ASSESMENT OF CHALLENGES OF SUSTAINABLE RURAL WATER SUPPLY: THE CASE OF GAMBELLA ZURIA WOREDA, GAMBELLA REGION, ETHIOPIA

MSc THESIS

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ASSESMENT OF CHALLENGES OF SUSTAINABLE RURAL WATER SUPPLY: THE CASE OF GAMBELLA ZURIA WOREDA, GAMBELLA REGION, ETHIOPIA

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DECLARATION

I, Seleshi Manaye Derseh**,** declare that this thesis is my original work and has not been submitted to any other university for similar or any other degree award.

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Signature

SCHOOL OF GRADUATE STUDIES

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This is certify that the thesis entitled "ASSESMENT OF CHALLENGES OF SUSTAINABELE RURAL WATER SUPPLY: THE CASE OF GAMBELLA ZURIA WOREDA, GAMBELLA REGION, ETHIOPIA" submitted in partial fulfillment of the requirements for the degree of Master with specialization in irrigation and drainage, the Graduate Program of the Department of Water Resource and Irrigation Engineering, and has been carried out by Seleshi Manaye Id. No PGIDE/011/09 under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence herby can submit the thesis to the department.

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Submission Sheet - 2

As members of the Board of Examiners of the final Master's degree open defense, we certify that we have read and evaluated the thesis prepared by Seleshi Manaye under the title " Assessment of challenges of sustainable rural water supply: The case of Gambella Zuria Woreda, Gambella region, Ethiopia" and recommend that it be accepted as fulfilling the requirements for the degree of Master of science in ______________________ with specialization in Irrigation and Drainage Engineering.

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Certification of final Thesis

I hereby certify that all the corrections and recommendation suggested by the Board of Examiners are incorporated in to the final Thesis entitled "Assessment of challenges of sustainable rural water supply: The case of Gambella Zuria Woreda, Gambella region, Ethiopia" by Seleshi Manaye.

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BIOGRAPHICAL SKETCH

Seleshi Manaye was born in East Gojam, Amanueal , Ethiopia to my father, Manaye Derseh, and my mother, Etayehu Ebstae, on October 19, 1981. I started my education at Amanueal Elementary School and completed for 8 years. I was spent four years in Gambella High School. I then completed my high school education and joined a Degree program in 2003 at Haramaya University.

In 2007, I received a BSc degree in Soil and Water Engineering from Haramaya University. After my graduation, I Joined at Gambella Water irrigation and electricity bureau as Office engineer in Gambella region. Seeing the announcement for the Minister of water irrigation and electricity Master's program, I applied and was admitted and then continued my Master of Professional Science study program in Irrigation and Drainage Engineering offered by Hawassa University. I have got deep knowledge, skill and experience on environmental concerns and challenges to human beings. As a result, I have been directed and helped my research interest to be on challenges that determine sustainable rural water supply systems.

I am eager to continue my education and earn a doctorate program so that I can aid my country, Ethiopia in general with the help of God.

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Last, but not least i would like to express my love and passion to my wife who gave courage and hospitality to me during the study period. In addition, the generous support and contribution of all my colleagues, friends and families are deeply acknowledged and emphasized in all cases of my future life.

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LIST OF ABBRIVATIONS

ADB	Africa Development Bank
ADF	African Development fund
AM	Abol mendere
AP	Abol police station
BC	Bonga chereqa
BE	Bonga elementary
EC	Electrical conductivity
EDWQ	Ethiopian drinking water quality
FWSSs	Functional water supply schemes
GRBoI	Gambella Region Bureau of Information
GWIEB	Gambella Water Irrigation and Electricity Bureau
GWSSA	Global Water Supply and Sanitation Assessment
HH	Household
IISD	International Institute for Sustainable Development
JMP	Joint Monitoring Programme
KC	Karmi catholic
KM	Karmi mendere
MoWIE	Minister of water irrigation and electricity
NFWSSs	Nonfunctional water supply schemes
NGOs	Non - Governmental organizations
O&M	Operation and Maintenance
OED	Operation Evaluation Department
RWS	Rural water supply
SD	Standard deviation
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Science
TDS	Total dissolved solids
TH	Total hardness
UNDP	United Nations development program

UNICF United Nations International Children's Fund

UNWWDR United Nations World Water Development Report

USDA United States Development of Agriculture

WASH Water, Sanitation and Hygiene

WHO World Health Organization

WPCs Water point Committees

ABSTRACT

Sustainability of water supplies is a key challenge both in terms of water resources and service delivery. Furthermore, it is the key to identify what enables a water scheme to remain operational over a long period of time. Consequently, the objective of this study was to identify the main challenges of sustainable rural water supply systems by evaluating and comparing functional and non-functional systems. The study was carried out in Gambella Zuria Woreda located in West of Gambella town, Gambella Region, Ethiopia. Both primary and secondary data sources were carefully examined. Both quantitative and qualitative research methodologies were used to analyze the data. Score matrix, questionnaire, and focus group discussions were among the selected methods. Water quality testing was done to examine suitability of water sources.

The result obtained from tested parameters indicated that except the pH and F values, all parameters values are out of the World health organizations (WHO) standards for drinking water. The parameter values were found to be in the range of pH (6.9- 8.0), Turbidity (2.21-15 NTU), EC (495 – 1123.00 μS/cm), TDS (230-1300 mg/L), TH (183-913.0 mg/L), Fe^{2+} *(0.06-0.67 mg/L), Fluoride (0.11-1.21mg/l),* Ca^{2+} *(5.3-78.00 mg/L) and* Mg^{2+} *(13-98.30 mg/L). Additionally, the overall quality of the groundwater low in the sampled sites of the study area and this situation needs urgent and strategic solutions. From this study all the water schemes non-sustainability problems are low water quality, lack of proper operation and maintenance, weak management which resulted in the Woreda's inability to achieve full coverage of the rural population with safe water services. On the other hand, the finding of this research show that, 45% of functional water supply schemes and 23% of nonfunctional water supply schemes respondents said that the collected water tariff cover the operation and maintenance cost of water supply schemes, and 35% of functional water supply schemes and 86% of nonfunctional water supply schemes respondents responded have problem of ability to pay water tariff. Therefore, regular maintenance of water schemes, awareness creation of the water users, training of water point committees and follow up to the community by the water Bureau of the Wereda can be a better solution to solve the problem before it gets worse.*

Keywords: Gambella Zuria Woreda, Functionality, Rural water supply scheme, Sustainability, Water quality, physical and chemical parameters

CHAPTER ONE: INTRODUCTION

1.1 Background

Water plays a major role in life and hence, it is said that "water is life". Living things use water for different purposes. For example human beings use water for domestic purposes such as for drinking, washing, sewer flushing and fire-fighting. In places where there is no water, disease is very common and death rate is high (ADB, 2010). On the other hand, water is the life blood of the planet and of critical importance for all socio-economic development. Moreover, from a social perspective, there are obvious connections between access to safe and adequate quantities of water and health, for drinking first, but also for hygiene and sanitation at the household, community and national levels (UNWWDR, 2015). Seventy five percent of earth surface is cover by water. But only 3% of it is available as fresh water in the form of lakes, river and ground water. As water is the basic necessity for life, it should be handled properly. Ethiopia is very well known for its enormous amount of water availability it is still known as the water tower in Africa. When human beings do not have access to potable water they do suffer physically, emotionally and socio – economically (UNDP 2006).

Recently, member states of the United Nations adopted the 2030 Agenda that comprises 17 Sustainable Development Goals (SDGs) and 169 targets addressing social, economic and environmental aspects of development, seeks to end poverty, protect the planet and ensure prosperity for all (UN,2015). The SDGs are aspirational target that are intended to be universally relevant and applicable to all countries. "With each member states settling their own national targets guided by the global level of ambition by taking in to account their national circumstances" (UN 2015). SDGs goals 1 to 6 are to ensure availability and sustainable management of water and sanitation for all and include targets addressing all aspects of fresh water cycle.

Globally, during the years between 2000 and 2015, the proportion of the population with at least basic drinking water services has increased by an average of 0.49 percentage points per year, but the increase was substantially faster by 0.88 percentage points in sub- Saharan Africa. However, in 2015 nearly 844 million people were still using water from unimproved sources such as shallow wells, rivers, streams, ponds and drainage ditches (JMP, 2017). As a result, they are susceptible to health and safety risks. Large numbers of those who lack access to improved water supply infrastructure live in rural areas (Andre, 2006).

Worldwide, the MDG drinking water target coverage of 88 per cent was met in 2010. Whereas 76 per cent of the global population had access to clean water source in 1990, 89 per cent of the global population had access in 2012, an increase of 2.3 billion people. Fifty-six per cent of the global population had access safe drinking water and sanitation (WHO and UNICEF, 2014). But in 2012, three years before the end of MDGs, on average about 36 per cent of the population of Africa did not have access to improved water sources and 70 per cent did not have access to improved sanitation (WHO and UNICEF, 2014). This clearly indicates that access to safe drinking water sources and sanitation continues to be a major problem in the developing world.

Hailu (2002) indicated that only 59% of the world's population had access to adequate sanitation systems. Africa faces huge challenges with multiple issues that adversely affect public health. The ability to access clean water and meet growing water demand are the biggest challenge for rural and urban Africans (Bekele, 2017). Consequently, water supply and sanitation conditions in Ethiopia are not different from the general situation of developing countries as a whole. The water supply coverage in Ethiopia has been one of the lowest in Sub-Saharan Africa (ADF, 2005). As of 2009, national water service coverage in Ethiopia was estimated at only 65.8 per cent (62 per cent rural coverage and 91.5 per cent urban coverage) and safe water access in Gambella region is 50 per cent (MoWIE, 2009). Similar to many African countries, parts of Ethiopia face water shortages, poor sanitation, and a lack of access to clean water sources (MoWIE, 2006). In addition, people are exposed to various water borne diseases because of the absence of clean water supply. Many people spend their time to fetch water besides illness (Abebe, 2012).

Gleitsmann (2005) stated that “sustainability of various types of water supply infrastructures is dependent upon the degree to which the technology corresponds to the needs of the local community and the community’s willingness and ability to maintain and protect it over time”. Quite often, rural people are traditional in their outlook and do not have knowledge, skills and financial resources to maintain broken water sources (Admasu et al, 2002; Brikké, 1997). Thus, community input and training are needed following the implementation of water resource development projects for long-lasting and safe water supply.

Understanding the willingness of individuals to manage their water sources is the hottest issues in the water supply and sanitation sector in developing countries (Schouten and Moriarty, 2003). The rational is that dedicating more time and resources to the protection and management aspects of rural water supply and development is a positive action that improves sustainability of newly installed water supply infrastructures (Gleitsmann, 2005). Willingly contribution of community members could be in the form of money, material, equipment, labor, and participation in project related committees and meetings (Sara and Katz, 1998; Admasu et al, 2002). Community participation in planning and implementation phases is pre requite of sustainable based safe and accessible improved water supplies.

Sustainability of water supplies is a key challenge, both in terms of water resources and service delivery (Awoke, 2012). The United Nations International Children's Fund (UNICEF, 2014), estimates that one third of rural water supplies in sub-Saharan Africa are nonoperational at any given time. Thus the general consensus is that the involvement of community during initiation and implementation of the water supply system is crucial for the success of a water supply system in such areas.

Potable or drinking water is defined as having acceptable quality in terms of its physical, chemical, and bacteriological characteristics so that it can be safely used for drinking and cooking (WHO 2011). These water quality characteristics throughout the world are characterized with wide variability. Therefore the quality of natural water sources used for different purposes should be established in terms of the specific water-quality parameters that most affect the possible use of water. The technical aspect of this study is to provide an overview of physical and chemical water quality characteristics of hand pump wells water.

1.2 Statement of the problem

Construction of potable water projects in rural area would definitely increase the access of the rural community to potable water and contribute to the health of citizen. However, providing water supply systems alone would not eliminate all problems, especially in rural areas. Consideration of its functionality, utilization by intended beneficiaries, and resilience of water projects are important for its sustainability (Harvey and Reed, 2003). ADF (2005) report shows that 33% of the rural water services in Ethiopia are non-functional due to lack of funds for operation and maintenance, inadequate community mobilization and commitment, as well as lack of spare parts. On the other hand, getting safe water for human consumption is essential for good health and a basic human right (Abigail, 2011). Quality of water source from wells needs to be checked periodically in order to ascertain whether they are good for human consumption. It is therefore important to investigate the possibility of pollution of the water sourced from the wells. Sustainable use of water schemes needs greater attention, such as better planning and follow ups, better operation, maintenance, and management. It is necessary to examine challenges that determine long term sustainability of rural water supply projects after implementation. Today, there will have no doubt that the need for such study in Ethiopia, focusing to assessing challenges of sustainable rural potable water supply systems.

Only a few of the water supply systems in rural Ethiopia have currently attained their financial status needed to run the schemes effectively through the collection of service charges from community members (Sahle, 2002). The lack of sustainability of improved rural water supply schemes in quality, management and operation and maintenance systems after huge investment dissipate is the worst scenario. But, the problem occurs to what extent and at what condition is not known properly.

Gambella Zuria Woreda has a serious water supply problem because of non-functionality of hand pump water wells (GWIEB, 2016). Due to this problem the community doesn't access adequate and safe drinking water in the study area. Therefore assessing the sustainability of the scheme is essential to provide vital information for sustainable scheme management. Furthermore, water supply schemes non functionality problems are one of the challenges in this Woreda and there was no documentation previously with this regard in the study area. Thus, as filling the gap, this study actually intend to assess water supply schemes functionality, customer satisfaction, willingness to sustain, operation and maintenance of water supply systems. Bearing in mind the above issues, this study assessed the root causes and the major challenges of sustainable rural water supply schemes sustainability problem in the study area.

1.3 General objective

The general objective of this study was to assess the sustainability of rural water supply system and identify the challenges by evaluating and comparing functional and non-functional water supply systems in the study area.

1.3.1 Specific objectives

- To examine the physical and chemical qualities of hand pump wells water by comparing the various parameters with World Health Organizations guideline values.

- ❖ To assess whether the provision of water service satisfies the needs of the target group.
- ❖ To measure the sustainability and investigate the operation and maintenance system of rural water supply system per selected schemes.
- ❖ To identify factors that hinders the continuous functionality of water supply points
- ❖ To identify options to improve sustainability of water supply schemes.

1.4 Research questions

1. What are the challenges of sustainability in rural water supply schemes in terms of quality, management and operational point of view?
2. Why the communities abandon improved water supply schemes within a short period of time after construction?
3. How can be sustainability of water supply scheme achieved the study area?

1.5 Significance of the study

This study will contribute to better understanding of problems and factors related to sustainable rural water supply system in terms of quality, management and operation and maintenance. Also to understand the existing water supply situation and to recommend necessary actions in order to improve sustainability of the water supply system and to examine the drinking water quality or suitability of six hand pump wells in the Abol, bonga and Eleiechwoye communities in the study area. Furthermore, it serves as reference for further investigation, planning and designing works of rural water supply and sanitation (RWSS) projects. Moreover, the outcome of this study is expected to contribute to the knowledge base on improvement of the quality, operation and maintenance systems of local water supplies in rural Ethiopia.

1.6 Scope of the study

This study covered three kebeles from Gambella Zuria Woreda (Abol, Eleiechwoye and Bonga). Also it was assessed the challenges of sustainable water supply system in terms of quality and management , operation and maintenance systems of water in sparsely populated rural areas of Gambella Zuria Woreda. The scope of this study also to assess some physicochemical parameters such as turbidity, pH, conductivity, TDS, total hardness, calcium, magnesium, fluoride and iron of hand pump wells water in the study area. The study was also delimited only to investigate physicochemical water quality parameters of the hand pump wells.

CHAPTER TWO: LITERATURE REVIEW

2.1 Water supply coverage in Ethiopia

The issue of sustainability is critical when resource scarcity and equity matters are raised. The sustainability of rural water supply (RWS) projects and the benefits they deliver are some of the overriding concerns of the sector. In recent time, there has been an increased focus and understanding of design and implementation phases of RWS projects as part of the efforts to make projects more successful and work more efficiently (Sara *et al*., 1997).

Aspects of water supply systems that promote sustainability but need improvement include better planning and follow ups, better operation, maintenance, and management. Development of rural water supply schemes remains too costly for poor countries (GWSSA, 2000). The lack of sustainability in supply and demand, management, quality and operation and maintenance of the water sources after huge investment dissipated is the worst scenario. One of the major challenges in the rural water supply efforts in Ethiopia is to sustain the community water use and sanitation behaviors while communities fail to manage and handle their water sources in a sustainable manner. According to the African Development Fund (ADF , 2005),the water supply coverage in Ethiopia has the lowest in Sub-Saharan Africa, Ethiopian water supply subsector has characterized by poor performance with a problems including reports, information and the necessary data were not well organized, documented and reached on time from implementers ,un sustainability and unreliability of water supply services (MoWIE, 2008).

Table 1: Comparison of Plan versus Accomplishments of water supply coverage

No.	coverage	Baseline in % 2010/11	Coverage up to 2013/14	Year's Plan in %	Achievement in %		
				GTP 1 (2015)	2014/15 achievement		End of GTP 1
					End of 2014	From the baseline	
1.	Rural	48.85	75.5	98	83.7	67.4	82
2.	Urban	74.64	84.2	100	91.0	64.5	91
3.	National	52.1	76.7	98.5	85.3	68.8	84
4	Rural non-functionality	25.5	15.52	10	89.3	92.3	11.2

Source: Ministry of Water, Irrigation and Electricity, 2008 Annual report

In this regard, reports show that the total water supply coverage in the country is increasing: 2010/11 (52.1%), 2013/14 (76.7%) and 2015 (84%) (MoWIE, 2008). On the other hand, reports show that the growth level is in 2014/15 drinking water coverage is improved than the coverage of 2013/14 budget year in the rural coverage has been grown from 75.5% to 82%, the urban coverage has been grown from 84.2% to 91%, at national level, the potable clean water coverage has been raised from 76.7% to 84%, But non-functionality rate of the rural water supply schemes in Ethiopia fluctuate due to operation and maintenance problems (MoWIE, 2008).

Despite these problems, to scale-up the water supply coverage of the country and achieve a 100% water supply coverage in most of the regional states including the Gambella Peoples Regional State (GPRS), the Government of Ethiopia adopted goals to Provide rural water supply access with GTP-2 minimum service level of 25 l/c/day within a distance of 1 km from the water delivery point for 85% of the rural population of which 20% are provided with RPS and decrease rural water supply schemes non-functionality rate from 11.2% to 7% by the year 2020 (MoWIE, 2015).

According to African Development Fund (2005) revealed that the continued functioning of rural water supplies in Africa is problematic, even though much progress over the past three decades. The major challenge to expand access is the high breakdown rate due to lack of maintenance, threatening the sustainability of what has already been achieved. Another study also indicated that a median 24-30 percent of rural water supplies are not functioning in Africa, with considerable variation among countries Rural Water Supply Network (RWSN, 2010).

2.2 Concept of sustainability and sustainable rural water supply

The idea of sustainability first arose within the environmental movement and attempts to protect natural resources and ecological systems from over-extraction, shocks or stresses. However, it has also been extended to incorporate other dimensions like economic, social and institutional ones. For example, the idea of economic sustainability is achieved only when a given level of expenditure can be maintained over time or is related to the resilience to risk of net benefit flows over time by the World Bank (OED, 2003)

According to Brundtland Commission of the United Nations report on March 20, (1987), "Sustainable development as development that meets the need of the present generation without compromising the ability of future generation to meet their own needs". Defining sustainability is not simple because it must apply to many ecological and social situations. A number of simple definitions for sustainable development have been developed by different organizations for instance International Institute for Sustainable Development, USA; describes:-

"To be sustainable, development must improve economic efficiency, protect and restore ecological systems and enhance the well-being of all peoples."(IISD, 2003 cited from Misgna, 2006).

2.3 Theoretical frame work of sustainability

According to David (2012), components of sustainability can be separated into standalone factors for analysis, this indicate that all components must function effectively for sustainability to be achieved. A weakness or failure of one component can affect the integrity of how other components operate. Figure1 presents theoretical framework demonstrating interdependencies between components as well as illustrating the importance of them all operating effectively.

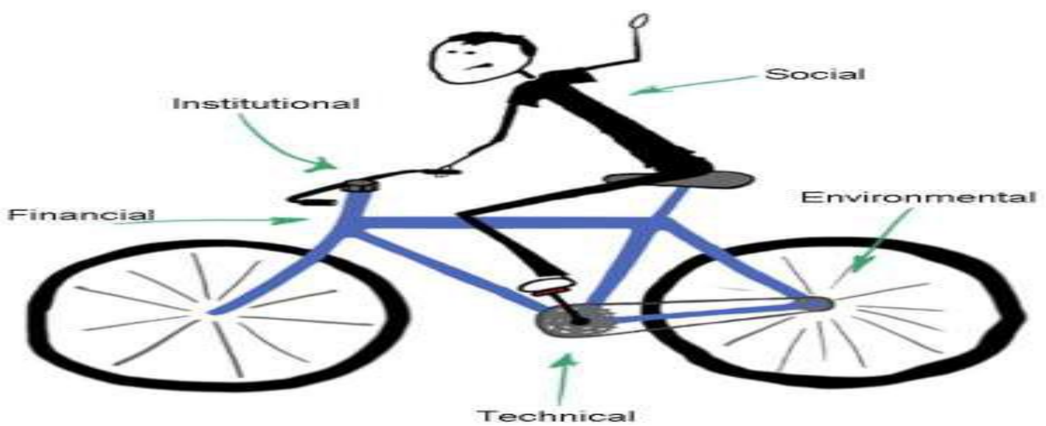

Figure 1: The sustainability bicycle (source: David Shaw, 2012)

A bicycle has been used to illustrate that components of sustainability depend upon each other; for a bike to work effectively, it needs a frame, handle bars, wheels, a crank and chain, and someone to ride it. Without any one of these, the bike will not work as it should. For sustainability, the social, financial, technical, institutional and environmental components must also be in place and working effectively. If there are deficiencies or failures in any of the components, sustainability of the water point will be compromised. Components of the bike are not analogies for components of sustainability; there are not particular characteristics of a wheel that make it inherently more representative of the environmental component than any other. This conceptual framework describe as the importance of all components depend upon each other in order for the system to work effectively (David, 2012).

Social components of sustainability can impact upon financial considerations, but can also be affected by institutional components. Money is needed to pay for repair and maintenance work, without it, required spare parts and technical support cannot be paid for. In sampled communities, contributions were collected only where a water point committee still operated. Where revenue was collected, the amount was below that required to pay for maintenance and repair. The financial component therefore has an impact on some technical considerations and is directly affected by water point committees (MoWIE, 2001). Consequently, it is essential that installed technologies are appropriate, acceptable and affordable to communities. Without access to appropriate and affordable spare parts, water points that fail cannot be effectively repaired. Yet, without sufficient money, spare parts cannot be purchased (the financial component), and without adequate technical support and expertise (the institutional component), repairs cannot be effectively performed.

The issue of social sustainability of rural water supply scheme is depend on the willingness of water beneficiary to provide available time, money, labor and raw material to keep the system functioning until its design period. Willingness is affected by political and socio economic aspect such as willingness of villager to work together, consumers satisfaction with the services (Eaden, 2015). Willingness of the community is an indicator of sustainability of water supply points as it provides evidence of community support (Zemenu, 2012). Consequently, willingness is important to measure the degree to which community members feel responsible for maintaining their water system.

The institutional category of sustainability relates to external support being available to communities from nongovernmental, national and local government institutions, as well as the private sector (Harvey and Reed, 2003). A lack of available funds and accessible spare parts has restricted the extent of support from the government and other partners should develop long-term plans to work with water users. Additionally, the environmental considerations are the importance of an adequate and reliable water resource, regardless of the length of time since its commission. Not being provided with a reliable source of water could affect the social component in terms of the willingness of community members to pay for repairs and motivation of WPCs to manage the water point (David, 2012).

Sanitary survey as component of water quality monitoring is the on-site inspection and assessment of potential contamination risks including water supply facility condition, health hazard application and practice around all schemes (MoWIE, 2003).

2.4 Issues of sustainable rural water supply systems

Obviously, for water supply services to be sustainable, they should be efficient, equitable and accessible (in terms of distance, time and affordability) to all members of a given community. Sara and Katz (1997) found that the sustainability of water points was improved by the existence of a water point committees. Water point committees were established to manage installed water points. The most important element identified by Schouten (2006) was a water committee to manage the water point, as well as contribute funds to pay for its maintenance and repair. Sustainability refers to water supply facilities being maintained in a condition that ensures a reliable and adequate potable water supply over a prolonged period of time (Brikke, 1997). Rural water supply (RWS) also refers to provision of clean and safe water to rural communities through construction of boreholes, springs and protected wells. A sustainable rural drinking water supply system involves a number of issues that are internal and external to the community. The following are key issues that are of a paramount importance to sustainable rural water supply systems (Misgina, 2006).

2.4.1 Overview of existing water supply sources

The current source of water supply in the study area are ground water source which includes borehole, RPS, shallow well and hand dug wells that was drilled by different non-governmental and government organizations. Currently, 64.2 % and 84% the water supply coverage was achieved at Gambella Region and Gambella Zuria Woreda respectively. A total of 63 water supply points (1 borehole, 1 RPS, 15 hand dug wells and 46 shallow wells with hand pump were constructed in the years of 2008 - 2017. Of these water points in 2017, 30 were functional and 33 were non-functional. Most of the water points were constructed by different non- governmental organizations and the rest were developed by the regional government. Currently, the number of non- functional water points increased over the 2008- 2017 as well as the number of functional water points. However, the number of nonfunctional water points decreased during 2009 and 2010 as organizations and individuals or community start to make participation and gave attention for sustainability of water points. Additionally, in the years of 2013, 2014, 2015 operation and maintenance works were carried out effectively than other years.

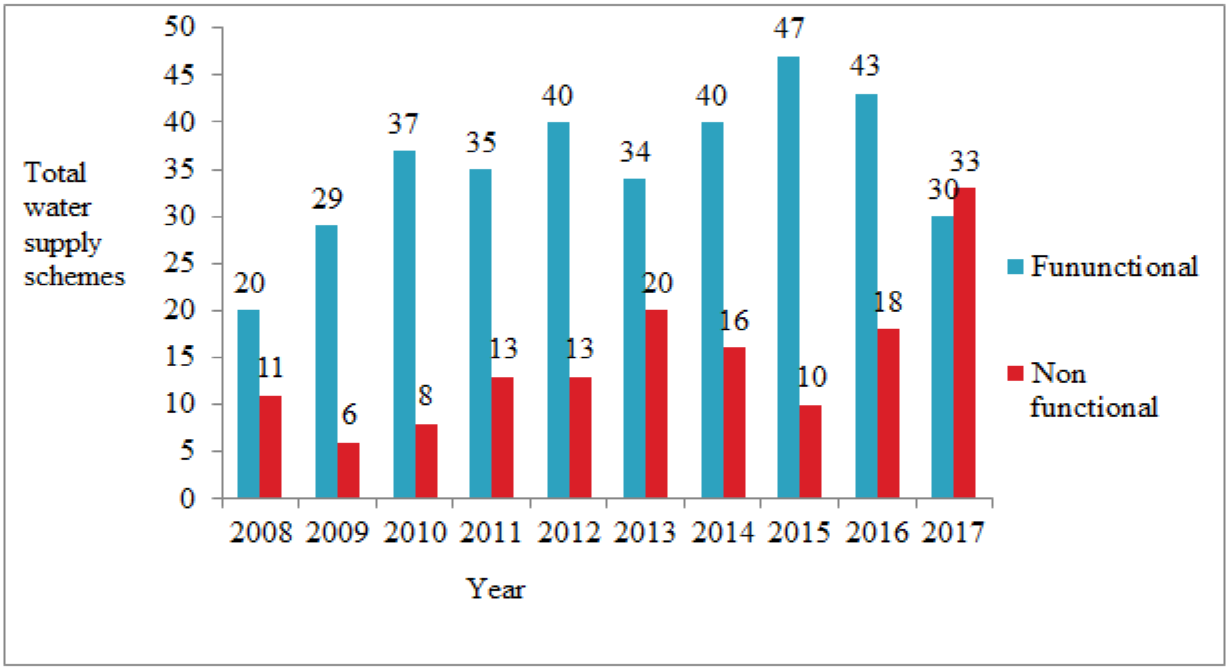

Figure 2 : Distribution of functional and non-functional water supply points (2008-2017) in the study area

2.4.2 Operation and maintenance service

The operation and maintenance aspect of a water supply system is one of the major determinants of sustainability. The way in which Operation and Maintenance lead to sustainability is it overcomes common problems. The problem of availability and supplying spare parts in rural areas for water schemes has often been a great issue. In essence, a sustainable spare parts supply has to fulfill the following requirements: available required components are rapidly delivered, accessible awareness of where to find spares parts and their proximity to the community and affordable priced within the means of the community (Harvey and Reed, 2006). Availability of spare parts and maintenance tools is obviously of primary importance to long-term sustainability. A study done by (Bezabih, 2008) in Menge Woreda of Benishangle Gmuz, Ethiopia indicated that the difficulty of access to spare parts at all community is the major technical related rural water supply schemes problems in the area. He further added that none of the implementing agencies has ensured availability of spare parts to the community.

2.4.3 Community participation and involvement

In rural water supply, a key issue of sustainability is community ownership and management (Cara F; Kerstin D, 2012). In sustainable community management of rural water supply systems, the community takes the final decision on important aspect of planning and implementation of water supply systems.

2.4.4 Willingness to pay and sustain the system

The term willingness to pay can be confusing as users may not be 'happy' paying a certain tariff; but they are willing to pay this amount rather than go without (Webster, 1999). It was assumed that users should pay as per the water delivered for their house hold consumption. In this respect, the user community is expected to assess the prevailing costs associated with the operation and maintenance of the scheme and thereby revising the existing water service fee as per the ever increasing cost of operation.

2.4.5 Management issue

Management is an indisputable issue to increase the performance and sustainability of a water supply scheme (Harvey and Reed, 2003*)*. Since, Woreda water office, water user communities, Artisans and every citizen should have to be responsible to manage their environment and keep the scheme sustainable in the life period. Zelalem (2005) identified external support as a key determinant factor for sustainability of rural water supply and sanitation. They pointed out that external support should focus on technical assistance, training, monitoring, follow up, coordination and facilitation. For rural water supply to be sustainable it must be community-based (MoWIR, 2001). According to Carter *et al*., (2010), sustainability of rural water supply relates to whether or not these services last over time and it is dependent upon numerous factors ranging from spare parts availability to effective community management models to finance for operation and maintenance and external support.

2.4.6 Raising awareness and training

Raising awareness and providing training to water management bodies or water committees could be important to equip users with the right knowledge in managing their scheme and responding to system failure (Zemenu, 2012). Moreover, by creating awareness and training the potential benefits of the community willing to take responsibility for handling operation and maintenance issues with sustainable manner

2.4.7 Consumer satisfaction

Sustainability is increasing by consumer satisfaction with quantity of water, color and test of water, distance and waiting time to fetch water, availability of spare parts and operation or maintenance funds (Abebe, 2012). In this regard, Figure 2 show that the major contributing factors for consumer satisfaction by rural water supply schemes.

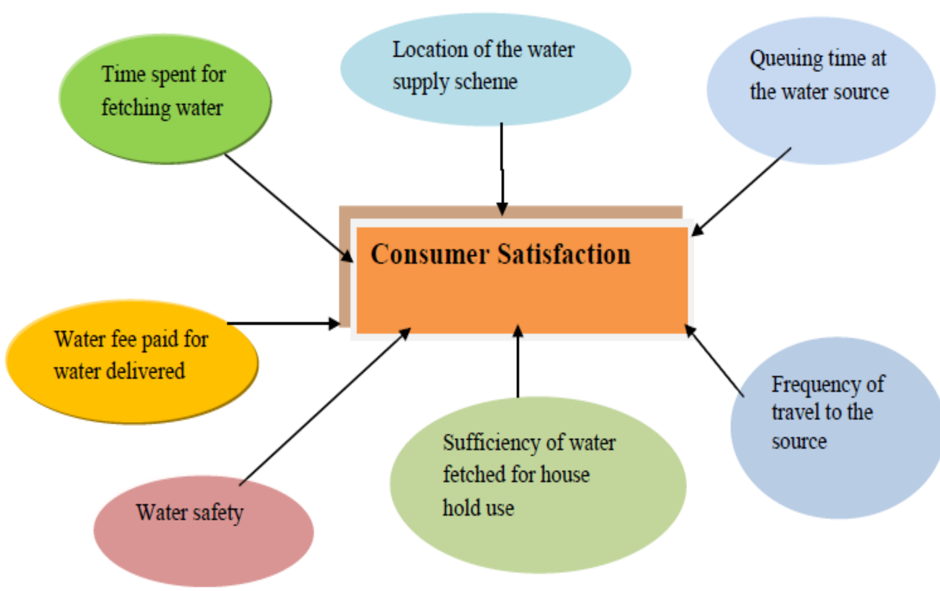

Figure 3: Major contributing factors for consumer satisfaction (Source: Abebe Tadesse , 2012)

According to Mimrose et al, (2011) "sustainability is about lasting beneficial change in WASH services and hygiene practices." With the many variables that influence sustainability of water supply schemes including institutional aspects, social aspects, financial aspects, technical aspects and sanitation aspect, the task of measuring sustainability between functional and nonfunctional water supply systems is acceptable. Sustainability scores are valuable tools to assess the sustainability of water supply systems and potential indicators of schemes sustainability level. It can be conducted at different scales ranging from local to national levels. According to Malik (2016) sustainability of a water supply system is “the maintenance of an acceptable level of services throughout the design life of the water supply system”. Furthermore, after the project completion, responsibility for management and ownership is given to the community. It has been identified that some projects become noticeably unsuccessful, even without any technical failures, while others have achieved their targets without facing much difficulties. Therefore, identification of underlying causes for the performance differences of community water supply projects would be important not only for sustainable management of existing projects, but also in establishing new development projects (Mimrose *et al*, 2011). Consequently, he adopted indicator for measuring sustainability of community water supply schemes. This indicator has six sub-indicators, such as, 1) financial management, 2) operation & maintenance practices, 3) consumer satisfaction, 4) physical condition of system and, 5) willingness to sustain the system 6) demand and supply of water schemes. Each sub-indicator is comprised of 5 to 15 questions with a total of 60 questions, from this 39 multiple choice and 21 supportive open end questions. Questionnaires were prepared to gather data required to assess the sub-indicator scores.

Table 2: Description on Indicators of sustainability measurement of water schemes (Mimrose *et al*, 2011)

Indicator	Description
Financial Management	Examines criteria for tariff setting, tariff structure, regular payment of water tariff by beneficiaries etc. Assessment is based on 12 questions.
O &M practices	Factors such as existence of a designated system operator and community’s capacity on repairing, access to spare parts. Assessment is based on 15 questions.
Consumer satisfaction	Overall consumer satisfaction with quantity and quality of water received, hours of supply the water system. Assessment is based on 10 questions.
Physical condition	Assesses the overall construction quality, contamination possibility of the RWSS. Assessment is based on 10 questions.
Willingness to sustain	Assesses community perception on tariff level, ownership, financial capacity, willingness to pay for improvements etc. Assessment is based on 8 questions.
Demand and supply	Assessment is based on 5 questions.

According to Mimrose *et al*, (2011) the adopted scoring method of sustainability score was lie between zero to ten. Consequently, scoring lower than 5.00 are considered "unsustainable", between 5.00 and 6.67 are considered "potentially sustainable," and systems scoring above 6.67 are considered "sustainable".

2.5 Conceptual frame work of sustainable rural water supply

In general, understanding and measuring sustainability is difficult. Based on this study the research design indicates inter linkage of different factors that affect sustainability of rural water supply systems as shown in figure 4.

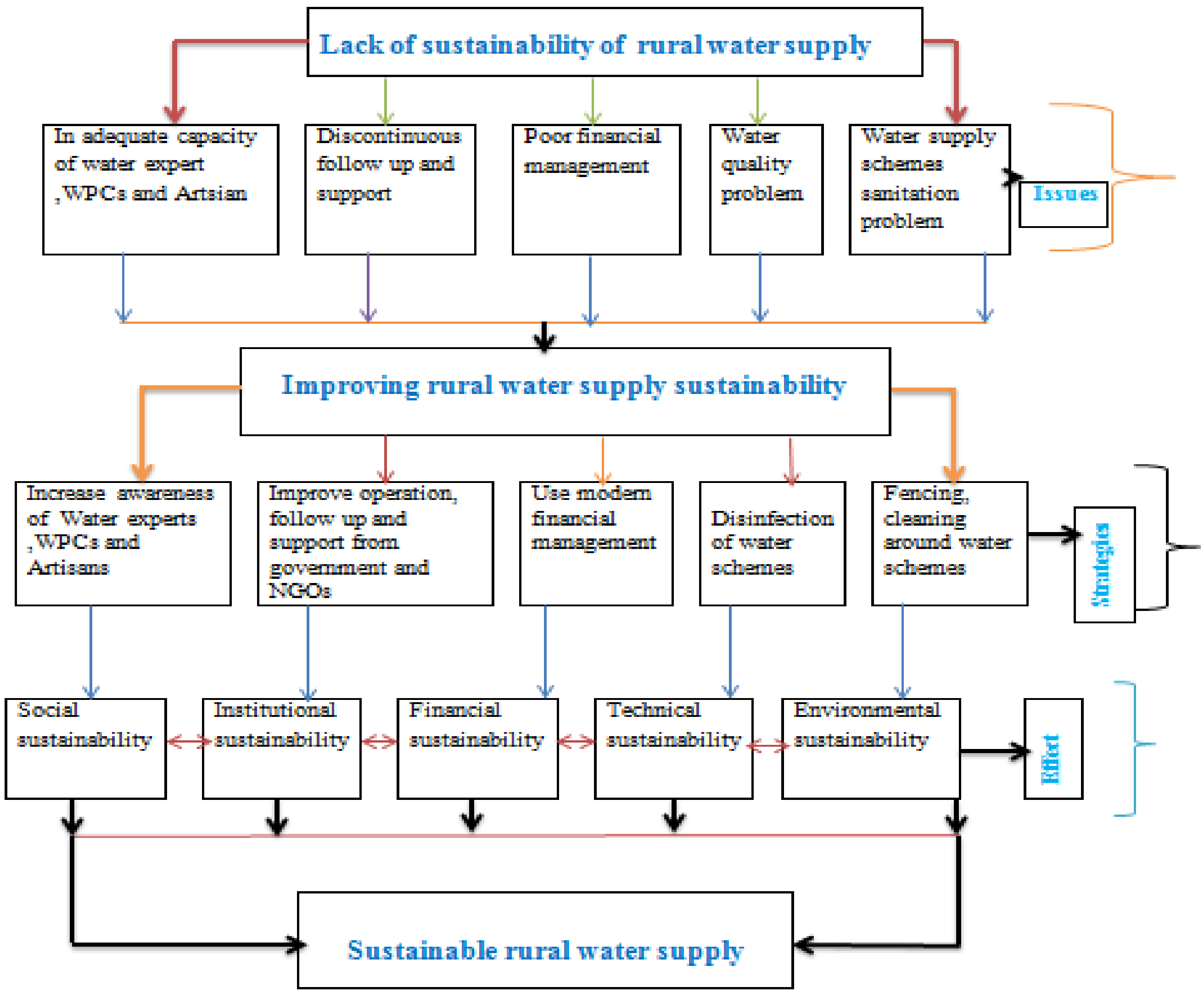

Figure 4: Conceptual framework of sustainable rural water supply

2.6 Source of water supply

To have efficient water supply scheme, we require permanent source of water. The capacity, quantity and quality of the source should be such as to meet all water requirements of the people. The best available source should be selected for meeting the demand. After knowing the population number and the demand of town or city the source should be clearly known in quality as well as quantity. The source of water in which the water flows over the earth's surface are surface sources and ground water is water that stored in pore or fracture of rock under the ground surface. The geological and hydrological investigations around Gambella Zuria Woreda indicated that the sand and gravel aquifer interbred is somehow better aquifer. The most suitable source of water for development of public water supply largely depends on the local condition, cost of water supply scheme, big in quantity and good in quality of water at the comparative least cost. The current water supply source of Gambella Zuria Woreda are ground water sources which includes only bore hole , shallow well and hand dug wells (GWIEB, 2016).

Ground water is an important source of water and is the dominant source for domestic supply in many areas, especially the dry areas where surface waters are scarce and seasonal (WaterAID, undated). In addition, many parts of Ethiopia have limited supplies of groundwater because of the poor permeability of the crystalline rocks and variable water-table depths. This indicates that, groundwater abstraction sources are mainly for domestic use as a result of small yields. Many communities in Ethiopia use unprotected water sources. Furthermore, rural communities mostly use unprotected springs, shallow/deep-drilled wells, and hand-dug wells. These sources are exposed for contamination from human activities and naturally occurring events (MoH, 2011).

2.7 Physicochemical Quality of Drinking Water

The WHO writes the Guidelines for Drinking Water Quality (2011) to protect public health and help make sure that people are drinking safe water around the world. A drinking-water quality guideline value represents the concentration of a constituent that does not result in any significant health risk to the consumer over a lifetime of consumption. If water supply schemes fail to meet acceptable drinking water quality standards (that is, physical and chemical) people may stop using the scheme and resort to unsafe sources.

Mohamed et al. (2016) had been discussed the levels of some physicochemical of different four bottled drinking water samples produced from Almazaq water factory Khartoum, Sudan. All samples were in plastic containers with plastic screw caps. . PH and Electric Conductivity of Samples About 250 mL of samples was taken and transferred into deferent four clean beakers, Then the pH electrometer was calibrated by 4, 7 and 10 buffer solutions, the PH of samples was determined directly. Electric conductivity was determined directly by conductor meter. The ion such as magnesium, calcium, potassium, sodium, aluminum, sulfate, chloride, phosphate, nitrate and nitrite were determined by Ion Chromatography (IC). The obtained results from analysis of anions and action's in marked bottled drinking water samples were lower than limits recommended by WHO(2011). All obtained results were found within the right permissible ranges.

On the other hand, to sustain service delivery of water points by maintaining good quality water, scheme/water point construction should follow proper planning complemented by design treatments such as locating water points at reasonable distance from potentially contaminating sources such as pit latrines and runoff (WHO, 2011). Moreover, protection of water points through natural vegetation barriers, regular chlorination of water points, fencing, preventing water stagnation around water points and preventing bathing and washing clothes at the top cover of the water schemes to prevent contamination of ground water will help maintain and improve water quality. Water gathers impurities from both natural and anthropogenic sources, and these cause the physical and chemical parameters of drinking-water to vary over time and by location (WHO, 2011). Additionally, many chemicals found in drinking-water sources affect the acceptability of water (i.e. turbidity, iron, conductivity, taste, color and odour) and lower the effectiveness of water treatment

Many groundwater sources are negatively impacted by parameters of aesthetic concern, such as turbidity and iron (Sorlini et al, 2013). Even though they do not affect human health, elevated levels of these parameters cause consumers to abandon improved water supplies, often in favor of surface water sources that are microbiologically contaminated. A number of physical and chemical contaminants have been shown to cause adverse health effects in humans as a consequence of prolonged exposure through drinking-water. These include both organic and inorganic chemicals. Some of them are toxic to humans or affect the aesthetic quality of water. In this regard the WHO (2011) has put forward guideline values that set limits for many of the contaminants in drinking water. Ethiopia has also prepared its own drinking water quality specification in line with the international norms and values. The Quality and Standards Authority of Ethiopia have stipulated legally binding drinking water quality specifications (i.e. ES 261:2001) in 2001 (MoH, 2011).

Yenus Tadesse et al. (2015) were reported the chemical quality of six commercially available bottled water samples were analyzed and compared with WHO and EC guidelines. A sets of three bottles each (volume 1-1.5 liter) from six major brands of commercially available bottled water was purchased randomly from grocery shops and supermarkets in Gondar town for assessment of their chemical quality in May 2015. They were used the following analytical reagents during the experiment, for calcium-calcicol tablet; for chloride-acidifying CD & chloricol tab; fluoride- floride No 1&2 tab; magnesium-magnicol tab. For each analysis single tablet or reagent was used and Chemical quality of some anionic and cationic balance were analyzed by standard 8000 photometer transmittance and flame emission spectrophotometer methods. Determination of common anions was carried out by using photometer 8000. Common anions fluoride, chloride, sulphate, nitrate were determined. All the brands of bottled water analyzed for anions nitrate, sulphate, chloride, fluoride showed levels below the WHO and the chemical analysis of common actions did not show much variation between analyzed and actual values on the bottles.

The physical and chemical quality of drinking water and the water pollution status was evaluate according to the standards suggested by WHO in order to calculate the numbers of samples that did not comply with guide line values. Water supplies, especially in developing countries, have been focused on quantity at the expense of quality and there are calls for marked improvement in quality-better management of chemicals and microorganisms content. Drinking water or potable water is defined as that having acceptable quality in terms of its physical, chemical, bacteriological and acceptability parameters so that it can be safely used for drinking and cooking (WHO, 2004). Physicochemical water quality of raw water is important not only in the assessment of the degree of pollution but also in the choice of the best source and the treatment needed (Mawuli, 2011).

2.7.1 pH

The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems (WHO, 2011). No health-based guideline value is proposed for pH. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. But, the direct effect of exposure of humans and animals to extreme pH values below 4 or above 10 (WHO, 2008) .It is a measure of acid-base equilibrium in natural water.

The pH of water is a measure of how acidic or alkaline (basic) the water is on a scale of 0 to 14. Pure distilled water is neutral with a pH of 7. pH measurement above and below 7 indicate that the solution is alkaline and acidic respectively. Water sample with low pH attributed to discharge of acidic water into these sources by agricultural and domestic activities (Mawuli, 2011).

2.7.2 Electrical conductivity

Conductivity is a measure of the ability of water to conduct an electrical current and is directly related to the total dissolved salt content of the water. Ions come from the breakdown of compounds and conduct electricity because they are negatively or positively charged when dissolved in water. Some ions also occur naturally as water flows over certain types of rocks or soil. The permissible limit for electrical conductivity (EC) is 400 μScm^{-1} (WHO, 2004). Conductivity is an indirect measure of the presence of dissolved solids and can be used as an indicator of water pollution. Tay (2004) did a study on drinking water from different sources in the Akatsi and Ketu Districts observed a conductivity range varying from 420 to 5180 µS/cm with a mean of 1737µS/cm. Electrical conductivity is widely used to indicate the total ionized constituents of water. It is widely related to the sum of cat ions or anions as determined chemically and is closely correlated, in general, with the total salt concentration (http://www.duluthstreams.org). Conductivity is an indirect measure of the presence of dissolved solids and can be used as an indicator of water pollution (Avinash, 2013).

2.7.3 Total Dissolved Solids

In natural waters, TDS consist of organic salts and dissolved materials. TDS can be taken as an indicator for the general water quality because it directly affects the aesthetic value of the water by increasing turbidity (Reda, 2016). Additionally, High concentrations of TDS limit the suitability of water as a drinking source and irrigation supply. The presence of high levels of

TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, boilers and household appliances (WHO, 2011). If TDS levels are high, especially due to dissolved salts, many forms of aquatic life are affected. The salt acts to dehydrate the skin of animals and high concentrations of dissolved solids cause water to have an unpleasant mineral taste (http://www.water-research.net/watrqualindex/index.htm).

2.7.4 Turbidity

Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in a straight lines through the sample. Turbidity may be due to organic and inorganic constituents in the water body (Mawuli, 2011). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5NTU is usually acceptable to consumers (WHO, 2004). Tay (2004) also recorded turbidity range of 0.4 to 23.5NTU in ground water in Ketu District.

2.7.5 Total Hardness

In groundwater hardness is mainly contributed by bicarbonates, carbonates, sulphates and chlorides of calcium and magnesium. So, the principal hardness causing ions are calcium and magnesium (Reda, 2016). Additionally, water hardness is a traditional measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to produce lather, and it also leads to scaling of hot water pipes and boilers (Mawuli, 2011). The presence of calcium in the ground water source favors formation of the mineral fluorite, CaF_2, which results in removal of dissolved fluoride (Water AID, undated). The research finding gained by Alam et al., 2017, indicates that total hardness (calcium and magnesium) of water below 300mg/L are considered essential to human health, but beyond this limits cause gastro-intestinal irritation. On the other hand inadequate intake of either nutrient can impair health which has been associated with increased risks of hypertension and stroke (Alam, 2017).

Saleem *et al.,* (2012) studied that ground water is a major source of municipal and private water supply in Gulbarga city. Water sample were collected from spatially referenced bore wells located in various wards of the city. 150 bore well water samples were analyzed for EC.TDS, pH, Ca^{2+}, Mg^{2+}, F, Fe and total hardness. All tests were performed as per the standard methods and water quality was compared with WHO drinking water standards. Significantly positive correlation at 1 and 5% was found between many parameters. EC prediction with multiple R2 value of 0.999 indicated that 99.9% variability in the observed EC. Multiple linear regression models can predict EC at 5% level of significance. Chloride, TDS and fluoride concentration exceeded permissible level of drinking water in 41, 95 and 3.33% of the sample respectively. It is recommended to treat prior to domestic use.

Table 3: Classification of water on the basis of total hardness and total dissolved solids (Source: WHO, 2004)

Total hardness		Total dissolved solids (TDS)	
Amount (mg/l)	Nature of water	Water type	Criterion
0 – 60	Soft	Very low mineral concentration	TDS < 50 mg/L
61 – 120	Moderate	Low mineral concentration	TDS 50-500mg/L
121 – 180	Hard	Intermediate mineral concentration	TDS 500-1500 mg/L
>181	Very hard	High mineral concentration	TDS > 1500 mg/L

2.7.6 Fluoride

Fluorine is a common element that does not occur in the elemental state in nature because of its high reactivity. Traces of fluorides are present in many waters; higher concentrations are often associated with ground water sources (Mawuli, 2011). Tay (2004) reported fluoride concentration varying from 0.001 to 1.5 mg/l, in ground water in Ketu District.

2.7.7 Iron

Iron is most commonly found in nature in the form of its oxides. The concentrations of iron in drinking-water are normally less than 0.3 mg/liter but may be higher in countries where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution (Tokalioglu *et al.*, 2002). Aeration of iron-containing layers in the soil can affect the quality of both groundwater and surface water if the groundwater table is lowered (Mensah, 2011). The result report by Sorlini et al, (2013) suggested that to prevent the effects of iron it is possible to persuade people to aerate and settle the collected water for up to one - two days before drinking it in order to improve the water’s taste.

Table 4: Comparison of WHO and EDWQ Guideline values for physical and chemicals that are found in drinking-water quality standards

Parameters	Unit	Maximum permissible level	
		WHO guideline	EDWQ guideline
Turbidity	NTU	5	5
Conductivity	µs/cm	400	1000
Total dissolved solids	Mg/l	600	1000
pH		6.5 – 8.5	6.5 – 8.5
Total iron (as Fe)	Mg/l	0.3	0.3
Fluoride	Mg/l	1.5	1.5
Calcium	Mg/l	75	75
Magnesium	Mg/l	50	50
Total hardness (as $CaCo_3$)	Mg/l	100 - 300	300

Source: Ethiopian Drinking Water Quality Standard: ES 261:2001 2nd edition and WHO, 2011

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of the study area

This research was conducted in Gambella Zuria Woreda which is 791km away from Addis Ababa, capital city of Ethiopia. Gambella Zuria Woreda is one of the 13 Woredas in the Gambella region. It consists 13 Kebeles (2 urban and 11 rural) and located between $6^{\circ}\,28'\,3''$to 8° $34'$ North latitude and 33° to 35° $11'$ $11''$ East longitude about 14 kilometers West of Gambella town. The Woreda is bounded to the North, North East by Oromiya, to the South and South East by the Southern Nations and Nationalities people's Regional state and to the Southwest, West and Northwest by the Republic of Sudan (Gambella Bureau of Information July, 2008). The mean annual rainfall is 1044.50 mm and the climate condition of the woreda is "Kola". On the other hand, the mean monthly temperatures ranges in significantly throughout the year from 28.5 ^{0}c with absolute minimum 16^{0}c in August and absolute maximum of temperature being 42 ^{0}c in mid-March respectively; (Regional 5 Years Strategic Plan, June 2006). According to the Gambella Region Bureau of Information (2016), Gambella Zuria Woreda has an estimated total population of 15,616 of whom 7652 were males and 7964 were females.

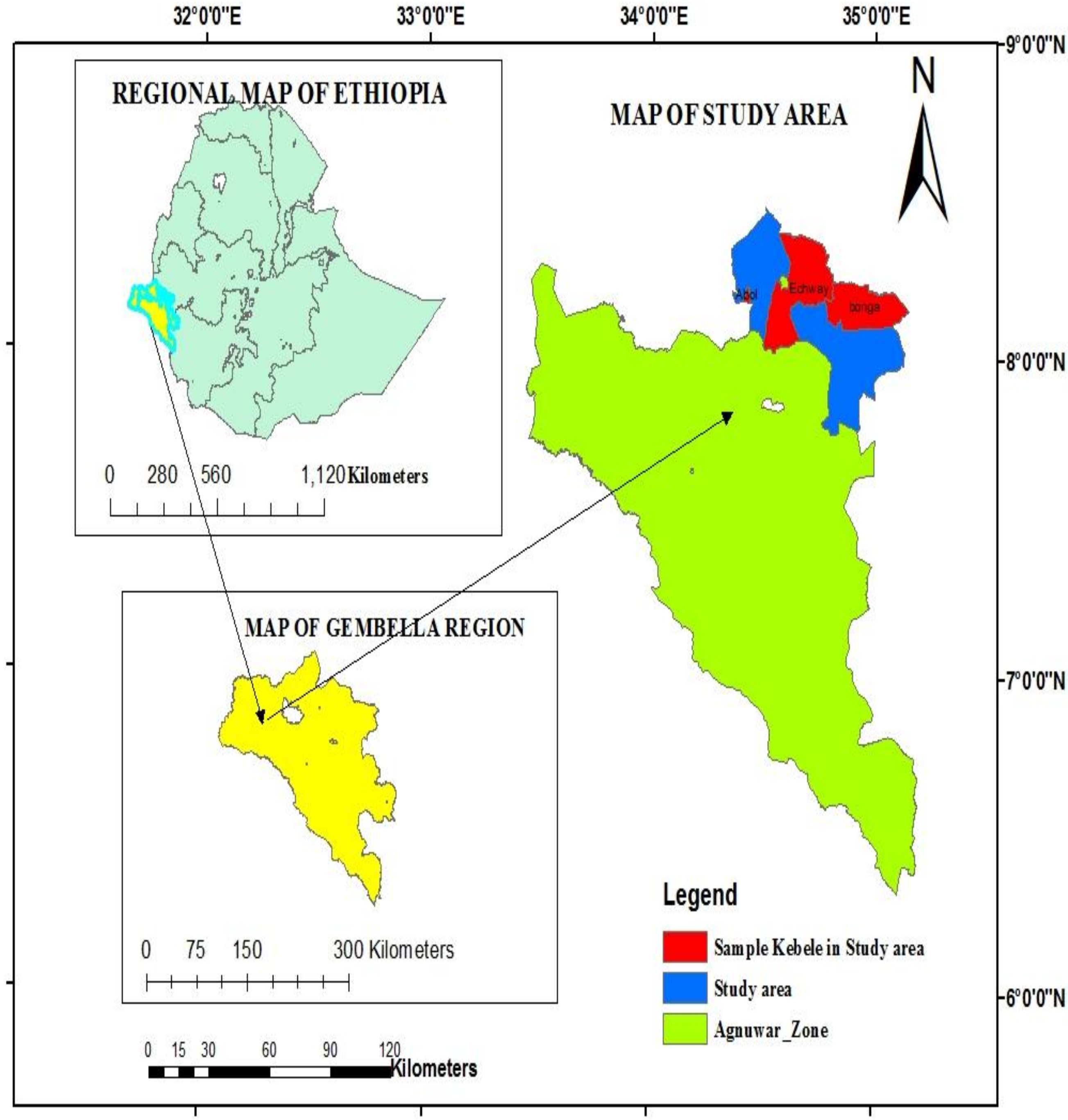

Figure 5 : Location map of the study area

3.2 Data Collection methods

This research used combination of both quantitative and qualitative research methods. In this study structured questionnaire, field observation, focus group discussion and other relevant documents especially written by regional water resource bureau was used. Additionally, in order to assess the safety of water with regard to drinking water quality, from the selected 12 water supply schemes, six different hand pump well water samples were collected randomly from functional hand dug and shallow wells then laboratory test was carried out on the selected physical and chemical drinking water quality parameters. All the sampling containers were washed with distilled water and then washed again with the target water before sampling. To collect water samples for analysis, plastic clean containers of half, one and two liters capacity were used. Hand pump well water samples were collected from three kebele sites at one hand dug well (coded BC) and five shallow wells (coded AM, AP,EC,EM and BH) in six separate containers and labeled station wise, sample code, time, date, and brought to the laboratory for analysis. Water samples were stored using a pre-cleaned plastic container in a cool environment (ice box) and properly transported to Gambella water utility agency treatment plant where laboratory test was done on six water well samples. In defining a methodology for sustainability assessments of water supply services, Mimrose *et al*., (2011) and Malik *et al.,(*2016) both developed a scoring matrix to determine water supply schemes sustainability. To identify trends and challenges of sustainability scoring matrix that developed by Mimrose *et al*., (2011) were carried out for sampled water points.

3.3 Data analysis

Both quantitative and qualitative research methods were useful to examine contemporary real-life situations and provide the basis for the application of ideas and extension of methods. Method of triangulation was incorporated in this study in order to fill the gaps of employed research methods. Water quality parameters were tested and analyzed according to WHO (2011) standard value. The selected physical and chemical drinking water quality parameters were pH, turbidity (NTU), conductivity (µs/cm), fluoride (mg/l), calcium (mg/l), magnesium (mg/l) total hardness (mg/l), total dissolved solids (mg/l) and total iron (mg/l). Descriptive statistics such as minimum, maximum, median, mean and standard deviation were used to analyze the data and to evaluate the dispersion of the values for each parameter. Furthermore conductivity, total dissolved solids (TDS), and turbidity were tested as physically and pH, calcium, magnesium, fluoride, total hardness and iron was tested and analyzed as chemically. As quality assurance of physicochemical parameters data samples were test in triplicates and the mean of each result was taken for the analysis.

For data analysis SPSS and Microsoft Excel soft wares were used in this study. Additionally, Arc GIS software, GPS, sustainability scoring matrix and digital camera were used to collect and evaluate the sustainability of existing water supply system. Arc GIS version 10.1 was used to execute preparation of study area map and show the verification of water schemes in the study area. Microsoft Excel was used to find out the Minimum, Maximum, Median, Mean and Standard deviation of the data's. SPSS soft were versions 20 (2011) were applied to analyzing and presenting data. GPS was used to measure elevation; X and Y coordinate for indicating the allocation of water schemes (points) in the study area, sustainability soring matrix method used to determine the sustainability level of water supply schemes per schemes and Digital camera was used for field photographs.

3.3.1 Sample Size and Sampling Techniques

From all 63 existing water schemes in the Woreda, water schemes constructed with in the last ten years were selected. From this, water schemes built between 2008 and 2017 G.C. were considered because of two reasons. The first was to observe if changes are up coming through time in the overall potable water development processes. The second was related to manageable size. Four water points were selected from three kebeles based on simple random sampling method. On aggregate, 12 water points incorporating functional (those delivering service) and nonfunctional were randomly selected as unit of analysis for this research as shown in Figure 5. Three kebeles were selected and household respondents who reside in each kebele were purposely selected. The main criteria for the selection of the kebeles are simply the existence of water source, most of the water supply schemes abandon by the community at those kebeles and accessibility factors and the main criteria for selection of sample respondents were that they are living within the vicinity of the water sources.

3.3.2 Apparatus

We were used the following apparatus and instrument during experiment such as Palintest photometer 7100 , Wagtech Z WAG –WE model 30020 pH meter, Turbidity tube , TDS and EC Tester 11 dual range model SP 610, Beaker, Syringe (PT 361), Round Test Tubes (PT 595) and ice box or container. All the instrument were calibrated while instrumental procedures were used, and recorded with the result of analyzed.

3.3.3 Samples collection and preservation

From the time of sample collection to the time of actually analysis, many physical and chemical reactions would change the quality of the water sample, therefore to minimize this changes all water sample bottles were preserved, sealed and refrigerate at 4^{o}c- 10^{0}c after the collection until the time of analysis. The water samples were preserved by lowering the temperature using ice box to retain the chemical properties of all the samples and protected from heat or direct sunlight during transportation and until estimated. In addition, the sample was collected in a relatively dry season; the result does not explain seasonal changes in water quality.

3.3.4 Experimental procedures of water quality physicochemical parameters

The selected physical and chemical parameters such as, total dissolved solids and conductivity were measured by the TDS Tester 11 dual range model SP 610 (conductivity and total dissolved solids), turbidity were measured by turbidity tube, while pH, total hardness (calcium and magnesium), fluoride and iron were carried out by Palintest photometer 7100 in the laboratory.

Apparatus and equipment were washed with detergents, tap water and rinsed then with distilled water. Then finally the test tube were rinsed with sample, with distilled deionized water and dried with clean soft lint free cloths before they used. Additionally, the experimental methods, equipments, reagents and procedures were used to test the physical and chemical drinking water qualities are given in below in Appendix C.

3.3.4.1 EC and TDS

The total dissolved solids concentration and electrical conductivity of a sample were measured directly by TDS Tester 11 dual range model SP 610 at 25^{0}C. After the instrument calibrated about 250 mL of sample water was taken and transferred into deferent six clean beakers, then immerse the instruments in to sample water and TDS and EC of the water sample were recorded through TDS Tester 11 dual range instruments model SP 610 model. The values of liquid samples of these dissolved solids levels were reported in ppm and the electrical conductivity were reported in ppt. Conductivity is a totality dependent upon concentration and number of ions. The results are measured at 25 ^{0}c (Avinash, 2013).

3.3.4.2 Turbidity test procedure

Turbidity was measured by using turbidity test tube. The tube was rinsed with distilled water, sample water and filled with the sample until seen cross sign bottom part of the tube (viewing disk). Then the reading was taken from measuring device. The procedure was repeated three times then average value was used.

3.3.4.3 pH measurement

pH was measured by using the Z WAG –WE 30020 pH meter and model 7100 Photometer. But, model 7100 Photometer test results were used for this study and all test tubes were washed rinsed by the samples and filled 10ml of water samples. Then blank (sample tube) was prepared, the other test tube was filled 10ml of well water samples .One phenol Red tablet or reagent was added in samples of test tube, then crush and mix to dissolve. Phot 27 was selected on Photometer 7100 then blank test tube was inserted in to the cell holder then Ok. The instrument was displays insert samples after that wiped the prepared samples and inserted it in to the cell holder, then ok. The instrument was displays the result.

3.3.4.4 Iron test procedure

Wagtech standard photometer 7100 was used to test iron concentration**.** All test tubes were washed, rinsed by the samples and filled 10ml of hand pump well water samples. Then blank was prepared, the other test tube was filled 10ml of well water samples. One iron reagents or tablets was added in samples of test tube, then crush and mix to dissolve, after that stand for one minute to allow full colour development and wiped the blank test tube and, select Phot 19 on

Photometer 7100 it was inserted in to the cell holder. The instrument was displays insert the sample. After one minute the timer was expired, wiped the prepared samples and inserted it in to the cell holder. Finally the instrument was displays the result as mg/l Fe and take Photometer reading.

3.3.4.5 Fluoride test procedure

Test tubes were washed, rinsed by the samples and filled 10ml of hand pump well water samples (the blank sample was prepared), the other test tube was filled 10ml of well water samples. One palintest fluoride No. 1 and 2 tablets was added in samples of test tube, then crush and mix to dissolve, after that stand for five minute to allow full colour development and wiped the blank test tube and, select Phot 19 on Photometer 7100 it was inserted in to the cell holder. The instrument was displays insert the sample. After five minute the timer was expired, wiped the prepared samples and inserted it in to the cell holder. Finally the instrument was displays the result as mg/l F and take Photometer reading.

3.3.4.6 Calcium hardness

Calcium hardness was determined by wagtech standard photometer model 7100. Test tubes were washed, rinsed by the samples and filled 10ml of hand pump well water samples (the blank sample was prepared), the other test tube was filled 10ml of well water samples. One palintest calcicol No. 1 and No. 2 tablets was added in samples of test tube, then crush and mix to dissolve, after that stand for two minute to allow full colour development and wiped the blank test tube and, select Phot 12 on Photometer 7100 it was inserted in to the cell holder. The instrument was displays insert the sample. After two minute the timer was expired, wiped the prepared samples and inserted it in to the cell holder. Finally the instrument was displays the result as mg/l $CaCo_3$ and repeated the sample reading three times to eliminate instrumental error.

3.3.4.7 Magnesium hardness

All test tubes were washed, rinsed by the samples and filled 10ml of hand pump well water samples (the blank sample was prepared), the other test tube was filled 10ml of well water samples. One palintest magnecol tablets was added in samples of test tube, then crush and mix to dissolve, after that stand for five minute to allow full colour development and wiped the blank test tube and, select Phot 61 on Photometer 7100 it was inserted in to the cell holder. The instrument was displays insert the sample. After five minute the timer was expired, wiped the prepared samples and inserted it in to the cell holder. Finally the instrument was displays the result as mg/l $CaCo_3$.

3.3.4.8 Total hardness

All test tubes were washed, rinsed by the samples and filled 10ml of hand pump well water samples (the blank sample was prepared), the other test tube was filled 10ml of well water samples. One palintest hardicol tablets was added in samples of test tube, then crush and mix to dissolve, after that stand for two minute to allow full colour development and wiped the blank test tube and, select Phot 15 on Photometer 7100 it was inserted in to the cell holder. The instrument was displays insert the sample. After two minute the timer was expired, wiped the prepared samples and inserted it in to the cell holder. Finally the instrument was displays the result as mg/l $CaCo_3$.

3.3.5 Water Sample Analysis

A sample bottles were kept, sealed and refrigerate at 4^{o}c- 10^{0}c until the time of analysis as indicated before at sample collection and preservation section.The result of hand pump well water samples have been reported and average values of three replicates were taken for each determination.

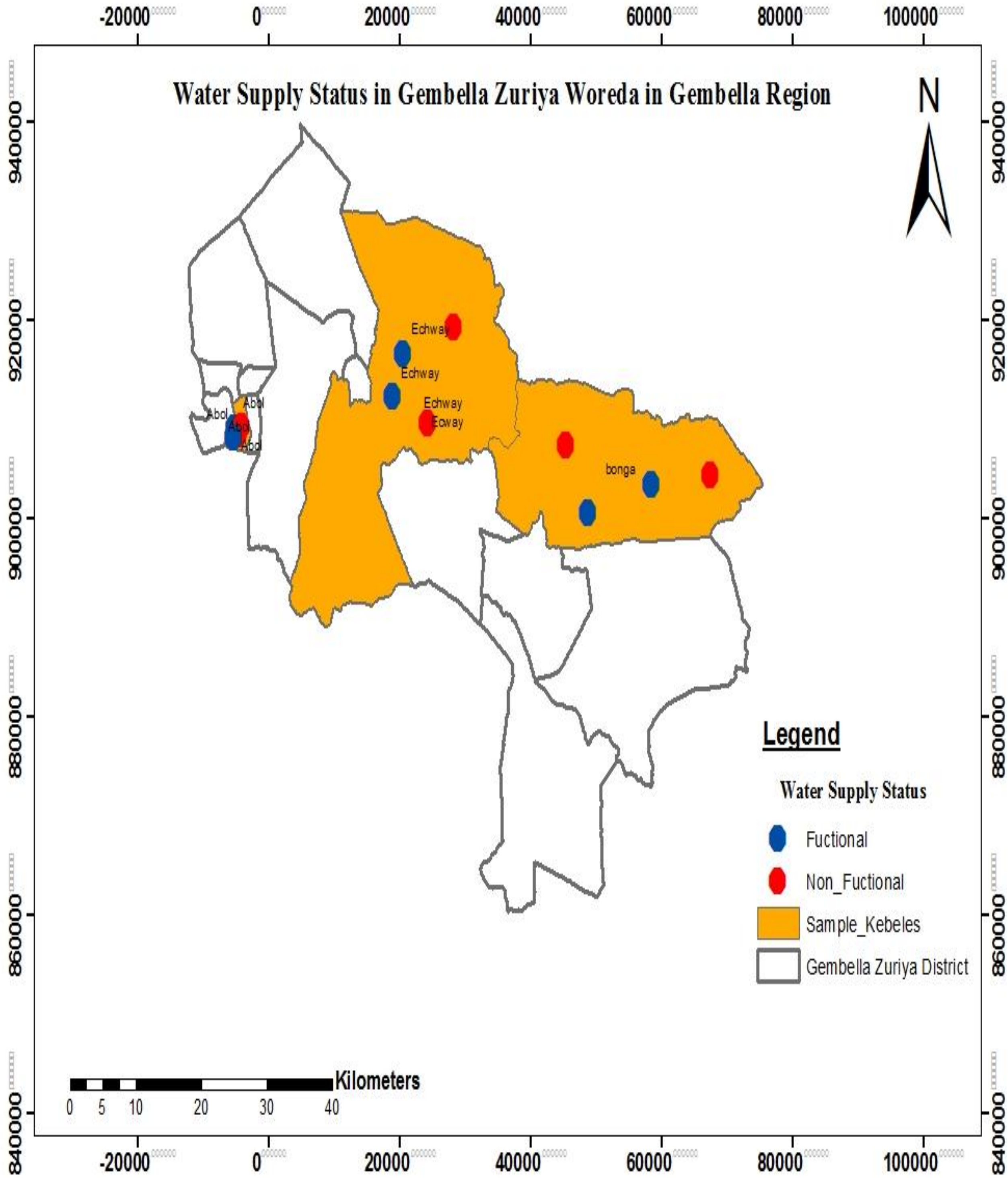

Figure 6: Location of sample wells verification used in the research

3.3.6 Sample population

The main criteria for selection of sample respondents were that they are living within the vicinity of the water sources. Out of 13 Kebele communities that makeup Gambella Zuria Woreda, three kebeles were selected or covered and studied in this research work. Beneficiaries are the main primary data sources in this study. In Gambella zuria woreda the three kebeles were purposively selected namely Bonga, Elei Ehiwoye and Abol. The total household of Bonga kebele is 291, Elei Ehiwoye 222 and Abol kebele is 229. The sums of total households of the three kebeles are 742 (GRBoI, 2016). The selected water supply scheme covers three Kebeles at Gambella Zuria Woreda. In accordance with the sampling procedure stated in the research methodology section, the sample population representing each Kebele community was selected based on simple random sampling technique. Carvarlho (1984) and Kothari (2004) developed sample size determination methods. As the sample size determination from among different methods the one which has been developed by Kothari (2004) was used.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Sustainability issues of rural water supply

4.1.1 Technical issues

The quality of groundwater sources can be one challenge for scaling-up coverage and assuring continued use of water supply services. During field observation all sampled water points under study were in hygienic conditions. The source of community water supply is ground water source less risk for bacteriological contamination. Due to dis functionality of bacteriological kits the bacteriological water quality parameters were not carried out. The samples were analyzed for their physical and chemical quality in order to identify the kebeles using unsafe sources and to suggest possible solutions to reduce the problems of contamination. Both in Abol, Eleiehwoye and Bonga kebeles, people were using different types of sources in addition to the primary one (i.e improved shallow well and hand dug wells). This means that people living in the same kebele can use both improved and unimproved sources, which may have different health effects. In particular, from the survey 75% of the population's participants in Eleiechwoye kebele were using unimproved sources. Under such a situation, the majority of the population will have a tendency to look for alternative unsafe water sources in order to cover their household basic needs.

A number of water quality physicochemical parameters were estimated quantitatively in water samples following methods and procedures as per the W.H.O guidelines. The comparison of estimated values of different water quality parameters with W.H.O drinking water standards revealed that water of the study area is polluted and quality management is needed. The water quality test analysis was done for different parameters and the results are given in Table 5.

4.1.1.1 Experimental details

In this study, the results showed that most of the measured values of physicochemical water quality parameters were within the WHO guidelines for drinking water quality (WHO, 2011) and Ethiopian drinking water quality guidelines(EDWQ, 2001) based on aesthetic and taste considerations (Table 5). Comparison of the concentration of physicochemical parameters in hand pump well water samples were significant differences observed between the mean concentrations of the determination for all the analyzed values.

pH: The test for pH of water was carried out to determine whether it is acidic or alkaline in nature. It was mentioned earlier that the pH of the water samples were determined by model

7100 photometer. In this study, the concentration of hydrogen ion (pH) ranges between 6.9 to 8.0 and all the water samples analyzed have concentration within the safe limit of 6.5 to 8.5 standard set by the WHO and EDWQ guideline value. Thus, indicated that the measured pH values of the drinking water samples were within permissible value of WHO and EDWQG; which will not cause any harmful effect to the consumers. In this regard, reports indicate that pH level recorded in Abol, Bonga and Eleiechwoye sampling sites were within the acceptable limit value of drinking water quality of EDWQG (6.5 – 8.5). The high pH values (over 7) are considered hard water and are more alkaline. This isn't as harmful, but it is known to make water taste bad, scale formation in plumbing fixtures, blockage or pipe encrustation and destroy house hold appliance like coffee pots and washing machines. Darko et al., (2005), did a study on drinking water from different sources and observed a pH range of 6.1 to 7.2. The hand pump well water of pH value is greater than seven because of natural alkali and alkaline earth metals mineral formations was found in water samples. So the values indicate that this greater value of pH hand pump water samples is not that much significant effect on water supply systems. On the other hand, the pH values obtained for the two hand pump wells (coded AP and KC) water are lower than seven (that are 6.90 to 6.95). In this regard, reports indicate that sometimes pH values lower than seven most often associated with soft, acidic water may cause corrosion of pipe or other metals (WHO, 2011). Extreme values of pH can result from accidental spills, treatment breakdowns and insufficiently cured cement mortar pipe linings applied when the alkalinity of the water is low. Table 5 also contains the values of different parameters of drinking water of WHO and EDWQ standard value. From the Table 5, it may be seen that all the water of the coded well source pH value stands in the WHO and EDWQ recommended standard values, i.e., accepted values. One of the major objectives in controlling pH is to minimize corrosion and encrustation in pipes and fittings.

Turbidity: Turbidity is a result of amount of suspended solids present in the water sources. It is a measure of light emitting properties of water and the test is used to indicate the quality of waste discharge with respect to colloidal matter. Regarding the values of turbidity, all the water samples showed less presence of contaminants except one shallow well, as the values ranged from 2.21 to 15 NTU. In this study, the result of turbidity in Eleiechwoye sampling sites was higher than the acceptable limit value of EDWQG (5 NTU).). The turbidity level recorded in Abol and Bonga sampling site were within the maximum limit of drinking water quality of

Ethiopia, (that is 5NTU). The results of turbidity showed that the drinking water doesn't cause health problem to the consumers. The measured turbidity values for AM sample code (2.21 NTU), AP (3.2 NTU), KC (3.44 NTU), BC (4.1) and BE (3.01NTU) are lower than the WHO and EDWQ recommended value of 5.00 NTU, while that of KM water sample (15.0 NTU) is higher than EDWQG maximum permissible level. Turbidity may be due to organic and / or inorganic constituents in the water body. On the other hand, one shallow well had higher turbidity level that is 15 NTU when compared with the EDWQG guide lines. Higher turbidity resulting from corrosion of pipes, rods and cylinder pump in hand dug well and shallow wells ground water sources.

Table 5: Comparisons of selected WHO and EDWQ guideline value drinking quality parameters and measured value of hand pump well water samples

Selected drinking water quality parameters	Sampling sites							EDWQ Standards	WHO Standards
	Kebeles	Abol		Eleiechyoye		Bonga			
	Well sample code	AM	AP	KM	KC	BC	BE		
pH		7.1	6.9	8.0	6.95	7.48	7.20	6.5-8.5	6.5-8.5
Turbidity (NTU)		2.21	3.20	15.00	3.44	4.10	3.01	5 NTU	5 NTU
Conductivity (µs/cm)		859.30	691.60	1123.00	761.40	495.00	937.00	1000 µs/cm	400 µs/cm
Iron (mg/l)		0.29	0.22	0.67	0.51	0.06	0.17	0.3mg/l	0.3 mg/l
Fluoride (mg/l)		0.25	0.11	0.29	0.37	0.22	1.21	1.5 mg/l	1.5 mg/l
Magnesium (mg/l)		15.00	13.00	49.60	45.00	61.00	78.00	50 mg/l	50 mg/l
Calcium (mg/l)		39.00	5.30	55.30	60.00	78.00	36.00	75 mg/l	75 mg/l
Total hardness(mg/L as Ca Co_3)		183.00	185.00	913.00	308.30	225.00	290.00	300 mg/l	100 -300mg/l
Total dissolved solids (mg/l)		630.00	640.00	1010.00	670.00	230.00	1300.00	1000mg/l	600mg/l

Conductivity: Electrical conductivity from literature is dependent on the concentration and mobility of ions. From the Table 5, it may be seen that the EC values of the hand pump waters are appeared to be in the range of 495–1123 μS/cm. The gap in between the lowest and the highest EC values is wide enough. It is well known that the conductance of water increases with salt, total dissolved solids and conductivity can be used to delineate each other; conductivity is proportional to the total dissolved solids Meybeck, (1997). It is recognized that EC is usually the measure of ionic concentrations present in a water sample. Therefore, it can be guessed that the sample coded BC consists of low ionic concentrations whereas the sample coded KM contains high ionic concentrations. The highest electrical conductivity value was observed at KM water sample (that is 1123.00 μS/cm) as compared the EDWQ guideline value and these might be due to high level of soluble salts such as salts comprising of anions such as carbonates, chlorides, sulphates and nitrates and cations such as potassium, magnesium, calcium and sodium in the sediment and soil of these sources.

Fluoride: Fluoride occurs naturally in some ground waters and it is often introduced into drinking water for the prevention of tooth decay. The higher concentration of fluoride leads to the discoloration of teeth (dental fluorosis) and deformation of the skeleton. In this study the measured value of F- ion of the water samples were ranged from 0.11 to 1.21 mg/L. The measured value of F- in BE sampling hand pump water was higher as compared to the levels of F- obtained from sample codes and thus higher value might be due to the presence of fluoride compounds in the underground water. In addition to this the measured value of F- in all sampling site was below the standard values of F- ion in drinking water set by EDWQG which is 1.5 mg/L.

Iron: Iron occurs widely in nature and is found in many natural and treated waters. Iron is an objectionable constituent in domestic water supplies. In this study, the results of iron in Eleiechwoye sampling sites ranged from 0.51 to 0.67 mg/L was higher than the acceptable limit value of EDWQG (0.3 mg/L) and WHO (0.3 mg/L). This may be occurred due to methods of natural formation mineral source of water that ensure the higher concentration of Fe. The average value of iron concentrations for two sampled wells, (Table 9 and 10) was higher than WHO maximum acceptable concentration (0.3 mg/L) for drinking water (EDWQG, 2001). At levels above 0.3 mg/l, iron stains laundry and plumbing fixtures. There is usually no noticeable taste at iron concentrations below 0.3 mg/l, although turbidity and colour may develop (WHO, 2011). The iron level recorded in Abol and Bonga sampling sites were within the drinking water quality of EDWQG (0.3 mg/L) and acceptable limit of WHO (0.3 mg/L). The contribution of Fe in water is common in deeper wells where the water has been in contact with rock for a longer time (Alam, 2017).

Total Hardness: Hardness of water, mainly governed by the calcium (Ca^{2+}) and to a lesser extent by magnesium (Mg^{2+}) contents with ions such as Fe, is a measure of the capacity of water to precipitate soap. It is an important criterion for determining the usability of water for domestic, drinking and many industrial applications. From Table 5, it may be observed that the total hardness values of the hand pump waters are found ranging from 183 – 913 mg/L. The difference between the highest and lowest value is so significant. Additionally, the concentration level of the ionic constituents present in the water samples are: 5.3 - 78 mg/L for Ca^{2+}; 13 - 98.3mg/l for Mg^{2+}; 0.06-0.67 mg/L for Fe (Table 5). Among the samples, it was observed that KM coded water sample contained highest amount of total hardness (that is 913.00 mg/l) and the lowest amount was found in AM coded sample (that is 183.00mg/l). Water can be classified as soft water hardness below 60 mg/l of $CaCO_3$, between 61 to 120 mg/l $CaCO_3$ are moderately hard; between 121 to 180 mg/L as $CaCO_3$ are hard and more than 181 mg/l as $CaCO_3$ are very hard (WHO, 2011).

Hardness levels above 600mg/l are generally considered to be aesthetically unacceptable (WHO, 2011). The experimental results obtained show that most of the sampled hand pumps drinking water quality parameters were within the World Health Organization (WHO) and Ethiopian drinking water quality guidelines (EDWQG) for drinking water quality, based on aesthetic and taste considerations. But, from six sampled hand pump wells two shallow wells had marginally higher level of total hardness (that is, 308.30 to 913 mg/l as $CaCO_3$). The acceptable limit of total hardness is 300 mg/L. The highest value of total hardness was observed at Eleiechwoye sampling site in KC and KM sample schemes, as shown in appendixes Table 10 and Table 9 respectively. The total hardness level recorded in Abol and Bonga sampling sites were within the drinking water quality of EDWQG (300 mg/L) and acceptable limit of WHO (100 - 300 mg/L). As per the above classification most of the samples comes under moderate to very hard category. On the basis of this classification it has been observed that no water samples are soft (Table 3).

Calcium: The calcium content of the one hand pumps well water was higher the maximum prescribed value of WHO standards. The calcium content varied from 5.30 mg/l -78.0mg/l. The lowest value was observed in coded AP (5.3 mg/L) and the highest value was observed in coded BC water containing 78.0 mg/L. The calcium level recorded in Abol and Eleiechwoye sampling sites were within the drinking water quality of WHO (75mg/l) whereas the calcium level recorded in Bonga sampling site was higher than the acceptable limit value of EDWQG (75 mg/L). Excess amount of calcium can alter water taste and cause scaling problem in pipes and household appliance.

Magnesium: The magnesium content of the analyzed hand pump well water is between 13 mg/l and 98.3 mg/l in all test samples (Table 5). Two hand pump well water coded BE and BC containing higher magnesium concentration which is 98.3mg/l and 61.00mg/l respectively than other hand pump wells. This indicates that, magnisium level recorded in Abol and Eleiechwoye sampling sites were within the drinking water quality of WHO (50 mg/l) whereas the magnesium level recorded in Bonga sampling site was higher than the acceptable limit value of EDWQG (50 mg/L). The recommended value of magnesium in drinking water by EDWQG (2001) is 50 mg/l. The role of magnesium is important for human health, but the rate of increase of the limit set will cause health problems (WHO, 2004). From Table 5, it may be seen that sample coded BC has higher concentration of Ca^{2+} and $Mg^{2+,}$ which has higher level of calcium and magnesium-rich minerals. At most wells water samples the concentration of Ca^{2+} was higher than Mg^{2+}, among the hand pumps; this means that hardness of water comes mostly from Ca^{2+} concentration. Ca^{2+} and Mg^{2+} concentration is also come from naturally occurring mineral sources in drinking water.

Total Dissolved Solids: TDS can be taken as an indicator for the general water quality because it directly affects the aesthetic value of the water by increasing turbidity. The acceptable range of TDS is 600 mg/L. The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 600 mg/l. In this study the range of TDS of analyzed water samples varied between 230.0 to 1300.00 mg/L as shown in Table 5. Tay (2004) reported a critical TDS value of 2450mg/l above which some long term health problems might be anticipated due to excessive concentrations of dissolved particles in drinking water. The remarkable fact that the lowest EC valued sample BC showed the lowest TDS value and the highest EC value sample BE showed the highest TDS value. Such coincidences among the EC and TDS values may be taken as the accuracy of the measurements. The total dissolved solids value of two sample wells coded KM (1010 mg/l) and BE (1300mg/l) that are higher than the WHO recommended value of 600mg/l (Table 5), and 1000 mg/L by the National guideline and standards for water quality in Ethiopia(EDWQ, 2001). The total dissolved solids level recorded in Abol sampling site were within the drinking water quality of Ethiopia, EDWQG (1000 mg/L) whereas the total dissolved solids level recorded in Eleiechwoye and Bonga sampling sites was higher than the acceptable limit value of EDWQG (1000 mg/L) and WHO (600 mg/L). However; most of the analyzed values were within the standard limit of WHO (600 mg/L) and EDWQ (1000 mg/l). But two water schemes code KM and BE samples are out of the EDWQG value. Therefore these two water supply schemes are unsafe for drinking in terms of TDS (Table 5).

Generally, hardness, iron, pH and total dissolved solids are not of health concern at levels found in drinking water, but fluoride is health concern in drinking water (WHO, 2011). However, majority of the water points had detectable levels of iron (0.06 to 0.67 mg/l), total hardness (183.00 to 913.00) and total dissolved solids (230.00 – 1300mg/l). This shows that the chemical water quality is of concern as majority of the water points in the study area.

The results obtained for various tests carried out on the physicochemical properties of the hand pump well water samples and their comparison with the World Health Organization (WHO) standard and Ethiopian drinking water quality (EDWQ) guideline specified for drinking water (Table 5). The table shows that in all sampled water points, the level of pH (6.9 to 8.00), turbidity (2.21 to 15.00 NTU), electrical conductivity (495.00 to 1123.00 μs/cm), fluoride (0.11 to 1.21 mg/l), magnesium (13.00 to 98 mg/l), calcium (5.30 to 78 mg/l), total hardness (183.00 to 913.00mg/l) and total dissolved solids (230.00 to 1300.00 mg/l) and most of the parameters were within the Ethiopian drinking water quality (EDWQ, 2001) guideline values. But the values of total hardness and total dissolved solids for the two hand pump wells (Table 5) are out of the EDWQG specification limits for drinking water and they are high enough to cause hardness of water. Therefore, this explains further the presence of carbonates or bicarbonates.

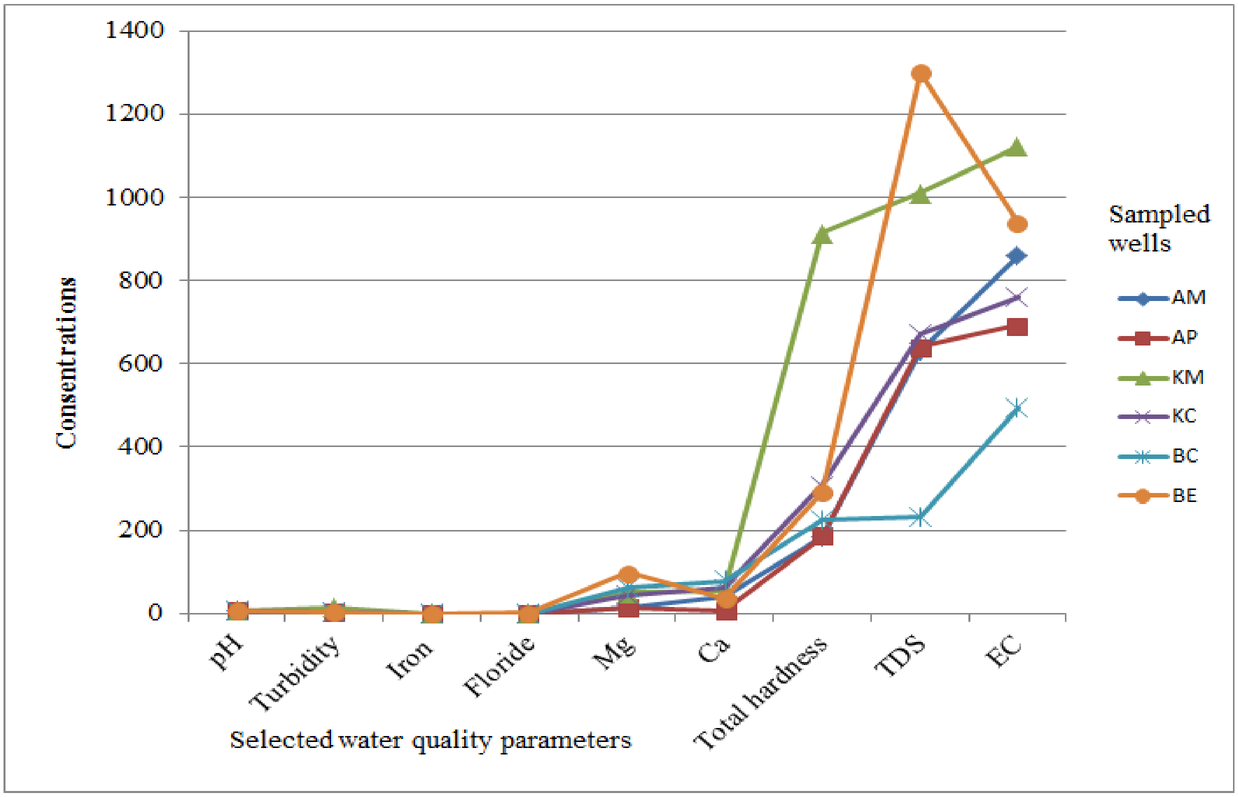

Figure 7: The comparison of parameters concentration between sampled wells

4.1.2 Social issues

The results in Table 7 show that community willingness to not sustain the water supply schemes includes inability to pay water tariff or problems in paying tariff, negative perceptions on water tariff level. In relation to this, when they receive the free systems community members don't pay adequate attention to operation and maintenance. Additionally, lack of awareness and motivation of water users' is also another problem in the study area that is cause due to low supervision and trainings so to mitigate that problem creating awareness and encouraging water user's community to take responsibilities for the scheme.

On the other hand, personal observations and focus group discussions with water experts and water point committee members were conducted to collect primary data. Since, a total of three focus group discussion sessions at three kebeles were held with participants of kebele level water point committees. It was mentioned earlier that in the methodology section sample size were determined by Kothari (2004) developed equation as follows

$$n = \frac{Z^2 * p * q * N}{e^2(N-1) + Z^2 * p * q}$$ (Kothari, 2004) --- (1)

Where N = Size of population (household size)

n = Sample size

e = 0.02 acceptable error

Z = 2.005 Standard value at a given confidence level

p = 0.02 population reliability (or frequency estimated for a sample of size n)

q = 1 – p , q = 1- 0.02 q = 0.98

Therefore, N = 742, $n = \frac{Z^2 * p * q * N}{e^2(N-1) + z^2 * p * q} = \frac{2.005^2 * 0.02 * 0.98 * 742}{0.02^2(742-1) + 2.005^2 * 0.02 * 0.98}$ = 156

Accordingly, 52, 52 and 52 sample households representing the three sample Kebeles (Abol, Bona and Eleiehwoye Kebele) were selected using simple random sampling technique. To that effect, a total of 156 households were covered as a primary data source in order to serve the purpose of this study.

Table 6: Summary of respondent's opinion on overall rural water supply schemes management

Opinion	Willingness to sustain the system				Consumer satisfaction with service delivery				Have financial management problem (willingness to pay water tariff)				Community participation and involvement on water supply management			
Yes	FWSS		NFWSS		FWSS		NFWSS		FWSS		NFWSS		FWSS		NFWSS	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
	59	76	47	60	61	78	56	72	57	73	62	79.5	56	72	43	55.1
No	15	19	23	30	11	14	12	15	18	23	11	14.1	22	28	31	39.8
N	4	5	8	10	6	8	10	13	3	3.9	5	6.4	0	0	4	5.1
Total	78	100	78	100	78	100	78	100	78	100	78	100	78	100	78	100

Source: Author's computation based on Survey results, FWSS = Functional water supply schemes, NFWSS = Nonfunctional water supply schemes, NR = No response

4.1.2.1 Consumer satisfaction

As Gambella zuria woreda is located in the semi-arid region, the climatic condition is characterized erratic rain fall pattern and the community members tend to rely on ground water sources, ponds and rivers as well. The possibility of being exposed to water born disease is quite evident as there are still communities who are not yet accessed with safe drinking water in their vicinity (ADB, 2010). Consumers are not to be satisfied with results such as quality of water, distance and waiting time to fetch water. Additionally, timing of water service varied between two periods: the first period is from 1 am to 6 am, while the second period is from 9 am to 12am local time based on the climate condition of the area and this is evidence during focus group discussions.

4.1.2.2 Community participation and involvement (especially Women's)

Women participation on the development of water supply and sanitation process is an important part of sustainability. Women's participation is being given consideration in any rural water supply development in Ethiopia (Zemenu, 2012).

Figure 8: Typical example of sustainability challenges of both functional (A) and non-functional (B) rural water supply systems in the Bonga and Eleiechwoye community respectively(Photo: Researcher)

As shown in Table 6 summery of respondent's opinion indicated that 73% of the functional water scheme users and 79.5% nonfunctional water supply scheme user respondents had financial problem to pay water fee, 76% of functional water scheme users and 60% of nonfunctional water users had willingness to sustain the scheme, 78% of functional and 72% of nonfunctional water scheme users had satisfied with system service delivery and by their status. Similarly, the participation of users community in both water supply schemes was not enough to manage, protect, operate and maintain the scheme by themselves, even if they have the skill to maintain, shortage or spare parts to buy locally is another main problem.

4.1.3 Institutional issues

The practice of community follow up and monitoring of the water supply system is very limited. In most cases, the water committee has no reporting mechanism to the community other than the one they communicate to district water mine and energy office. Gambella Zuria Woreda water mine and energy office is responsible to provide all the required support to the rural community for the development of clean water supplies. As per the discussion with the water experts and water point committees training was offered but the training provided was not enough.

As per the result obtained from focus group discussion with the water experts and water point committee members, the Woreda water mine and energy office was providing water development facilities and support to the community. Only 5 BSc degree professional staffs and 2 Diploma experts are there in the Woreda (see Table 4) as indicated in Appendixes. Focus group discussion with Woreda water office experts identified that the staffs are not enough to provide the necessary water development service. This is the area where the district water and energy office need to work hard mobilizing partners in line with ensuring the technical capacity of the water experts and management body's to upkeep financial records, operation and maintenance and thereby contributing towards water system sustainability.

Table 7: Respondent responses results on water supply overall schemes sustainability

Questions for the water supply overall sustainability	Water supply schemes						
		FWSS			NFWSS		
		Yes	No	NR	Yes	No	NR
Operation and Maintenance							
1. Is the community managing the water supply schemes effectively?	Frequency	68	7	3	51	23	4
	Percentage	87	9	4	65	30	5
2. Has the water point ever broken down or required a repair?	Frequency	63	10	5	75	3	0
	Percentage	80	13	7	96	4	0
3. Have woreda water office and donors given you some sorts of support for your water supply scheme?	Frequency	76	2	0	67	9	2
	Percentage	97	3	0	86	11	3
4. Does the water supply system give efficient service?	Frequency	72	4	2	0	76	2
	Percentage	92	5	3	0	97	3
5. Does the water tariff cover the operation and maintenance cost of water supply schemes?	Frequency	35	41	2	18	55	5
	Percentage	45	52	3	23	70	7
6. Do you pay additional fee for operation and maintenance of water supply schemes?	Frequency	23	55	0	9	61	8
	Percentage	30	70	0	12	78	10
7. Are you member of the water supply committee?	Frequency	25	53	0	16	62	0
	Percentage	32	68	0	20	80	0
8. Do you think representation of women in the water committee is enough?	Frequency	17	49	12	10	68	0
	Percentage	22	63	15	13	87	0
Financial Management							
1. Do you support the idea that users should pay water fees?	Frequency	68	10	0	34	44	0
	Percentage	87	13	0	43	57	0
2. Do you pay for water?	Frequency	8	71	0	7	70	0
	Percentage	10	91	0	9	91	0
3. Are the bills that you receive accurate?	Frequency	0	78	0	0	78	0

	Percentage	0	100	0	0	100	0
4. Before the water point was installed, did you contribute anything towards it?	Frequency	21	46	11	2	76	0
	Percentage	27	59	14	3	97	0
5. Does every household pay the same water tariff?	Frequency	13	55	10	39	30	9
	Percentage	17	70	13	50	38	12
6. Do you think the collected fee is properly managed?	Frequency	10	63	5	3	75	0
	Percentage	13	80	7	4	96	0
7. Do you have problems of ability to pay water tariff?	Frequency	27	51	0	67	11	0
	Percentage	35	65	0	86	14	0
Willingness to sustain the water supply scheme							
1. Does community have financial capacity to sustain the service?	Frequency	46	28	4	33	45	0
	Percentage	60	35	5	42	58	0
2. Do the water committee members given adequate capacity build and technical training?	Frequency	8	64	6	6	72	0
	Percentage	10	82	8	8	92	0
3. Did you think the available water supply is sufficient for all the community?	Frequency	4	74	0	0	78	0
	Percentage	5	95	0	0	100	0
Customer satisfaction with service delivery							
1. Is water a major problem in your community?	Frequency	78	0	0	78	0	0
	Percentage	100	0	0	100	0	0
2. Are you satisfied with the water supply system?	Frequency	5	73	0	0	78	0
	Percentage	7	93	0	0	100	0
3. Are you satisfied with the quality of water supply system?	Frequency	7	71	0	3	75	0
	Percentage	9	91	0	4	96	0
4. Are you satisfied with the quantity of water available?	Frequency	13	65	0	0	78	0
	Percentage	17	83	0	0	100	0
5. What is your perception of water point's	Frequency	69	9	0	61	17	0

taste, odour and colour?	Percentage	88	12	0	78	22	0
Physical condition of water supply schemes							
1. Does the water point provide water at all times throughout the year?	Frequency	75	3	0	68	10	0
	Percentage	96	4	0	87	13	0
2. Is the water supply system functioning?	Frequency	78	0	0	0	78	0
	Percentage	100	0	0	0	100	0
3. Is there any cracks/broken parts on the top work of water supply schemes?	Frequency	2	74	2	74	35	4
	Percentage	3	95	3	95	45	5
4. Do you think contamination possibility in water supply service?	Frequency	6	72	0	11	65	2
	Percentage	8	92	0	14	83	3
5. Are the drainage channels of water schemes functioning?	Frequency	73	2	3	47	29	2
	Percentage	93	3	4	60	37	3
6. Is the water supply scheme having fence?	Frequency	78	0	0	14	64	0
	Percentage	100	0	0	18	82	0
Demand and supply							
1. Is there community needs additional water schemes /points?	Frequency	78	0	0	78	0	0
	Percentage	100	0	0	100	100	100
2. Have your organization followed water supply demand responsive approach?	Frequency	4	5	69	3	2	73
	Percentage	5	7	88	4	3	93

Guide: NR= No response, FWSSs = Functional water supply schemes, NFWSS = Nonfunctional water supply schemes

In general, there was a very poor financial management system in terms of tariff collection for operation and maintenance in both functional water supply points and nonfunctional water supply points in Gambella Zuria Woreda. The water point committee is responsible to mobilize for construction, operation and management of hand dug wells and shallow wells and collecting and managing water fees. No structure was used to determine service fees but the common understanding of the community is that those individuals who want to use water should pay. The field survey result (Table 7) shows that 87% and 43% of respondents support the idea of water fee payment in functional water supply schemes and nonfunctional water supply schemes respectively. The rest of respondents do not support water payment for the service provided. In this case, respondents should be made aware of improved water supply water payment necessity in the study area. We can see the percentage of beneficiaries supporting water fees and paying water fees decreased in both systems (see Table 7). These shows there are people who fully support the idea of paying service charge but are unable to pay. In addition to this, the majority of water supply schemes have no bill for the payment; this makes unequal distribution of payment with different with family size and household. In the study area operation and maintenance of the scheme is not uniform throughout the whole water user community. According to discussion with the water point communities the committee showed that the collected water fees do not cover the operation and maintenance cost of water supply schemes. Consequently, due to lack of continuous monthly fee failure of the scheme didn't maintain frequently sometimes operation and maintenance exceed for two months and above due to budget constraint.

According to the respondents' point of view, large percentage of operation and maintenance cost is covered by the government. About 87% of the respondent in functional water supply schemes stated that the community is managing the water supply schemes effectively. However, 80 % of the respondent also mentioned that water points ever broken down or required a repair frequently. In addition to this, the majority of the respondent did not know about the spare parts of water supply schemes and simple maintenance. In this particular study, discussion with the beneficiaries as well as water committee members found that there were beneficiaries using water from other sources (rivers ,ponds and rain water) in order to reduce the burden during damage of improved water supply schemes. Accordingly, beneficiaries' perception of alternative water sources and its importance in sustainability were assessed. It was found that most of the respondents use alternative water sources continuously.

In the study area, consumer satisfaction with service delivery was assessed and the result presented in Table 7. The finding show that 93% of the respondents are not satisfied at all by the water supply they get, 7 % fully satisfied in functional water supply schemes and 100% of the respondents are not satisfied by the developed water supply systems in nonfunctional water supply schemes, Refer Table 7. The reason behind the consumers are not satisfied with service delivery is the frequent failure of the water supply. The frequent failure is because of the poor management and operation. Finally, the physical condition of water supply schemes is an indicator of sustainability. The physical condition of water supply schemes must include appropriate fencing and line of drainage ditch. The field survey result show that, 100 % of functional water supply points were currently fenced. In nonfunctional water supply schemes only 18 % were fenced. In this regard, the possibility of animal entering in water supply schemes is very high causing contamination of the service. As a result, sustainability of water supply schemes is higher in those water schemes that are fenced properly with adequate door and key. Hence, considerable attention should be given by water supply project owners to consider fencing of schemes.

4.1.4 Financial issues

“Water tariff management is one of the many areas where issues pertaining to community participation and water supply system sustainability highly linked” (Abebe, 2012). Consequently, existence of community’s designated treasurer or accountant, tariff structure covers operation /maintenance costs and availability of generated savings are also other issues that affect financial sustainability. According to the data collected from the field, there is no standard water tariff structure in place in the study area or elsewhere in other rural areas of the woreda. As per the sample communities selected for the study, the amount paid for water supplied varies in accordance with the type of technology used for operating the water supply scheme and the amount paid for the repairs of water supply schemes also varies in accordance with the house hold income level. Consequently, the water supply scheme in Bonga and Abol community used to have operated hand pumps and the amount of money paid per pair of jerrycan (20 liters) at Bonga kebele is very expensive (1 birr) as compared to Abol kebele water supply hand pumps. This is due to the non-functionality of other water supply schemes and the repair or maintenance cost leave to be covered by the beneficiaries in order to maintain the service. In the case of Abol kebele, where their water supply used to be operated by hand pumps the amount paid per pair of jeerycan (20 liters) is quite cheap (0.35cent).

The community is not expected to pay for water fetched from hand pumps, rather they provide labor contribution/cash in order to repair or maintain their hand pumps. Most of the community needs to fetch water free from the hand pumps installed in their community. One of the many factors contributing for unsustainable rural water supply system is low practice of cost sharing associated with consumers’ payment for water service delivered. Finally, from the focus group discussion with community level water point committees and local elders, it is understood that households are not paying the monthly or daily water fee due to one of the following reasons: payment collection has not begun, old age (low income), and the belief that water is gift from God and should not be paid for it.

4.1.5 Environmental issues

4.1.5.1 Water supply scheme sanitation

Sanitary survey is not an alternative to water quality analysis but is an important component and may be a prerequisite to conduct laboratory based analysis. During field observation at the sample sites the overall status and sanitary conditions of functional water scheme and non-functional water scheme were assessed. In this regard, the sanitary and physical conditions of nonfunctional water supply schemes are lower sanitation condition than functional schemes. This indicates that at nonfunctional water supply schemes the participation of community to protect and manage the sanitation of water supply schemes is very low.

Assessing the current status of rural water supply is important to know the current supply and future demand, to identify factors against scheme sustainability and set directions for enhancing water supply operation and management system to get adequate water supply to the target community in sustainable base. According to the information gathered from respondents most of the community use alternative water supply source for different purposes due to the distance and quality problem of water supply points. As per the respondents' traditional water sources, like rivers and ponds used for drinking purpose during the breakage of water supply wells (hand pumps).

In the study area there is a shortage and water quality problem of hand pumps. Consequently, the majority of beneficiaries suggested that if they can get additional water points to overcome this shortage of water. Water supply projects are usually designed for a certain period after the completion of construction works in order to satisfy the population demand. It is necessary to fix the design period and forecast the population of the area in the design of any water supply scheme.

Regarding water discharge (Table 6) as indicated in Appendixes, machine - dug wells or shallow wells and hand – dug wells generate a median of 0.37 and 0.3l Liter of water per second, respectively. From the selected schemes only one hand dug well and shallow well water points had discharge rate or yield reduction occurred, this may be due to the effect of climate change and over extraction or consumption of water from hand pump wells. The water supply schemes implemented in the sample kebele not satisfy the demand of community water supply. Consequently, the finding shows that 100% of the respondent’s response indicates that the community needed additional water supply schemes at each kebeles.

Table 8: Sustainability score results of community water supply schemes in sample kebeles

Name of water supply schemes	Sample kebeles	Demand and supply	Financial management	O &M	Consumer satisfaction	Physical Condition	Willingness to sustain	Overall sustainability
Sustainable (overall sustainability score of >6.67)								
Abol police station	Abol	5	2.5	4.44	2.86	7.15	7.5	7.75
Abol chatolic	Abol	5	3.75	5.7	6.67	4.3	2.5	7.34
Abol mendere	Abol	5	5	6.67	5.7	7.14	7.5	9.74
Bure	Eleiechwoye	5	2.5	7.78	7.14	5.7	7.5	9.37
Chereqa	Bonga	7.5	7.5	6.67	7.14	7.14	5.0	10
Merima	Bonga	5	5	4.44	5.7	4.29	2.5	7.0
Potentially sustainable (overall sustainability score between 5.00-6.67)								
Qarmi mender	Eleiechwoye	2.5	1.25	3.33	4.29	7.14	2.5	5.53
Elementay school	Bonga	5	6.25	5.5	5.7	2.86	0	6.66
Bonga uduk mendere	Bonga	5	5	3.33	5.7	2.86	2.5	6.4
Unsustainable (overall sustainability score of <5.00)								
Qarmi chatolic	Eleiechwoye	5	5	5.60	2.86	2.86	2.5	4.79
Tena kela	Eleiechwoye	2.5	3.75	5.55	4.28	1.43	0	4.6
Abol tita	Abol	2.5	2.5	2.2	2.86	2.9	0	3.41
Average		4.58	4.16	5.10	5.07	4.65	3.33	6.9

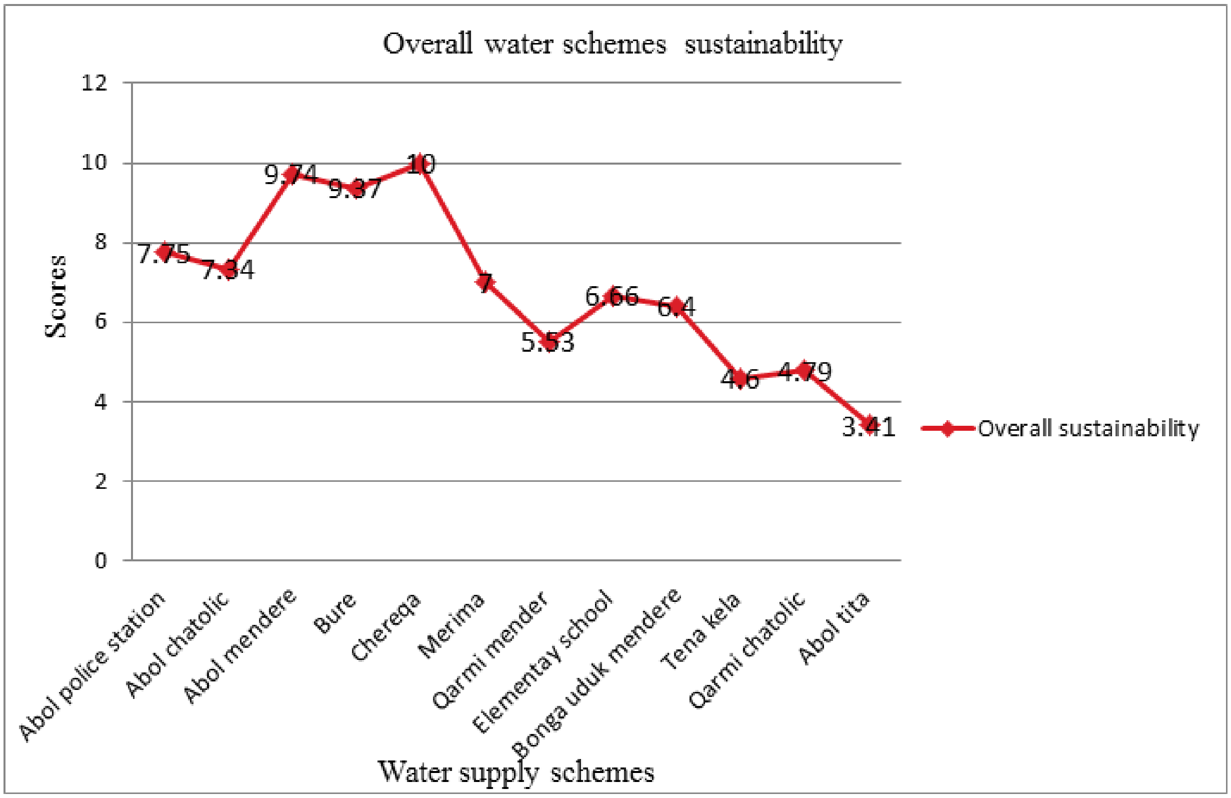

Figure 9: Community water supply schemes overall sustainability in sample kebeles

According to the adopted scoring method indicated in methodology section, the sustainability score can lie between zero to ten. Furthermore, the sustainability scores were conducted using twelve water supply schemes in three kebeles in the study area. In this regard, scoring lower than 5.00 are considered "unsustainable", between 5.00 and 6.67 are considered "potentially sustainable," and systems scoring above 6.67 are considered "sustainable". The results of the sustainability assessment of 12 schemes studied are given in Table 8. The overall sustainability of selected schemes lies between 3.41 and 10. The average sustainability score across twelve schemes is 6.90 implying that schemes are considered sustainable well on the technical, institutional and social aspects. According to the assessment, 6 out of 12 schemes were found to be sustainable whilst three and three schemes were found to be potentially sustainable and unsustainable respectively. A scheme with high scores in overall sustainability usually has high scores in most of the sub-indicator categories as well. On average, the performance of consumer’s satisfaction with service delivery appears to be the best (5.07) whilst performance of community willingness to sustain the water supply schemes was the poorest (3.33) among all the schemes studied.

4.2 The main challenges of sustainability of RWSS in the study area

4.2.1 Water tariff collection and financial Management problem

Water tariff collection and financial management is one of the many areas where issues pertaining to community participation and water supply system sustainability highly linked. The starting point for tariff management starts on collecting water supply service fee as per the amount of water collected by households in the target community. According to the data collected from the field, there is no standard water tariff structure in place in the study area. As per the sample communities selected for the study, the amount paid for water supplied varies in accordance with the household income level and type of technology used for operating the water supply scheme.

The challenges of sustainable rural water supply are insufficient water committee training on operation and maintenance, lack of knowledge and awareness on management of water schemes, poor monitoring, support, and follow up. This was evidence by the focus group discussion with communities’ water committee members. Accordingly, 45% of the respondents in functional water supply schemes and 23% of the respondents in nonfunctional water supply schemes (Table 13) have perceived out the payment of water fee is covering the operation and maintenance cost. While those respondents which represent 52% of functional water supply schemes and 70% of nonfunctional water supply schemes of the total sample used to have understood their payment of water fee is not covering the operation and maintenance cost. Additionally, the focus group discussion results show that the overall water supply scheme management capacity of water staff, water point committees and artisan are very weak.

4.2.2 Lack of operation and maintenance spare parts

The availability of spare parts and maintenance tools is obviously of primary importance to long-term sustainability. Another very important factor identified by different literatures was concerning with the provision of follow-up, support by water supply owners and other private sectors to the rural communities in related to long-term sustainability.

The study area has shortage of spare part which used to repair the nonfunctional water supply schemes. Consequently, the reasons behind these issues are budget constraint, lack of monitoring mechanisms during and after the spare parts release for repair or maintenance works. However, technicians from the Woreda water mine and energy office used to support communities in repair needs. Nearly 52 % functional water supply scheme and 70 % of nonfunctional water supply schemes respondents said that operation and maintenance costs are the major challenges of water supply scheme sustainability. Since, the operation and maintenance cost of water supply schemes comes from additional contribution. This indicates that community lost ownership of asset and don’t want to contribute money for operation and maintenance especially in nonfunctional water supply schemes. This is one reason why water supply schemes become unsustainable. Similarly, the result was also reported by Sara (1997).

During filed observation 50% of retaining wall (top cover of water supply schemes) of the study area has made crack this indicate the scheme built with low grade materials. The technical problems noticed in the sample kebele are also considerable in causing scheme failure. The common technical problems seen in the study area were poor construction quality, (poor quality of drainage ditch and fence), lack of spare parts were the main problem.

4.2.3 Water quality problem

The aesthetic value, total dissolved solids and hardness content are the main problem of the water supply sample schemes in the study area. According to the discussion with the water point committees the water supply scheme was not disinfected by chlorine and not often cleaning the water supply schemes. In this regard, the laboratory test result show that the majority of water supply schemes had detectable level of iron, higher level of total hardness and total dissolved solids (see Table 5).

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study elicited the main reasons why water supply systems have become nonfunctional within a short period of time after installation in Gambella Zuria Woreda. Predicting the sustainability of community-based water supply systems has its challenges. Field survey, focused group discussion and field observations were done to collect the relevant information about twelve water supply schemes in the study area. The limitations of this study were bacteriological water quality laboratory kits, equipments and documentation that were done prevesiouly. In addition to these, the participants might not accurately state the challenges for the sustainable rural water supply in the localities. And also, sustainability of water supply systems includes a number of aspects.

In general, the findings on sustainability challenges of rural water supply systems in Gambella Zuria Woreda reflect a critical situation. Currently, from the total 63 water supply schemes 30 are functional and 33 water points are not providing a service to the community. For all water supply schemes (both functional and nonfunctional) the community was similarly involved independent of whether the system failed afterwards or not. Therefore, People in the study area largely dependent on unimproved water sources for drinking and other domestic activities. Comparing the two cases, relatively better willingness of the community to sustain the system, satisfaction with service delivery, operation and maintenance systems and better financial management is observed in functional water supply schemes than nonfunctional water supply schemes. The other major difference observed between the two cases is physical condition of water supply schemes in relation to fence (100% of FWSS and 18% of NFWSS had fence). Furthermore, capacity build training aimed at scaling up technical knowhow and capacities to manage and operate the technology employed and carry out simple maintenance need to be given for water committee members. Most of the respondents were cited there are no training gained about water supply and sanitation .The same kind of response was cited during the focus group discussion session. But when questioned about the frequency of the training, they used to state a onetime training that was given to the water committee. Similarly, the response was cited during key focus group discussion with water committees indicated that the possibility for refresher training is unthinkable in most cases due to the budget constraint of the district water and energy office.

In this study drinking water samples were collected from three sites of Gambella Zuria Woreda and have been analyzed for some physico-chemical parameters like pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), fluoride (F^-), iron (Fe), calcium (Ca^{2+}), magnesium (Mg^{2+}) and total hardness (TH). The result obtained from Table 5 indicated that, most of the physicochemical parameters were within the WHO and EDWQ maximum contaminant levels. The results from this study clearly demonstrate that the water quality obtained from hand pump wells (KM and KC) at Elei echwoye kebele is unfit for human consumption due to high level of iron, total hardness and total dissolved solids. The overall quality of groundwater is low and this situation needs urgent and strategic solutions. Furthermore, it contributed to identify the main concerns regarding the quality of drinking water, in order to suggest appropriate solutions to reduce the observed contaminations and to motivate the local public authorities to plan future interventions in this sector.

In this study, six hand pump well water of the ABol , Bonga and Elei echwoye kebele were assessed for the physical and chemical parameters. The taste, colour and odor complaints may lead users to an immediate rejection of water points with the possibility of ultimate abandonment or to the fact that people stop using the water points for drinking purposes. Acceptability aspects of drinking water quality such as pH and turbidity were generally good. The presence higher total dissolved solids, turbidity, iron and total hardness levels in few of the water points may affect their continued use.

The results revealed that that most of the hand pump well physicochemical water quality parameters were within the World Health Organization (WHO) and Ethiopian drinking water quality (EDWQ) guidelines for drinking water quality. Only two shallow-wells (KM and KC) at Elei echoye kebele had marginally higher level of total dissolved solids, iron and total hardness, while one shallow well water point had higher turbidity and electrical conductivity when compared with the WHO and EDWQ guidelines. This identified that chemical water quality concern is significant and an immediate intervention is required to prevent widespread and long-term exposure. Since, the community of this kebeles forced use of another unimproved source of water. This study presents baseline data for future reference especially for drinking water assessment. To plan correct actions in the Gambella Zuria Woreda it is necessary to clarify the origin of this element in the ground water sources. This aesthetic property of water supplies are an issue in the Gambella Zuria Woreda especially Elei echwoye kebele and should be taken into consideration before developing water supply program. Since consumer acceptance can play a critical role in the long-term sustainability of water supply projects. In fact, in this sample kebele all of the participant's people abandon improved water supplies (shallow wells and hand dug wells) for drinking purpose which are rich in iron, TDS and total hardness which favor of surface water sources that are unsafe and microbiologically contaminated. One of the reason that user community to abandon the water supply schemes are high level of iron , total hardness and total dissolved solids contamination.

On the other hand, the practice of cost sharing for operation and maintenance of the water supply scheme is another important issue when the benefiting community is expected to commit itself and act responsibly for the water supply systems extends its services over time. In this regard, findings of the study have indicated that the communities in the study area have limited experience concerning users pay principle and are acting accordingly. To this effect, the financial sustainability aspect of the water supply systems under investigation has been needed more efforts and not covered the costs of operation and maintenance. Concerning the issue of water supply system technical sustainability, there appears greater interest and commitment of the study communities to maintain and manage the water supply scheme services and benefits over time. But, respondents indicate that the challenges are lack of spare parts and training about WASH operation and maintenance. Additionally, 100% of functional water supply system and none of nonfunctional water supply system respondents indicated that their water supply scheme was well functioning without any damage or technical problems and 3% of functional water supply schemes and 95% of nonfunctional water supply schemes respondents indicated that community were used to have functioning with some breakage/technical problem. This indicates that the issue of technical sustainability is not yet adequately addressed.

5.2 Recommendations

A total of 63 water supply points were constructed in the years 2008 to 2017. In 2017, of these water supply points 30 were functional and 33 were non-functional. This indicates currently the non-functionality of water supply schemes is increased and that a decent effort is being made to improve water supply access or sustainability in the rural communities. It can be even better when more attention is paid to the following factors.

- In both functional and nonfunctional water supply schemes training artisans and water point committees, monitoring construction quality, appropriate fencing, system area conservation practices and effective supervision of rural water supply projects enhance sustainability of schemes.
- It is recommended that appropriate cost sharing and recovery could improve financial sustainability of water supply systems. However, water payment of the users in the study area was very weak. More awareness creation efforts should be done related to the importance of water tariff payment and users should be encouraged to set a reasonable tariff that enables them to recover sufficient reserve fund for replacement and rehabilitation of schemes.
- In both functional and nonfunctional water supply scheme user communities use alternative water sources. Therefore, water treatment at household level and mixing the existing water source with another water source are possible solutions to improve the quality of drinking water especially in the Eleiehwoye kebele. Furthermore, the regional government especially regional water bureau give attention to address the water quality problem and made additional RPS for the community of Eleiechwoye kebele is better.
- Finally, further research in sustainability challenges of rural water supply systems especially; in water quality aspects should be conducted in different seasons considering other water quality parameters such as biological water quality parameters for drinking and irrigation purpose would be very beneficial in the development of a future water resource program in the study area. In fact, the origin of iron needs to be investigated by also considering the hydro-geological characteristics of the sampling sites. Only by identifying the sources contamination will it be possible to select and implement the most correct and appropriate solution to these quality issues.

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7 Appendixes

Appendix A: Focus group discussion

Introduction

I am a graduate researcher from the Department of water Resource and irrigation engineering at Hawassa University. I am conducting my master thesis research on and I am here to find basic feeling of the users and service providers at Woreda level. The inquiry will be done with various discussion sessions for different part of the community based on the questionnaire here under. These parts of discussions in this questionnaire are means to undertake the research on *assessment of challenges of sustainable rural water supply: the case Gambella Zuria Woreda*. The research is very significant to bring efforts into sustainable manner for the woreda and for local communities. As a matter of random sampling, you are one of the respondents selected for this study. Thus, I would like to appreciate your participation and for your genuine responses in advance. At this point, I want to assure you that all your information would be valued to find out causes of non-functionality of rural water supply systems and your replies, comments, and suggestions will be confidential.

I thank you in advance for you cooperation!

Appendix B: Group Discussion questions with the water point committees and technical employers or experts

The discussion is to assess the challenges of sustainability of community based rural water supply scheme management.

1. What are the major challenges of your water supply systems?
2. What are the major causes for sustainability and suggested solutions to sustain the operation of water supply systems?
3. Is the water supply available enough to meet the demand of customer’s consumption?
4. How do you see the quality of water you are using?
5. Degree of community participation in planning and implementation of the water supply systems?
6. Capacity of water committee reporting systems, financial management and collection of water fee?
7. What do you suggest to improve and sustain the existing water supply schemes?

Figure 1: Focus group discussion session one at Abol community (left) and session two at Eleiechwoye community (right), photo: Researcher

Appendix B: Questionaries' used for scoring matrix and identifying sustainability challenges of rural water supply

A) Operation and Maintenance

1. Is the community managing the water supply schemes effectively?

   1. Yes 2.No 3. Don't know

2. Who manages the water point?

   1. Water point committee 2. Local leaders 3. Water facility office 4. All 5.unkown

3. Has the water point ever broken down or required a repair? 1.Yes 2.No
4. How did you manage the repair and what did it cost? specify -----------------------------------
5. Where did you get the spare parts from?

   1. From regional water bureau 2. From NGOs
   2. From both government water office and non-government organizations
   3. All 4. others specify ---

6. Have woreda water office and donors given you some sorts of support for your water supply scheme? 1. Yes 2.No
7. If your answer to question number 6 is yes what kind of support donor (NGOs) and woreda water office in the management of community water supply scheme?

   1. Training 2. Financial support 3. provide repair and maintenance
   2. Monitoring and evaluation 4. Both financial and maintenance support 5.Others

8. Does the water supply system give efficient service? 1. Yes 2. No
9. What is needed for successful rural water supply scheme operation and maintenance by the community?
    1. Empowerment of the community for community management of RWSS
    2. Technical and financial training of O&M staff
    3. Government or NGOs consults water artisans
    4. Technical and human resource support from Regional water bureau
    5. All 6. Others ---
10. Does the water tariff cover the operation and maintenance cost of water supply schemes?
    1. Yes 2. No
11. How to achieve a sustainable support for operation and maintenance/repairs
    1. Government/ NGOs support technical, financial and community awareness training
    2. Government/ NGOs assistance for larger repairs
    3. Provisions of materials and spare parts
    4. Specialist /experts support for schemes improvement on O&M 5. All 6.Others
12. Do you pay additional fee for operation and maintenance of water supply schemes?
    1. Yes 2. No
13. Are you member of the water supply committee? 1. Yes 2. No
14. Do you think representation of women in the water committee is enough?
    1. Yes 2.No 3. Don't know
15. How the response of Regional water bureau for follow up, monitoring and maintenance of the water supply schemes? 1. Excellent 2. Good 3. Satisfactory 4. Weak

    B) Financial Management

16. Do you support the idea that users should pay water fees? 1. Yes 2. No
17. Do you pay for water? 1. Yes 2.No
18. How much do you pay a month? ---------------------- birr
19. Are the bills that you receive accurate? 1. Yes 2. No
20. What do you see about the water tariff (prices) in Gambella Zuria Woreda?
    1. Cheap 2. Expensive 3. Fair 4.Unfair
21. Before the water point was installed, did you contribute anything towards it?1. Yes 2. No
22. If yes, in what items? (Multiple responses is possible)

1. Labor 2. Material 3. Money 4.Equipment 5. All 6. Others

23. Who collects and manages the contributions? Specify --------------------------------------

24. Does every household pay the same water tariff? 1. Yes 2.No

25. How much money is currently available for maintenance and repair? specify ------------------

26. Do you think the collected fee is properly managed? 1. Yes 2. No 3. Don't know

27. Do you have problems of ability to pay water tariff? 1. Yes 2. No

C) Willingness to sustain the water supply scheme

28. What are the causes of sustainability of water supply schemes?

1. High maintenance cost 2. Low income of the community

3. Little support from Regional water Bureau and NGOs

4. Lack of Spare parts 5. All 6. Others ----------------

29. What do you do as a community member in order to enable the water supply scheme be sustainable? (Multiple responses is possible)

1. Actively participate in water scheme administration

2. Labor contribution during operation and maintenance

3. Paying service fee 4. All 5. Others specify --------------------------------------

30. Does community have financial capacity to sustain the service? 1. Yes 2. No 3. Don't know

31. What to be done in order to sustain the water supply systems?

1. Continuous repair and maintenance 2. Paying water fee in time 3. Practice good financial management

4. Community participation during planning and implementation of water schemes

32. Do the water committee members given adequate capacity build and technical training? 1. Yes 2. No

33. Do you pay water fees on time? 1. Yes 2. No

34. Did you think the available water supply is sufficient for all the community? 1. Yes 2. No

35. Where from you had been collecting water before this source is introduced?

1. River 2. Pond 3. Streams 4. Rain water collection 5. Others

D**). Customer satisfaction with service delivery**

36. Is water a major problem in your community? 1. Yes 2. No

37. Are you satisfied with the water supply system? 1.Yes 2.No

38. Who is responsible for the construction of the water supply facilities?

1. Government 2. Aid organizations (NGOs) 3. The residents 4.All

39. How far is the water source from your home? (Please specify in kilometers)

1.< 0.5k 2. 0.5 -1 km 3. 1-2km 4. >2km

40. What is the frequency of water supply?

1. 24 hour supply 2.More than once a day 3. Once a day 4.Once in two days
5. Once in three days 6. Others ----------------------------------

41. Are you satisfied with the quality of water supply system? 1. Yes 2. No

42. How often would you like to get water?

1. 24 hour supply 2. More than once a day 3. Once a day 4. Other -------------------------

43. Are you satisfied with the quantity of water available? 1. Yes 2. Very much 3.No 4.Depends on season

44. Do you need new water schemes / points? 1. Yes 2. No

45. What is your perception of water point's taste, odour and colour? 1. Good 2. Fair 3. Bad

E) Physical condition of water supply schemes

46. Which of the following affects the safety of your water source?

1 = Turbidity due to flooding 2 = Algae development

3 = Livestock contamination 4 = Bird and wild life contamination

47. How do you view the current safety of water from your local source? 1=Safe 2=Unsafe

48. What do you think are the characteristics (qualities) of clean water? ----------------------------

49. To your understanding, what are the signs of safe drinking water? 1. Taste 2. Colour 3.Odour 4. All 5. others

50. Does the water point provide water at all times throughout the year? 1. Yes 2. No

51. Is the water supply system functioning? 1. Yes 2.No

52. How is the functionality of your community water supply system in terms of water availability?

1. Not functioning at all 2. Well-functioning without damage 3. Functioning with some breakage 4. Others

53. Is there any cracks/broken parts on the top work of water supply schemes? 1.Yes 2.No

54. Do you think contamination possibility in water supply service? 1. Yes 2. No

55. If the answer is yes what type of contamination? 1. Animal contamination 2. Cloth washing on water schemes 3. Human faeces 4. others

56. How do evaluate the construction quality of water supply system?

1. Very good 2. Good 3. Fair 4. Bad

57. Are the drainage channels of water schemes functioning? 1. Yes 2. No

58. Is the water supply scheme having fence? 1. Yes 2. No

F) Demand and supply

59. How do you evaluate the water supply in Gambella Zuria Woreda?

1. Very satisfactory 2.Satisfactory 3.Unsatisfactiory

60. Is there community needs additional water schemes /points? 1. Yes 2. No

61. How severe are problems with water service in your community? 1.Low 2.Fair 3.Strong 4.No problem

62. what are the problem of water supply in the district

1. Adequate failure of generator or water pumps 2. Low pressure of water /inadequate quantity 3. Low quality 4. Water interruption 4.All

63. Have your organization followed water supply demand responsive approach? 1. Yes 2.No

Appendix C: Method, Reagents, Equipment and Procedure of physical and chemical water quality test

1. Fluoride

Test method: Palintest photometer was used to test fluoride concentration by using two tablet reagents.

Reagents and Equipment

- Palintest fluoride No. 1 tablets
- Palintest fluoride No. 2 tablets
- Palintest Automatic wavelength selection photometer
- Round test tubes ,10ml glass

Procedure

1. Fill test tube with sample 10 ml mark
2. Add one fluoride No.1 tablets ,crush and mix to dissolve
3. Add one fluoride No.2 tablets ,crush and mix to dissolve
4. Stand for five minutes to allow full colour development
5. Select phot 14 on Photometer

6. Take photometer reading in usual manner
7. The result is displayed as mg/l F.

2. Iron

Test method: the Palintest iron concentration test is based on tablet or reagents and the test was carried out simply by adding tablets to a sample of water and measure by using a Palintest Photometer.

Reagents and Equipment

- Palintest Iron tablets
- Palintest Automatic Wavelength Selection Photometer
- Round Test Tubes, 10 ml glass

Test Procedure

1. Fill test tube with sample to the 10 ml mark.
2. Add Iron tablet, crush and mix to dissolve.
3. Stand for one minute to allow full colour development.
4. Select Phot 19 on Photometer.
5. Take Photometer reading.
6. The result is displayed as mg/l Fe.

3. pH Measurement - Palintest Photometer test method

The Palintest Phenol Red test uses a tablet reagent containing the precise amount of Phenol red indicator required for the test. The pH value was measure using a palintest photometer.

Reagents and Equipment

- Palintest Phenol Red tablets
- Palintest Automatic Wavelength Selection Photometer
- Round Test Tubes, 10 ml palintest glass

Procedure

1. Fill test tube with sample to the 10 ml mark.
2. Add one phenol Red tablet, crush and mix to dissolve.
3. Select Phot 27 on Photometer.
4. Take Photometer reading in usual manner

4. Calcium : Test method

The palintest calcium hardness test is based on the calcicol indicator reagent method. The Palintest calcicol test is a simple method of determining calcium hardness over the range 0-500mg /l $CaCo_3$ and was measure using a palintest photometer.

Reagents and Equipment

- Palintest calcicol No. 1 tablets
- Palintest calcicol No.2 tablets
- Palintest Automatic Wavelength Selection Photometer
- Round Test Tubes, 10 ml glass (PT 595)

Test procedure

1. Filter sample if necessary to obtain clear solution
2. Fill test tube with sample to the 10 ml mark.
3. Add one calcicol No. 1 tablet, crush and mix to dissolve.
4. Add one calcicol No. 2 tablet, crush and mix to dissolve.
5. Stand for two minute to allow full colour development
6. Select Phot 12 on Photometer for result as mg/l $CaCo_3$ or Phot 60 for result as mg/l Ca.
7. Take Photometer reading in usual manner

5. Magnesium

Test method

The Palintest Magnecol test is based on a simple colorimetric procedure. Magnesium reacts with an organic reagent to produce an orange colour complex. The reagents itself is yellow and thus over the range of the test a serious of colours from yellow through to orange is produced.

Reagents and Equipment

- Palintest Magnecol tablets
- Palintest Automatic Wavelength Selection Photometer
- Round Test Tubes, 10 ml glass (PT 595)
- Measuring syringe ,10ml (PT 361)

Procedure

I. Using the measuring syringe 10ml sample of water transfer to the round test tube and make up to the 10ml mark.

II. Add one Magnecol tablet, crush and mix to dissolve.

III. Stand for five minute to allow full colour development

IV. Select Phot 21 on Photometer for result as mg/l Mg or Phot 61 for result as magnesium hardness mg/l Ca CO_3.

V. Take Photometer reading in usual manner

6. Electrical Conductivity (EC)

Conductivity is the capacity of water to carry an electrical current and varies both with number and types of ions the solution contains.

Test method

The Wagtech EC meter is simple, cost effective and direct measuring methods of water samples.

Procedure

a. Rinse the sample container at least twice
b. Fill 30ml sample water at beakers
c. Remove the cap of EC meter and turn on ,then wait to appear zeros
d. Deep the meter in to sample container (cup), so the prove are water covered
e. Be careful not to put the meter deeper the measure line and shake it
f. Allow time the number value display on the screen to stabilized and then record the result
g. Clean the meter with deionized water (distilled water) and off the meter

7. Total dissolved solids(TDS)

Test method

The total dissolved solids of water supply schemes (hand pumps) were determined by using TDS Tester 11 dual range equipment by direct measurement.

Procedure

1. Fill the beaker with sample water to 250ml
2. Remove cap and On the TDS tester meter
3. Immerse the meter in to the sample water
4. Wait until the reading is stop
5. Take the reading

8. Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed. Turbidity in water is caused by suspended matter such as clay, silt and finely divided organic and inorganic matter.

Method: The turbidity of water was determined by using the turbidity tube

Procedure

The tube was rinsed with distilled water, sample water, then fill test tube with sample of water until seen cross sign bottom part of the tube (viewing disk), the reading were measured from measuring device and then take the average value. Figure 2 and 3 below shows that the water quality test equipments, reagents and sampling techniques of physicochemical parameters of drinking water.

Figure 2: Sample collection with preservation mechanism (A), water quality equipment and reagents (B) and laboratory photo during water quality testing (C), Photo: Researcher

Figure 3: Palintest photometer 7100 (A) and TDS Tester 11 dual range and Wagtech pH meter respectively (B) Photo: Researcher

Table 1: The existing water supply schemes in the study area (Gambella Zuria Woreda)

No	Kebele	Total No. of wells	Type of water schemes				FWS	Non-functional water schemes		
			BH	RPS	SW	HDW		NFWSS with some breakage	Minor maintenance needed	Major maintenance needed
1	Ngykowo	4			4		2	1	1	
2	Upaga	5			3	2	1	2	2	
3	Abolkir	5			3	2	1	2	1	1
4	Pinkiwo	8			7	1	4	1	2	1
5	Eleiechwye	6			3	3	4	1		1
6	Pukong	5			3	2	1	2		2
7	Pimoli	4			3	1	2	1		1
8	Solen	3			3	1	1	1		1
9	Bonga	9		1	3	5	4	4	2	
10	Koben	4			3	1	4			
11	jewe	2			2		2			
12	Seri mejeng	2			2		0	1	1	
13	Abol	6	2		5		4	1	1	
	Total	63	1	1	43	18	30	16	10	7

Source: Gambella Zuria Woreda water mine and energy office, 2018, BH = Borehole, HDW = Hand dug well, SW = Shallow well, RPS = Rural piping system

Table 2: Institutional water supply schemes distribution and there in Gambella region (2009)

Regional Water supply schemes Data end of 2009 EFY																							
		Rural including institutions											Towns										
		For Community				For institution																	
						School				Health													
NO	Woreda	HDW	SW	SOS	RPS	HDW	SW	SOS	RWH	HDW	SW	SOS	HDW	SW	SOS	RI	BH	RuralTotal	Urban Total	Institution Total	Total Schemes	Functional	Non- Functiona
1	Jor	21	25	0	0	0	2	0	0	0	0	0	0	14	0	0	0	49	9	1	58	47	11
2	GOG	14	39	0	0	0	14	0	0	0	6	0	0	12	0	0	1	73	13	20	86	82	4
3	Abobo	18	47	0	0	0	14	0	0	0	7	0	0	7	0	0	2	75	9	21	84	80	4
4	Gam/Woreda	16	35	0	0	0	3	0	0	0	4	0	0	3	0	1	1	58	5	7	63	45	18
5	Dima	11	29	0	0	0	1	0	0	0	2	0	0	3	0	1	0	46	4	3	50	41	9
6	Godere	10	9	73	1	0	5	0	0	0	2	0	0	0	5	0	0	100	5	7	105	96	9
7	Mengeshi	6	26	47	0	0	0	0	2	0	7	0	0	5	0	0	0	90	5	7	95	82	13
8	Wantowa	6	85	0	0	0	3	0	0	0	2	0	0	16	0	0	1	95	17	5	112	110	2
9	Jikawo	11	77	0	0	0	3	0	0	0	3	0	0	15	0	0	0	94	15	6	109	99	10
10	Akobo	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	10	10	0
11	Makoy	15	50	0	0	6	6	0	0	0	4	0	9	21	0	0	0	81	30	16	121	111	10
12	Laree	16	75	0	0	0	12	0	0	0	14	0	0	16	0	0	1	117	17	26	126	100	26
13	Itang Special	36	73	0	0	0	12	0	0	2	4	0	3	16	0	0	2	127	21	19	148	107	41
	Total	190	570	120	1	0	75	0	2	2	55	0	12	128	5	2	8	1017	150	138	1167	1010	257

Source: Gambella Region water irrigation and electricity bureau, 2009 annual report

Table 3: Sample water supply wells status and GPS data at sampled kebeles

Name of kebele	Name of water scheme	Schemes code	Status	X coordinate	Y coordinate	Z Elevation
Abol	Abol police station	AB	functional	660461	914220	445
Abol	Abol chatiolic	AC	non functional	659966	914371	457
Abol	Tita	AT	non functional	659579	914386	441
Abol	Abol mendere	AM	functional	660141	914312	455
Elei echwoye	Tena kela	KTK	non functional	683164	903717	465
Elei echwoye	Karmi mendere	KM	functional	683411	904353	457
Elei echwoye	Karmi chatolic	KC	functional	682603	903717	465
Elei echwoye	Bure mendere	EEBM	non functional	672133	911051	472
Bonga	Uduk mendere	BU	non functional	703825	904896	482
Bonga	Chereqa sefere	BC	functional	703494	904815	571
Bonga	Bonga elementary	BE	functional	704099	904965	452
Bonga	Mereima sefere	BM	non functional	703255	904896	478

Source: researcher self-computation

Table 4: Gambella Zuria Woreda water staff based on their education and qualification

No	Field of study	Responsibility	Education level	
			Diploma	BSc
1	EDPM	Office head		1
2	General mechanics , civil , soil and water engineering	Operation and maintenance expert	1	3
3	Rural water supply and sanitation	Rural water supply expert	1	
4	-	Water quality expert	-	-
5	Management	Planning and documentation expert		1

Table 5: Water supply schemes distribution in the study area (2008-2017)

Year	BH			RPS			SW			HDW			Grand total	Coverage (%)
	F	NF	Total	F	NF	Total	F	NF	Total	F	NF	Total		
2008							12	6	18	8	5	13	31	39.42
2009							18	3	21	11	3	14	35	41.44
2010							21	2	23	16	6	22	45	52.7
2011	1		1				20	6	26	15	7	22	48	49
2012							22	8	30	18	5	23	53	55
2013							19	13	32	15	7	22	54	57
2014							22	10	32	18	6	24	56	59
2015					1	1	28	8	36	19	2	21	57	68
2016							27	11	37	16	7	23	61	75.5
2017							23	16	39	7	17	24	63	84

Source: Gambella Zuria Woreda water mine and energy office, 2018

Table 6: Location, number, yield and type of water points investigated

S/N	Kebeles	Specific name of water supply points	Number of water points	Design discharge of wells	Actual discharge of wells	Water point type
1	Abol	Abol police station	1	0.36 l/s	0.32 l/s	SW fitted with Indian mark Ⅱ hand pump
2	Abol	Abol chatiolic	1	0.29 l/s	-	SW fitted with Indian mark Ⅱ hand pump
3	Abol	Tita	1	0.33 l/s	-	SW fitted with Indian mark Ⅱ hand pump
4	Abol	Abol mendere	1	0.49 l/s	0.49 l/s	SW fitted with Indian mark Ⅱ hand pump
5	Elei echwoye	Bure mendere	1	0.28 l/s	-	HDW fitted with Indian mark Ⅱ hand pump
6	Elei echwoye	Tena kela	1	0.31 l/s	-	SW fitted with Indian mark Ⅱ hand pump
7	Elei echwoye	Karmi mendere	1	0.38 l/s	0.38 l/s	SW fitted with Indian mark Ⅱ hand pump
8	Elei echwoye	Karmi chatolic	1	0.22 l/s	0.22 l/s	SW fitted with Indian mark Ⅱ hand pump
9	Bonga	Chereqa sefere	1	0.34l/s	0.31 l/s	HDW fitted with Indian mark Ⅱ hand pump
10	Bonga	Uduk mendere	1	0.48 l/s	-	SW fitted with Indian mark Ⅱ hand pump
11	Bonga	Elementary	1	0.35 l/s	0.35 l/s	SW fitted with Indian mark Ⅱ hand pump
12	Bonga	Mereima sefere	1	0.31 l/s	-	HDW fitted with Indian mark Ⅱ hand pump

Source: Researcher self-computation, SW – Shallow well, HDW= Hand dug well

Table 7: Comparison of water sample code AM measured values with WHO and EDWQ standards values

Well sample code (AM)	Selected drinking water quality parameters								
	pH	Turbidity	EC	F	Fe	Ca	Mg	TH	TDS
WHO standard	6.5- 8.5	5 (NTU)	400(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	100- 300 (mg/l)	600 (mg/l)
EDWQ standard	6.5- 8.5	5 (NTU)	1000(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	300 (mg/l)	1000 (mg/l)
T1	7.30	2.12	859.50	0.23	0.32	37.60	14.70	182.85	629.76
T2	6.80	2.36	860.20	0.25	0.28	39.10	15.65	184.28	631.29
T3	7.20	2.15	858.20	0.27	0.27	40.30	14.65	181.87	628.95
Max	7.30	2.36	860.20	0.27	0.32	40.30	15.65	184.28	631.29
Min	6.80	2.12	858.20	0.23	0.27	37.60	14.65	181.87	628.95
Mean	7.10	2.21	859.30	0.25	0.29	39.00	15.00	183.00	630.00
Median	7.20	2.15	859.50	0.25	0.28	39.10	14.70	182.85	629.76
SD	0.265	0.131	1.015	0.020	0.026	1.353	0.563	1.211982	1.188

Table 8: Comparison of water sample code AP measured values with WHO and EDWQ standards values

Well sample code (AP)	Selected drinking water quality parameters								
	pH	Turbidity	EC	F	Fe	Ca	Mg	TH	TDS
WHO standard	6.5- 8.5	5 (NTU)	400(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	100- 300 (mg/l)	600 (mg/l)
EDWQ standard	6.5- 8.5	5 (NTU)	1000(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	300 (mg/l)	1000 (mg/l)
T1	6.90	3.32	688	0.09	0.25	5.10	12.00	183	638
T2	7.10	3.2	695	0.1	0.22	5.30	13.00	185	642
T3	6.90	3.1	691.6	0.14	0.2	5.70	14.00	187	640
Max	7.10	3.32	695	0.14	0.25	5.70	14.00	187	642
Min	6.90	3.1	688	0.09	0.2	5.10	12.00	183	638
Mean	6.97	3.206667	691.52	0.112	0.224	5.38	13.00	185	640
Median	6.9	3.2	691.6	0.1	0.22	5.30	13.00	185	640
SD	0.1155	0.110151	3.500476	0.026458	0.025166	0.305505	1.00	2	2

Table 9: Comparison of water sample code KM measured values with WHO and EDWQ standards values

Well sample code (KM)	Selected drinking water quality parameters								
	pH	Turbidity	EC	F	Fe	Ca	Mg	TH	TDS
WHO standard	6.5- 8.5	5 (NTU)	400(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	100- 300 (mg/l)	600 (mg/l)
EDWQ standard	6.5- 8.5	5 (NTU)	1000(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	300 (mg/l)	1000 (mg/l)
T1	8.50	17.00	1123.00	0.31	0.67	58.00	55.00	907.00	999.00
T2	7.00	15.00	1120.00	0.28	0.72	56.00	50.00	913.00	1015.00
T3	8.50	13.00	1125.00	0.29	0.61	52.00	44.00	919.00	1015.00
Max	8.50	17.00	1125.00	0.31	0.72	56.00	55.00	919.00	1015.00
Min	7.00	13.00	1120.00	0.28	0.61	52.00	44	907.00	999.00
Mean	8.00	15.00	1122.67	0.293	0.667	55.33	49.67	913.00	1009.66
Median	8.50	15.00	1123.00	0.29	0.67	56.00	50	913.00	1010.00
SD	0.866	2.00	2.517	0.0153	0.0551	3.055	5.507	6.00	9.238

Table 10: Comparison of water sample code KC measured values with WHO and EDWQ standards values

Well sample code (KC)	Selected drinking water quality parameters								
	pH	Turbidity	EC	F	Fe	Ca	Mg	TH	TDS
WHO standard	6.5- 8.5	5 (NTU)	400(μs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	100- 300 (mg/l)	600 (mg/l)
EDWQ standard	6.5- 8.5	5 (NTU)	1000(μs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	300 (mg/l)	1000 (mg/l)
T1	7.25	3.52	760.78	0.38	0.52	59.00	41.00	255.00	669.25
T2	6.79	3.39	762.83	0.38	0.49	59.00	46.00	320.00	671.15
T3	6.81	3.41	760.59	0.35	0.52	62.00	48.00	350.00	669.60
Max	7.25	3.52	762.83	0.38	0.52	62.00	48.00	350.00	671.15
Min	6.79	3.39	760.59	0.35	0.49	59.00	41.00	320.00	669.25
Mean	6.95	3.44	761.4	0.37	0.51	60.00	45.00	319.00	670.00
Median	6.81	3.41	760.78	0.38	0.52	59.00	46.00	320.00	669.6
SD	0.26	0.07	1.242	0.017	0.017	1.732	3.610	48.560	1.011

Table 11: Comparison of water sample code BC measured values with WHO and EDWQ standards values

Well sample code (BC)	Selected drinking water quality parameters								
	pH	Turbidity	EC	F	Fe	Ca	Mg	TH	TDS
WHO standard	6.5- 8.5	5 (NTU)	400(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	100- 300 (mg/l)	600 (mg/l)
EDWQ standard	6.5- 8.5	5 (NTU)	1000(µs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	300 (mg/l)	1000 (mg/l)
T1	7.51	4.18	496.64	0.23	0.06	78.36	60.49	226.54	231.67
T2	7.52	4.18	494.75	0.24	0.08	79.59	62.56	224.31	229.55
T3	7.41	3.94	493.61	0.19	0.04	76.05	59.95	224.15	228.78
Max	7.52	4.18	496.64	0.24	0.08	79.59	62.56	226.54	231.67
Min	7.41	3.94	493.61	0.19	0.04	76.05	59.95	224.15	228.78
Mean	7.48	4.10	495.00	0.22	0.06	78.00	61.00	225.00	230.00
Median	7.51	4.18	494.75	0.23	0.06	78.36	60.49	224.31	229.55
SD	0.061	0.139	1.531	0.027	0.020	1.797	1.378	1.336	1.497

Table 12: Comparison of water sample code BE measured values with WHO and EDWQ standards value

Well sample code (BE)	Parameters								
	pH	Turbidity	EC	F	Fe	Ca	Mg	TH	TDS
WHO standard	6.5- 8.5	5 (NTU)	400(μs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	100- 300 (mg/l)	600 (mg/l)
EDWQ standard	6.5- 8.5	5 (NTU)	1000(μs/cm)	1.5 (mg/l)	0.3 (mg/l)	75 (mg/l)	50 (mg/l)	300 (mg/l)	1000 (mg/l)
T1	6.9	3.01	929	1.15	0.17	34	95	175	1262
T2	7.40	3.00	950	1.20	0.02	36	100	245	1340
T3	7.3	3.00	932	1.27	0.32	38	100	450	1300
Max	7.40	3.01	950	1.27	0.32	38	100	450	1300
Min	6.9	3.00	929	1.15	0.02	34	95	175	1262
Mean	7.2	3.003333	937	1.206667	0.17	36	98.33333	290	1300
Median	7.2	3.00	932	1.2	0.17	36	100	245	1300
SD	0.2646	0.005774	11.36	0.060277	0.15	2.00	2.886751	142.9161	39.00