	______ ______	______ ______	______ ______	______ ______	______ ______	______ ______

21. What is your **preferred improvement** to the water source in the future (Multiple)

1)	Re-deepening	☐
2)	Lining	☐
3)	Drainage channel construction	☐
4)	Apron/top slab construction	☐
5)	Soak-away	☐
6)	Lifting device change	☐
7)	Raised walls around well mouth	☐
8)	Well cover replacement	☐
9)	None	☐
10)	Other (Specify) ______________	☐

Appendix [B]

Scoring Protection

	Yes	No		
Lifting Device			**Measure of Protection**	
Handpump/pump	10	5	Fully protected (borehole with hand pump)	45-50
Windlass/ pulley	5	3	Protected (improved)	30-44
Other lifting mechanism	2		Partially Protected	15-29
Bucket and rope	1		Not Protected	<15
Scoop	1			
Max Total	10			
Protection				
Raised wall/ casing to protect from inflow	5			
Raised ground around well mouth		3		
Lining at least for top metre of shaft	3			
Concrete apron	5			
Apron but in poor condition		2		
No apparent route for surface water to seep in	5			
Top slab	5			
Cover	3			
Drainage channel	3	1		
Functioning soakaway	3	1		
No water ponded on ground within 5m	3			
Max total	35			

Appendix [C]

Onsite Sanitary Inspection Form

Ⅰ. Type of Facility **HAND DUG WELL**

1. General Information: Water Source No.: ____________________
   : District: ____________________
   : Ward: ____________________
   : Village: ____________________
   : GPS Reading (South) ____________ (North) ____________
2. Date of Visit: ______________

Ⅱ. Specific Diagnostic Information for Assessment RISK

1. Is there a latrine within 10m of the well Y / N
2. Is there a faeces within 10m of the well Y / N
3. Are there any other sources of pollution within 10m of well Y / N
4. Is the fence missing or faulty Y / N
5. Is the cement less than 1m in radius around the top of the well Y / N
6. Is there any animal roam around the well Y / N
7. Can water flow back into the well Y / N
8. Is the well mouth higher than the surrounding ground Y / N
9. Is the rope and bucket leave on the ground Y / N
10. Is the well cover insanitary Y / N

Risk score: 9-10= very high; 6-8= High; 3-5= Medium; 0-2= Low

Variables	Value	Remarks
Faecal coli.	FC/100ml	

Appendix [D]

Sanitary Inspection Forms

Ⅰ. Type of Facility **BOREHOLE WITH HANDPUMP**

1. General Information: Water Source No.: ________________
   : District: ________________
   : Ward: ________________
   : Village: ________________
   : GPS Reading (South) ________________ (North) ________________

2. Date of Visit: ________________

Ⅱ. Specific Diagnostic Information for Assessment RISK

1. Is there a latrine within 10m of the borehole Y / N
2. Is there any animal roam around the borehole Y / N
3. Are there any other sources of pollution within 10m of boreholes Y / N
4. Is there drainage faulty allowing ponding within 2m of the borehole Y / N
5. Is there drainage channel cracked, broken or need cleaning Y / N
6. Is the fence missing or faulty Y / N
7. Is the apron less than 1m in radius Y / N
8. Does spilt water collect in the apron area Y / N
9. Is the apron cracked or damaged Y / N
10. Is the handpump loose at the point of attachment to apron Y / N

Risk score: 9-10= very high; 6-8= High; 3-5= Medium; 0-2= Low

Variables	Value	Remarks
Faecal coli.	FC/100ml	

Appendix [E]

Household Water Quality Inspection

Ⅰ. Type of Facility of Water Source

1. General Information: Household No.: ____________________
   : Water Source No.: ________________
   : District: __________________________
   : Ward: ____________________________
   : Village: __________________________
   : Interviewee's name: ________________
2. Date of Visit ________________

Ⅱ. Specific Diagnostic Information for Assessment RISK

1. Is drinking water kept in a separate container (ask to be shown this) Y / N
2. Is drinking water container kept above floor level and away from contamination Y / N
3. Do water containers have a narrow mouth/opening Y / N
4. Do containers have a lid/cover Y / N
5. Is this in place at time of visit Y / N
6. How is water taken from the container Y / N
7. Is the utensil used to draw water from the container cleaner Y / N
8. Is the utensil used to draw water the container kept away from surfaces and stored in a hygienic manner Y / N
9. Is the inside of drinking water container clean Y / N
10. Is the outside of drinking water container clean Y / N

Risk score: 9-10 = very high; 6-8 = High; 3-5 = Medium; 0-2 = Low

Table1: Water quality sampling

Variables	Value	Remarks
Faecal coli.	FC/100ml	

Appendix [F]

Questionnaire for Household Survey

Water Source No. in use:	Date& Time :
District & Ward:	Interviewee's name & sex:
Village:	Interviewee's occupation:
GPS (south): (East):	Number of family member:

22. What is the major source of your **drinking water** you use at home

1) Borehole ☐
2) Hand dug well (Own) ☐
3) Hand dug well (Neighbor's ____________) ☐
4) Spring ☐
5) Pond/stream/swamp/lake ☐
6) Other (Specify________________) ☐

23. How **far** apart are household and that water source

1) Yard or house ☐
2) Less than 250m (__________m) ☐
3) Less than 500m (__________m) ☐
4) Less than1000m (__________m) ☐
5) More than 1km (__________m) ☐

24. How much water did you collect **yesterday** (if not yesterday, the last time when collected)

Container	Volume	Number of trips	Total Volume
1.			
2.			
3.			
4.			
TOTAL			

25. How long did you need to **wait** to collect water __________min.

26. How is the quality of water from this water source
    1) Good (Has no smell, no colour, no objectionable taste) ☐
    2) Fair (minimal smell, colour and taste) ☐
    3) Bad (Water smells, has milky colour, tastes salty etc) ☐

27. If "Bad" in above the question, why do you perceive the water quality to be bad?
    (Multiple)
    1) Muddy ☐
    2) Odour ☐
    3) Salty ☐
    4) Other ________ ☐

18. What is the **other usage** water from that source (Multiple)

	Use at Source	Carry to House
1) Cooking	☐	☐
2) Washing	☐	☐
3) Bathing	☐	☐
4) Gardening	☐	☐
5) Income activity (________)	☐	☐
6) Other (________________)	☐	☐

19. Degree of **satisfaction** to the water source in use

Aspect	Very  Satisfied	Satisfy	Neither	Unhappy	Very  Unhappy	Reasons
Water quality						
Quantity						
Distance						
Waiting time						
Cost of water						
Reliability (Water Source)						
Reliability (Supply system)						

20. Do you use **alternative** water source
    1) Yes ☐
    2) No ☐

21. If Yes, what is the **alternative** water source in use

1) Borehole ☐
2) Hand dug well (own) ☐
3) Hand dug well (Neighbor _______) ☐
4) Spring ☐
5) Pond/stream/lake/river ☐
6) Other (Specify _______________) ☐

22. If Yes, what is the **reason to not use** alternative source as primary source for **drinking water**

1) Different water usage ☐
2) Bad water quality ☐
3) Less water quantity ☐
4) Far distance ☐
5) Less availability ☐
6) Higher Cost ☐
7) Queuing ☐
8) Other (Specify _______________) ☐

23. If Yes, what is the **advantage** of **alternative** source

1) Water quality ☐
2) Water quantity ☐
3) Distance ☐
4) Availability ☐
5) Cost ☐
6) Queuing ☐
7) Other (Specify _______________) ☐

24. If Yes, What is the water from **alternative** source used for (multiple)

	Use at Source	Carry to Home
1) Drinking	☐	☐
2) Cooking	☐	☐
3) Washing	☐	☐
4) Bathing	☐	☐
5) Gardening	☐	☐
6) Income activity (____________)	☐	☐
7) Other (__________________)	☐	☐

25. How long did you need to **wait** to collect water ________ min.

26. What is the **distance** to the nearest alternative source
   1) Yard or House ☐
   2) Less than 250m (__________ m) ☐
   3) Less than 500m (__________ m) ☐
   4) Less than1000m(__________ m) ☐
   5) More than 1km(__________ m) ☐

27. If No, **why** you don't use **alternative** source
   1) No alternative source ☐
   2) Bad water quality ☐
   2) Less water quantity ☐
   3) Far distance ☐
   4) Less availability ☐
   5) Higher Cost ☐
   6) Queuing ☐
   7) Other (Specify __________) ☐

28. Did you use different water source **in the past**
   1) Yes ☐
   2) No ☐

29. If Yes, what water source did you use **previously**
   1) Borehole ☐
   2) Hand dug well (own) ☐
   3) Hand dug well (Neighbor__________) ☐
   4) Spring ☐
   5) Pond/stream/lake/river ☐
   7) Other (Specify __________) ☐

30. If Yes, what is the **distance** to the previous source
   1) Yard or house ☐
   2) Less than 250m (__________ m) ☐
   3) Less than 500m (__________ m) ☐
   4) Less than1000m(__________ m) ☐
   5) More than 1km (__________ m) ☐

31. If Yes, what is the **reason** to change water source from previous to current

1) Water quality ☐
2) Water quantity ☐
3) Distance ☐
4) Availability ☐
5) Cost ☐
6) Queuing ☐

32. In what ways do you **prefer** a **community** well

____

33. If both private well and community well are available in the village what you would **change** about each

____

34. What type of **household water treatment** use (Multiple)

1) Well Chlorination ☐
2) Household Chlorination ☐
3) Filter ☐
4) Solar disinfection (SODIS) ☐
5) Thermal disinfection (boiling) ☐
6) None ☐
7) Other (Specific ______________) ☐

35. **Why** you do not use household water treatment (Multiple)

1) Taste ☐
2) Cost ☐
3) Other (specify _________________) ☐

36. **What** chlorine do you use (Multiple)

1) Klorin ☐
2) Hyperchlorite powder ☐
3) tablets ☐
4) Other (Specific _________________) ☐

37. **Where** does it come from

1) Shop ☐
2) Health Centre ☐
3) NGOs (specific _________________) ☐
4) Other (Specific _________________) ☐

38. If use well chlorination, how often do you use
    1) Every Day ☐
    2) Once a week ☐
    3) Once a month ☐
    4) Only rainy season (________________) ☐
    5) Only when taste is bad (_____________) ☐
    6) Only when purchase (______________) ☐
    7) Only when free distribution (_________) ☐

39. If use household chlorination, how often do you use
    1) Every Day
    2) Once a week ☐
    3) Once a month ☐
    4) Only rainy season (________________) ☐
    5) Only when taste is bad (_____________) ☐
    6) Only when purchase (______________) ☐
    7) Only when free distribution (_________) ☐

Section for Private Well Owner

40. **Why** do you like to have your **own** well
    1) Better water quality ☐
    2) Accessibility ☐
    3) Increase water quantity ☐
    4) Availability ☐
    5) Avoid payment ☐
    6) Gardening ☐
    7) Avoid queuing ☐
    8) Ownership (_______________) ☐
    9) Other (specify _______________) ☐

41. Does it give some **advantages** over a community well ____

42. Do you know is there any **promoting** supply improvement
    Yes (Who _______________) ☐
    No ☐

Section for Non Well Owner

43. Do you **pay** anything to use water source
    Yes (Specify ____________) ☐
    No ☐