JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

CHAIR OF HYDRAULIC ENGINEERING

SYSTEM EVALUATION AND CHALLENGES OF SUSTAINABLE WATER SUPPLY IN ARERTI TOWN, MINJAR-SHENKORA WOREDA, AMHARA REGION, ETHIOPIA

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF JIMMA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN HYDRAULIC ENGINEERING

BY

PAULOS MESFIN HAILE

March, 2016

Jimma, Ethiopia

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March, 2016

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DECLARATION

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HYDRAULIC ENGINEERING CHAIR

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BY

PAULOS MESFIN HAILE

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ABSTRACT

Arerti town faces a serious unsustainable water supply problem. Even if the modern water supply system was installed since 1956's still, the town is not getting adequate amount of water from the system. These means, the current water supply is not meet the town's water demand. Sometimes, even the water is available; some of the community does not get enough amount of water from the system. Actually, the existing water supply system is designed for 20 years design period, but the problem is happen before 15 years left. As a result of these, residents are forced to get water from unprotected sources which are far from their homes or do not get efficient water for day to day activities. Besides, they also buy water frequently from vendors and incur additional cost. At the same time, because of system failure before completion of design period the water supply utility currently expose for another work with additional cost. In line with these the main objective of this study is to evaluate the system and assess the status of water supply, demand, its challenges and dynamics associated with inadequate water supply in Arerti town. A survey was conducted on a randomly selected 258 households, interview with purposefully selected key informants and focus groups. And also 83 nodes, 109 links/pipes (in different length, diameter and type), 1 tank, 4 reservoirs with 4 pumps and etc. properly were gathered for distribution network hydraulic performance evaluation. The institutional arrangement, the households' water source accesses, availability of water, daily water consumption, water interruption rate, time taken and distance to fetch water, cost of water, water source status, demand and supply gap, amount of water delivered out of the town, distribution network pressure and velocity, challenge and cause of none sustainable water supply in the study area were touched by this study. The result of a survey of 258 sample households living in the town revels that 51.6% of the households get water 3 times per week for a few hour. During water interruption, 53.5% of households do not get water trough yard or house connection and 70% of the respondent say there is no equal distribution of water in the town. Water consumption is 12.2 l/c/d which is below WHO standards; and regarding the distance and time taken to fetch water, 43 percent of household travel above 1000m and 39.9 percent of households take above 30 minute. The average total water demand at base year 2014 is 1548.13m^3/day, and the forecasted required amount of water for 2020 to achieving GTP-II is 3237.12m^3/day. The amount of water delivered out of the town is approximately equal to 20% of the total consumption of water in 2014. The household in low pressure zone especially on Junction-19, Junction-20 and Junction-30 coupled with inadequate water supply do not get enough amount of water almost in all time. The root causes of the challenging problems are institutional, financial, human and material resource constraints. That is, the water supplying service in the town is unsustainable; it is socially inequitable, economically inefficient. Therefore, this study presents the following recommendations to ensure sustainable water supply in the study town. These are; solve rural community water problem, use alternative power source, demand and supply management, use existed best alternatives, facilitate credit, use pressure zoning method, use alternative water source with pipe water and adapting new technology.

Key words: *sustainability, Arerti town, demand, supply and distribution system.*

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LIST OF ABBREVIATION

ATWSSO	Arerti Town Water Supply Service Office
ABD	Arerti Base Demand
ATM	Arerti Town Municipality
C^0	Degree Centigrade
CBOs	Community Based Organizations
CSA	Central Statistical Authority
DCI	Ductile Cast Iron
DWD	domestic water demand
ETB	Ethiopian Birr
GI	Galvanize Iron
GPS	Global positioning system
GTP	Growth and Transformation Plan
HHs	Households
HGL	Hydraulic grade line
J	Junction
Km	Kilometer
l/d/c	Litter Per day Per Capita
L/s	Litter per Second
m	Meter
m^3	Meter Cube
MDD	Minimum daily demand
MM	Millimeter
MoFED	Ministry of Finance and Economic Development
MoWR	Ministry of water Resource
MoWIE	Ministry of Water Irrigation and Energy
NGOs	Non-Governmental Organizations
O&M	Operation and Maintenance
PHD	Peak hourly demand
S.C	Share Company
SPSS	Statistical package for social study
UAP	Universal Access plan

UFW	Uncounted for Water
UN	United Nations
UN-HABITAT	United Nations Centre for Human Settlements
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
uPVC	unPolyvinyl Chloride
WB	World Bank
WSP	Water supply and Sanitation Program
WSSO	Water supply and Sanitation Service Office
WTP	Willingness to Pay
WHO	World Health Organization

1. INTRODUCTION

1.1. Background

Water is one of a vital resource, without which live could be difficult. Thus water is a critical factor for sustainable live-hood. Households need water for domestic use (drinking, cooking, washing cleaning etc.) and productive use. Safe drinking water is not a luxury but it is a question of survival and death (Olajuyigbe, A., & Fasakin 2010). Access to clean water and sanitation is declared as human right by United Nations in 2010(UN, 2013). It is a pre-requisite for the realization of human rights, including those relating to population's survival, education and standard of living. To a greater or lesser extent, these rights are denied where people are unable, for whatever reason, to access safe water. Due to different reason the water sectors, providing potable water face many challenges.

Particularly, of any region in the world, the problem of water supply is deep rooted and multi-dimensional in Africa.

Today, their struggle for economic and social development is related with water. According to Unicef & WHO (2014), more than 700 million people still lack of improved sources of drinking water; nearly half are in sub-Saharan Africa. More than one third of the global population, i.e., some 2.5 billion people do not use an improved sanitation facility, and of these 1 billion people still practice open defecation (Unicef & WHO, 2014).

Similar to the urban water sector in many developing countries, there are serious constraints in meeting the challenge to provide adequate water sustainably for all urban residents. In addition to water supply shortages and quality deteriorations, pressure and velocity are among the problems which require greater attention and action. Various strategies are always being developed to make water accessible to all inhabitants. But, due to insufficient infrastructures coupled with rapid population growth and urbanization, the gap between demand and supply of water continues to widen (Abebaw *et al*., 2011 and Tadesse *et al*., 2013).

As mentioned on the above, the water supply problem in Arerti town is not different from such realities. Even, the town gets piped drinking water supply service since 1956 from a borehole (Bore Hole One) source dug in the same year; still the supply had not been meet the needs of the residents.

The problem may arise from inadequate water supply, high electric power interruption, town expansion, neighboring Kebels, environmental condition and improper design.

In short, evaluating the system and assessing the challenges of sustainable water supply is the one that ensures adequate and equal distribution of clean water to all residents, gives priority for customers' selection of service type, considers economic viability of various society groups. But the situation of water supply in Arerti town is out of the consideration of some of these points and the sustainable supply of water has never been achieved in the town's history of water supply service.

In fact, different researches have been conducted in the town in relation to water supply including socioeconomic and baseline studies, but none of these studies addressed the concern water sustainability of existing system. Therefore, this study was evaluating the system and assessing the challenges of sustainable water supply of the study area. To this end, it will be the baseline for existing system and come up with different planning solutions for the sustainability of the service.

1.2. Statement of the problem

Adequate, quality, safe and affordable supply of drinking water is a basic need for human life. However many people across the planet do not have access to safe and adequate water supply services which affects their life in various ways (Yibeltal, 2011).

The provision of adequate clean drinking water in the study area has been through challenging situations in the past years and until now. But the reason is not clearly demarcated. Without any research, Arerti town water supply service office simply says, the water shortage is happened because of power supply problem; the other says it happened because of high water demand of the population; still the rest says it happened because of low capacity of water sources and inadequate pressure but the problem is increasing from year to year. In addition to this, the legitimate body to supply water for the town has many problems as an institution to ensure a sustainable water supply. Budget shortage, lack of man power to handle regulatory issues and plan, operate and maintain the service and poor institutional coordination were some of them (Abebaw, Mulat and Friends S.C., 2007).

As result of the rapid expansion of the town in the last time has not been fully supported by infrastructural developments. While the town grew spatially, expansion of water supply service did not. There has been a wide gap, particularly in the water supply service even compared to other infrastructural developments in the study area.

The problem of water supply in the town is not only the problem of fairly distribution of water and reliability but also it has problem of adequacy and accessibility coupled with pressure and velocity problem. Because of elevation difference and inadequate pressure, some of the residences do not get water from the system as the same time like the other residences.

Therefore, Arerti town is currently getting water once in three or seven days intermittently for just a few hours. So, the water is inadequate for day today activities of the household, like, for drinking, cooking, cleaning utensils and washing clothes. The shortage of water supply in the town has caused various burdens on the community related to economic and health matters. To cope up with the water supply shortage, the residents are forced to get water from unprotected sources which are far from their homes. Besides, they also buy water frequently from vendors and incur additional cost. In addition to this the overall health of the population has deteriorated with water related diseases and families have to spend money for the consequential illness.

Women, in particular, carry the sole entire burden of water problem. They travel, to different places to get water. After getting the water, carry and bring to home to accomplish day-to-day domestic activities. Also waste much of their time and energy. All these in general affect their engagement in other activities within and outside the home.

Thus, the issue of sustainability is critical when resource scarcity and equity matters are raised. The sustainability of water supply projects and the benefits they deliver are some of the overriding concerns of the sector. Design and implementation of water supply projects has been unsuccessful and inefficient, it has shortcomings and needs improvement related to the planning and follow-up, operation, maintenance and management issues.

Therefore, in the light of the above mentioned problems, this research project was undertaking to evaluate the system and assess the challenges of sustainable water supply in the study area, Arerti town.

1.3. Objective

1.3.1. General Objective

The overall objective of this research is to evaluate the adequacy of water supply distribution system interims of pressure and velocity and assess the challenges of sustainable water supply in the study area, Arerti town.

1.3.2. Specific Objectives

- To evaluate the current water supply service coverage, consumption and accessibility status of the town;
- To project future water supply and water demand of the study area;
- To Model the existing water supply distribution system and analyze nodal pressure and link velocity, using WaterCAD standalone software; and
- To identify the major challenges and causes of unsustainable water supply in the study area.

1.4. Research Questions

In order to achieve the above mentioned research objectives and seek answers for the stated objectives the following major research questions were formulated.

1. What is the current water supply service coverage, consumption and accessibility status of Arerti town?
2. How is projected water demand and water supply gap of the town?
3. Is the pressure distribution and velocity in the water supply system adequate at all times?
4. What are the major challenges and causes of unsustainable water supply in the study area?

1.5. Significance of the study

Since, the research is focus on evaluating the system and assessing the challenges of sustainable water supply in Arerti town. The study is expected, to give the present status of the water supply condition, reveals the expected work for the future and increases the knowledge and up to dated information on about urban water supply systems and its adverse impacts on the urban population. It is also serves as a worked document to policy makers in the water sector, the None-Governmental Organization (NGOs) and the community. The study will further serve as baseline data for any further investigation, as a useful material for academic purposes, and as an additional literature to the existing knowledge.

1.6. Scope of the study

The scope of the study was limited in space and subject. Specially, the research was conducted to evaluate the distribution line of the system and assess the challenges of sustainable water supply in Arerti town.

The scope of the study in terms of subject was limited to evaluate the existing water distribution system and assess the challenges of sustainable domestic water supply only in terms of the equitability of water in the town, its adequacy, quality, accessibility (distance travel to fetch water, time consumed and affordability), distribution pressure reaching to all residents, how much the surrounding kebeles affect the town water supply and estimate present water demand and forecast future water demand and supply.

2. LITERATURE REVIEW

2.1. Sustainable water supply

In general, sustainable water supply system involves a number of issues that are internal and external to the community. According to Zelalem (2005), the following are key issues that are of a paramount importance to sustainable water supply systems:

- Community participation and involvement;
- Women's participation and involvement;
- Cost-sharing and cost recovery;
- Community awareness raising and education;
- Water resource and baseline survey;
- Repair and maintenance service;
- Water users management body and structure;
- Community Based Organizations (CBOs) and conflict management;
- Management capacity building/management procedures of water committees;
- Technology;
- Institutional Support;
- Demand driven approach in the identification of user groups.

Observing the above factors separately as pre and post implementation factors, they of course form the building blocks for areas of investigation and measurement.

2.2. Potable water supply in Ethiopia

Ethiopian has long been characterized by limited access to safe drinking water services. In 1990, for instance, only 19 percent of the community's population had access to safe drinking water supply (Abebaw *et al*., 2011). By 2014 this figure had reached 76.7 percent. Table 2.1 gives an overview of Ethiopian's safe drinking water coverage for some selected years.

Table 2.1 Percentage of Ethiopian population with safe drinking water coverage for selected years

Category	2011	2012	2013	2014
Rural	48.85	55.21	66.54	75.5
Urban	74.64	78.71	81.31	84.2
National	51.12	58.25	68.45	76.7

Source: (MoWIE, 2014).

In Ethiopia, the problem of drinking water supply is further compounded by physical distance. A recent estimate reveals that about 52 percent of the population traveled half an hour to collect water every day (CSA, 2006). This long travel distance to the nearest water source directly affects women and children, who are mainly responsible for fetching water. This has an implication on the productivity of women. The long hours spent in fetching water taking a significant amount of time that could be employed in other income-generating activities. The human capital implication for young girls cannot be overlooked as well. Most girls in Ethiopia find it too difficult to attend and succeed in school because a significant amount of their time is used for domestic chores, including fetching water (CSA, 2006).

In the Amhara region, although the region is well endowed with a substantial amount of water resources potential, the performance of potable water supply and distribution is found to be low. Based on 2009/10 data, the regional water supply coverage was below 60%. This indicates that 40% of the people have no access to clean water (Amhara, Region Health Bureau Report, 2011). This coverage is less than the standard set by world health organization which is a daily requirement of 45 liters per person and Ethiopian water access of 20 l/c/d in the 0.5 km source distance. Thus, people who do not have access are forced to use unsafe drinking water from unprotected wells, rivers, and ponds. According to the report, drinking water supply coverage in the region has reached around 87% in the urban and 54% in the rural areas.

2.3. Challenges of Sustainable urban water supply

In the provision of adequate clean water to urban dwellers, the world faced many challenges, which are related to capacity of the nations, (i.e. technological knowhow and institutional), inadequate finance, rapid urbanization and declining of global water resource un-expansion of water supply work for rural community(Cofie & Drechsel, 2007).

2.3.1. Lack of capacity

According to Wallace *et al*., (2008), capacity is a flexible concept and encompasses the public sector, academia; community based organizations and the private sectors, and ranges from the individual to institutions to society as a whole. Capacity can be described in terms of the human, technological, infrastructural, institutional and managerial resources required at all levels from the individual through to national governance. Not only does capacity have to be built within each of these levels, but it has to be institutionalized and local communities need to be empowered to use it effectively. Additionally, capacity building incorporates the followings.

1. The capacity to engage, educate and train; including community awareness building, adult training and formal education; so as to provide sufficient numbers of competent human resources to develop and apply enabling systems within the local environment.
2. The capacity to measure and understand aquatic systems through monitoring, applied research, technology development and forecasting, so that reliable data are used for analysis and decision making.
3. The capacity to develop policies and programs and to legislate, regulate and achieve compliance through effective governmental, non-governmental and private sector institutions and through efficient enforcement and community acceptance, particularly for rural areas.
4. The capacity to identify and provide appropriate and affordable water technologies, infrastructure services and products through sustained research, investment and management.

Technological capacity

Innovative technologies are essential to overcome barriers to water service provision**.** Technological capacity includes the development and application of new technologies, the technical skills needed to effectively construct, operate and manage a technical solution; the translation of information regarding technologies to promote informed decision making when implementing a technical solution; the availability and accessibility of spare parts (Sijbesma, 1989). However, technology providers need a better understanding of local conditions and policies.

Institutional capacity

According to Wallace *et al*., (2008) in any institution a need of different disciplines such as engineering, health, natural science and social science are essential, from the institution, and different sector, to achieve the plan and goal of the institution and solve environmental water and health problems.

2.3.2. Inadequate financing

Historically, water has suffered from severe under financing. These results from inadequate internal financial capacity in the poor countries to achieve water goals; poor political decisions for allocation of development aid; an overall reduction over time in development aid; and the limited cost recovery potential in poverty stricken regions (Wallace *et al*., 2008).

2.3.3. Population growth and urbanization

Population growth and rapid urbanization will create a severe scarcity of water as well as tremendous impact on the natural environment. According to UNDP (2006) in Wonduante 2013, in less developed countries, urban population will grow from 1.9 billion in 2000 to 3.9 billion in 2030, averaging 2.3% per year.

Besides having less or not invested in urban infrastructure, Africa is urbanizing faster than any other region. Between 1990 and 2025, the total urban population is expected to grow from 300 to 700 million; and by 2020, it is expected that over 50% of the population in African countries will reside in urban areas. According to Cleophace (2007), in order to meet the established millennium development goal of 'halving the unsaved population by 2015', urban Africa will require 80% increase in the numbers of people served. This objective would require, on average, about 6,000 to 8,000 new connections every day. Political commitment to these goals, backed by resources and action is essential if utilities are to prevent a widening of the gap between 'saved' and 'unsaved' households.

According to the 1994 and 2007 Ethiopia population census report showed, the total urban population was 7,323,122 (13.7% of the total population), after thirteen years (i.e. 2007) the total urban population increased to 11,873,900 (16.1%) and by the year 2013 urban population is going to increase 16,061,243 (18.7%) (Ethiopia Central Statistical Authority (1994, 2007 and 2013 projection). In order to meet the future water demand, cities will need to tap their water supply either from a deep ground or surface sources situated at far distance away from the urban area (Challa, 2011).

2.3.4. Global water stress

UN-HABITAT (2006) stated that, not only is the numbers of those requiring better water supplies very large, but also water itself is becoming scarcer. The number of people living in water stressed and water scarce area over the world is estimated to increase approximately six fold from 1995 to 2025 to reach 2.8 billion.

2.3.5. Poverty

Bereket (2006), stated that the single most influential factor related to the sustainable provision of basic water service in turn is that of poverty. The lack of availability of basic services is a primary measure of poverty and poverty is the primary obstacle in the provision of basic services. Poverty affects basic water supply in a number of ways, ultimately being so all pervasive that it overwhelms the application of even the very best practice incorporating all the lessons learned. It is therefore important to understand the full significance of poverty.

2.4. The role of access to clean drinking water

According to Unicef, (1999), there are a number of potential benefits to improved access to water supply, in addition to the reduction of disease. That is the reason why many communities give emphasis for placing a high priority on improved water supply is usually relate to benefits beyond health. These benefits are of particular importance to women. A closer, cleaner source of water can produce immediate and far-reaching improvements on women's lives.

2.4.1. Suitability

Most people, when identifying improved access to water as a priority, are thinking of convenience. Everybody wants water as close as possible to their home, simply because it is more convenient. As such, convenience is as important a consideration as health benefits. In some societies and situations, convenience is also related to the security of women: water closer to home can minimize the chances of abduction or assault (Wonduante, 2013).

2.4.2. Time saved

Women and girls can spend many hours a day collecting water from distant sources and thus the time saved by having a safe water source closer to the household can be very significant. The time saved is used for much needed leisure or, possibly (but not necessarily) activities relating to improved child care, or economic production. Less time spent fetching water is less possible excuse for not allowing girls to attend school or in some extreme cases, even to marry (World Vision, 2013).

2.4.3. Energy saved

Studies have shown that women who walk long distances to collect water can burn as much as 600 calories of energy or more per day, which may be one third of their nutritional intake. Closer sources of water can thus improve the nutritional status of women and children (and hence health and wellbeing) (UNICEF, 1999).

2.4.4. Prevention of injuries

When girls are forced to carry heavy loads of water over large distances, there is a danger of lasting spinal column and pelvis injury and deformations. Closer water sources minimize this (UNICEF, 1999).

2.5. Impacts of water inaccessibility

Although water is a primary need of human being, unimproved water service has many negative impacts on people livelihood. Among which, health, socio-economic and environmental are the major impacts(Abdisa & Reddy, 2012).

2.5.1. Health impacts

The improvement of water and sanitation in developing countries is largely driven by the need to reduce the incidence and prevalence of infectious disease caused by pathogenic micro- organisms (Konjit, 2015).

The majority of pathogens that affect humans are derived from feces and transmitted by the fecal-oral route. Pathogen transmission may occur through a variety of routes including food, water, poor personal hygiene and flies (Challa, 2011).

2.5.2. Socio-economic impacts

Poor access to water supply and sanitation limits opportunities to escape poverty and exacerbates the problems of vulnerable and marginalized groups especially those affected by HIV/AIDS and other diseases (Challa, 2011).

2.6. Connection types

In most part of Ethiopia people getting water from different sources. From those, the main are listed as below (Konjit, 2015).

These are:-

1. i. House connection: - Connection in single household use in the house.
2. ii. Yard tap: Tap in compound for single household use but not house connection
3. iii. Public tap: Community taps in public area, which can be used by household livening in the area.
4. iv. Shared yard tap: Tap in compound shared by more than two households
5. v. Water vendors: people who have their private tap and water to their neighboring and near dwellers.
6. vi. Other water sources: - The people use river, traditional pond and rain water harvesting etc..

2.7. The purpose of distribution network of water

The objective of water distribution system is to delivered water of suitable quality to individual users in an adequate amount and at satisfactory pressure. It should be capable of delivering the maximum instantaneous design flow at a satisfactory pressure (Juwono, 2011).

The water distribution networks should meet demands for potable water; it should be designed correctly, the network of interconnected pipes, storage tanks, pumps, and regulating valves provides adequate pressures, adequate supply, and some areas may have low pressures, poor fire protection and health risks (Hopkins, 2012).

2.8. Water Distribution Modeling

2.8.1. **WaterCAD** (Beatley Water CAD/GEMs, 2008)

- A water distribution modeling software;
- Used in the modeling and analysis of water distribution system;
- Used for firefighting flow and constituent concentration analyses, energy consumption and capital cost management; and
- Popular for water supply design.

WaterCAD provides sensitive access to the tools needed to model complex hydraulic situations. Some of the key features allow us to:

- Perform steady state and extended period simulations
- Analyze multiple time-variable demands at any junction node.
- Perform hydraulically equivalent network skeletonization including data scrubbing branch trimming and series and parallel pipe removal.
- Efficiently manage large data set and different "what if" situations with database query and edit tools.

2.8.2. Hydraulic models

Hydraulic models of the system should be used to check that the system will be or is operating to the required standard. Models are valuable during design and operation of a system. A model can be used to identify problem in existing system (e.g. closed valves that should be open) by comparing modeled pressure with actual pressures in the system (Juwono, 2011).

2.8.3. Principles of Network Hydraulics

In networks of interconnected hydraulic elements, every element is influenced by each of its neighbors; the entire system is interrelated in such a way that the condition of one element must be consistent with the condition of all other elements. Two basic equations that govern in Water CAD modeling network of all these interconnections (Beatley Water CAD/GEMs, 2008).

- Conservation of mass or continuity principle.
- Conservation of energy or energy principle.

2.8.3.1. Conservation of mass

For steady incompressible flow:

Mass $_{in}$ = Mass $_{out}$

$\sum Q_{in}\Delta t = \sum Q_{out}\Delta t + \Delta V_s$--2.1

Where:

Q_{in} = Total flow into the node (m^3/s)

Q_{out} = Total demand at the node (m^3/s)

ΔVs = Change in storage volume (m^3)

Δt = Change in time (s)

2.8.3.2. Conservation of Energy

The energy equation is known as Bernoulli's equation (Ven Te Chow & Mays, 1968). It consists, the pressure head, elevation head, and velocity head. There may be also energy added to the system (such as by a pump), and energy removed from the system (due to friction). The changes in energy are referred to as head gains and head losses (Ven Te Chow & Mays 1968).

In hydraulic energy is converted to energy per unit weight (ft-lb/lb) of water, reported in length units (ft) called "head". Balancing the energy across any tow points in the system, the energy equation will be as follow: Figure 2.1 shows head losses in a pipeline.

$P_1/\gamma + Z_1 + V^2{}_1/2g = P_2/\gamma + Z_2 + V^2{}_2/2g + h_L$--2.2

Where:

P = the pressure (N/m^2)

γ = the specific weight of the fluid (N/m^3)

Z = the elevation at the centroid (m)

V = the fluid velocity (m/s)

g = gravitational acceleration (m/s^2)

h_L= the combined head loss (m)

There are three forms of energy:

- Pressure head - P_1/γ
- Velocity head - $V^2{}_1/2g$
- Elevation head – Z

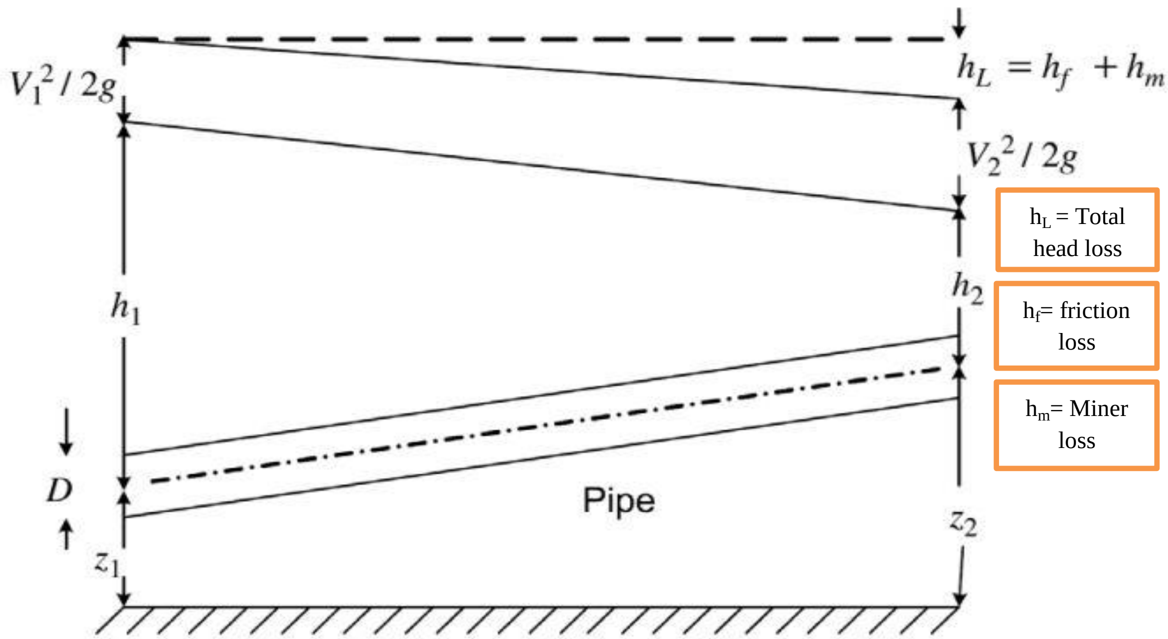

Figure 2.1 Forms of energy in water pipe (Amdework,2012)

2.8.4. Appropriate pressures

Pressure at any point in the system should be maintained within a range whereby the maximum pressure avoid pipe bursts and the minimum ensures that water is supplied at adequate flow rates for all expected demands(Dighade *et al*., 2014).

2.8.5. Head Loss Water Flow Resistance

The total water loss in the distribution pipe and pipe fitting between two points of consideration is called head loss(Dighade *et al*., 2014). There two types of head losses which are major loss and miner losses.

2.8.5.1. Surface Resistance (Major losses)

Head loss on the account of resistance, friction factor:

- Pipe length.
- Coefficient of surface resistance, frictional factor.

Surface resistance is categorized as major loss.

2.8.5.2. Form resistance (Miner losses)

The form-resistance losses are due to bends, elbows, valves, enlargers, reducers and so for the categorized as minor loss.

- Darcy -Weisbach
  - Colebrook White
  - Swamee Jain
- Hazen Williams
- Manning

Friction losses are estimated with:

Table 2.2 Head loss equation and their application area

Equation	Formula	Remarks	
Manning's	$V = \frac{1}{n} R^{2/3}\ S^{1/2}$	This equation is commonly used for open channel flow	V = fluid velocity n = Mannings's coefficient R = hydraulic radius S = bed slope
Chezy's (Kutter's)	$V = C\sqrt{RS}$	widely used in sanitary sewer design and analysis	C = proportionality S = hydraulic slope(head loss per unit length) V = fluid velocity R = hydraulic radius
Hazen-Williams	$V = kCR^{0.63}\ S^{0.54}$	Commonly used in the design and analysis of pressure pipe systems	k = conversion factor (1.32 custom unit 0.85 SI unit) C = Roughness coefficient R = hydraulic radius Slope of the energy line (head loss per length of pipe or h_l /L)
Darcy-Weisbach	$V = \sqrt{\frac{8g}{f} RS}$	Can be used for pressured pipe systems and open channel flows	V= fluid velocity f = Darcy frictional factor g = gravitational acceleration R= hydraulic radius R = hydraulic radius Slope of the energy line (head loss per length of pipe

Source:(Hopkins, 2012)

3. MATERIAL AND METHOD

3.1. General description of the Study area

3.1.1. Location of study town

Ararti town is found in north eastern part of Ethiopia in Amhara Regional State North Shoa Zone in Minjar - Shenkora Woreda. It is a capital of the woreda and situated 130 km East of Addis Ababa and 695 km away from the regional capital Bahirdar. It is lies between 8^0 55' 45" N latitude and 39^0 25' 33'' E longitudes at an average elevation of 1700 m a.s.l.

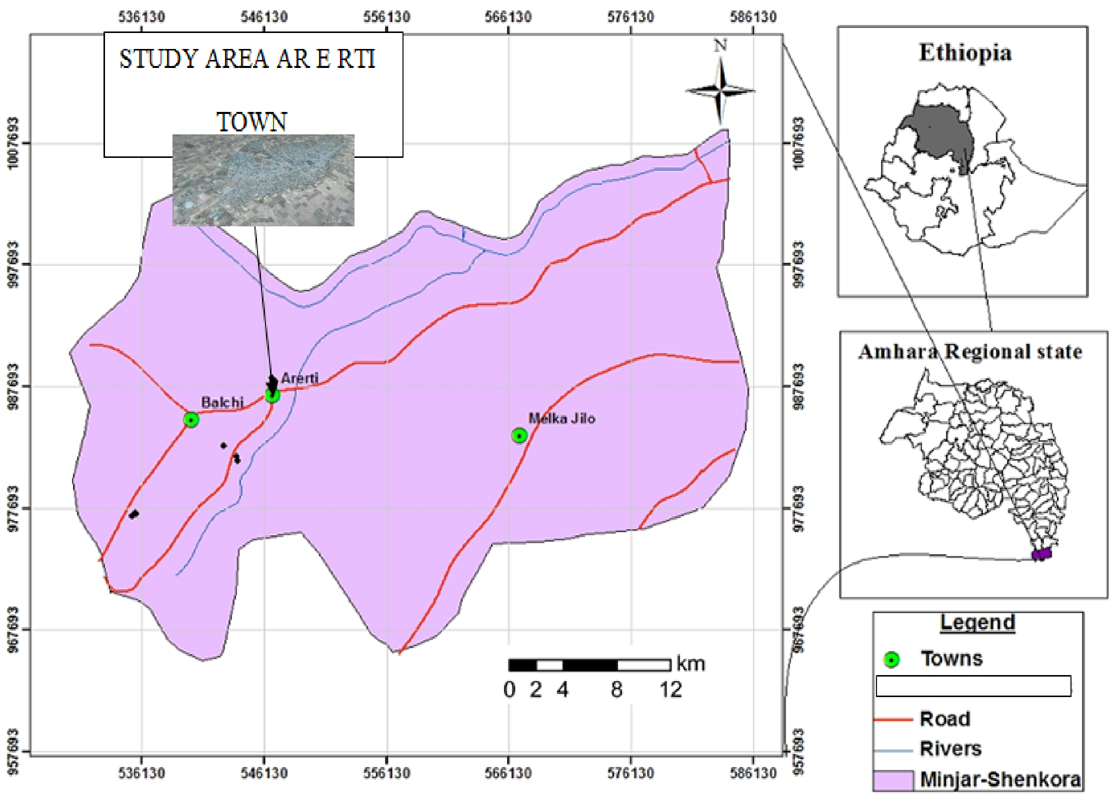

Figure 3.1 Map of Minjar – Shenkora Woreda and location of research site

Source: (Tekeste, 2012).

3.1.2. Climatic Condition

The rainfall pattern of Arerti is unimodal type one rainfall peak during July and August. About 80%-90% of the mean annual rainfalls are in the main rainy season ("Kiremt"), which starts in June/July and extends into August/September.

3.1.3. Population of the Study Area

According to 1994 CSA population and housing census, Arerti town one Kebele projected population to 2014 is 15,821. But, the previous and currently established new Kebeles town municipality population number in 2014 is 28011.

3.1.4. Selection of the Study Area

The selection of Arerit town as a study area from the other towns is due to the degree of current water supply problem, the interest of town population and the utility, researcher's personal experience of severe water shortage in the area for more than four years as an expert in Bureau and why the water shortage happens before the end of design period of the existing water supply system. Therefore to evaluate or identifying the problem of the water supply and show the direction of the solution is the main reason for selection of the study area.

3.2. Study design

This research was used to collect, generate and analyze relevant data on the existing water supply system in the study area and on factors that impede the provision of safe and adequate water supply and its socioeconomic implication on the community by descriptive and exploratory methods. For hydraulic performance evaluation, Water CAD standalone software was used. Generally, the necessary data that has been collected from primary and secondary sources were (calculated nodal demand pipe length and diameter and coordination) inserted readily available software and generate the input and analyses the output data.

3.3. Sample Size and Sampling Techniques

3.3.1. Sampling Techniques

One of the main objectives of this research is evaluating the distribution system, investigating the magnitude of water supply and its dynamics and challenges in Arerti town; to this end, to get the representative population and the necessary information accordingly, this research used the combination of random and purposive sampling techniques to select household respondents, focus group discussants and key informants. Random sampling was applied to select the sample households to get representative informants whereas purposive sampling was used to select the focus group discussants and key informants. The other required or necessary data's were collected one by one from the existed water supply system (like nodal data link data and etc.).

To carry out the study, approximately the whole part of the town has been considered, based on the administrative division system. The town's current administrative division has 1 urban and 1 rural kebeles.

3.3.2. Sampling Size

In general the study covered only randomly selected 258 households from a total of 5,831 estimated households of the town and other required data (like nodal data link data and etc.) were taken one by one. As to the household sample size determination, from among different methods, the one which has been developed by Carvalho (1984), as cited by Wonduante (2013) was used (see Table 3.1 below).

Table 3.1 sample size determination

Population size	Sample size		
	Low	Medium	High
51-90	5	13	20
91-150	8	20	32
151-280	13	32	50
281-500	20	50	80
501-1200	32	80	125
1201-3200	50	125	200
3201-10000	80	200	315
10001-35000	125	315	500
35001-150000	200	500	800

Source; Carvalho (1984), Cited from Wonduante, 2013

By the reason of population number variation, a sample size of 258 which is in between the high and medium sample sizes was applied.

3.4. Data type

Both qualitative and quantitative data were collected to counter balance the limitation of the one by the other. These data were generated through questionnaires, focus group, discussion, key Informant Interview, field survey and Personal observation to supplement, complement, validate and triangulate data obtained from the Household survey.

The qualitative method was used to gain a better understanding of the existing condition of water supply and status through questionnaire and interview, households and stakeholders respectively. The quantitative data collection method was used in the household survey to explain information about the household where they are served sufficient and affordable water by assessing their daily water consumption, walking distance, time taken to fetch water and how many days are receiving pipe water per week.

3.5. Data Sources

All the necessary data required for the study were obtained from both primary and secondary sources. The major sources of secondary data were from government and non-government publications, annual and inventory reports, previous studies, and books as well as internet. Whereas the primary data were collected from sample households, focus group discussion and key informant interview which were made with various stakeholders, community representatives, field survey, water service officers, municipality and other concerned and affected bodies. In addition, personal observation and informal discussion with users were also the other data sources, which reinforced the required data from the study area and served as a check for data reliability. For hydraulic performance evaluation purpose, the main data sources was field collected data, calculated data and from other supportive materials.

3.6. Data collection process

Data collection for the existing water supply system and number of population was done by having the yield of functional schemes like boreholes and taking number of current population from CSA, town municipality and water supply service office.

To evaluate the hydraulic performance of the distribution pipeline network, data like latitudinal, longitudinal and elevation coordinates were taken using GPS and the nodal demand was taken from this research calculation result. Other required data were collected from water supply service office and from different water supply design guide line. In addition to this the accessibility was checked and water point locations were taken by GPS.

The study included consultation and discussion with the officials of various agencies and institutes such as Minjar Shenkora Woreda Administration and Woreda Water development Office, town municipality and ATWSSO. The secondary data were also gathered from the available data sources such as reports and project documents, census and survey reports, books, journals, internet as well as other published and unpublished documents.

3.7. Population, water supply and demand of the study area

3.7.1. Population projection

Population figure of beneficiaries were from CSA (1994), municipality and water supply office. This was projected for the design period 10 years uses the method suggested by Chatterjee, (2005) and population growth rate shows in Table 3.2

Table 3.2 Growth rates as established by CSA 1994 for Urban Population Projection of Amhara Region

Variant	Years						
	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030
Low variant	4.8	4.1	4.2	4.0	3.9	3.8	1.9
Medium variant	4.9	4.4	4.5	4.3	4.1	4.0	3.8
High variant	5.0	4.8	4.9	4.7	4.6	4.4	1.5

Source: *The* 1994*Population and Housing Census of Ethiopia Results for Amhara Region, Volume II Analytical report.*

Applying the above growth rates in the geometric mean method, the population of Arerti town was projected up to year 2026 (starting from 2016-2026).

The premise of geometric rate or constant percentage rate assumes that the rate of increase is proportional to population. This method is mostly applicable for growing areas having constant percentage rate (Chatterjee, 2005). It is written as:

$$P_n = P_o\,(1 + r)^n \quad \text{……} \quad (3.1)$$

Where: P_o: Present population

P_n : Population at the end of the n years

n: Number of year

r: Annual rate of increase of population

3.7.2. Water demand projection

To determine the total quantity of water utilized by various purposes in the town, water demand need to be known. In order to achieve reliable water demand data, existing consumption records were obtained and analyzed. After considering several factors which affect all types of water demands, the water demand forecast database of Arerti town were established and the forecast consumption for each group were determined to evaluate capability of the existing water supply sources and distribution system by the average water requirements of the town.

3.7.3. Domestic demand

In order to project the domestic water demand of Arerti town the following procedures were followed:

Mode of Services and Projection of domestic water demand

Estimation of future water demand dividing by mode of service (from 2014 to 2026) for this study is done as per the guidelines of MoWR urban water supply, 2006 and in GTP II plan (2015-2020). In GTP II (2015-2020) the accessibility of water for level three water supply service town is 60 liters per capita per day within 250 m radiuses (ATWSSO GTP-II Plan, 2015).

Modes of services commonly prevalent in most Ethiopian towns are classified into five categories, namely: -

- Traditional Source users (TSU)
- Public tap users (PTU)
- Neighborhood tap users (NTU)
- Yard tap users (YTU)
- House tap users (HTU)

For this study the consumption of water by mode of service stated by MoWR, 2006 was adopted.

Table 3.3 Per capita water demands by mode of service (l/c/d)

Service Year	**Demand category**		
	HTU	**YTU**	**PTU**
Base year	60	40	20

Source: MoWR, (2006)

Projected water demand calculation

To calculate projected water demand the following simple calculation was used. The projected population by each mode of service times by each mod of service liter of water.

$Q_C = \%a * P_{YTU} + \%b * P_{HTU} + \%c * P_{PTU}$ (l/c/d)

Where:-

Q_C = Total calculated demand of water (l/c/d)

%a = liters of water used by yard tap users (l/c/d) P_{YTU} = yard tap user population

%b = liters of water used by house tap users (l/c/d) P_{HTU} = house tap user population

%c = liters of water used by public tap users (l/c/d) P_{PTU} = public tap user population

3.7.3.1. Non- domestic water demand

Non-domestic water supply demand for urban areas is many. But for Arerti town under non-domestic water supply the following were only considered:

- Public Water Demand and
- Some Livestock Water Demand

Public Demand

This category includes water requirements of restaurants, cinema houses, school, hospitals, hotels, offices etc. In general based on Oromia Water Work Design and Supervision Enterprise Design Guideline (OWWDSE), 2010, assumes 20% of the average daily domestic demand as public demand. For this study the same approach were adopted and 20% average daily domestic demand was taken. Because, there is no well documented public service data to calculating the required public water demand by each category.

Livestock Water Demand

Ararti town is composed of urban and rural Kebeles and there is high cultural influence from agrarian societies, and hence they have large amount of domestic animals for farming purposes. Even though, there are nearby surface waters (Burka and Kesem Rivers) for their animals, the people use the existing water system to drinking their domestic animals. Thus the use of water from the system is very high. However, animal demand is also considered in this study.

When we consider the water requirement of domestic animals varies between species, between breeds or varieties within species and between individuals within breeds. But because of lack of well documented data, livestock demand only depends on the collected data from the sample respondents.

3.8. Distribution network of the existing system

The required data of distribution network were collected from existing system from the field and town water supply service office and sketch the distribution line on Google Earth and followed by master plan of the town. The collected data were used, to evaluate nodal pressure and link velocity of the existing water distribution network.

The data used for analyses were: type, length and the size of pipes and GPS reading of service reservoirs, water point, water source and junctions or nods of the pipes above or equal to one inch.

Computer software called WaterCad Standalone (version name) was used to evaluate this existing water supply distribution system by 24 hours extended period simulation model. To compute friction head losses Hazen-Williams equation was used. The model components and equations WaterCad Standalone on used were taken from the users' manual. By WaterCad Standalone software can model a water distribution system as a collection of links and nodes or junctions. The links represent pipes and the nodes represent pumps, joining points and valves (Rossman, 2000).

3.8.1. Junctions/ Nodes

Junctions/Nodes are points in the network where links join and where water enters or leaves the network. The basic input data required for junctions/Nodes were elevation above some reference (usually mean sea level) and water demand (rate of withdrawal from the network). The output results computed for junctions were pressure and discharge.

3.8.2. Reservoirs

The term reservoir has a specific meaning with regard to water distribution modeling that differs slightly from the normal use of the word in normal water distribution construction and operation. Reservoirs are nodes that represent an infinite external source or sink of water to the network. The primary input properties for a reservoir are its hydraulic head. Because a reservoir is a boundary point to a network, its head cannot be affected by what happens within the network. Therefore, it has no computed output properties. However, its head can be made to vary with time by assigning a time pattern to it.

3.8.3. Tank:

A storage tank is a boundary node, but unlike a reservoir, the hydraulic grade line of tank fluctuates according to the inflow and outflow of water. Tanks have a finite storage volume, and it is possible to completely fill or completely exhaust that storage (although most real systems are designed and operated to avoid such occurrences). For steady-state runes, the tank is viewed as a known hydraulic grade elevation, and the model calculates how fast water is flowing into or out of the tank given the hydraulic grade line (HGL). Given the same HGL setting, the tank is hydraulically identical to a reservoir for a steady-state run. In extended-period simulation (EPS) models, the water level in the tank is allowed to vary over time. Regardless of the shape of the tank, several elevations are important for modeling purposes. The maximum elevation represents the highest fill level of the tank. The over flow elevation, the elevation at which the tank begins to overflow, is slightly higher than the maximum elevation. Similarly, the minimum elevation is the lowest water level in the tank should ever be.

3.8.4. Pipes:

Pipes are links that convey water from one point in the network to another. Flow direction is from the end at higher hydraulic head to that at lower head. The principal hydraulic input parameters for pipes were start and end nodes, diameter, length, roughness coefficient, status (open, closed, or contains valves). Computed outputs for pipes were flow rate, velocity and head loss. The hydraulic head loss by water flowing in a pipe due to friction with the pipe walls computed using the Hazen-Williams formula (Walski *et al*., 2003).

$$H_f = \frac{10.68L}{C^{1.852+}D^{4.87}} Q^{1.852} \quad \text{……………………………………………...………3.2}$$

Where: H_f: Friction head loss

D: Diameter of the pipe in mm,

L: Length of the pipe in m,

Q: Flow rate in m^3/s and

C: Friction factor

Table 3.4 lists a roughness coefficient 'C' value varies for different pipe materials and can change with age. Minor head losses (also called local losses) are caused by the added turbulence that occurs at bends and fittings. The importance of including such losses depends on the layout of the network and the degree of accuracy required. Minor head loss becomes the product of a coefficient and the velocity head of the pipe.

Table 3.4 Hazen-Williams roughness coefficients for pipe material (Walski *et al.*, 2003)

Pipe status	**Pipe type**		
	DCI	GI	uPVC
New	130	130	150
10 years old	105	105	125
$\geq$ 20 years old	96	96	105

3.8.5. Pumps:

A pump is an element that adds energy to the system in the form of an increasing hydraulic head grade. Since water flows "downhill" (that is, from higher energy to lower energy), pumps are used boost the head at desired locations to overcome piping head losses and physical elevation differences.

3.9. Data coding, entry, control and cleaning

Prior to data entry, the data collected through pre-coded questionnaires were checked and verified by the researcher for consistency and legibility. Data cleaning was done using SPSS version 20 by looking into frequency distributions and cross tabs to identify outlier cases. Random visual comparisons between the original questionnaire forms and the computer database were also undertaken after the data was entered. Variables in the questionnaire that were supposed to have an answer, but were not filled out in the paper questionnaire were entered in the database with the value different to the answered value. For example the answer may be "1" or "2" but if not filled value of 3 was entered representing "missing". In other words, the 100% value in the graphs represents the total for all answers excluding the "missing" answers. Data inconsistencies have been kept to a minimum using SPSS 20 capability to quickly tabulate frequency tables for values entered in the questionnaires, all variables were checked to ascertain whether any strange values were entered.

For waterCAD data entry, all required data was entered step by step. For example nodal data such as demand and elevation were entered from calculated demand and field survey data.

3.10. Data processing and analysis

Descriptive statistical technique was used for analyzing the data collected using the questionnaire survey and the respondents were given numbers for identification purposes. The sub-Kebeles of each respondent were coded with numbers so that the situation in each sub-Kebele under the different questions in the questionnaire can be analyzed. Each question in the questionnaires was identified by a variable name and within variables there were values and value labels for identification of responses from the respondents.

After coding the information from the questionnaires, template for entering data in the computer program SPSS 20 was created. The results were presented in the form of photos, tables, bar graphs and pie charts.

For distribution network analyses waterCAD software was used to run the collected data from nodes, links, tank, reservoirs and pumps. The collected data was entered into the software one by one and compute the result with (World Bank) W.B and MoWR, (2006) design guideline value of pressure and velocity (15 m - 70 m H_2O and 0.6-2.5 m/s pressure and velocity respectively).

4. RESULT AND DISCUSSION

4.1. Sustainable Water Supply Status of Arerti Town

4.1.1. Institutional arrangement

Arerti Town Water Supply Service Office (ATWSSO) is the responsible governmental organization for the production, treatment, transmission, distribution and sales of potable water to the town of Arerti. It is managed by a board of eight members composed from ATWSSO, Minjar Shenkora woreda; water resource development office, business and economy main office, revenue office and health office. The representation is one from each and three from the community.

Table 4.1 Personnel profile of ATWSSO

Department	Male	Female	Total
Water supply core process	6	1	7
Plan and public relation	0	1	1
Finance and property administration support process	5	3	8
Personnel Administration Support Process	13	1	14
Total	24	6	30

Source: Arerti Town Water Supply Service Office personnel support process owner, Sep. 2015.

At shown by Table 4.1 Arerti town water supply service office has 30 workers, from this 24 are males and the remaining 6 are females.

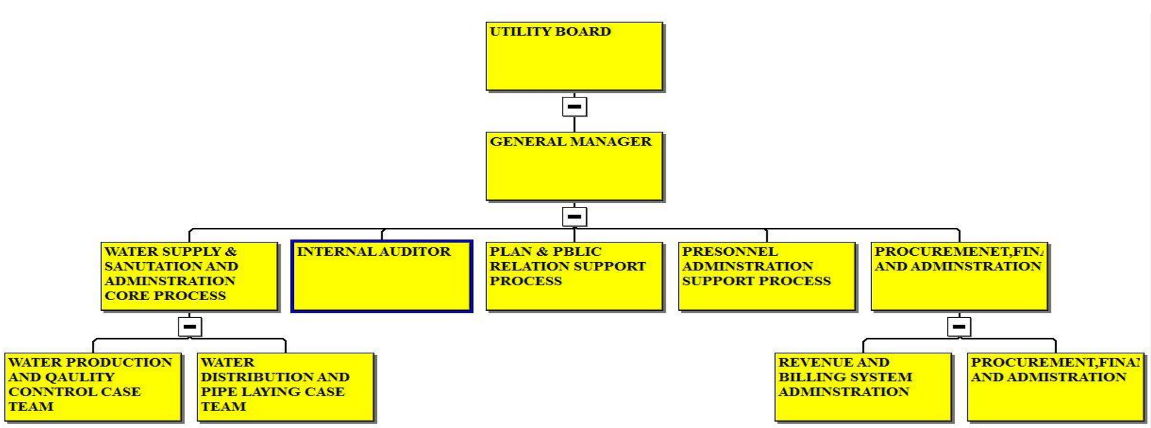

Figure 4.1 Organizational structure of Arerti town water supply office

(Constructed by Primavera software), source ATWSSO, 2015.

From the organizational structure of Arerti town water supply service office all the departments are functional by delegation and some departments have no staff and covered by presently working staff and all lead by delegated process owners. The department is indirect executive position and thus constituent the functioning core of ATWSSO. The Arerti town water supply service office manager, report all the activity of the office to the management board.

Table 4.2 Educational background of Arerti town water supply service office workers

Level	Frequency	Percent
Degree	3	10
Level four diploma	3	10
Level three diploma	3	10
10+3 diploma	4	13.3
grade 9 and above complete	15	50
Only reading and writing	2	6.7
Total	30	100

Source: Arerti Town Water Supply Service Office, 2015.

From the Table 4.2 as shown above, 56.7% of Arerti town water supply service office workers are unqualified and have no appropriate education and training in water supply service delivery which in turn affects the effective management and governance of the service.

4.1.2. Socioeconomic Status of the Households

The responds household profile desire in Table 4.3 shows that from the total of 258 sample respondents 60.1% are male and 39.9% are female. Number of household size is between1-12 and average household number is approximately 5.

Table 4.3 Socio-economic data of respondents

Variable	Value
Total number of household respondents	258
Percentage of male respondents	60.1%
Percentage of female respondents	39.9%
Range of household size	1 – 12
Mean household size	4.26
Percentage of respondents living in their own house	78.3
Percentage of household with above primary education	62.4

Source: Filed survey July, 2015

Regarding with occupation, out of the total 258 sample households 38.4% and 34.1% are trade businessmen and farmers respectively. They are constitute, the dominant section of the town population. Retired constitute 2.3%, whereas governmental employee and daily labor accounts 15.5% and 9.7% respectively. There are four marital characteristics among the respondents in the sample households. About 23.3%, 9.3% and 4.3% of all respondents were single, widowed and divorced, respectively while about 63.1% were married. Concerning toilet facilities, 98.1% of the households have toilet facilities among which 14.3% is flush toilets, 77.9% is private pit latrine, 4.3% is pour toilet and 1.6% is public toilet users whereas 1.90% has neither flush nor pit latrine, and practice open defecation. The respondents were also interviewed about their prior social services they need to be provided, 60.1% of the respondents answered water supply as first demand, 31.8%, 5.9%, 1.9% and 0.80% of the respondents replied that they preferred health, electric power services, education and road as their priority, respectively.

As obviously known, women are highly participating in water management. From the study result shown in Table 4.4 that the participation of women in all condition is 83.9% and 8.8% children (of which 4.50% are girls) to fetch water. In such case the participation of females in development and management of water service is crucial for sustainability. Therefore, the provision of safe water supply and adequate sanitation is of much more important to women than to most men as accessible sources of water reduce labor burdens and health to most women.

Table 4.4 Responsible body to fetch water for domestic demand

Category	Frequency	Percent
Male> 15 years	33	12.8
Male<15 years	9	3.5
Female > 15 years	95	36.8
Female < 15 years	11	4.3
Male and Female > 15 years	63	24.4
Male and Female < 15 years	2	0.8
all are responsible	9	3.5
Female < 15 years& Female >15 years	28	10.9
Female < 15 years& Male>15 years	3	1.2
Male < 15 years& Male >15 years	3	1.2
Male < 15 years& Female <15 years	2	0.8
Total	258	100

(Source: Field survey July, 2015)

4.1.3. Primary and Alternative Water Source of Arerti Town

Household Primary Water Sources

Due to the difference in the living standards of the town dwellers, use different types of water sources as their primary source. The following Table 4.5 shows the alternate primary water source of Arerti town households.

Table 4.5 Household primary water source

Type of primary water source	Frequency	Percent
public tap	38	14.73
Yard tap	184	71.32
Venders	23	8.92
Other water sources	13	5.03
Total	258	100

(Source: Field survey July, 2015)

Based on this sample survey, out of 258 sample households, 14.73% public tap, 71.32% yard tap and that of 8.92% water venders, 5.03% other water sources are their primary water sources. Therefore it can be inferred that 28.68% of the households depend on primary water source of public tap, venders or other sources.

The presence of alternative water sources

In the study area, not easily found the alternative water source for domestic water use. Because, no surface water in shorter distance, no hand dug well and even ground water is not easily found and have short rainfall season. So the sample household respondents tell whether present or absent of alternative water sources are discus in the following Table 4.6.

Table 4.6 Availability of secondary water source

Description		Frequency	Percent	Valid Percent
Valid	Available	54	20.9	21.1
	Not Available	202	78.3	78.9
	Total	256	99.2	100
Missing	3	2	0.8	
Total		258	100	

(Source: Field survey July, 2015

As shown the Table 4.6, out of valid 256 household respondents, 78.30% said that no alternative water source and the remaining 20.90% are said there is alternative water source.

Generally it shows that a high water scares area and incurs high stress on existing pipe water supply system. Because, in most of the time the consumer use or depend on only pipe water system for all needs.

4.1.4. Alternative Water Source during Primary Water Supply Interruption

During the interruption of primary water sources in the study area, the households reported that thy use different sources as a secondary source. The percentage distributions of these secondary water sources in the study area are shown in the Figure 4.2 below.

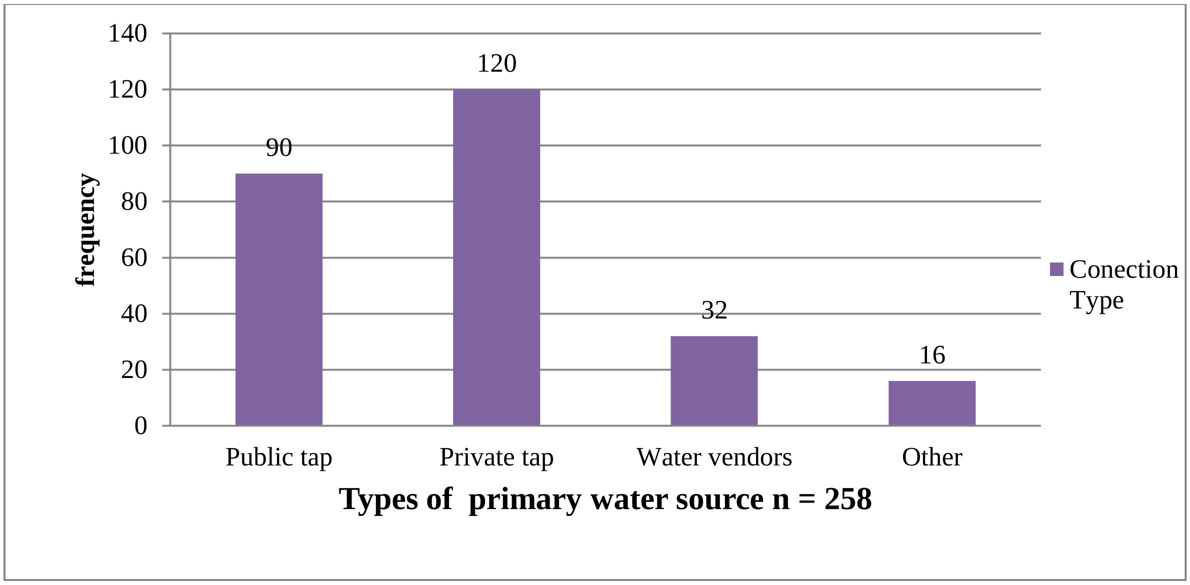

Figure 4.2 Alternative water sources during primary water supply interruption

To conclude from the Figure 4.2, from the whole sample households, majority of them are used private tap as their first alternative water source which accounts 46.5%. The other 34.9% and 12.4% are public tap and water vendors respectively. The remaining 6.2% of households are used other water sources when an interruption occur on the main water sources. This shows that water supply interruption is affect water consumption of town population. It means that the amount of water supplied from the source is too low because of power interrupting, lowering of ground water table and yield reduction.

4.1.5. House level water treatment practices

In the household level how much respondent culture water treatment activities shown as in Table 4.7.

Table 4.7 Trend of treating drinking water after fetching, before drinking

Category	Frequency	Percent
Yes	85	32.9
No	173	67.1
Total	258	100

Source: Field survey July, 2015

Depend on the information gathered from the sample households related with quality problem, as showed in the above Table 4.7, 67.1% of the sample respondents are not treating water by own method after fetching in the home to make safe, but the remaining 32.9% of the sample respondents responded that sometime they are treating their water by own method to add house level water chemical like ”wuha ager”, boiling, add chlorine and strain though clothe at a time of fetched water staying for long period of time in water collection material.

4.1.6. Occurrence of water borne diseases

To approving the existence of water borne diseases in their home in the last one year and indirectly insure the quality of water problem, the sample household interviewed if there were an occurrence of diseases in their family related with quality problem of the water, as it is seen in the Table 4.8 below, only 9.3% of them answer, yes, whereas the remaining 90.7% responded that there is no quality problem.

Table 4.8 Households affected by water born disease in the last one year

Category	Frequency	Percent
Yes	24	9.3
No	234	90.7
Total	258	100

Sources: Field survey July, 2015

According to the information gathered from the water supply service office, only bacteriological water analysis properly carried out.

As per ATWSSO water quality expert, bacteriological water quality carried out once in month. The other like, chemical water quality test is not carried out. To keep the quality of water, for drinking and other purpose, the water supply serves add chlorine in to the tank at all morning.

Based on filed observation, and unstructured interview with some household around “Habesha” cafeteria to “Kolegna Ber” respondents, sometimes water is turbid and give bad test. It may be arise from sewerage contact with water pipe and it is very harm full risk for human health. Even now, the people along this line mainly attacked by water related disease. Informal discussion with Arerti town health office expert, realize that the people comes from "Addis Ketema" mostly infected by water related diseases. Moreover, because of the low quantity of water and contamination the residents are exposed for water washed and water related disease like ameba, diarrhea, jardia, and typhoid and incur additional cost.

4.1.7. Water supply and distribution status of Arerti town

Water sources and supply

The only and main water source of the town is ground water. Currently the town has six boreholes including nonfunctional Boreholes. From the total, four boreholes are properly functioning. The others two, because of yield reduction, pump faller and different reason, are not functional.

Generally all the town wells are distributed at south east and north east of the town. As the information gathered from field survey and the annual reported document, two boreholes namely borehole-I and borehole-II, are the major of town's water supply scheme until the four boreholes are drilled in 2007. The average depth of the well is about 166m with a minimum of 150m and a maximum of 188.3m. The estimated yield of the well at the time of their construction ranged from less than 2 to 11.25 l/s. AWB/AR(Amhara Water Resource Bureau/Arerti)-2/99 or "Kechin Ashal" well was drilled in 2007 and it is the highest yielding water well in the area (11.25l/s).

4.1.7.1. Existing condition of town water source/wells

As observed from the field most of the wells are working properly, but in the time of electric power interruption most are not functional. However, the four boreholes drilled by regional government are relatively in good condition and the main water source of the town in all season.

Table 4.9 Existing water supply source

Description		Water supply sources/ schemes					
Well ID		No -1	No-2	AWB/AR-1/98	AWB/AR-2/99	AWB/AR-4/99	No-4
Specific place		------	--------	Shawa Genet	Kechin Ashal	Worku Kure	Compashin (Arega Ashal)
Geographical Location(m)	Easting	547546	547529	546486	548056	547229	548219
	Northing	986988	986636	984686	987350	986019	987785
	Elevation	1759	1757	1777	1749	1763	1742
Safe Yield (l/se) during pump test		5	5	7	11.25	5.6	4.37
Currently Yield (l/se) at well out let H_2O meter reading		1.38	1.38	4.4	10.2	3.8	5.8
Static water level (m)	During pump test	127	132	143.30	118.84	133.22	115.6
	Current measured	Main Gate locked	Clump problem	140.00	117.9	130.11	113.15
Status		NF	ON and Off	Functional	Functional	Functional	Functional

Source: Field survey and Arerti Town Water Supply Service Office Well hand over document, 2010 (Appendix Figure 6).
NF= none functional

As shown in Table 4.9, except the two almost all boreholes are properly working. But as the information gathered from water office, sample respondents and field observation almost all are not operating at a time of electric power interruption. Because, the stand-by generator fuel cost is not much with the production cost. Which means the sold water is not recover the operation cost. Therefore, during in this study time the water production is very low as compared to the water that produced by electric power. In general the total amount of water produced is inadequate in all time even electric power is available because of yield reduction as shown the Table 4.9 above and electric power interruption more aggravate the water shortage.

In other way, the water production of the existing source is observed to be much lower than the water demand of the town. Since 2011, the yield of the sources has been gradually decreasing due to high consumption, environmental factors, and high electric power interruption generally in the Woreda particularly in the town and failure of mechanical and electrical equipment.

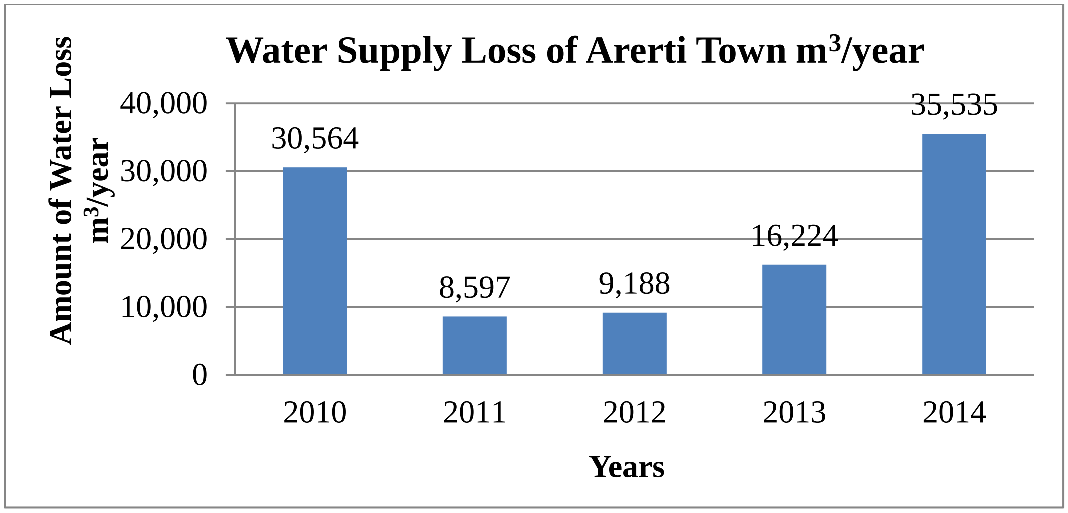

Figure 4.3 Yearly water loss progress of Arerti Town water supply.

Field survey July, 2015

From Figure 4.3 it is shown clearly that every year because of leakage and other problem significant proportion of the clean water produced is lost before it reaches the consumers. The percentage of water loss as showed in the Figure 4.3 indicated that there is progress of water loss increment at present as well as for future. If there is town expansion and high population number, the management of water scheme becomes complex and also increase the water loss.

Regarding to these problem, the interviewed respondents including households and different sections of the society identified incompatibility of the supply with population growth and the expansion of the town; frequent interruption of the supply especially in dry season (November -July); and the limited capacity of the WSS office in terms of technical personnel, finance, materials such as machines, equipment, spare parts and fittings etc. as the major problems among others.

4.1.7.2. Water Distribution

The system of distribution is the most important aspect of water supply in any community. The type and efficiency of water supply system greatly affect the rate of household consumption. The process of distribution starts from the place of production or the source of supply, in this case from the boreholes.

Water from boreholes is pumped by each own submersible pumps into the main reservoir, which is located Fitawurari Getabicha junior school compound. The water distribution of the system of the town contains service reservoir and distribution pipes. These are six transmission mains conveying water from six boreholes to reservoirs. Besides, there is no well documented map showing the exact aliment of distribution line pressure zone of the distribution line. According to annual report of Arerti town water supply service office of 2014 the total estimated length of distribution pipes in the town is greater than 62 km with varying pipe size (ATWSSO, 2014).

Obviously, the important of reservoir as part of the distribution system is to guarantee a continuous supply of water at the time of interruptions in the process of production. This indeed, depends on the number and capacity of reservoirs and on the relative ground elevation where they are situated, if water is to be distributed by gravity.

Table 4.10 Town water reservoir capacity and location

I.No	Name	Capacity (m^3)	Specific place	Geographic location			Remark
				Easting	Northing	Ground elevation	
1	Ground reservoir (Main reservoir)	500	Fitawurari Geta Bicha no1 Junior school	546732	986670	1820	F
2	6mEleveted reservoir	50	>>	>>	>>	>>	IPF
3	Masonry reservoir	20	>>	>>	>>	>>	NF

F= functional, IPF = indirectly functional and NF = non functional

Currently there are three service reservoirs in the same compound. But, only one of them is directly connected with the water distribution system of the town. The remaining one which is constructed by masonry, because of cracking is not functional. The other which is 6 m elevated concrete reservoir but not directly join with the distribution line but join with the main reservoir indirectly is functioning rather the main purpose instead reserving water. In general the sizes and locations of the reservoir are presented in Table 4.10.

The previous purpose of constructed elevated reservoir in the town was to increase the water head for some parts of the town so that residents have a fair distribution in different parts of the town, but improper usage and inadequate consideration currently have made it less important. Therefore the peoples surrounding, in front of the reservoir and some G+ buildings should be get from this elevated reservoir, rather joining with the main reservoir. Because, currently the customer stated above are not getting sufficient amount of water from the main reservoir.

Frequent interruptions in production coupled with water shortage in the surrounding Kebeles on one hand and the growing need of water on the other hand are ever widening the existing unbridgeable gap between the demand for and supply of water.

Furthermore, currently the role of leakage is insignificant in affecting water supply service in the town. As indicated in Table 4.22 every year from the total clean water produced average 8.5% of water is lost during distribution and because of head loss. During this study time, three months water utility 2008 E.C budget year first quarter report (July- September) indicted that the loss is highly increase, which is 20% (ATWSSO, 2015b).

In order to realizing the existences of leakage problem along the town distribution line, the researcher asking the household respondents and they responded as given in the following Table 4.11below.

Table 4.11 Presence of leakage by simple observation

Category	Frequency	Percent
Yes	122	47.3
No	136	52.7
Total	258	100

Source: Field survey July, 2015

During the household survey of this study, the sample respondents assured what is written on the above. As it is clearly shown on Table 4.11, nearly equal number of household sample respondents responding 122(47.3%), responding that there is problem of leakage on the water supply system, whereas 136(52.7%) answered “no” leakage problem. From this we can conclude that leakage is a common phenomenon occurring repeatedly in the town but its significant effect on distribution of clean tap water currently is not a headache and it is in allowable range of MoWR, 2006 Design guideline. Therefore the water supply service office should act strongly and must work hard to tackle these burning issues; otherwise the progress of water loss is increasing at alarming rate, and the amount of produced water will reduce thereby also negatively affects the amount of revenue.

4.1.8. Leakage mechanisms

The sample households were also interviewed about the causes which they consider for leakage problem and they have responded in the following way:

Table 4.12 Mechanism of water leakage given by respondents

Category	Frequency	Percent
Pipe breakage	42	16.3
Lack of maintenance	34	13.2
System failure	30	11.6
Pipe bursting	18	7
No leakage	134	51.9
Total	258	100

Source: Field survey July, 2015

According to the data collected from sample households shown in Table 4.12, 16. 3%, 13.2 %, 11.6% and 7%, of them put pipe breakage, lack of maintenance, system distribution failure, and pipe bursting as prior causes respectively while 51.9 % put no leakage courses.

Continuous water supply service is examined mostly realized by water supply factors which are frequency and duration of water supply. According to the survey, frequency and duration of interruptions differ from one area to the other. In some areas (like “sub-Kebele-5”, “Adiss Ketema” and “Kolegna Ber”) water supply interruption is relatively less frequent and they always get water while others do not get even in three or seven days especially in dry season.

The field data, group discussion and key informant interview, it is clearly evident that especially in dry season almost all parts of the town get water once in three days, the service hours being divided in to equal intervals among the different parts of the town by making shifts for a few hours. But, some part of the town like surrounding & in front of the reservoir and those in a bit higher elevated area are getting water once in seven days in dry season and once in three day in wet season. The following Figure 4.4 shows the average water receiving time of town population.

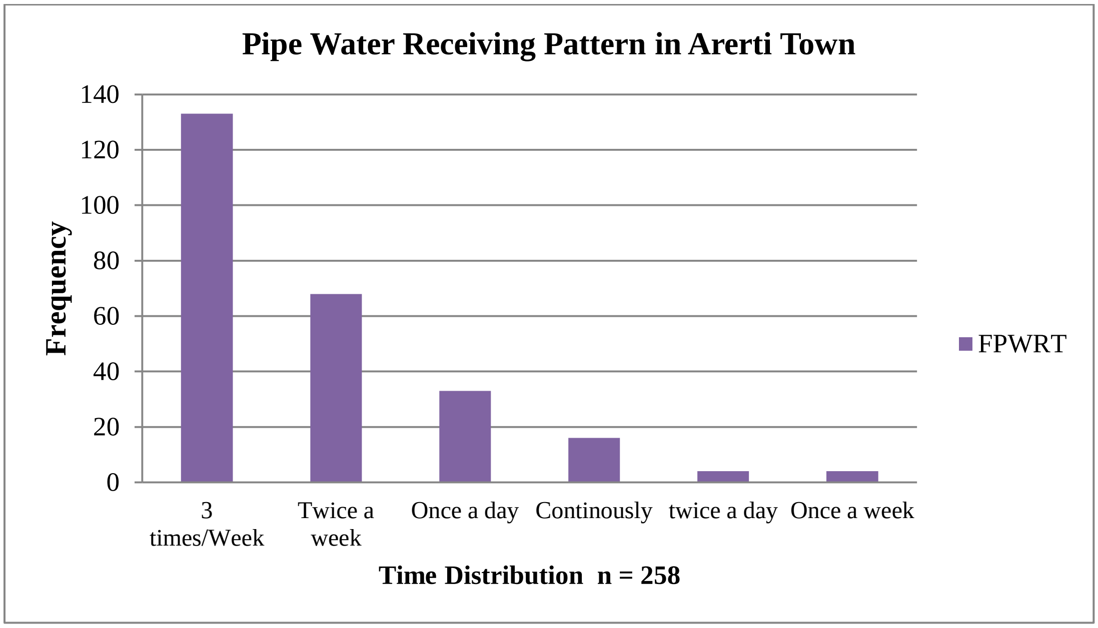

Figure 4.4 Average water receiving time of the household respondents
FPWRT = Frequency of Pipe Water Receiving Time

(Source: Field survey July, 2015).

It is clearly shown in Figure 4.4, 51.55% of the respondents get water three times per week, 26.36% twice a week, 12.79% once a day, 6.2% continuously get water, 1.55% twice a day and 1.55% of the respondents get once a week for a few hours.

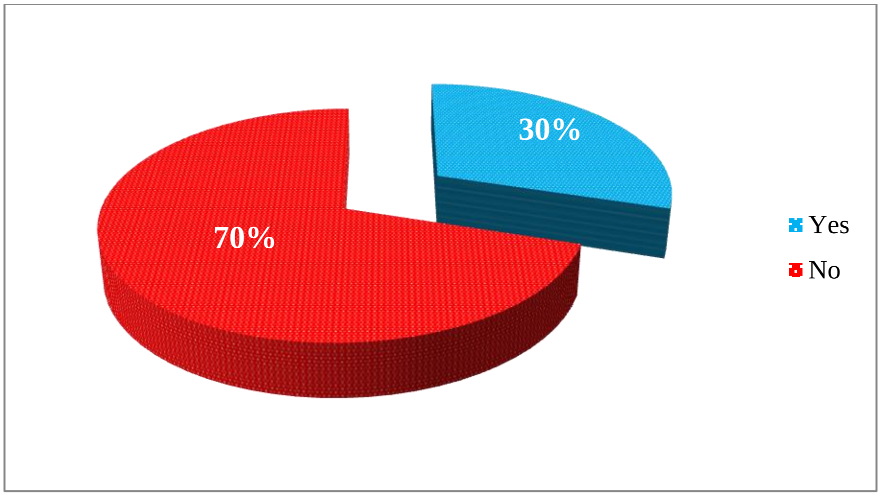

Figure 4.5 Distribution of water in the town

(Source: Field survey July, 2015)

In relation with the distribution of water in the town, the respondents were asked whether they believe that there is equal distribution of water or not, and most of them answered that there is no equal distribution of water among the different parts of the town. Based on Figure 4.5, 30% of the respondents answered that there is equal distribution of water, whereas 70% of them answered that there is no equal distribution of water.

This study founded that the interruption is more aggravated because of the area found in high water shortage area and the surrounding Kebeles absence of drinking water for human need as well as their livestock's. According to Mebratu, (2015) livestock demand is double of domestic demand. Therefore they consume much water from the town for day today activities and leave the households in danger.

It was mentioned during the discussion that, water distribution in the town also varies from season to season. Even though water supply has been in problem throughout the year since some years back, the problem worsens during dry season. The data collected from the sample respondents, field survey and key informants revealed the water supply distribution interruption occurs because of imbalance between population growth, and town expansion with water supply. In addition to these neighboring (approximately 12) Kebeles are the other causes of water supply interruption especially in dray season ("Bega" time). So the water supply problems become wider and deeper at this time. The following Table 4.13 below shows water supply interruption by season.

Table 4.13 Seasonal occurrence of water interruption

Category	Frequency	Percent
Dry season (Bega)	225	87.2
Wet season (Kiremt)	1	0.4
All season	32	12.4
Total	258	100

Source: Field survey July, 2015

The survey result also showed that 87.2% of the informants responded that the water supply interruption occurs during 'Bega' season and 0.4% responded interruption occurs in Kiremt season, and the remaining 12.4% responded that interruption occurs in all seasons (See Table 4.13).

In this regard the sample respondents were also interviewed to forward their own assumptions for the existing problems in the town related to water supply; like an interruption and in equal distribution is presented in Table 4.14.

Table 4.14 Reasons of no equal distribution of water all over the town

Description	Frequency	Percent
Frequent Electric power interruption	104	40.3
High amount of water delivered out of the town	19	7.4
Low capacity of water source	30	11.6
Management problem	62	24
Topography	23	8.9
Narrowness of Pipe diameter	5	1.9
Rapid population growth and town expansion	11	4.3
I don't know the reason	4	1.6
Total	228	100

Source: Field survey July, 2015

As clearly shown in the Table 4.14, from the sample households, 40.3% replied that unequal distribution of water among the different parts of the town is because of a frequent electric power interruption, 7.4% responded that it is due to high amount of water delivered out of the town, 11.6% due to low capacity of water source, 24% due to management problem, 8.9% due to topography, 1.9% due to narrowness of pipe diameter, 4.3% due to rapid population growth and town expansion and the remaining 1.6% replied that they do not know the reason.

To know how much the neighboring Kebeles are affecting the town's water supply, the sample respondents were interviewed and 200 (77.5%) replied that they are affect town water supply. And also highly aggravate water shortage in the town. The other 58 (22.5%) replied that neighboring Kebeles don't have effect on the town's water supply.

In general from the preceding discussion, it can be understood that the production and distribution systems of the town's water supply are inefficient and tied up with serious problems.

4.1.9. Water supply service coverage

The distribution system covers almost all part of the town. As per the official data of ATWSSO report 2014, currently the office has a total of 3600 customers of which 3,400 are domestic, and the rest 200 are commercial organizations and governmental and social institutions. Although this number is increasing from time to time, still there are many lags behinds because there are many households which from getting water through private meter connections.

Based on the standard indicated on First Ethiopian growth and Transformation Plan for urban water accessibility (UAP, 2011), which is 20 liter per day per person in 500m radius, the office except water interruption problem achieved 100% service coverage. But in the revised second Ethiopian Growth and Transformation Plan (GTP-II) of 2015, while the plan is to ensure water accessibility of 60 liter per day per person in 250m radius, it is still referred that the existing water supply service coverage (with compered to consumption in 2014 = 735.51m^3/day and required for GTP-II = 28011 populations*60 liters = 1680.66 m^3/day) is only 43.76%.

According to Zemenu, (2012), inhabitants who do not have access to the piped system draw their water from vendors, private hand dug wells, or from somewhere else that have their own private connection and selling it at a higher price.

Obviously, the spatial extension of pipeline over any settlement area is a pre-condition for supplying the community with piped water. Nevertheless, the efficiency of water supply is determined primarily by the density of pipelines; yet the major factor is the presence of adequate amount of water. In the absence of this crucial element, the density of pipe network is not enough to determining the water supply efficiency. In the other words, the integration of the two elements is fundamental for the system to be considered as in better condition. The efficiency of water supply is therefore, determined primarily by the presence of enough amount of water and the density of pipelines which are in turns influenced by other factors such as socioeconomic and physical factors(Konjit, 2015). Among these factors, the presence or absence of water, regularity of water supply and the income level of the community are the major ones.

As per the data collected from the town water supply service office, and the filed data measurement made from existing town water distribution pipe line for modeling purpose, as indicated in this study at section 4.3, of this study, there is no significant problem on the density of pipe network in the town rather than other technical problems (like pipe diameter, type of pipe, velocity, pressure etc.). Especially, in dry season with frequent interruption of electric power and high demanders from the town, the water supply activities are highly affected and the town faces high shortage of water instead of accessibility. As a result of this the people living in the town highly suffer from the absolute absence of water supply around their residence. They usually go far-off distances in search of water and carry it along and also spend much time even in queuing up near the water taps during dry times waiting for their turn, because of surrounding rural Kebeles population coming to fetch water (Appendix Figure 4).

Distributing water through house connection use is obviously the most convenient system of water supply for households(Abdisa & Reddy, 2012). However, the installation of the residential meter connection involves much higher cost. From which most of the households in the community under consideration could not afford. For example the fee for meter connection varies according to the house’s distance from the main distribution pipelines. The payment for houses that only requires single pipe is 1500 ETB. This is not an affordable for many residents. Because of such financial and other socioeconomic factors, the rate of private meter connection for household service in Ararti town is have a limitation but it increasing from time to time as compared to the previous years and it is relatively in good condition.

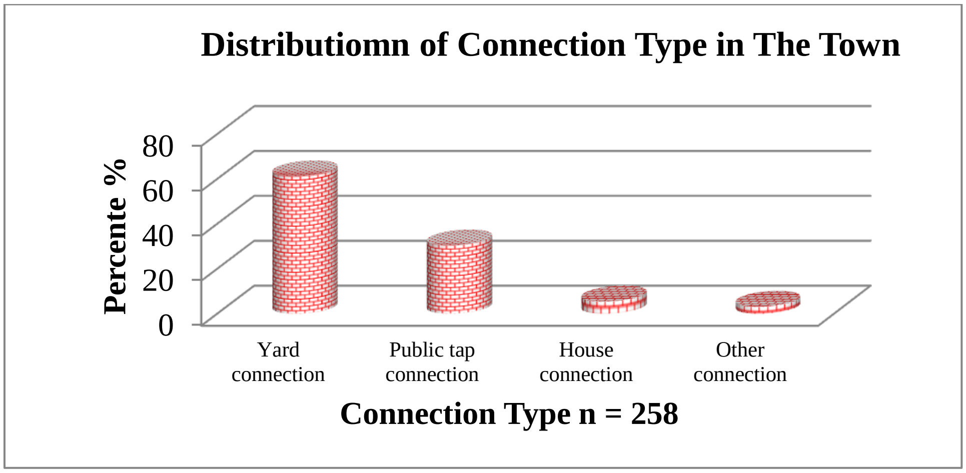

Figure 4.6 Accessibility of water by mode of serves

(Source: Field survey July, 2015).

It can be observed from Figure 4.6 that out of total sample households, 61.15 % have private yard meter connection, 5.4% house connection, 30.35% public meter connection and 3.1 % have other connection types while 33.45 % of the sample households have no private meter connection at all.

The implication of this finding can be expressed in terms of principles of optimal use of water, equity of access, efficiency of use and sustainability of the source. The first implication is that low variation in number of households with and without meter connection shows there is a tendency of equity of access to potable water supply. Eventually water shortage leads to inefficient use of water in the community. Last but not least, the majority of the people do not get adequate potable water, meaning that they forced to use other alternative sources. This consumption characteristic of water implies absence of optimal use in terms of sustainability of the source in the study area.

Due to such constraints households face serious shortages of water supply. They, therefore, collect water for any kind of household use from other sources or from water vendors which obviously costs them a considerable time, energy and money.

The impact of this is that households lose their income and time which leads to low productivity, burden on home duties and work especially on girls and women.

4.1.10.Water consumption

The following Table 4.15 shows water consumption trade of the town.

Table 4.15 Average town water consumption liter per family per day

	Total amount of water use (liter/ family/day)	Total amount of water use (liter/family/week)	Amount of water used for toilet (liter/family/day)
N	258	258	258
Mean	A = 53.68	403.08	B = 4.94
	liter/family/day	C = 57.58	
	average the A &C liter/family/day	D = 55.63	
	Total amount of water (Sum of B+D) liter/ family/day		61 l/family/day

As per the result shown in Table 4.15, the average per capita water use of member of each household was calculated and found that 61 liters of water per family per day for domestic purposes.

It can be visualized that the households in the study area get a very little amount of water for their daily water needs and in any criteria these per capita water use values are very little.

According to UN-HABITAT (2003), as stated also by Konjit (2015) a household needs a minimum of 150 l/day and for good hygiene up to 600 l/day. Obviously domestic consumptions in cities differ mainly due to development opportunity, climate, living standard, household size, etc. But from this study it can be concluded that the per capita water usages of the study areas are rather very low and needs to be improved.

4.1.11. Factors that affects town water consumption

In urban communities the problem related to household water consumption patterns involve various components even though its effects vary from one urban center to the other and among communities. Among other factors, physical and socioeconomic factors are the major ones (Konjit, 2015).

The rate of water consumption in a particular area is a function of various factors. The first and the most influential factor which has been affecting water consumption in Arerti town especially in dry season is the capacity/nature of the source of water with respect to quantity. Low quantity was expressed as a more serious problem by different sections of the society interviewed for their water consumption.

The other physical factor which affects the use of water within each household is the physical distances of housing units from the water point. For instance "Bono water" users fetch water out of their compound. From this study result, bono users are traveled average distance of 357.8 m for round trip.

The total numbers of stand pipes in the town are 25. But, most of them are nonfunctional. Currently only 7 of them are giving service and the remaining are idle or endanger (See Appendixes Figure 3). Thus by means of these and other reason, the distance travel to fetch water in the town is greater than the reasonable access defined by the World Health Organization (WHO), 2004 and stated in Assefa (2006:69) to safe drinking water in urban areas i.e. 200 m for the housing unit.

It is observed that average water consumption per individual per day for houses with private meter connection is 40 liters whereas, for houses using public standpipes it is only 20 liters. From this it can be conclude that physical distance of the housing units from the water point had an inverse relationship with the amount of water consumption despite other factors, that affecting water consumption such as purchasing power, household size, and household income.

The rate of water consumption is also affected by system pressure inadequacy. If pressure is in efficient in the system to address the water for the consumers, they do not get water as they want.

On the other hand, the rate of consumption is indirectly affected by electric power. If no power no other water production and if no water production, no water at water point. Therefore, one of the main problems of water supply challenge in Arerti town is high electric power interruption. Pump with gravity distribution method need energy to force the water from the source to the reservoir even though gravity system is there also. This incurred power cost. In addition to this, power failures mean a complete interruption in the water supply system and less consumption.

Interruption mostly occur in dry season when consumption in reverse increases. This is because of the fact that, water table decreases from the sources especially in dry season (Bega) and in the study area high amount of water consuming by surrounding Kebels (see Appendix Table 2). When such unexpected power cut or failure occurs and complete interruption is caused, the households faced different challenges. That is lead to low productivity and low income. In addition to these, frequent electric power interruption is highly affect the town development rather water production.

4.1.12.Water Accessibility

Water collection journey

The respondent to the distance travelled to alternative sources is presented in Table 4.16.

Table 4.16 Distance travel to alternative water source during water interruption

Category	Frequency	Valid Percent
<100m	11	4.26
100-300m	25	9.7
400-500m	107	41.47
500-1000m	4	1.55
>1000m	111	43.02
Total	258	100

(Source: Field survey July, 2015)

From the above Table 4.16, it can be seen that some households i.e. 11(4.26%) are getting their water from the primary source at less than 100 meters walking distance which is within the Intermediate Access, according to WHO, 2004 accessibility standard. While 25(9.7%) HHs get water from 100 to 300 meters distance range and 107(41.47%) get water at a distance range of 400-500 meters which is within the first Ethiopian growth and transformation plan accesses plan 2011 and 4(1.55%) are travel in between 500-100m but 111 (43.02%) HHs travel over 500 meters to get their water. According to WHO accessibility standard, 2004 they have no access to clean drinking or tap water even GTP-I plan of Ethiopia.

All these together shows that the distance travelled to collect water from the primary sources is reasonable. But in water interruption time especially women and children force to collect water from far distances spending their time, energy and additional costs.

4.1.13. Water collection time

As Table 4.17 presented, 60.1% of them access within 30 minutes walking time, the rest 39.9% the households were walking for more than 30 minutes. Which is far from the WHO and Ethiopia water policies time standards.

Table 4.17 Required water collection traveling time

Category	Frequency	Percent
<5 minute	87	33.7
5-30 minute	68	26.4
>30 minute	103	39.9
Total	258	100

(Source: Field survey July, 2015)

4.1.14. Water Tariff

A water tariff beneficiary pay is presented in Table 4.18.

Table 4.18 Arerti Town Previous and Current Water Tariff

Consumption Range (m^3)	Previous Tariff up to June 2015 (Birr/m^3)	Current Tariff (Birr/m^3) from July 2015
For Privet household use		
0.1-5	3.50	5.90
5.1-10	4.50	7.00
10.1-15	6.50	7.25
15.1-20	7.50	7.84
20.1-25	8.00	8.36
>25	-	9.11
For company and governmental organization		
0.1-5	3.50	6.61
5.1-10	4.50	7.36
10.1-15	6.50	8.11
15.1-20	7.50	8.86

20.1-25	8.00	9.61
>25	-	9.86
Public taps	5	7.50

Source: Arerti Town Water Supply Service Office September, 2015

Give in the Table 4.18 for private pipe connection users; the one who consumes more pay less price and vice-versa, i.e. after a certain limit of consumption, the tariff remains the same, 9.11 ETB/m^3. This pricing approach subsidizes the high-income level community and increases burden on the poor people, particularly public standpipe users because they are paying using flat rate charging system. And currently the water tariff increase approximately as considered as double. Therefore, the new water tariff is also affects the households water consumption. Affordability of water tariff discuss in Figure 4.7.

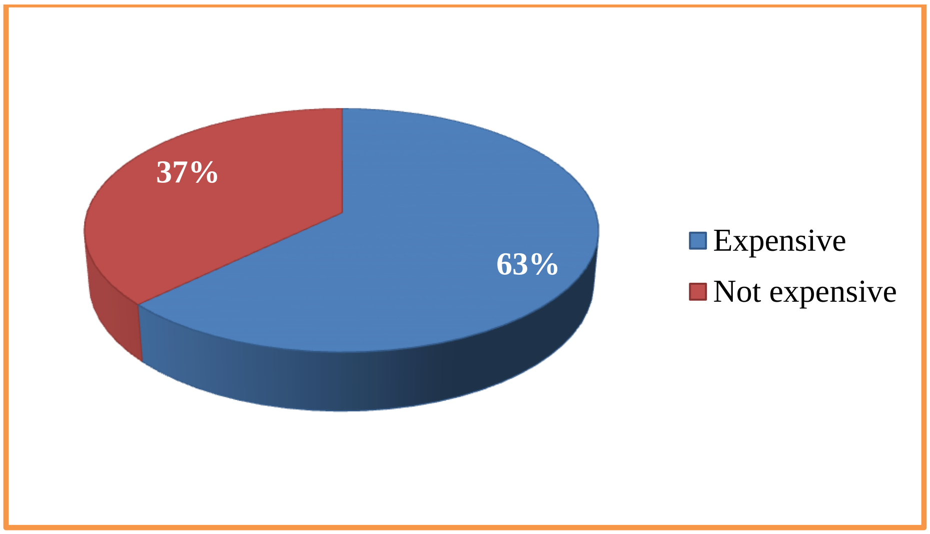

Figure 4.7 Affordability of water tariff (Source: Field survey July, 2015)

As presented before average house holed water consumption is 1.83 m^3, that means they used in the range of up to 5m3. However, for this amount of water consumption, they spent high amount of money for water. This is also contrary ATWSSO progressive block tariffs principles, the higher consumer, should pay higher (MoWR, 2001). The result below indicates that water is expensive for the majority of households and they are paying more than the World Bank recommendations, which stated the household monthly water cost should not exceed 3-5% of their monthly income (Shanmugham, S., & Tekle 2011).

A customer who consumed up to 5 from utility water pays ETB 5.9 per m^3 plus ETB 1.5 for the water mere rent per month. Public tap user pay for all consumption in flat rate, i.e. ETB 7.5 per m^3. In the field observed, the household who used water from public tap ETB 0.15 for one "20 liter jerry can" water. Therefore, the household respondents respond as shown in Figure 4.7, the sample households were interviewed, out of the total sample households, 163 (63 %) answered the current tariff is expensive whereas the rest 95 (37%) of them responded it is not expensive.

It was also found that households pay on average ETB 25/m^3 for vendors, which is about 5 times the unit cost set by ATWSSO for public taps and it increase during dry season which is ETB 50/m^3. Households spend on average ETB 0.37 per capita per day on water. In general, this per capita expenditure by the households is high and clearly shows how much the service is unaffordable.

The reason why the water tariff is increase, because of fuel cost recovery and currently the utility repaying the investment cost of the water supply project.

4.1.15. Further demand and willingness to pay for improved water supply

Table 4.19 Type of connections household prefer to have

Category	Frequency	Percent
Yard private connection	80	61.54
House connection	20	15.38
Yard shared connection	5	3.85
Public connection	25	19.23
Total	130	100

Source Field survey July, 2015

Table 4.19 shows that, it was found that about 61.54% of the respondents prefer to have private yard taps, 15.38% house tap, the other 3.85% shared yard taps and the rest 19.23% public taps. It is generally understood that most people prefer yard private taps. This study shows this fact to be true that, 76.92 % of the households prefer private connections. The other preferences for shared yare and public taps were come from fear of the initial costs for private taps connection.

Table 4.20 Willingness to pay for improved water

Answer	Frequency	Percent
Yes	254	98.4
No	4	1.6
Total	258	100

Source: Field survey July, 2015

The willingness of consumers to pay an improved water service is presented as shown in Table 4.20, 254 (98.4%) of the respondents reported that they are willing to pay and 4(1.6%) household respondents were not willing to pay due to various reasons like dissatisfaction with the current water supply service.

Therefore, the survey result indicated that households are willing and able to pay more than what they were paying. Similarly, the data collected from Focus Group Discussion discussants confirmed that users of water supply systems are willing and capable of paying for the improved service. This was because, as indicated by the Focus Group Discussion discussants, the inhabitants were not satisfied with the current water supply service. There were also lacking of transparency and accountability in fund management in ATWSSO.

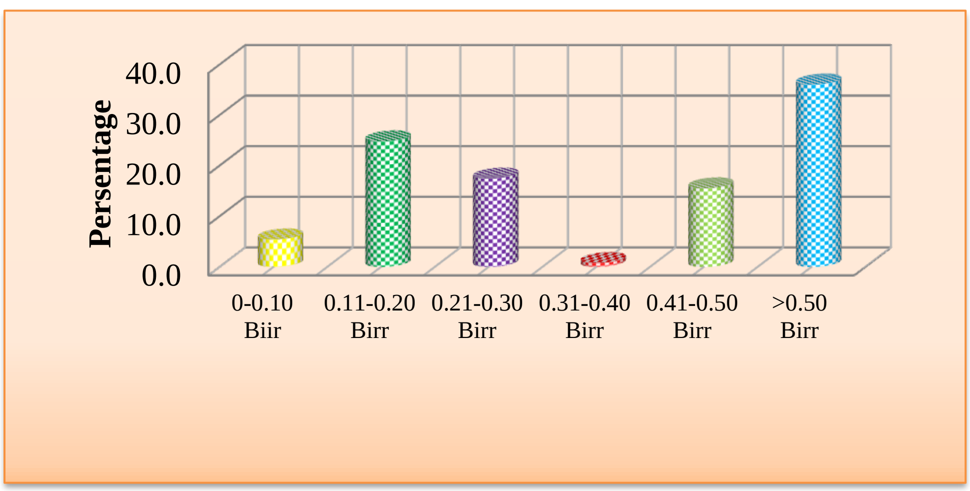

Figure 4.8 Willingness to pay birr for 20 liter “Jerican” of water in the study area (Source: Field survey July, 2015).

Related with the amount of money they could pay, Figure 4.8 shows that 14 (5.4%) and 64 (24.81%) of respondents reported that they are willing to pay less than ETB 0.10 and

0.11 - 0.20 ETB per Jerican and 45 (17.44%) and 2(0.8%) sample households responded that they could pay 0.21 – 0.30 and 0.31-0.40 ETB, respectively. While 40(15.5%) and 93(36.05%) sample households responded that they could pay 0.41 - 0.50 and > 0.5 ETB respectively for clean potable water. Therefore, the study found that the majority of the households were able and willing to pay for the service and willingness to pay is not a problem related to sustainability of urban water supply in the study area.

4.2. Population, water supply and demand analysis

4.2.1. Existing population, water supply and demand

Data collected on the existing population, water supply demand of the study area was reviewed, showing the estimated population of Arerti town to be 28011 in 2014(ATM, 2014) with a varying population growth rate (Table 3.2) and average family size of 5 (Abebau, Mulat and Friends Consulting S.C, 2007). Even though water demand, in 2014, of the study area is estimated to be 1548.13m^3/day, about (100%) of the population supplied by ATWSSO gets water from borehole.

4.2.1.1. Population projection

The population of the study area up to the end of the project period is estimated to reasonably quantify the inhabitants of the area. In the Table 4.21 the future population projection in medium scenarios adopted for analysis purpose is described.

Table 4.21 Projected Populations

Year	Growth rate	CSA population	Municipality Population	
1994		6,492		
2014	4.3	15,821	28,011	base year Used for analysis
2015	4.3	16,501	29,216	
2016	4.1	17,178	30,414	
2018	4.1	18,616	32,959	
2020	4.1	20,174	35,717	
2022	4	21,820	38,632	
2024	4	23,601	41,398	
2025	4	24,545	44,776	
2026	3.8	25,478	48,244	

As the result reveals, the projected population of these areas increases from 2014 to the end of the design period (2026). This can be substantiated by autonomous growth and migration in the future times. Autonomous growth is population growth within the areas. Whereas migration describes, the population that comes from other places.

Annual water production, consumption and losses

Table 4.22 shows the results of annual water production, consumption and losses. Bothe production and consumption shows increasing trend by 25%.

Table 4.22 Recorded annually Water production, Consumption and losses

Category	2010-2014						
	Unit	**2010**	**2011**	**2012**	**2013**	**2014**	**Average**
Total water production	m^3/year	208,478	201,346	224,818	251,424	304,730	238,159.2
	m^3/day	569.61	551.63	615.94	688.83	832.6	651.722
Total water consumption	m^3/year	177,914	192,749	215,630	235,200	269,195	218,137.6
	m^3/day	486.1	528.08	590.77	644.38	735.51	596.968
Loss	m^3/year	30,564	8,597	9,188	16,224	35,535	20,021.6
	m^3/day	83.51	23.55	25.17	44.45	97.09	54.754
	%	14.66	4.27	4.07	6.45	11.66	8.22

Source: ATWSSO, 2014

From this result, the amount of water loss is very low but the consumption as indicated in this Table 4.22 not only consumed by town domestic demand but also consumed by nearby rural Kebeles and other demands.

The 30 days recorded data from five main gates of the town indicated that high amount of water delivered out of the town which is approximately 20% (see Appendix Table 6 and Appendix Figure 7). This amount of water accounts 147.33 m^3/day of the total water consumption. Therefore, amount of water delivered out of the town has high influence on town population consumption even on economy of the town. So the consumption figure stated above Table 4.22 is not indicting exact water consumption only by town population.

4.2.1.2. Present water demand

Domestic Water Demand

The estimated domestic piped water demand through different mode of services is shown is Table 4.23.

Table 4.23 Domestic water demands in 2014

Type of service		No. of people	Per capita Demand (l/d)	Average Demand (l/d)	Average Demand m^3/day
House connection		1513	60	90780	90.78
Yard connection	Private	16728	40	669120	669.1
	Organization	401	40	16040	16.04
Public tap connection with NTU		9369	20	187380	187.38
Population		28011		963320	963.3
Factors	Climatic				1
	Socioeconomic				1.05
Total average domestic demand					1011.465
All required total average demands of the town					1548.13

NTU = neighboring tap user

Comparing the present domestic water consumption as per the town water service record (Table 4.22) against the estimated present domestic water demand (Table 4.23) results: -

- Total consumed water for different activities and groups = 735.51m^3/day
- Water delivered out of the town =147.33 m^3/day
- Total average consumption for all town activities = 588.18 m^3/day
- All required total average demand of the town = 1548.13 m^3/day

Hence, from the above figures it can be seen that the existing system supplies for the town in the order of 37.99 percent of the present piped water demand. This mean the amount of water supplied is lower than the required demand.

4.2.1.3. Future Domestic water demand

Mode and Level of Services

The water service office, serve the community by the three major modes of services namely public tap, yard connection and house connection. In Figure 4.6 properly explain the actual practice of Arerti town modes of services.

In the study town there are traditional source users who get water from river for cattle drinking purpose and use pond water for their daily needs and take only small amount of water from the proper water supply system mainly for drinking & cooking purposes. And also there are some percentages of population who depend on neighborhood taps. The existence of such type of users are due to the limited capacity of the available water supply system, affordability to pay, avoiding long walking distance to public taps, lack of awareness and others. However after the implementation of this study, other than affordability, all the hindrance to use proper water supply system will be solved. For the analysis of this study it is assumed that about 80% neighborhood tap users will have the chance to use their own yard connection and about 20% will be supplied from public tap connection. Therefore, there will be no neighborhood tap users after 2018.

The other water consumption in town is livestock. The amount of water required for livestock demand has been considered from this study result is averagely 5.15 litters of water per person per day. Therefore, in this study considered the amount of water stated above, times by total population number as livestock demand. Because almost all the people use water from the existing pipe system for their cattle.

Growth of Domestic Water Demand

Following, the implementation of the study the per capita water demand by each mode of service changes with time. To estimate the projected per capita water demand corresponding to each mode of service the researcher assumed water demand to grow at the following rates: 5% per annul for public taps users, 7% per annul for yard and 8% house connection users based on achieving of 2020 GTP-II 60 litters of water per person per day for level three water service office. Thus the projected per capita water demand by mode of service is presented in the following Table 4.24.

Table 4.24 Projected per capital water demand by mode of service (l/c/d)

Year	Demand category		
	HTU	YTU	PTU
2014	**60.00**	**40.00**	**20.00**
2018	79.20	51.20	24.00
2020	91.87	58.37	26.40
2022	93.71	59.54	29.04
2024	103.08	60.73	31.94
2026	105.14	61.94	35.14

Population distribution by Mode of services

The analysis made on the present water consumption data collected in field survey found out that about 33.45% of the population of the town are public tap users and about 61.15% of the population are yard connection users. Only 5.4% of the population are served through house connection. For the reason it is assumed that there will be no traditional source users. The following Table 4.25 shows the present percentage of population by mode of service.

Table 4.25 Percentage of population through mode of services

Mode of service	Percentage of Population
House connection	5.4
Yard connection	61.15
Public tap connection	30.35
Neighborhood users	3.1

Source own field survey July 2015

It is assumed that the existing system will be functional and no additional source will be added till the new system is implemented. Hence the collected data for the year 2014 may be assumed the same till 2018. The neighbourhood users is not included in the year 2018 as the new system will cover the whole town and satisfies the demand requirement till the end of the design period. It is also expected that as the standard of living increases mode of service users upgrade their service. Many yard connections will be changed to house connections and public tap users will have their own yard connection. The projected level of service based on achieving second Ethiopian GTP plan 2020, 60 litter of water for level three water services is presented in Table 4.26 below.

Table 4.26 Projected Percentage of Mode of Service

Mode of service	2014 Base year	2018	2020	2022	2024	2026
House connection	5.4%	6.48%	7.13%	7.27%	7.42%	7.57%
Yard connection	61.15%	73.38%	80.72%	82.33%	83.98%	85.66%
Public tap connection	30.35%	20.14%	12.15%	10.4%	8.6%	6.77%
Neighbourhood connection	3.1%	-	-	-	-	-

The estimated number of people to be served by each mode of service during the year 2014 – 2026 is calculated from Table 4.26 and Table 4.21 and is tabulated below in Table 4.27.

Table 4.27 Projected population by Mode of Service

Mode of service	2014 Base	2018	2020	2022	2024	2026
House connection	1,513	2,136	2,546	2,809	3,070	3,649
Yard connection	17,129	24,185	28,831	31,807	34,766	41,325
Public tap connection	8,501	6,638	4,341	4,017	3,562	3,270
Neighbourhood connection	868	-	-	-	-	-
Total population	28,011	32,959	35,717	38,633	41,398	48,244

Projected Average per capita Domestic Water Demand

The projected average per capita day domestic water demand for a particular year is obtained by multiplying the per capita demand in each category. For the year under consideration obtained from Table 4.24 with the corresponding population figures for the same year obtained from Table 4.27, and summing the results for all demand categories. The following Table 4.28 presents the projected average per capita domestic water demand from the year 2014 as base and design period starting from 2016 up to the end of the 10 year design period 2026.

Table 4.28 Projected Average per capita domestic water demand

Year	2014(base)	2018	2020	2022	2024	2026
Average demand (l/c/d)	34.39	47.54	56.87	58.85	61.39	63.39

Climatic Grouping

Climate of an area is one of the factors, which is directly related to water consumption. Hence this research climate adjustment factor which is taken from Oromia water work design and supervision enterprise design guideline, (2008) has been considered. From field survey result, Arerti town is found in between 1600 and 1820 m a.s.l, which makes the town to fall under group C (See Appendix table 1). Therefore, climatic factor of 1.0 is adopted to refine the average per capita domestic water demand.

Socio-Economic Adjustment Factor

Arerti compared to other towns has lower standard of living. According to this study under sub topic 4.1.2, most of the inhabitants are involved in farming and private business with some government employees. But the town has an appreciable infrastructure and social services like hotels, roads, power supply and banking system. However, presently there are activities which will contribute to the economic development of the town. Hence the study town is expected to have good prospect for development.

In view of the above facts Arerti is categorized under Group B- towns with very high potential for development but lower living standard at present (Appendix Table 2). Therefore socio-economic adjustment factor of 1.05 is adapted to refine the average per capita domestic water demand.

The adjusted average daily per capita domestic demand applying climatic & socio-economic factors is presented in Table 4.29.

Table 4.29 Adjusted Average Daily Per capita Domestic Demand

Category	Year					
	2014	**2018**	**2020**	**2022**	**2024**	**2026**
Average per capita demand (l/c/d)	34.39	40.09	43.65	45.82	48.12	50.47
Climatic adjustment factor	1.0	1.0	1.0	1.0	1.0	1.0
Socio-economic adjustment factor	1.05	1.05	1.05	1.05	1.05	1.05
Adjusted per capita domestic demand (l/c/d)	36.11	49.91	59.71	61.79	64.46	66.56

Summary of projected population, Growth in Domestic Demand by mode of service and calculate Adjusted Domestic Demand.

The following Table 4.30 presents summary of the discussions on population projection, percentage of population served by different mode of services, water demand determination and its growth in the expected service year of the new system and the calculated adjusted average domestic demand in liter per second.

Table 4.30 Summary of adjusted domestic demand

Year	Population	% of population				Population				Per capita Demand (l/c/d)				Domestic Demand (m3/d)				Total Domestic m^3/day	Adjustment Factors		Total Adjusted l/s
		HTU	**YTU**	**PTU**	**NHU**	**HTU**	**YTU**	**PTU**	**NHU**	**HTU**	**YTU**	**PTU**	**NTU**	**HTU**	**YTU**	**PTU**	**NTU**		**Climatic**	**Socio-**	
2014	28011	5.4	61.15	30.35	3.1	1513	17129	8501	868	60	40	20	20	90.756	685.149	170.03	17.37	963.30	1.0	1.05	11.707
2018	32,959	6.48	73.38	20.14	-	2136	24185	6638	-	79.20	51.20	24.00	-	169.151	1238.288	159.31	-	1566.75	1.0	1.05	19.040
2020	35,717	7.13	80.72	12.15	-	2546	28830	4341	-	91.87	58.37	26.40	-	233.90	1682.75	114.60	-	2031.25	1.0	1.05	24.685
2022	38,632	7.27	82.33	10.4	-	2809	31807	4017	-	93.71	59.54	29.04	-	263.21	1893.67	116.65	-	2273.53	1.0	1.05	27.630
2024	41,398	7.42	83.98	8.61	-	3070	34766	3562	-	103.08	60.73	31.94	-	316.46	2111.18	113.78	-	2541.42	1.0	1.05	30.885
2026	48,244	7.56	85.66	6.78	-	3649	41325	3270	-	105.14	61.94	35.14	-	383.70	2559.70	114.90	-	3058.30	1.0	1.05	37.167

4.2.2. Non-Domestic Demand

Public Demand

The estimated public demand is shown in Table 4.31 is calculated based on Oromia Water works design and supervision water supply design guideline, 2010, which is 20% of average domestic demand because of lack of adequate information.

Table 4.31 Estimated Public Demand

Year		2014	2018	2020	2022	2024	2026
Total adjusted Domestic Demand	m^3/d	1011.46	1645.09	2132.82	2387.21	2668.50	3211.22
	l/s	11.71	19.04	24.69	27.63	30.89	37.17
Public Demand 20% of Total adjusted Domestic demand	m^3/d	202.29	329.02	426.56	477.44	533.70	642.24
	l/s	2.34	3.81	4.94	5.53	6.18	7.43

Livestock demand

Most urban water supply project not consider livestock demand. But in this study, was considered depends on the study result. From the study result approximately 5.15 litters of water use per person for livestock demand. Therefore 5.15 litter times by total population of the town is equal to amount of water that considered for livestock demand for this study.

Table 4.32 livestock demand

Category	Unit	Year					
		2014	2018	2020	2022	2024	2026
Population	No	28011	32959	35717	38632	41398	48244
Estimated(collected) amount of water used for livestock demand	l/day	5.15	5.15	5.15	5.15	5.15	5.15
Estimated average Livestock demand	l/day	144256.7	169739	183943	198955	213200	248457
	m^3/day	144.257	169.739	183.943	198.955	213.200	248.457

Livestock demand shows some amount of water is consuming by livestock. It accounts approximately 20% of the total consumption of water in 2014 (735.51m^3/day). From this result inconsiderable amount of demand is one of the influential factors of unsustainability of water supply in the town.

Water loss

Water loss include leakage in the pipe due to breakage, lose jointing, illegal connections, flushing, wastage at public taps and fittings in house connections. However as the age of the existing system is about 5 years it is expected that there will be a considerable amount of loss.

Loss will be minimal at the beginning of the design period and will increase gradually with time in the expected service life of the new system unless intermediate leakage detection & subsequent remedial work is carried out. Because leakage detection requires skilled manpower, equipment and strong organization which is unlikely to be established in our country in general and Arerti in particular, it is logical to presume an increase in water loss with time in designing water supply system. Hence as mentioned in the design criteria report the approach used in previous study by Alexander Gibbs in 12 town's water supply study has been adopted. The approach relates the percentage of losses to both the age of the distribution system and to the percentage of the total pipe length which is made up the new distribution system from the existing network. The adopted chart to estimate water loss is presented under Appendix Figure 8. From the curve the percentage losses used for 2014, 2018, 2020, 2022, 2024 and 2026 are 14%, 17%, 18%, 20%, 21% and 23% respectively.

4.2.3. Total Average Daily Demand

This demand is considered to be the sum of adjusted domestic demand, livestock demand, public demand, and system water losses. The total average day demand for the design period of the study town is presented as shown in Table 4.33.

Table 4.33 Total Average Day Demand

Year	2014	2018	2020	2022	2024	2026
Domestic Demand (m^3/d)	1011.47	1645.09	2132.82	2387.21	2668.50	3211.22
Public Demand (m^3/d)	202.29	329.02	426.56	477.44	533.7	642.24
Livestock Demand (m^3/d)	144.257	169.739	183.943	198.955	213.2	248.457
Average Day Demand (m^3/d)	1358.01	2143.85	2743.32	3063.61	3415.40	4101.92
Losses in the system (%of average day demand)	14	17	18	20	21	23
Total Average Day Demand (m^3/d)	1548.131	2508.303	3237.121	3676.326	4132.634	5045.358

4.2.4. Variation of Water Use

The rate of water use varies from season to season, from day to day and hour to hour. Water requirements in the dry season are more than in wet season. The use of water is also more during weekends than working days. More water is also required at rush hours when people come back from work than on normal working hours. Therefore, to satisfy this variation of demand the average day demand is scald up by certain factors to get the maximum day demand and peak hourly demand. These scaled up water demand figures are used to size or determine the capacity of pump stations, rising main and pipe distribution network.

Maximum Day Demand

The deviation of consumption from the average day demand is taken care of as per the maximum daily coefficient figures presented in Appendix Table 3. This value is adopted from design guideline which has been followed by WSSA (water supply and sewerage Authority) in previous studies.

The maximum day demand is computed applying the maximum daily coefficient corresponding to the total average day demand of a particular year with in the design period. Table 4.34 presents the computation of maximum day demand.

Table 4.34 Maximum Day Demand

Year	Average Day Demand (m^3/d)	Maximum Day Coefficient	Maximum Day Demand	
			m^3/d	l/s
2014	1548.134	1.78	2755.678	31.894
2018	2508.303	1.63	4088.534	47.321
2020	3237.121	1.55	5017.538	58.073
2022	3676.326	1.55	5698.305	65.953
2024	4132.634	1.55	6405.583	74.139
2026	5045.358	1.54	7769.851	89.929

Source: MoWR, 2006 and Calculated result

Peak hourly demand

The peak hour demand is greatly influenced by town size, mode of service and social activity patterns. Previous studies on hourly variation of demand show the peak hour factor is greater for a smaller population. The adopted Peak factor for the study town is based on the design criteria (MoWR, 2006) and is presented in Appendix Table 4. The projected population at the end of the design year is 48,244 which is in between 20,000 and 50,000. Hence the peak hour factor to be applied to estimate the peak hour demand is 1.9.

4.2.5. Summary of Water demand

The revised and projected total water demand for Arerti is summarized and presented in Table 4.35

Table 4.35 Summary of water demand

Year		2014	2018	2020	2022	2024	2026
Population		28011	32959	35717	38633	41398	48244
Average Day Demand	m^3/d	1548.134	2508.3	3237.121	3676.33	4132.634	5045.358
	l/s	17.918	29.031	37.467	42.550	47.831	58.395
Max Day Coefficient		1.78	1.63	1.55	1.55	1.55	1.54
Maximum Day Demand	m^3/d	2755.678	4088.53	5017.538	5698.31	6405.583	7769.851
	l/s	31.894	47.321	58.073	65.953	74.139	89.929
Peak hour coefficient		1.9	1.9	1.9	1.9	1.9	1.9
Peak Hour Demand	m^3/d	2941.454	4765.776	6150.530	6985.019	7852.005	9586.180
	l/s	34.045	55.159	71.187	80.845	90.880	110.951

4.2.6. Comparison of demand and supply of the town

The existed and future supply and demand is compered in the following Table 4.36. From these result demand is greater than supply. To address minimum requirement of town demand, the utility has been required 7.85 l/se additional water to the system in 2014. For GTP-II (2020) achievement 28.56 l/se water is required in addition to the existing supply.

Table 4.36 Summary of average total demand and supply

<table>
<tr><td rowspan="2" colspan="2">Category</td><td colspan="8">Year</td></tr>
<tr><td colspan="2">Unit</td><td>2014 Base year</td><td>2018</td><td>2020</td><td>2022</td><td>2024</td><td>2026</td></tr>
<tr><td colspan="2">Population</td><td colspan="2">No</td><td>28011</td><td>32959</td><td>35717</td><td>38633</td><td>41398</td><td>48244</td></tr>
<tr><td colspan="2">Average total daily demand</td><td colspan="2">m^3/day</td><td>1548.13</td><td>2508.3</td><td>3237.12</td><td>3676.33</td><td>4132.63</td><td>5045.36</td></tr>
<tr><td colspan="2">Total yield from 4 boreholes with 2% annual reduction</td><td colspan="2">l/se</td><td>24.20</td><td>22.26</td><td>21.37</td><td>20.52</td><td>19.70</td><td>18.77</td></tr>
<tr><td colspan="2">production in 10hr operation time currently operation time because of power interruption</td><td colspan="2">m^3/day</td><td>871.2</td><td>801.36</td><td>769.32</td><td>738.72</td><td>709.2</td><td>675.72</td></tr>
<tr><td colspan="2">The seam procedure and 16 hr operation time and WB, 2006 standard</td><td colspan="2">m^3/day</td><td>1393.92</td><td>1282.176</td><td>1230.912</td><td>1181.952</td><td>1134.72</td><td>1081.152</td></tr>
<tr><td rowspan="8">Average total demand and supply in 10 and 16 hours comparison</td><td rowspan="4">At 10 pumping hours</td><td>demand</td><td>m^3/d</td><td>1548.13</td><td>2508.3</td><td>3237.12</td><td>3676.33</td><td>4132.63</td><td>5045.36</td></tr>
<tr><td>Supply</td><td>m^3/d</td><td>871.2</td><td>801.36</td><td>769.32</td><td>738.72</td><td>709.2</td><td>675.72</td></tr>
<tr><td>supply deficit</td><td>m^3/d</td><td>676.9337</td><td>1706.943</td><td>2467.801</td><td>2937.606</td><td>3423.434</td><td>4369.638</td></tr>
<tr><td>% of supply deficit at 10 hours</td><td>%</td><td>44</td><td>68</td><td>76</td><td>80</td><td>83</td><td>87</td></tr>
<tr><td rowspan="4">At16 pumping hours</td><td>demand</td><td>m^3/d</td><td>1548.13</td><td>2508.3</td><td>3237.12</td><td>3676.33</td><td>4132.63</td><td>5045.36</td></tr>
<tr><td>Supply</td><td>m^3/d</td><td>1393.92</td><td>1282.176</td><td>1230.912</td><td>1181.952</td><td>1134.72</td><td>1081.152</td></tr>
<tr><td>supply deficit</td><td>m^3/d</td><td>154.21</td><td>1226.13</td><td>2006.21</td><td>2494.37</td><td>2997.91</td><td>3964.21</td></tr>
<tr><td>% of supply deficit at 16 hours</td><td>%</td><td>10</td><td>49</td><td>62</td><td>68</td><td>73</td><td>79</td></tr>
</table>

From the above Table 4.36 showed that the demand is greater than in two conditions of supply. In 10hr operation time currently the supply deficit is 44% and in 16hr pump operation time the current supply deficit is 10%. It showed that power interruption is how much affecting the water supply activities. To achieving 2020 growth and transformation strategic plan, the supply deficit is higher and higher. So, to ensure GTP-II target and satisfy the current demand, the water supply sector need additional water source.

4.3. Analysis of existing water distribution system

4.3.1. Hydraulic Modeling of continuous supply system

Model results of existed distribution network of Arerti town are discussed as follow:-

4.3.1.1. Layout of distribution system and nodal and link result

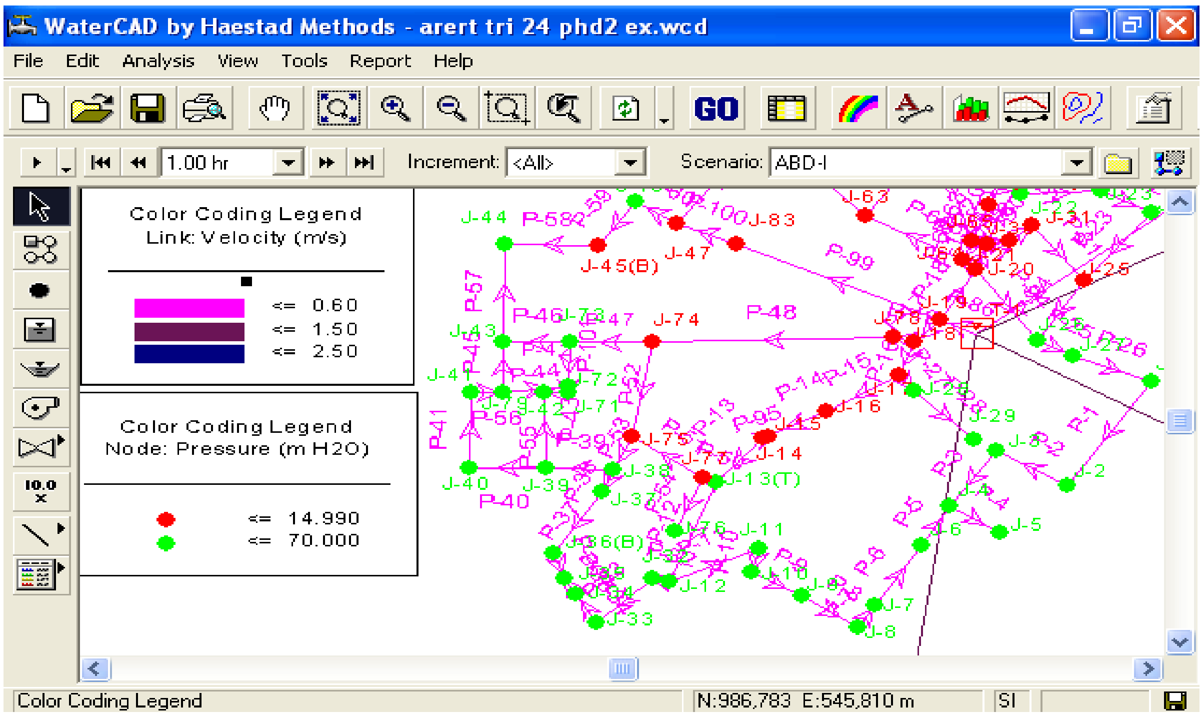

Figure 4.9 Layout of distribution line, nodal pressure and flow velocity (waterCAD result)

From the above layout result, the red and pink colors are shows the system is unsatisfactory. But, the green color indicates that the system is perfectly satisfied.

4.3.1.2. Nodal pressure result

The pressure in a water distribution system is at a minimum when the flow and subsequent head loss in the pipes are at peak demand. On the other hand, the pressure is a maximum when the flow is at a minimum normally at night time while most consumers are sleeping and institutions are shutdown. The Ethiopian guideline criteria for the minimum and maximum operating pressure value in the distribution network are 15 and 70 m respectively (MoWR, 2006) and the velocity is 0.6 and 2.5m/s.

The nodes which are around the supply point or tank and high levels suffer for low pressure values at its shown in Appendix Table 10. Registered at the nodes (At time 00:00; J-14, J-16, J-17, J-18, J-19, J-20, J-21, J-25, J-30, J-31, J-45, J-47, J-61, J-62, J-63, J-64, J-65, J-66, J-67, J-68, J-74, J-78 and J-83 below MoWR, 2006 standard level).

The result of the whole system as shown the ability of system to satisfy the needed pressure that are necessary with some extreme values neither smaller nor larger them, the specified values of pressure. This conclusion lead to suggest the capability of the system to serve the people in the future in the case of adding some developing measures such as, providing adequate quantities of water and use zoning system.

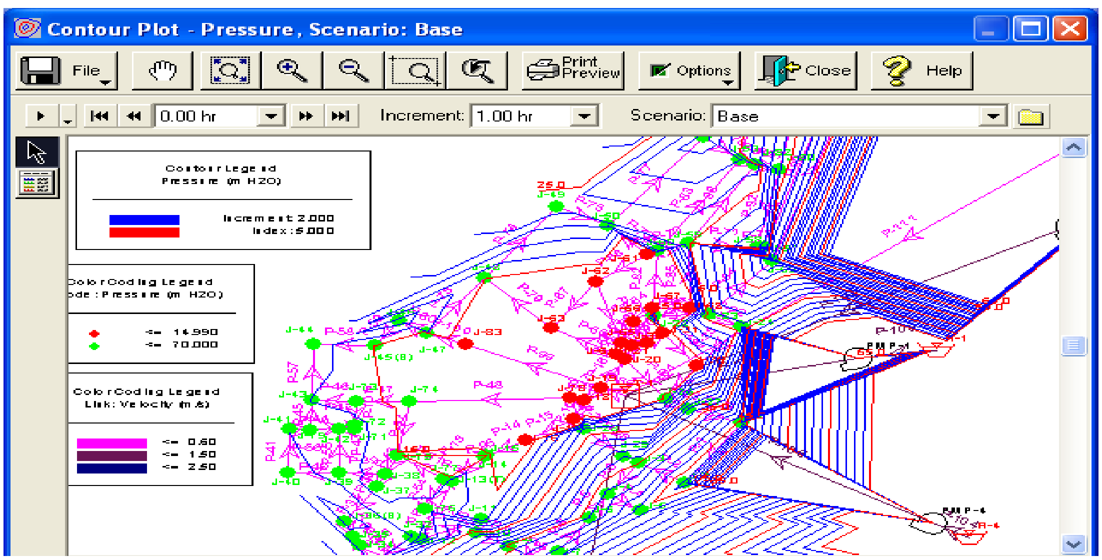

Figure 4.10 Contour map of nodal pressure

From this resulet the system need minimum two zone to satisfay MoWR and adequt pressur for the customers. The result as shown in Appendix Table 10 the nodal pressure is categorised in two main groups. One is under recomendeble or standared pressure group and the other is in bellow standard group. From Figure 4.10 the green color can be categorized under standard pressure zone and the red one is in another zone.

4.3.1.3. Velocity result

The result of velocities in the modeled continuous system as shown in (Appendix Table 11) appear a some values of velocities which are parallel to the assumed limits of velocities to avoid stagnation and quality water problems, also to save the pipes from deterioration due to the high velocities. But some are below standard level. Low velocity incurs health risk and inadequate water providing for the user. So the system requires some modifications.

The negative sigh of the discharge in the pipes as shown in (Appendix Table 11) is an indication to the wrong in assuming direction only.

Some figure from the result as an example of pressure and flow versus time

Junction 14

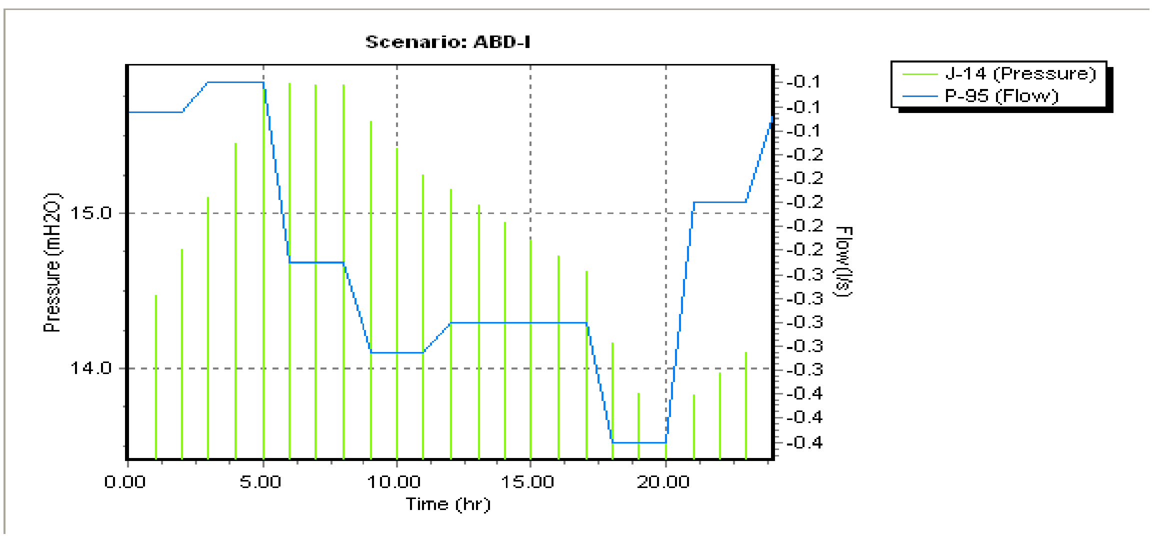

Figure 4.11 Pressure at junction 14 and flow in pipe 95 versus time

Junction 16

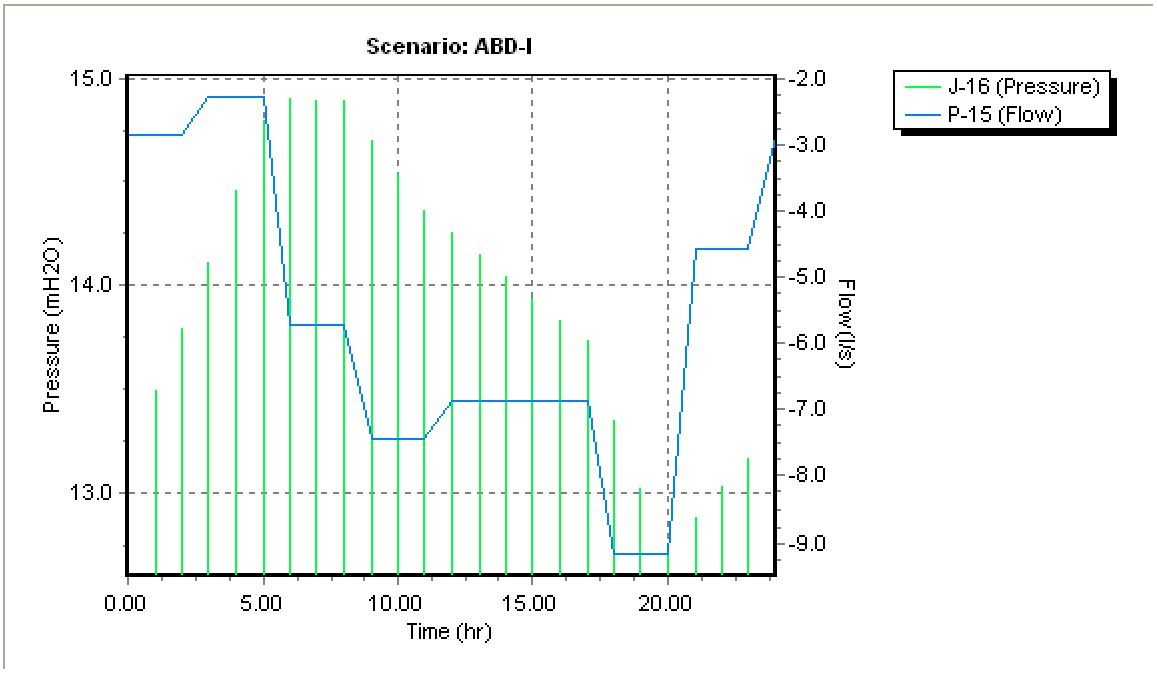

Figure 4.12 Pressure at junction 16 and flow in pipe 15 versus time

Junction 75

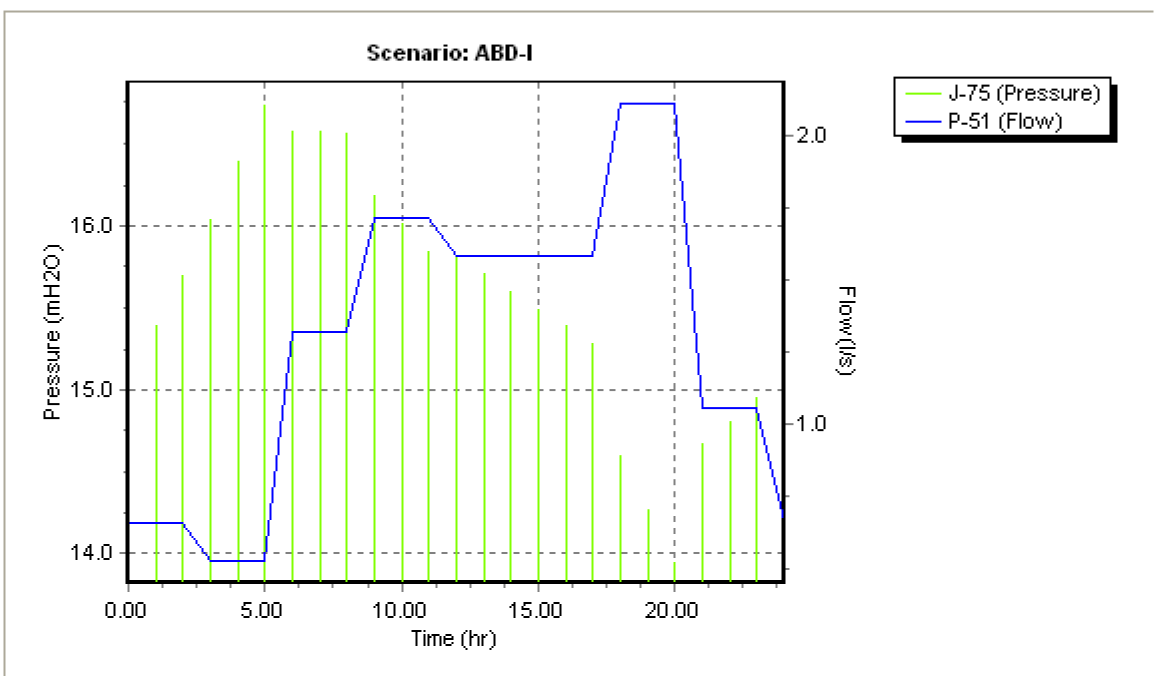

Figure 4.13 Pressure at junction 75 and flow in pipe 51 versus time

Junction 17

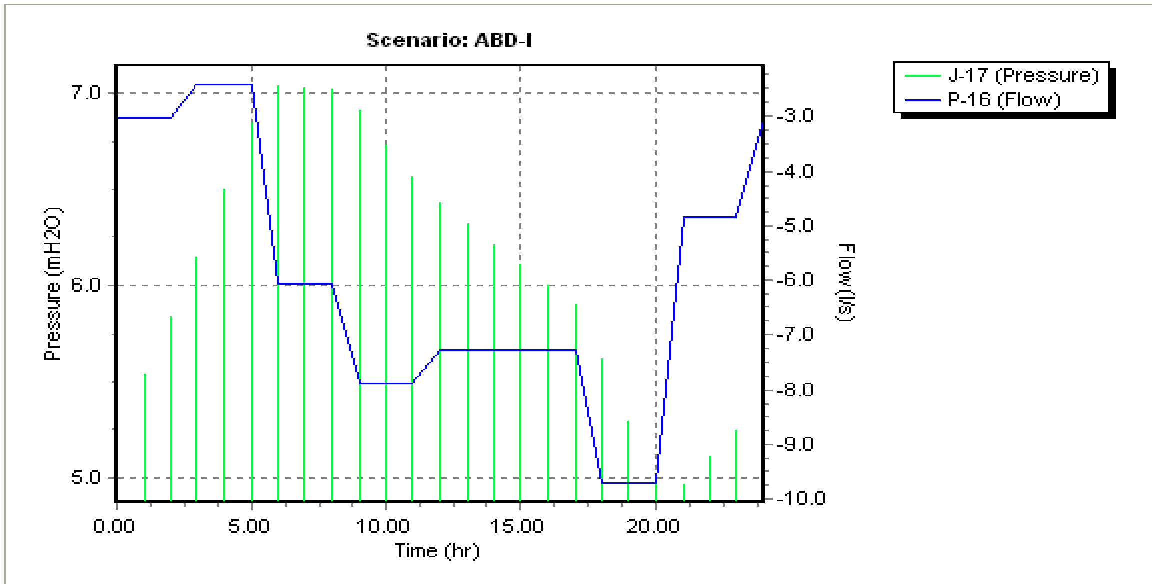

Figure 4.14 Pressure at junction 17 and flow in pipe 16 versus time

4.4. Challenges and causes of non-sustainable water supply in Arerti town

4.4.1. None-sustainable water supply Challenges in Arerti town

High construction and town development: Any area in development stage consume high amount of water for construction, hygienic, business and infrastructure. During the construction of existing water supply project the town develop is almost nothing, because no asphalt road, no electric power, no banking, no hospital, no G+ building, no college and no small scale industry and the like. But now some are under construction and stile the municipality gives land for investors and residential purpose. Therefore the town water supply office imposed high burden upon water supply facility.

Rapid population growth: The existence of current water supply of the town and the steady growth of the town's population due to natural increase and migration also imposed higher burden on the utility office of Arerti town and it becomes difficult to accommodate the ever growing population. The problem is exacerbated by the failure to design optimum use of water for the town due to underestimation of population growth based on national population growth rate while the growth rate for Arerti is beyond that growth rate.

Frequent electric power interruption: In the study area there is unlimited or unbelievable frequent electric power interruption. This problem is highly affect, the water production as well as all the town development.

Borehole capacity: The presence of much number of boreholes, do not mean that they give much amount of water with management problem. The same is true in the study area. Because the number of boreholes are 6 but the total yield is lower than nearby Kebele one borehole (Agirat Kebele borehole). Especially in electric power interruption, all the pumps are operated by diesel generator and it incur additional cost with management difficulty in addition to frequent water supply interruption. If you manage many, you manage one is better because operation cost, investment cost and management cost is low. Therefore spatially in electric power interruption time, operation and management cost is high and affects the water production of the study area.

High amount of water delivered out of the town: the main and critical issue of the town water supply today is amount of water delivered out of the town. In dry season almost all low land area of the woreda rural kebeles (12 Kebeles) use town water for their day to day activities and livestock's even Balchi town (Appendix Table7). In addition to these there is also emergence water demand from the past until now and the water travel more than 45km out of the town. During the study time there is a water truck for emergency purpose for farthest Kebele. In general amount of water deliver out of the town is very high so, it is highly aggravate town water supply shortage.

Illegal water use: Illegal water use in this study means the water use other objective rather than own objective and illegal connection. In the town there is an illegal water use practice. As discuss in the above, some people use water for farming purpose rather than drinking purpose. In the study woreda and Arerti town agricultural activities are well known practices. As observed from the field (refer photo Appendix Figure 2), there are onion nursery even though the water supply office give the rul. As obviously known the seed at adult growing stage consume high amount of water. By this reason high amount of water illegally consumed. Therefore, the produced water for main objective was reduced illegally and affects water distribution.

Unfair tariff and connection charges for the poor: The water tariff set by the Ararti water supply service office and the Board of Ararti town water supply for private connection and its connection charges is unfair to the poor segments of the community. This is because of the fact that those who consume more volume of water pay low price due to the price set in this manner and also the high connection charges. This implies that the tariff subsidizes the urban rich, as they are the one that can afford and consume more than the poor and can also sell from their private matter for the poor at a higher price than the price they paid for WSS office. The payment for the installation of new meter connection lines is not affordable for poor households. The minimum fee is 1500 ETB which is very expensive.

Limits to water consumption: Various physical and socioeconomic factors limited water consumption by households in Ararti town. To mention some of them: inadequate supply, the physical distance of housing units from water points, unreliable distribution due to weak pressure and frequent interruption etc. Among these factors, which limit the amount of water consumption, interruption of water supply is a more serious problem. During unexpected water supply interruption households encounter multidimensional problems as mentioned in the preceding sections. The growth of the town in terms of population, household size and income has also its own influence upon the water consumption by households.

4.4.2. Main causes of non-sustainable water supply in Ararti town

Obviously, for water supply service to be sustainable, they should be efficient, equitable and accessible (in terms of distance, time and affordability) to all members of a given community. This in turn requires sufficient material, capital and man power resources, advanced and up-to-date technology, organizational and institutional capacities. Because of the shortage of these factors, the water supply service of Ararti town is not sustainable mean it is inefficient, in equitable and inaccessible to society. Condition of the factors in the study area explained in the following way:

Professional and Management problem: Management problems caused by inefficient organizational structure, understaffing and almost all proses owners work by delegation, low salaries and lack of staff motivation and inability of the WSS office to retain trained and experienced staff is the main constraints of service delivery.

Lack of institutional coordination: Different professionals are not incorporated in Board members to exploit their technical knowledge. The community is represented by the three-delegated members. Thus, the poor institutional coordination hampered the efforts to achieve WSS office goals.

Limited budget and funds: Delivery of urban water supply requires a high level of investment and in addition to this Arerti town currently repaid the investment cost. Lack of sufficient funding has limited the quantity of water supply service of the WSS office.

Even though, the current cost recovery mechanism of Arerti water office seems better and able to cover expenditure cost, it is not sufficient enough to sustain even the existing service and fulfilling its mandates (like high maintenance).

Limited capacity: Inadequate equipment facilities and other material resources are a critical issue faced by the WSS office. Spare parts for the pumps of bore holes do not easily provide to the concerned bodies and easily maintain. Even when the office is capable of providing the required money, there is a problem of delay in purchasing the materials. In addition to this shortage of skilled manpower further exacerbated nature of the problem. These constraints are the most limiting factor in the fulfillment of its desired service provision. During field observation the researcher has observed that two among the six boreholes was not functioning because of mechanical and electrical failures and they were waiting for higher technicians from the Regional Water and Energy Bureau.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Water is a very essential element for all human being with adequate quantity and recommendable quality. But, the absence or inefficiency of this crucial element, over all activities is nonfunctioning. The same is true in the study area, Arerti town. The supply of potable water is inefficient or unsustainable. The reason why water is inefficient and getting worse is due to electric power interruption, town development/town expansion, inadequacy of pressure, high amount of water delivered out of the town, population growth and inconsiderable consumption which outstripped its ability to supply sufficient water for its inhabitants.

The only and main potable water source for the existing water supply system is only groundwater which reaches the customers or end users through private meter connection and public water point. However, since the source is decreasing in amount of production it is not adequate even for those who have access to it. The amount of production is also further reduced by lower number of working hours (because of hydroelectric power interruption), low capacity of boreholes and through losses (mechanical, frictional head loss and leakage).

In addition to these, the state of water supply in the town in terms of coverage of spatial and population reliability, accessibility, and sustainability are not at the required standard. The distribution system is also inefficient (pressure and velocity). The major constraints of distribution systems identified are partially inadequate nodal pressure and low flow velocity. As a result, water consumption is affected in the town due to these physical factors and socioeconomic factors such as population growth, household income, married and single and size that affected their water consumption.

The water tariff set in the town is not properly performing and does not enable the office to cover all costs of the service to fulfill principles of cost recovery. This is because of the fact that the price does not charge additional fee on volume of water consumption. After a certain limit of consumption the customers pay the lowest price for high volume of water consumption. Such price charging, subsidized the rich and favors water vendors. The majority of the victims of the problem are the poor as they cannot afford the connection charges.

Because of high interruption of hydroelectric power and absence of water, from the existing water supply service, most of the households in the town are interested for additional water supply expansion work. From the total of 258 sample households (97.7%) have expansion work interest the remaining 2.3% have no interest. High interest of expansion work indicated that the improved water service is inefficient and have future demand. This shows that, WSSO should have produced additional water if it has really been better water supply service giving body than the existing one.

Hence the problems of water supply in Arerti town are multidimensional in terms of efficiency (service coverage, equal distribution, etc.) and equity. Among the challenges identified, inadequate water supply, inequitable and inefficient distribution and imbalance of demand and supply high amount of water delivered out of the town, unfair and the resultant limited consumption are the major ones. These problems imposed different challenges on inhabitants such as loss of time, energy and money; exposure to water related disease which penalizes the poor medical cost and high price for water vendors.

The present and future demand is greater than the existing supply. Calculated average total demand in 2014 was 1548.13m^3/d; but, the total supply in the same year is 832.6m^3/d. By this condition, the deficit of supply is 715.53m^3/d. For achievement of 2020 GTP-II plan, the supply deficit is 2467.8 m^3/d which means there is a need of 28.56 l/s of additional water and for the end of this design period (2026) the need of additional water is 50.57l/s. The problem is coming from high town development, continuous hydroelectric interruption, high amount of water delivered out of the town and population increments are the major one.

The pressure at some node is bellow given standard by MoWR which is between 15 and 70m. But, the model result showed as between 2 and 50 which mean some nodes are below standard level. To alleviating this problem the system need minimum of two zones.

5.2. Recommendation

This research has revealed existing condition and consequences of inadequate water supply (parameter of sustainable), demand and supply gap, distribution system hydraulic performance and challenges & courses for unsustainable water in Arerti town to the utility and higher governmental organ for further work.

Alleviating the existing water supply problem in the town in terms of quantity, reliability and sustainability means keeping the town people from sever water problem and also the surrounding Kebeles. Thus, the following improving recommendation needs to be taken to reverse the existing challenges:

- Provide water for the surrounding community: presently the surrounding rural community has no potable water around their home except town water for daily consumption. And also in every year, especially in peak dry season, the water is delivered out of the town up to 45 km for emergency water supply. So, to reduce the amount of water delivered out of the town, any concerned body as much as possible should be provided potable water for rural community at their habitats. It is directly sustain town water supply and indirectly keep the rural community from many problems.
- Use alternative power sources: the study area found in rift valley zone. These means the area found in long dry or sunny period area. This situation is good for solar energy power. So, to reducing water interruption by means of hydroelectric power interrupting and increasing water production by long term plan, the utility should be use solar energy instead of hydroelectric power or diesel generator.
- Conduct detail study: conduct detail study on underground water to create additional source of water supply if environmental and financial condition allow. Planning on the development of adequate, reliable, sustainable and efficient water supply should be plan based on approximately approaches to real condition of the existing need and willingness to pay of the people.
- Demand and supply management: demand and supply management must be considered the existing condition of the town. Which means demand and supply information should be updated with town development and each category of demand rather old experience. In most of the time demand is not determined on

recorded data rather determining by supply. This kind of demand determination, open for supply and demand gap. So, the demand and supply plan should be stand from the recorded and reliable data. And the utility practice recording of amount of water required for the town under each category.

- ❖ Use existed best alternatives: presently there are two existing best alternatives; one is 6m elevated and 50m^3 capacity tank in the same compound of main reservoir. This is currently not properly functioning. So, to overcome pressure problem around the main reservoir (tank) and specified in this study the elevated tank should be join with them. The other is 350m deep and 37 l/se capacity BH is found on upper part of the town in best place as test-well idly in "BoloSilase" Kebele. So, to increase more than double and above of the current water production as a whole by single source with low management cost the utility and the concerned body should be use this alternative as further and current sustainability.

- ❖ Faire distribution of water: for faire distribution of water the utility should be use zoning system rather clos and opening get valves and for the poor community reopening the closed public water pointes. Accessibility and the required amount of water are taken in to consideration.

- ❖ Use alternative water source with pipe water: pipe water should be used only for domestic demand and some commercial and public demand. The other demand such as animal watering and agricultural purpose use other source such as river and traditional pond.

- ❖ Technology adaptation: for easily managing of the whole system up-to-date technology should be applied. So, to model the system as a whole or partly should be use appropriate technology or modeling material such as waterCAD, EPANET or other.

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APPENDICES

Appendix 1 Questionnaires for Sample Households in Ararti town

This questionnaire is prepared as an instrument to conduct an academic research for the fulfillment of degree of Master of Science (M.Sc.) in Jimma University, Institute of Technology, Department of Hydraulic Engineering. The main objective of the research is to evaluated the system and assess the challenges of sustainable water supply in Ararti town. Therefore the information you give to me is very important for the research. Furthermore, the information you give will be used for only the academic research.

Thank you for your cooperation.

I. Background

1. Kebele --------
2. Ketena ---------
3. Sex -------------
4. Age ------------
5. Marital status:-

a) Married **b)** Single **c)** Widowed **d)** Divorced

6. Educational level:-

a) Unable to read and write (illiterate) **b)** Primary school (1-8 Grade)

c) 12 Grade **d)** Diploma and above

7. Number of family member's (Male and Female)
8. House ownership:-

a) Government **b)** Private **c)** Rent **d)** Other--------

9. Income source of the family:-

a) Business/peaty trade **b)** Government employee **c)** Daily labor

d) Retired **e)** Farming **f)** If others specify

10. Prioritize the social service you need. (Water, Road, Health, Education, Electricity, Telephone, etc.) 1^{st}, 2^{nd}, 3^{rd}

II. Status of the existing Water Supply system

Issues related with water sources, consumption, quantity and current status.

1. What is the main source of drinking water for your household?

Sources	Dry season (Bega)	Rainy season (Kiremit)
Dug well		
Traditional pond		
stand pipe Public		
Rainwater harvesting		
River		
Tape water		
Other (specify)		

2. Do you have secondary source of water for drinking? (Yes or No)
3. During dry season distance of water source from your home (meters, kilometers)
4. Time required to the nearest alternative source of water (minutes, hours).
5. What is the main source of water used by your household for other purposes, such as cooking and washing?

Sources	Dry season (Bega)	Rainy season (Kiremit)
Public tap/stand pipe		
well/borehole		
Protected dug well		
Surface water (River, pond, stream)		
Unprotected dug well		
Harvested Rain water		

6. Is the water point secure? (Yes or No)
7. Do you use water for toilet? (Yes or No)
8. If your answer for Q No 7 is Yes, How much liter of water do you use per day?
9. Do you have a livestock? (Yes or No)
10. If your answer for Q No 9 is Yes, How much liter of water do you need per day for livestock?

11. Who is the responsible body to fetch water for your domestic consumption? Sex: Male (age under15, above 15) Female (age under15, above 15)

12. The water born disease from the main or alternative sources in the past one year:

  a) Affected my households

  b) Not affected my households

13. What container do you use to fetch water mainly?

14. What is the queuing up time at the water point? (Min, Max)

15. What kind of toilet facility your household members usually use?

A) Flush toilet B) Pour toilet C) Pit latrine D) Public toilet

E) No facility/bush/field/river courses

16. What type of connection you usually use for water supply in your home?

a) Private meter connection b) Yard connection c) Shared (public) meter connection

d) No connection

17. If your answer is Q 16 c, is the water tariff fair? (Yes or No)

18. Which connection type is your preference for your home?

  a) Private meter connection b) Yard connection c) Shared (public) meter connection

  d) No connection

19. Do you know the total amount of water used in your house? Please indicate unites of measurement (liters per day, liters per week).

20. On average how often do you receive piped water?

a) Continuous b) Once a day c) Twice a day d) Every other day e) Once a week

f) Twice a week g) Others Describe--------------------------------

21. If your answer is different from Q No 20a what is the main source of water supply variation? (if you know the reason list two main source of water supply variation)

  1 --

  2 --

22. Do you treat your water in any way to make it safer to drink?

  a) Yes b) No

23. Which method do you use if your answer is yes for question no 22?

a. Boil **b.** Water “Agar” c) Add chlorine d) Strain it through a cloth

f) If there is any other (specify)

24. Who is responsible for providing water in town?

A) Governmental organizations (Gos) B) Community based organization (CBO)

C) None governmental organizations (NGO) D) doesn't know

25. Is water equally distributed over the whole town? A) Yes b) No

26. . If 'No' why? Give your reason

27. Are there leakages at different levels? A) Yes b) No (by simple observation)

28. If 'Yes' what are the reasons?

a) Lack of maintenance and operation b) System distribution failure

c) Pipe breakage d) Mechanical loss e) head loss f) Bursting

29. From your experience when is more water supply interruption occurs:-

a) 'Bega' b) 'Kiremt' c) in all seasons

30. Are your neighboring rural kebeles affecting your town water supply? (Yes or No)

31. If your answer is "Yes" why? Give your reason.

32. Do you pay for water? a) yes b)No

33. If 'YES' which type of tariff is used in your area?

a) By flat rete charge b) based on progressive meter reading

34. Is the current tariff expensive? A) Yes B) No

35. Are you willing to pay for improved water supply? A)Yes B)No

36. If "YES" willing to pay vales per "Jerikan" in Birr.

37. What are your comments for achieving sustainability (all season supply) of water services in your town?

III. Key Informant Interview

1. How is the technical capacity of ATWSSO to manage the system? Regarding training.
2. How much is the water use tariff? When was set? Did it take in to account the different socio-economic conditions of the society (users)?
3. How do you explain the functionality of the systems in the town developed?
4. How do you see the schemes capacity/ability to meet the water demand of its user community?
5. Have your organization followed demand driven approach?
6. Are there any complaints by the user community on the quality of the water

delivered?

7. If the scheme gets dry during some period in a year, when does it dry (which months)? If the scheme provides low quantity of water, what do you think the reason to be for the low quantity of water supplied by the scheme?
8. Is the water supply project providing water only for the town?
9. If “No” Which group demanding from the town water supply?
10. How much liters of water delivered per day out of the town?
11. What is your source for supply, ground or surface water?
12. What is the trend of demand over supply of water in the town?
13. If there is shortage of water, what are the causes?
14. Do you think water is fairly distributed over the town?
15. How do you see water supply management of the town?
16. What are the major solutions that can be raised to overcome the challenges of water supply systems?

IV. Check list for focus group discussion

1. What is the alternative source? When do you use the alternative sources?
2. For what purpose do you use the water from the main source and alternatives?
3. Is the water sufficiently good for drinking? If not, please state why?
4. For how many days of a week do you receive water?
5. Is the existing water price of Arerti town is reasonable?
6. Do the existing water supply service is satisfactory?
7. What are the major challenges of sustainable water supply system of the town?
8. If the scheme provides low quantity of water, what do you think the reason to be for the low quantity of water supplied by the scheme?
9. What do you suggest about water supply management in your town?

Comment on possible solutions to address water supply problem at hand?

Appendix 2 Water demand calculation factors

Appendix Table1 Climatic adjustment factors

Group	Altitude	Factor
A	>3300	0.8
B	2300-3300	0.9
C	1500-2300	1.0
D	500-1500	1.3
E	<500	1.5

Source: Design Guideline for Water Supply Projects, Oromia Water Works Design and Supervision Enterprise (December, 2008)

Appendix Table 2 Socio-Economic Grouping

Group	Description	Factor
A	Towns enjoying high living standards and with very high potential for development	1.10
B	Towns having a very high potential for development but lower living standard at present	1.05
C	Towns under normal Ethiopian conditions	1.00
D	Advanced Rural Towns	0.90

Source: MoWR, 2006

Appendix Table 3 Maximum Daily Coefficient

Total Average Daily Requirement (m^3/d)	Maximum Daily Coefficient
200	2
3000	1.55
40000	1.45
300000	1.35

Appendix Table 4 Peak Hour Factor

Town Population	Peak Hour Factors
<20,000	2
20,001-50,000	1.9
50,001-100,000	1.8
>100,000	1.6

Source: MoWR, 2006

Appendix 3 some study results

Appendix Table 5 Interests of water supply expansion work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	252	97.7	97.7	97.7
	No	6	2.3	2.3	100.0
	Total	258	100.0	100.0	

Appendix Table 6 Amount of water delivered out of the town June 20 - July 19 /2015 (a month)

Date	water delivered out of the town "Jerican" per day							
	Kolegna ber	Kembolisha ber	Modjo and Addis Abeba ber	Buliga ber	Balichi Town ber	Total Jerican	Average liter 25	m3/day
satar day20	2000	1350	1400	1600	150	6500	162500	162.5
21	1800	1200	1300	1500	400	6200	155000	155
22	1600	1400	1030	1880	700	6610	165250	165.25
23	1200	1058	700	1450	100	4508	112700	112.7
24	1500	800	1000	1040	156	4496	112400	112.4
25	1800	1038	1500	1450	350	6138	153450	153.45
26	2008	880	933	1089	253	5163	129075	129.075
27	1500	800	1000	1040	156	4496	112400	112.4
28	1800	1038	1500	1450	350	6138	153450	153.45
29	2008	880	933	1089	253	5163	129075	129.075
30	2236	1350	1400	1600	150	6736	168400	168.4
1	1899	1200	1300	1605	555	6559	163975	163.975
2	1747	1400	1030	1880	831	6888	172200	172.2
3	1388	1058	700	2018	129	5293	132325	132.325
4	2489	1350	1400	1637	150	7026	175650	175.65
5	2058	1200	1600	1500	402	6760	169000	169
6	1849	1400	1030	1880	699	6858	171450	171.45
7	2054	1058	700	1000	100	4912	122800	122.8
8	1500	800	143	1040	156	3639	90975	90.975
9	1800	1038	1500	1450	501	6289	157225	157.225
10	2008	880	933	1089	253	5163	129075	129.075
11	2000	1003	1243	1082	334	5662	141550	141.55
12	1800	1038	1500	1608	350	6296	157400	157.4
13	2008	1436	933	1089	253	5719	142975	142.975
14	2000	1350	1360	1809	150	6669	166725	166.725
15	1800	1200	1499	1500	450	6449	161225	161.225
16	1600	1400	1078	1890	800	6768	169200	169.2
17	1200	1058	700	1800	139	4897	122425	122.425
18	2000	1350	1400	1680	150	6580	164500	164.5
19	1800	1200	1300	1500	422	6222	155550	155.55
							4419925	4419.93
							4419.93	147.331

Appendix Table 7 People they have livestock or not

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	123	47.7	47.7	47.7
	No	130	50.4	50.4	98.1
	3	5	1.9	1.9	100.0
	Total	258	100.0	100.0	

amount of water use for animal liter per day per household		
N	Valid	258
	Missing	0
Mean		25.75

Appendix Table 8 Junction, household, population and base demand

Name	Easting	Northing	Elevation	HHs	Population	Demand
Reservoir	546732	986670	1818			
J-1	547043	986570	1772	40	200	0.13
J-2	546894	986351	1770	70	350	0.22
J-3	546767	986424	1783	84	420	0.27
J-4	546686	986308	1780	43	215	0.14
J-5	546773	986249	1774	44	220	0.14
J-6	546634	986224	1781	70	350	0.22
J-7	546553	986098	1776	38	190	0.12
J-8	546523	986053	1775	60	300	0.19
J-9	546421	986117	1782	150	750	0.48
J-10	546333	986168	1792	70	350	0.22
J-11	546346	986219	1802	41	205	0.13
J-12	546187	986147	1802	310	1550	0.99
J-13(T)	546271	986356	1800	0	0	0.00
J-14	546354	986449	1804	51	255	0.16
J-15	546362	986452	1803	78	390	0.25
J-16	546465	986505	1805	62	310	0.20
J-17	546596	986584	1813	28	140	0.09
J-18	546623	986653	1812	64	320	0.20
J-19	546669	986700	1816	112	560	0.36
J-20	546730	986806	1813	51	255	0.16
J-21	546751	986857	1805	52	260	0.17
J-22	546810	986964	1797	53	265	0.17
J-23	546954	986969	1792	120	600	0.38
J-24	547042	986924	1792	135	675	0.43
J-25	546923	986783	1805	130	650	0.42
J-26	546840	986656	1802	39	195	0.12
J-27	546902	986623	1787	55	275	0.18

J-28	546622	986548	1795	47	235	0.15
J-29	546727	986447	1785	30	150	0.10
J-30	546791	986865	1815	22	110	0.07
J-31	546832	986899	1805	51	255	0.16
J-32	546158	986156	1799	34	170	0.11
J-33	546058	986062	1799	45	225	0.14
J-34	546021	986121	1799	80	400	0.26
J-35	546001	986156	1798	80	400	0.26
J-36(B)	545982	986209	1796	0	0	0.00
J-37	546069	986336	1802	56	280	0.18
J-38	546089	986382	1802	54	270	0.17
J-39	545967	986387	1800	37	185	0.12
J-40	545831	986388	1798	83	415	0.27
J-41	545834	986546	1799	83	415	0.27
J-42	545965	986547	1799	38	190	0.12
J-43	545893	986652	1801	31	155	0.10
J-44	545896	986859	1800	83	415	0.27
J-45(B)	546061	986855	1803	0	0	0.00
J-46	546127	986947	1798	116	580	0.37
J-47	546210	986904	1804	52	260	0.17
J-48	546354	987102	1803	62	310	0.20
J-49	546546	987365	1794	43	215	0.14
J-50	546686	987293	1797	200	1000	0.64
J-51	546941	987618	1800	80	400	0.26
J-52	547027	987902	1790	40	200	0.13
J-53	547038	987538	1797	83	415	0.27
J-54	547110	987887	1791	30	150	0.10
J-55	547137	988025	1785	30	150	0.10
J-56	547415	988227	1768	30	150	0.10
J-57	547109	987215	1786	76	380	0.24
J-58	547086	987212	1794	56	280	0.18

J-59	546903	987230	1793	120	600	0.38
J-60	546819	987202	1799	54	270	0.17
J-61	546791	987191	1812	40	200	0.13
J-62	546654	987087	1806	50	250	0.16
J-63	546536	986918	1809	170	850	0.54
J-64	546708	986824	1813	117	585	0.37
J-65	546723	986866	1816	65	325	0.21
J-66	546753	986941	1814	50	250	0.16
J-67	546804	986992	1808	53	265	0.17
J-68	546907	986991	1806	112	560	0.36
J-69	547124	987167	1777	122	610	0.39
J-70	547346	987828	1773	25	125	0.08
J-71	546007	986547	1800	83	415	0.27
J-72	546007	986560	1800	31	155	0.10
J-73	546010	986651	1802	31	155	0.10
J-74	546156	986651	1804	120	600	0.38
J-75	546122	986453	1803	56	280	0.18
J-76	546197	986254	1800	65	325	0.21
J-77	546246	986367	1803	90	450	0.29
J-78	546586	986663	1811	110	550	0.35
J-79	545893	986552	1800	31	155	0.10
J-80	547144	987502	1785	53	265	0.17
J-81	547248	988046	1786	80	400	0.26
J-82	547080	897517	1796	40	200	0.13
J-83	546305	986859	1805	33	161	0.10

Appendix Table 9 Minimum, base and maximum demand

Label	Easting (m)	Northing (m)	Elevation (m)	Min. D(l/s)	Bese D (l/s)	Peak D(l/s)
J-1	547043	986570	1,772.00	0.01	0.13	0.25
J-2	546894	986351	1,770.00	0.02	0.22	0.42
J-3	546767	986424	1,783.00	0.03	0.27	0.51
J-4	546686	986308	1,780.00	0.01	0.14	0.27
J-5	546773	986249	1,774.00	0.01	0.14	0.27
J-6	546634	986224	1,781.00	0.02	0.22	0.42
J-7	546553	986098	1,776.00	0.01	0.12	0.23
J-8	546523	986053	1,775.00	0.02	0.19	0.36
J-9	546421	986117	1,782.00	0.05	0.48	0.91
J-10	546333	986168	1,792.00	0.02	0.22	0.42
J-11	546346	986219	1,802.00	0.01	0.13	0.25
J-12	546187	986147	1,802.00	0.1	0.99	1.88
J-13(T)	546271	986356	1,800.00	0	0	0
J-14	546354	986449	1,804.00	0.02	0.16	0.3
J-15	546362	986452	1,803.00	0.03	0.25	0.48
J-16	546465	986505	1,805.00	0.02	0.2	0.38
J-17	546596	986584	1,813.00	0.01	0.09	0.17
J-18	546623	986653	1,812.00	0.02	0.2	0.38
J-19	546669	986700	1,816.00	0.04	0.36	0.68
J-20	546730	986806	1,815.00	0.02	0.16	0.3
J-21	546751	986857	1,805.00	0.02	0.17	0.32
J-22	546810	986964	1,797.00	0.02	0.17	0.32
J-23	546954	986969	1,792.00	0.04	0.38	0.72
J-24	547042	986924	1,792.00	0.04	0.43	0.82
J-25	546923	986783	1,805.00	0.04	0.42	0.8
J-26	546840	986656	1,802.00	0.01	0.12	0.23

J-27	546902	986623	1,787.00	0.02	0.18	0.34
J-28	546622	986548	1,795.00	0.02	0.15	0.28
J-29	546727	986447	1,785.00	0.01	0.1	0.19
J-30	546791	986865	1,815.00	0.01	0.07	0.13
J-31	546832	986899	1,805.00	0.02	0.16	0.3
J-32	546158	986156	1,799.00	0.01	0.11	0.21
J-33	546058	986062	1,799.00	0.01	0.14	0.27
J-34	546021	986121	1,799.00	0.03	0.26	0.49
J-35	546001	986156	1,798.00	0.03	0.26	0.49
J-36(B)	545982	986209	1,796.00	0	0	0
J-37	546069	986336	1,802.00	0.02	0.18	0.34
J-38	546089	986382	1,802.00	0.02	0.17	0.32
J-39	545967	986387	1,800.00	0.01	0.12	0.23
J-40	545831	986388	1,798.00	0.03	0.27	0.51
J-41	545834	986546	1,799.00	0.03	0.27	0.51
J-42	545965	986547	1,799.00	0.01	0.12	0.23
J-43	545893	986652	1,801.00	0.01	0.1	0.19
J-44	545896	986859	1,800.00	0.03	0.27	0.51
J-45(B)	546061	986855	1,803.00	0	0	0
J-46	546127	986947	1,798.00	0.04	0.37	0.7
J-47	546210	986904	1,804.00	0.02	0.17	0.32
J-48	546354	987102	1,803.00	0.02	0.2	0.38
J-49	546546	987365	1,794.00	0.01	0.14	0.27
J-50	546686	987293	1,797.00	0.06	0.64	1.22
J-51	546941	987618	1,800.00	0.03	0.26	0.49
J-52	547027	987902	1,790.00	0.01	0.13	0.25
J-53	547038	987538	1,797.00	0.03	0.27	0.51
J-54	547110	987887	1,791.00	0.01	0.1	0.19
J-55	547137	988025	1,785.00	0.01	0.1	0.19
J-56	547415	988227	1,768.00	0.01	0.1	0.19
J-57	547109	987215	1,786.00	0.02	0.24	0.46

J-58	547086	987212	1,794.00	0.02	0.18	0.34
J-59	546903	987230	1,793.00	0.04	0.38	0.72
J-60	546819	987202	1,799.00	0.02	0.17	0.32
J-61	546791	987191	1,812.00	0.01	0.13	0.25
J-62	546654	987087	1,806.00	0.02	0.16	0.3
J-63	546536	986918	1,809.00	0.05	0.54	1.03
J-64	546708	986824	1,813.00	0.04	0.37	0.7
J-65	546723	986866	1,816.00	0.02	0.21	0.4
J-66	546753	986941	1,814.00	0.02	0.16	0.3
J-67	546804	986992	1,808.00	0.02	0.17	0.32
J-68	546907	986991	1,806.00	0.04	0.36	0.68
J-69	547124	987167	1,777.00	0.04	0.39	0.74
J-70	547346	987828	1,773.00	0.01	0.08	0.15
J-71	546007	986547	1,800.00	0.03	0.27	0.51
J-72	546007	986560	1,800.00	0.01	0.1	0.19
J-73	546010	986651	1,802.00	0.01	0.1	0.19
J-74	546156	986651	1,804.00	0.04	0.38	0.72
J-75	546122	986453	1,803.00	0.02	0.18	0.34
J-76	546197	986254	1,800.00	0.02	0.21	0.4
J-77	546246	986367	1,803.00	0.03	0.29	0.55
J-78	546586	986663	1,811.00	0.03	0.35	0.66
J-79	545893	986552	1,800.00	0.01	0.1	0.19
J-80	547144	987502	1,785.00	0.02	0.17	0.32
J-81	547248	988046	1,786.00	0.03	0.26	0.49
J-82	547080	987517	1,796.00	0.01	0.13	0.25
J-83	546305	986859	1,805.00	0.01	0.1	0.19

Appendix Table 10 Hourly pressure variation

Label	0:00	3:00	6:00	9:00	12:00	15:00	18:00	21:00	12:00	Remarik
	Time with 3 hours interval(hr)									
	Pressure (m H2O)									
J-1	46	47	48	48	48	47	47	46	47	
J-2	48	49	49	49	49	48	47	48	49	
J-3	35	36	36	36	36	35	34	35	36	
J-4	38	39	39	39	39	38	37	38	39	
J-5	44	45	45	45	44	44	43	44	45	
J-6	37	38	38	38	38	37	36	37	38	
J-7	42	43	43	43	43	42	41	42	43	
J-8	43	44	45	44	44	43	42	43	44	
J-9	36	37	38	37	37	36	35	36	37	
J-10	26	27	28	27	27	27	25	26	27	
J-11	16	17	18	17	17	17	16	16	17	
J-12	16	17	18	18	17	17	16	16	17	
J-13(T)	18	19	20	20	19	19	18	18	19	
J-14	14*	15	16	16	15	15	14*	14*	15	*=BSL
J-15	15	16	17	17	16	16	15	15	16	
J-16	13*	14*	15	15	15	14	14	13	14	
J-17	5*	6*	7*	7*	7*	6*	6*	5*	6*	
J-18	6*	7*	8*	8*	8*	8*	7*	6*	7*	
J-19	2*	3*	5*	5*	4*	4*	3*	2*	3*	
J-20	3*	4*	5*	5*	5*	5*	4*	3*	4*	
J-21	13*	14*	15	15	15	15	14*	13*	14*	
J-22	21	22	23	23	23	22	22	21	22	
J-23	26	27	28	28	28	27	27	26	27	
J-24	26	27	28	28	28	27	27	26	27	
J-25	13*	14*	15	15	15	14*	14*	13*	14*	
J-26	16	17	18	18	18	17	17	16	17	

J-27	31	32	33	33	33	32	32	31	32
J-28	23	24	25	25	25	24	24	23	24
J-29	33	34	35	35	35	34	34	33	34
J-30	3*	4*	5*	5*	5*	4*	4*	3*	4*
J-31	13*	14*	15	15	15	14*	14*	13*	14*
J-32	19	20	21	21	20	20	19	19	20
J-33	19	20	21	20	20	20	19	19	20
J-34	19	20	21	20	20	20	18	19	20
J-35	20	21	22	21	21	21	19	20	21
J-36(B)	22	23	24	23	23	23	21	22	23
J-37	16	17	18	17	17	17	15	16	17
J-38	16	17	18	17	17	17	15	16	17
J-39	18	19	20	19	19	18	17	18	19
J-40	20	21	22	21	21	20	19	20	21
J-41	19	20	20	20	19	19	18	19	20
J-42	19	20	20	19	19	19	17	19	20
J-43	17	18	18	18	17	17	16	17	18
J-44	18	19	19	19	18	18	16	18	19
J-45(B)	15	16	16	16	15	15	13*	15	16
J-46	20	21	22	22	21	21	20	20	21
J-47	14*	15	16	16	15	15	14*	14*	15
J-48	15	16	17	17	16	16	15	15	16
J-49	24	25	26	26	25	25	24	24	25
J-50	21	22	23	23	22	22	21	21	22
J-51	18	19	20	19	19	18	17	18	19
J-52	28	29	30	29	29	28	27	28	29
J-53	21	22	22	22	21	21	20	21	22
J-54	27	28	28	27	27	27	25	26	27
J-55	33	34	33	32	32	31	29	32	33
J-56	50	51	51	50	49	49	47	49	50
J-57	32	33	33	32	32	31	29	31	32

J-58	24	25	25	24	24	23	22	23	24
J-59	25	26	26	26	25	25	24	25	26
J-60	19	20	21	21	21	20	20	19	20
J-61	6*	7*	8*	8*	7*	7*	6*	6*	7*
J-62	12*	13*	14*	14*	13*	13*	12*	12*	13*
J-63	9*	10*	11*	11*	10*	10*	9*	9*	10*
J-64	5*	6*	7*	7*	6*	6*	5*	5*	6*
J-65	2*	3*	4*	4*	3*	3*	2*	2*	3*
J-66	4*	5*	6*	6*	5*	5*	4*	4*	5*
J-67	10*	11*	12*	12*	12*	11*	11*	10*	11*
J-68	12*	13*	14*	14*	13*	13*	12*	12*	13*
J-69	41	42	43	43	43	42	42	41	42
J-70	45	46	47	47	47	46	46	45	46
J-71	18	19	19	18	18	18	16	18	19
J-72	18	19	19	19	18	18	16	18	19
J-73	16	17	17	17	16	16	15	16	17
J-74	14*	15	16	15	15	15	14*	14*	15
J-75	15	16	17	16	16	16	15	15	16
J-76	18	19	20	20	19	19	18	18	19
J-77	15	16	17	17	16	16	15	15	16
J-78	7*	8*	9*	9*	9*	9*	8*	7*	8*
J-79	18	19	19	19	18	18	17	18	19
J-80	33	34	34	33	33	32	31	32	33
J-81	31	33	31	29	30	29	26	30	32
J-82	22	23	23	22	22	22	20	22	23
J-83	13	14	15	15	15	14	14	13	14

*BSL- Below standard level

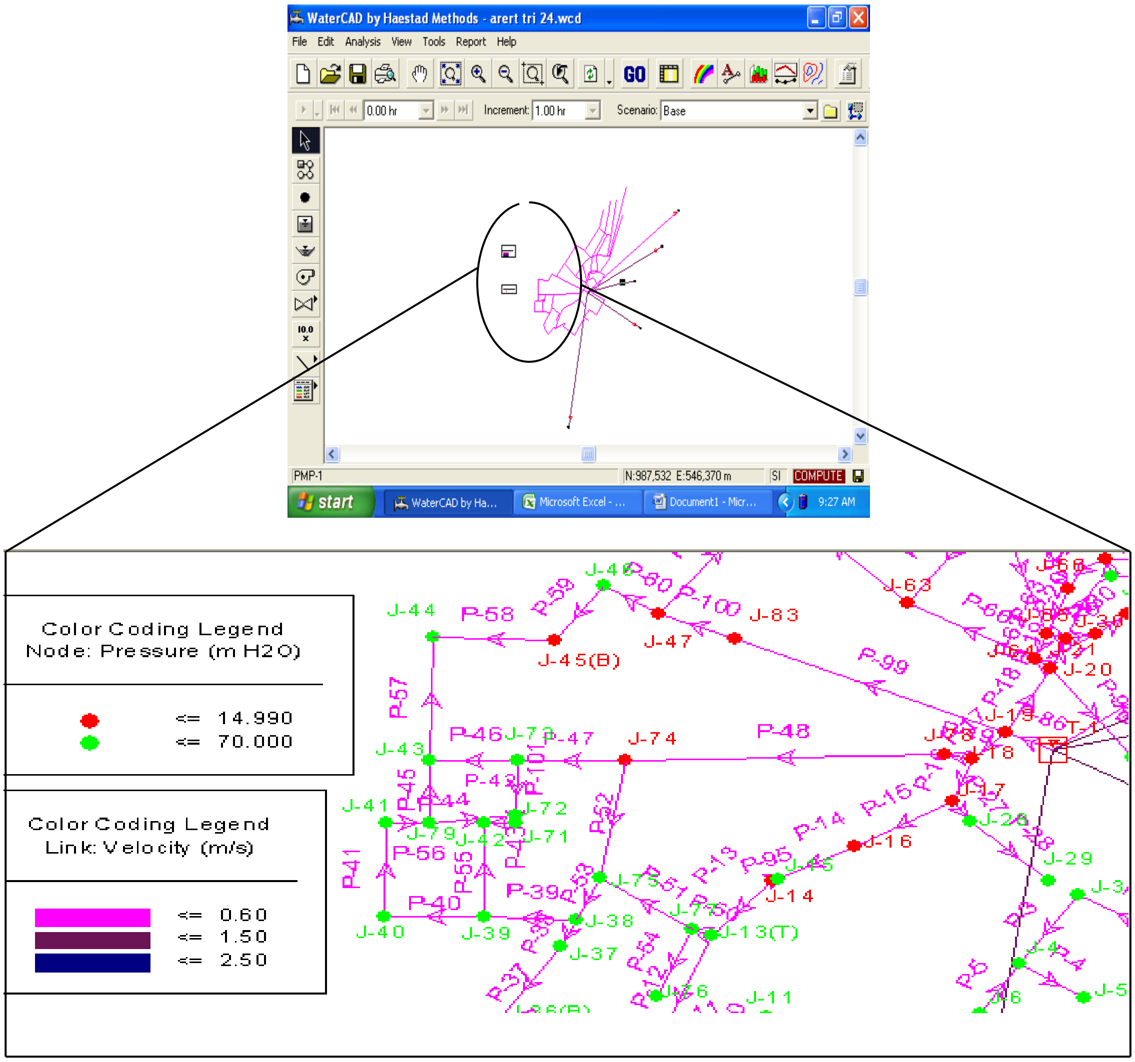
Appendix Table 11 WaterCAD result of pipe length, diameter, material, discharge and status of existing water distribution line.

Label	Length (m)	Diameter (mm)	Material	Velocity (m/s)	Discharge (l/s)	Initial Status	Start Node	Stop Node
P-1	300	50	PVC	0.14	0.27	Open	J-1	J-2
P-2	148	100	PVC	0.02	0.16	Open	J-2	J-3
P-3	147	80	PVC	0	0.02	Open	J-3	J-4
P-4	100	50	GI	0.04	0.07	Open	J-4	J-5
P-5	92	80	uPVC	0.02	-0.12	Open	J-4	J-6
P-6	152	80	uPVC	0.05	-0.23	Open	J-6	J-7
P-7	57	80	uPVC	0.06	-0.29	Open	J-7	J-8
P-8	119	80	uPVC	0.08	-0.38	Open	J-8	J-9
P-9	101	80	uPVC	0.12	-0.62	Open	J-9	J-10
P-10	131	100	uPVC	0.09	-0.73	Open	J-10	J-11
P-11	200	100	uPVC	0.1	-0.8	Open	J-11	J-12
P-12	246	150	uPVC	0.09	-1.65	Open	J-12	J-13(T)
P-13	131	150	uPVC	0.14	-2.56	Open	J-13(T)	J-14
P-14	112	150	uPVC	0.16	-2.76	Open	J-14	J-16
P-15	152	150	uPVC	0.16	-2.86	Open	J-16	J-17
P-16	152	150	uPVC	0.17	-3.03	Open	J-17	J-18
P-17	77	200	uPVC	0.13	-3.94	Open	J-18	J-19
P-18	105	200	uPVC	0.14	4.29	Open	J-19	J-20
P-19	67	200	uPVC	0.12	3.65	Open	J-20	J-21
P-20	260	200	uPVC	0.11	3.39	Open	J-21	J-22
P-21	145	200	uPVC	0.03	0.96	Open	J-22	J-23
P-22	107	100	uPVC	0.07	0.53	Open	J-23	J-24
P-23	203	80	uPVC	0.06	0.32	Open	J-24	J-25
P-24	228	80	uPVC	0.03	0.17	Open	J-25	J-26
P-25	40	100	uPVC	0.04	0.29	Open	J-26	J-27
P-26	229	100	uPVC	0.03	0.2	Open	J-27	J-1
P-27	40	100	uPVC	0.02	0.13	Open	J-17	J-28
P-28	130	100	uPVC	0.01	0.05	Open	J-28	J-29
P-29	50	50	GI	0.09	0.18	Open	J-21	J-30
P-30	60	50	GI	0.07	0.14	Open	J-30	J-31
P-31	140	50	GI	0.03	0.06	Open	J-31	J-25
P-32	50	80	uPVC	0.07	0.35	Open	J-12	J-32
P-33	131	80	uPVC	0.06	0.3	Open	J-32	J-33
P-34	80	50	uPVC	0.12	0.23	Open	J-33	J-34
P-35	45	50	uPVC	0.05	0.1	Open	J-34	J-35

P-36	35	50	uPVC	0.02	-0.03	Open	J-35	J-36(B)
P-37	189	80	uPVC	0.01	-0.03	Open	J-36(B)	J-37
P-38	51	80	uPVC	0.02	-0.12	Open	J-37	J-38
P-39	125	80	uPVC	0.09	0.44	Open	J-38	J-39
P-40	138	80	uPVC	0.07	0.34	Open	J-39	J-40
P-41	161	50	uPVC	0.11	0.21	Open	J-40	J-41
P-42	40	25	uPVC	0.05	-0.02	Open	J-42	J-71
P-43	10	50	GI	0.08	-0.16	Open	J-71	J-72
P-44	115	25	GI	0.03	-0.02	Open	J-72	J-79
P-45	105	50	uPVC	0	0.01	Open	J-79	J-43
P-46	115	50	uPVC	0.06	-0.12	Open	J-43	J-73
P-47	100	50	uPVC	0.18	-0.36	Open	J-73	J-74
P-48	500	80	uPVC	0.13	-0.63	Open	J-74	J-78
P-49	50	80	uPVC	0.16	-0.8	Open	J-78	J-18
P-50	50	150	uPVC	0.05	0.91	Open	J-13(T)	J-77
P-51	153	80	uPVC	0.13	0.66	Open	J-77	J-75
P-52	208	80	uPVC	0.02	-0.08	Open	J-75	J-74
P-53	73	80	uPVC	0.13	0.65	Open	J-75	J-38
P-54	126	80	uPVC	0.02	0.1	Open	J-77	J-76
P-55	160	25	GI	0.07	-0.04	Open	J-42	J-39
P-56	61	50	uPVC	0.04	-0.07	Open	J-79	J-41
P-57	200	50	uPVC	0.04	0.08	Open	J-43	J-44
P-58	171	80	uPVC	0.01	-0.06	Open	J-44	J-45(B)
P-59	103	25	GI	0.12	-0.06	Open	J-45(B)	J-46
P-60	106	80	uPVC	0.05	-0.24	Open	J-46	J-47
P-61	100	50	uPVC	0.19	0.38	Open	J-20	J-64
P-62	50	50	GI	0.04	-0.07	Open	J-64	J-65
P-63	100	50	GI	0.08	-0.15	Open	J-65	J-66
P-64	70	50	GI	0.12	-0.23	Open	J-66	J-67
P-65	98	50	GI	0.11	0.22	Open	J-67	J-68
P-66	178	100	uPVC	0.03	0.27	Open	J-64	J-63
P-67	213	80	uPVC	0.05	-0.23	Open	J-63	J-62
P-68	169	80	uPVC	0.07	-0.34	Open	J-62	J-61
P-69	45	80	uPVC	0.22	-1.12	Open	J-61	J-60
P-70	100	50	uPVC	0.29	0.56	Open	J-60	J-59
P-71	200	50	uPVC	0.13	0.25	Open	J-59	J-58
P-72	100	50	uPVC	0.09	0.17	Open	J-58	J-57
P-73	292	80	uPVC	0.01	0.06	Open	J-47	J-48
P-74	326	80	uPVC	0.04	0.19	Open	J-48	J-49
P-75	159	80	uPVC	0.02	0.12	Open	J-49	J-50
P-76	133	80	uPVC	0.14	-0.72	Open	J-50	J-61

P-77	416	80	uPVC	0.1	0.51	Open	J-50	J-51
P-78	55	50	GI	0.16	0.32	Open	J-51	J-53
P-79	297	80	uPVC	0.04	0.22	Open	J-63	J-48
P-80	200	50	uPVC	0.01	-0.03	Open	J-65	J-62
P-81	50	150	uPVC	0.13	2.34	Open	J-22	J-67
P-82	215	150	uPVC	0.1	1.81	Open	J-67	J-60
P-83	410	25	uPVC	0.09	0.04	Open	J-60	J-53
P-84	264	100	uPVC	0.03	0.23	Open	J-23	J-69
P-85	241	25	GI	0.08	0.04	Open	J-68	J-59
P-86	68	250	uPVC	0.18	8.85	Open	T-1	J-19
P-87	298	50	uPVC	0.03	0.07	Open	J-51	J-52
P-88	400	50	GI	0.05	0.1	Open	J-53	J-54
P-89	223	25	GI	0.1	0.05	Open	J-54	J-55
P-90	700	50	uPVC	0.02	0.04	Open	J-69	J-70
P-91	1,100	50	uPVC	0.03	0.05	Open	J-57	J-56
P-92	300	25	uPVC	0.01	-0.01	Open	J-58	J-80
P-93	600	40	GI	0.1	0.13	Open	J-80	J-81
P-94	200	50	uPVC	0.09	0.18	Open	J-20	J-26
P-95	20	150	uPVC	0.01	-0.13	Open	J-15	J-14
P-96	60	50	GI	0.06	0.13	Open	J-53	J-82
P-97	132	50	GI	0.11	0.22	Open	J-82	J-80
P-98	340	75	GI	0.04	0.16	Open	J-59	J-82
P-99	472	80	uPVC	0.09	0.44	Open	J-19	J-83
P-100	58	50	uPVC	0.2	0.39	Open	J-83	J-47
P-101	100	50	uPVC	0.1	0.19	Open	J-73	J-72
P-102	1	75	GI	0.76	3.36	Open	R-2	PMP-2
P-103	1,900	75	GI	0.76	3.36	Open	PMP-2	T-1
P-104	1	100	GI	0.68	5.38	Open	R-4	PMP-4
P-105	900	100	GI	0.68	5.38	Open	PMP-4	T-1
P-106	1	100	GI	1.02	8.02	Open	R-3	PMP-3
P-107	1,300	100	GI	1.02	8.02	Open	PMP-3	T-1
P-108	1	100	GI	0.21	1.68	Open	R-1	PMP-1
P-109	1,900	80	GI	0.33	1.68	Open	PMP-1	T-1

Appendix 4 Appendix figures



Appendix Figure 1 Detail of existing distribution network (WaterCAD result).

Appendix Figure 2 water use for onion nursery

Appendix Figure 3 Current status of public water point (Source: field survey July 2015)

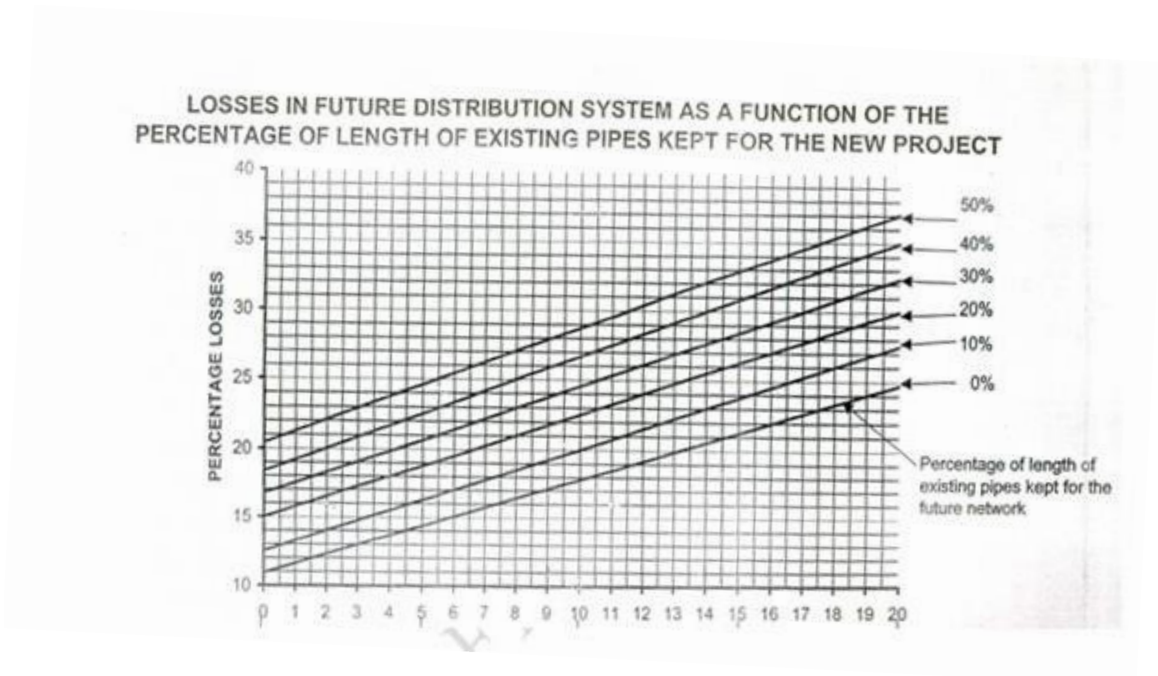
Appendix Figure 4 queuing up at “Ketena-3” WP and responsible body to fetch water (July 2015) (Source: field survey July 2015)

Appendix Figure 5 Surface (Main) and elevated water Tanks
(source: field survey Sepember 2015)

Appendix Figure 6 static water masearment at “Kechin Ashal” BH
(Source: field survey Sepember 2015)

Appendix Figure 7 Water delivered out of the town
(Source: field survey June - July 2015)

Appendix 5 Chart



Appendix Figure 8 Alexander Gibbs chart