JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING MASTERS PROGRAM

ANALYSIS OF WATER SUPPLY COVERAGE AND WATER LOSSES IN DISTRIBUTION SYSTEM; A CASE STUDY AMBO, ETHIOPIA

BY ASMAMAW HIRPESSA

A THESIS SUBMITTED TO JIMMA UNIVERSITY, JIMMA INSTITUTE OF TECHNOLOGY, FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING, ENVIRONMENTAL ENGINEERING CHAIR IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL ENGINEERING

MARCH, 2018

JIMMA, ETHIOPIA

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MARCH, 2018

JIMMA, ETHIOPIA

DECLARATION

This thesis is my original work and has not been presented for a degree in this university or any other university.

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This thesis has been submitted for examination with my approval as university supervisor

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Title: Water supply coverage and water losses in distribution system; a case study of Ambo town. I declare that the proposed research work has not been done anywhere else before or is not part of any ongoing work. We have agreed to supervise the proposed research work.

We have evaluated the contents of the research, found to be satisfactory, complete, and according to the standards and formats of the University. We have also verified that the work has not been done anywhere else before.

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ABSTRACT

The life of an individual is directly related to water. Inadequate water supply, unsafe water resources and inequitable access of water consume time, increase disease and costs of health facilities. This would finally lead to poverty in the area. Reduction of non-revenue water is one of the major challenges facing many water utilities in Ethiopia in general and Ambo water supply system in particular. So, the study focuses on analysis of water supply coverage and water losses in distribution system of Ambo town, using statistical analysis, water audit and water CAD software. A statistical analysis was applied to analyze the current water supply coverage of the entire town. Water audit software was used to analyze water loss components and the efficiency of the system was evaluated using Water CADv8i software. The result showed that the network is exposed to relatively low values of pressure and velocity, which has negative effect on the performance of the network. In assessing the water supply distribution coverage and the distribution network for the town and determining its hydraulic performance, Water CADv8i software has been used. The study indecates that an increase in loss of hydraulic reliability during water flow directly affect water quantity, the existing design of water distribution network of the town should be redesigned and hence this deduction gives room for developing the town in all directions, as the municipality is not clear about the future industrial zone and development area of the town.It was observed that the total water loss in Ambo water supply system is high reaching up to 24.41% of the system input volume and about 7.82% of the total system loss is real losses and 16.6% apparent losses. Besides, the average daily per capita water consumption of the town is 29.73 liter/person/day. In general, the low water supply coverage of the town was highly influenced by the availability of water. However, the main reasons for the high loss of water in Ambo water supply system are the present way of water network management with ad-hoc maintenance and insufficient financial resources of the utility. Thus, it is necessary to identify the losses encountered in the water supply system so as to take remedial actions in reducing the water loss more significantly.

Key words. Ambo town, analysis of water loss, population for cast, water supply coverage and water supply network.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ASOCE	American Society of Civil Engineering
AWWA	American Water Work Association
AWSSE	Ambo Water Supply & Sewerage Enterprise
CAD	Computer Aided Manual
CSA	Central Statistics Agency
DCI	Ductile Iron
DMA	District Meter Area
DUOT	Deift University of Technology
ECSCIOU	Ethiopian Civil Service College Institute of Urban
GI	Galvanized Iron
GIS	Geographical Information System
GPS	Global Positioning System
GTP	Growth and Transformation Plan
GWP	Global Water Partnership
HCU	House Connection Users
HDPE	High Density Polyvinyl Etoile
L/c/d	Liter per Capital per Day
L/p/d	Liter per Person per Day
MDGR	Millennium Development Goal Report
MDGs	Millennium Development Goals
MNF	Minimum Night Flow
MOWR	Ministry of Water Resources
NRW	Non Revenue Water
ODSWE	Oromia Design Supervise and Water Work Enterprise
PTU	Public Tap Users
(ROUMWE	Republic of Uganda Ministry of Water and Environment
SI	System International
SSA	Sub Sahara Africa
SWNDSS	Smart Water Network Decision Support System

UPVC	Un Plasticized Polyvinly Chloride
WBCSD	World Business Council for Sustainable Development
WDR	World Bank World Development Report
WDN	Water Distribution Network
WDS	Water Distribution System
WHO	World Health Organization
WSP	Water and Sanitation Program
YCO	Yard Connection Own Uses
YCS	Yard Connection Shared

CHAPTER ONE

INTRODUCTION

1.1 Back ground

All peoples, what ever their stage of development and social and economic condition, have the right to have access to drinking water in quantities and of a quality equal to their basic needs (WHO, 1997).

Water is the precious gift of nature, the source of prosperity, most crucial for sustaining life, basic to most economic activities and its role in human survival and health is well known. So, it is not exaggerate to say that supplying and distributing of adequate water form the foundation of contemporary life (NRC, 2006).

One of the principal roles of public work is providing water in sufficient quantity to users. Water supply and distribution is a complex system and that exists to satisfy the various needs of peoples. Where by, it consists of various components of physical assets including reservoirs, pipes, pumps, and different hydraulic controlling accessories that make up the water distribution system. It is generally desired that water should be supplied continuously in the required quantities with adequate pressure and flow from sources to all customers. However, occasional disruptions due to failures of their system components and variation of demands may occur over the service life (Jalal, 2008).

Problems with to sufficient water are most happen in the developing world, and more than with one billion people were suffer with out access to water for their basic needs. There by, the united nations millennium declaration and the plan of implementation of the world; was set reducing the proportion of people having with out adequate access to water by one half for the year 2015. Hence adequate water distribution is one of the international goals for sustainable development (Renwik, 2013)

Most water distribution system across the world was built decades ago, and many are reaching their expected life spanes within 30 years (NRC, 2006). Accordingly, in developing countries; one of the commonly cited constraints to effective water provisioning is the aging infrastructure problem. And these were presents many technical limitations for effective and continues water distribution system to customers (Grady *et al*., 2014).

Intermittent piped water networks were found all over the developing world. And it is estimated that one thired of urban water supplies in Africa were opoereted intermittently. As result of; high population growth rate, scarcity of source water, treatment plant size, reservoirs and storage tank capacity, power out ages to run water pumps, high leakage problems, or some combination of these conditions were the primary causes for intermittent water distribution in the water system (Renwick, 2013) The other major factor which affecting water utilities are the considerable difference between the amount of water produced in to the distribution system and water billed to consumers. Current stastical surveys indicated that Non Revenue water developing countries is around 45 to 50% i.e, half of the total system input volume. This is largely because most of the water utilities do not have enough attention and monitorung systems within water losses and itsmanagement. Further; water theft, metering error, and lack of effective data recording and handling system is the other problems of the water utility in developing countries. Accordingly, the water distribution system in such countries does not meet the need of water for various demands since high levels of water losses in their distribution net works (Dighade, *et al*., 2014).

Large quantity of water is also losses through leaking pipes, joints, valves and fittings of the distribution systems. Age of installations, bad quality of materials used, and/or poor workmanship are the main sources of these water losses. There fore, constraints to water access also include limitations directly related to the aging, operation and maintenancecapacity of the water services (Grady *et al*., 2014).

Water utilities in many developing countries are struggling to ensure that customers to be receive a reasonable supply of adequate drinking water. But, problems related with less engineering aspects, low level of technology and costs associated with water provisioning were lead to poor management and controlling of the water system including Non- Revenue water. Thus, the water tariff system and revenue collection policies were not reflect the true value of water supplied, which limits the utility’s cost recovery and encourages customers to under value the service (Farley, *et al*., 2008).

In general, water problem is a growing global concern and that has an impact on countries economic prospects. Rising water stress, large supply variability, and lack of access and adequate drinking water are a frequent problems in many parts of the world. Especially, developing countries face greater challenges of adequate water distribution because of their larger populationgrowth rate, poor infrastructure, lower income levels, and less developedp olicy and institutionalcapacity (Kochhar, *et al*., 2015).

According to town water supply service office, one of the common problem in the town water system was related with intermittent supply due to the current performance of the water distribution system. There by, there were inadequate amount of water supply and low coverage in the town. Therefor, this research work was prepared to assass Ambo town water distribution network in terms of the hydraulic performance, water loss and leakage management practice.

1.2 Statement of the Problem

Water loss or Non-Revenue (NRW) represents inefficiency in water delivery and measurement operations in transmission and distribution networks and, for some systems, can amount to a sizeable proprtion of total water production. The water losses for a whole system or for a partial system are calculated as the difference of systems input volume and authorized consumption. Water loss occurs on all the systems, it is only the volume that varies and it reflects the ability of a utility to manage its network.

To understand the reasons why, how and where water is being lost managers have to carry out an appraisal of the physical characteristics of the network and the current operational practice. In many instances the problem of water loss is caused by age and size of pipe, illegal connection,

pressure, poor constraction and back filling, data handling error and poor maintenance practice.

A high level of real or physical loss reduces the amount of precious water reaching customers, Increases the operating costs of the utility and makes capital investments in new resource schemes larger. A high level of apparent or commercial losses reduces the principal revenue stream to the utility. Components of water loss or Non-Revenue Water (NRW) are real losses or physical losses. Real (physical) losses are: reported and unreported bursts on pipes, background leakage on pipes and fittings, and Leakage and overflows from service reservoirs. Apparent (commercial) losses are errors on source and production meters, Errors on customer's meters, unauthorized use i.e. illegal connections and.

The volume of water lost through physical leakage depends on the condition of the infrastructure and the leak detection and repair policy of the particular utility. The factors that affect the amount of water lost are pressure in the system, frequency of bursts and their flow rates, length of time the leak runs before it is located and repaired, level of undetectable small leaks (background losses). The level of apparent losses depends upon: Utility's customer meter change policy and Utility's law enforcement policy for dealing with unauthorized use.

Although the total loss of water can be easily estimated by comparing billing on water consumption and the total water produced and distribution to the network system, there have been inadequate studies on identifying where and how much water is lost and what are main the cause of water loss in many intermediate towns including Ambo. Thus, this study was contributed to some highlight on the issue of water loss in supply network at Ambo town, Oromia regional state, Ethiopia.

1.3. Objectives of the study

1.3.1. General Objective

The general objective of this research was to analyze water supply coverage and water losses of Ambo town water supply in distribution system.

1.3.2. Specific Objectives

The specific objectives of this study:

- To evaluate water supply coverage of Ambo town.
- To determine the total loss of water (unaccounted for water) at the town level,
- To explore thecauses of water losses .
- To analysis the hydraulic performance of water distribution network with modeling

1.4. Research Questions

The general and specific objectives of the study will be achieved by way of seeking answers to the following questions.

1. How much water is produced and distributed to the network system?
2. How much water is lost in the entire town while compared with the water produced?

3. What are the causes of water losses in the water distribution system?
4. How was the distribution system assessed with modeling?

1.5 Justifications

In Ambo town, reforms had taken place in the water sector to address irregularities that exist in water resources management which affect water supply coverage and equity in water supply and water loss in distribution system. Among some of the reforms which include access to water for primary use for all, water to be beneficially used, water to be treated as an economic good and consideration to be taken for those unable to pay full price during water tariffing. Constraints to sustainability aggravated by the macro economic challenges face by Ambo town during the period 2004- 2008 the water not sufficient in the hole towns. Capacity of local authorities to operate efficienly. Among some of the water problem associated with service delivery in Ambo, which include in sufficient cover age of services, water losses, and financial problem. Little has been done to riview and analyze the performance of the urban water supply utilities.

1.6 Significance of the study

This study was expected to increase the understanding and provide up to data information of the town water supply size and its undesirable impacts on the urban community due to shortage of water supply. It would also serve as a working document to decision makers in the water sector and the non- governmental organizations. Moreover, the findings would further serve as reference material for any further investigation in the area.

1.7 Scope of the study

The scope of this research include, water demand, produce and cosumption of exesting water supply, flow pattern/ velocity, flow rate and pressure, population projection,hydraulic analysis of water supply networks and those the main factors of water loss. Forecast population with acceptable formula that CSA use. In this study, the water that delivers to community has assumed quality water and all populatio use only from existing Ambo water supply distribution system. The demand of livestock assumes river or other source. Un meter water loss and illegal water connection are considering water loss and finance analysis of water supply system part of this study. But, due to lack of enough budgets, chemical reagent, resource/ logistics and distance of the study area from laboratory this research exclude the water quality analysis in the distribution system of the study area.

CHAPTER TWO

LITRATURE REVIEW

2.1 General concept of water distribution system

Water distribution system is the systems of urban water supply networks that transportpotable water over vast geographical areas from treatment plant to millions of consumers to the demand areas. Water utilities world wide face increasing challenges to preserve the hydraulic and water quality integrity of their water distribution networks. These challenges stem from burgeoning population and migration to urban cities that continue to increase the load on aging, inefficient, and already stained infrastructures American Water Work Association (AWWA, 2014).

The distribution system is classified transmission main and the distribution. Tansmission mains convey water from the source, treatment, or storage facilities to the distribution system normally via storage reservoir. There may be a few service connection on the transmission main, but the purpose of this larger diameter pipes is to deliver water to the distribution mains where most of the service connections. Distribution mains deliver water to individual customer service lines and provide water for fire protection through fire hydrants, if applicable. The distribution mains normally deliver water from a storage reservoir to the consumers. The extend and routing of the transmission and distribution network depends largely on the location and characterstics of the demand areas to be served, the topography of the service area and the source of water, the quantity of water to be transmitted and the available infrastructure in the area such as roads, under ground facilities and infrastructures etc. Republic of Uganda Ministry of Water and Environment (ROUMWE, 2013).

The purpose of system of pipes is to supply water at adequate pressure and flow. However, pressure is lost by the action of fraction at the pipe wall. The pressure loss is also dependent on the water demand, pipe length, gradient and diameter. A low flow rate lead to ineffective to meet demand and high sedimentation in distribution system due to low velocity. To large pressure values increase water losses (due to pipe waste) and incure a large blow out probability. Additionally water supply network regularly experience pressure drops and

interruption of water supply when there isan unexpected increase in water demand. There fore,
safe and efficient operation of the large scale networks is crucial for the survival of urban life (Duot, 2010).

Several researches and authors have been made to study the behavior of water distribution systems and to reach an optimal solutions and assumptions in order to improve the hydraulic performance, cost effective and to increase the efficiencies of the water supply networks. Prabhata K. Swamee (2008) in his study house are connected through service connections to water distribution network pipe-lines for water supply. From these connections, water is drawn as any of the water taps in a house opens, and the withdrawal stops as the tap closes. Generally, there are many taps in a house, thus the withdrawal rate varies in an arbitrary manner. The maximum withdrawal rates occure in morning and evening hours. The maximum discharge (withdrawal rate) in a pipe is a fuction of the number of houses (persons) served by the service connections. In the analysis and design of pipe network, this maximum withdrawal rate is considered. There fore the hydraulic performance and its parameters determined maximum hourly and daily demand of water discharge. Nemanja and Trifunovic (2006) in the books of urban water distribution system, is elaborating general principles and practices in water transport and distribution in a practical and straight forward way.

Water distribution systems consists of a network of smaller to larger pipes with numerous connections that supply water directly to the users. The flow variations in such systems are much wider than in cases of water transport systems.In order to achieve optimal operation, different types of reservoirs, pumping station, water toeers, as well as various appurtenances (valves, hydrants, measuring equipment, etc) can be installed in the system.

Nemanja and Trifunovic (2006) analysis of a pipe network is essential to understand or evaluate a physical systems. In case of a single- input system, the input discharge is equal to the sum of withdrawals. The known parameters in a system are the input pressure heads and nodal withdrawals discharge. In the case of a multi- input network system, the system has to be analyzed to obtain input discharge pipe discharges and nodal pressure heads. (Masri, 1997) studied the optimum design of water distribution networks. A computerized technique was developed for the analysis and optimal design of water distribution networks. The result show that the selection of the hydraulic restriction should be reasonable and reflects the real capacity of the water distribution system. (Jon Rostum, 2000) studied the cause of pipe failure of the distribution system. Static water pressure and pressure surges in a distribution system can affect pipe failure. Pressure surges can occure when water and air valves opened and close during repair activities. This cause of pipe in the distribution system network is termed as the hydraulic failure of the pipe in water supply distribution system network. The pipe failure in the distribution system other than hydraulic impacts is due to poor installation, material quality of pipe and age of the pipe. The most cause of hydraulic impact of pipe failure is termed as water hammer. Water hammer is the result of an event which is associated with rapid velocity (or pressure) change, the result of an accident or a normal operational matter in a pipeline system.Trondheim (2010) state that the water hammer transient is non uniform which is a change in the pressure resulting from a sudden change in the flow.

This wave of altered pressure is propagating with the speed of sound through the pipe, and accompanying this pressure wave is change of the flow which was the cause of the pressure change in the first place. At boundaries the pressure can be reflected and propagate back to the origin of the pressure change and the flow behaves there after. This pressure and flow variation continues to travel between boundaries, and the friction present in this flow is damping the valve of these variation. Finally giving a new steady state value for the flow under consideration. Naeeni (1996) developed a computer program, which enables to obtain the optimum design of various kinds of water distribution networks so that all consstraints such as pipe diameters, flow, velocities, and nodal pressures are satisfied. James, *et.al* (1994) made a study about distribution systems. Data about pressure and flow rate water obtained by continuous monitoring of their system. Transient analysis, time lagged calculations and inverse calculations were applied as a tool for calibration and leak detection.

James (1994) studied the behavior of water distribution systems during transient operatios. He conclude that during transient operations, pressure much higher than steady state values could develop. The causes of transient operation can be a result of pumps stopping or starting, values opening or closing, and system start up or shout down, Perez, Martinez and vela (1993) suggested a method for optimal design by considering factors other than pipe size. Pressure reducing valves were suggested to reduce the pressure in the down stream pipes, Vairavamoorthy, *et.al* (2000) suggested a new method of design sustainable water distribution systems in developing countries. They developed a modified mathematical modeling tool specifically developed for intermittent water distribution systems.this modified tool combined with optimal design algorithms with the objective of providing an equitable distribution of water at the least cost forms the basis of this new approach. They also develop guidelines for e ffective monitoring and management of water quality in intermittent water distribution syste ms. Modified network analysis program has been developed that incorporates pressure dependent out flow functions to model the demand. Vairavamoorthy and Lumbrs (1998) studied the leakage reduction ΔV water distribution system depending on optimal valve control. The inclusion for pressure dependent leakage terms in network analysis allows the application of formal optimization techniques to identify the most effecive means of reducing water losses in distribution systems. They describe the development of an optimization method to minimize leakage in water distribution system through the most effective settings of flow reduction valves. The following Joukowsky (water hammer) equation may be developed hydraulic transient design for pipe line system which is applicable for a wave propgattting in the upstream direction.

$\Delta p = -pa\Delta V$

Where Δp =Change of pressure, ρ= fluid density, kg/m^3, a= characterstic wave celerity of the fluid, m/s, ΔV= Change in fluid velocity, m/s, and ΔH = Change in head, m, Where VE and PE are the volumetric modulus of elasticity of the fluid and pipe material (Pa) respectively, Δv is the density of the liquid (Kg/ m^3), D and E are the internal diameter and the wall thickness (m) of the pipe respectively, and C~ 1 constant, which depends on the axial movement of the pipe. In practical calculations.The water hammer is reduced or controlled by the surge control. The purpose of surge control is to stop kinetic energy from beging converted in to elastic deformation energy. This can be done by the following basic methods are energy storage, one way surge and venting facilities, optimizations of valve closing characteristcs, optimization of the strategy designed to control the piping system Tan Wee choon (1213) in international journal states the preventive methods of water hammer effect. As his study some preventive measures are; by decreasing the flow velocity, the effect of the water hammer should be minimized. Increasing the moment of inertia of the pump can reduce the water hammer effect install by pass pipe with a non – return valve install pressure control valves in pipe system install the vacuum valves to the piping system.

2.2 Head losses in the water distribution system

Whene a real fluid flows through a pipe, part of the total energy of the fluid is spent in maintaing the flow. This used up energy is converted to thermal energy due to internal friction and turbulence. Such a conversion, which is the loss of energy as far as its utility is concerned, is usually expressed in the form of head of liquids and therefore termed as head loss.The hydraulic loss is the energy loss generated by two cases:

- Friction between the water and the pipe wall (Head loss due to friction),
- Turbulence caused by obstructions of the flow (minor head loss),

The frictional head loss in a pipe is due to the viscosity of the fluid and the turbulence of the flow and is present through out the length of the pipe. As the frictional head loss in a long pipe is relatively larger than the other head losses, the frictional head loss is alsotermed major head loss. When there is a sudden or gradual change in the boundaries of the fluid or when there is a local obstruction to flow, the flow pattern changes. This results in a change in the magnitude, direction or distribution of the velocity of flow. Such a change introduces additional head loss which is of a local nature and is usually much less than the frictional head loss in a long pipe. It is therefor termed as minor head loss. Trifunovic (2006) in the books of the urban water distribution system. The most popular equations used for the determination of friction losses are: The Darcy- Weisbach Equation, the Hazen- Williams Equation and the Manning Equation.

Table 2.1: Head loss equations and their application area

Equation	Formula	Remarks
Manning's	$V=\frac{1}{n}R^{2/3}S^{1/2}$	The equation is commonly used for open channel flow
Chezy's (Kutter's)	$V= C\sqrt{R}$	Widdly used in sanitary sewer design and analysis
Hazen William	$V= 0.85CR^{0.65}S^{0.54}$	Commonly used in the design and analysis of pressure pipe systems
Darcy- Weisback	$V=\frac{\sqrt{8g}}{f}RS$	Can be used for pressure pipe system and open channel flow

Source: (Bentley Water CAD/GEMs ,2008).

In all three cases, the friction loss hf should be calculated in meters of water column (mwc) for the flow Q expressed in m^3/s and length (L) and diameter (D) expressed in m. the use of prescribed parameter unities in equation 3.5 is to be strictly obeyed as the constants was need to be read justed depending on the alternative unit used. In the above equations C and N are expermentally determined factors that describe the impact of the pipe wall roughness on the friction loss. Nemanja and Trifunovic (2006) in the books of the urban water distribution system, minor (in various literature local or turbulence) losses are usually caused by installed valves, bends, elbows, reducers, etc. although the effect of the disturbance is spread over ashort distance, the minor losses are for the sake of simplicity attributed to a cross section of the pipe. As a result, an instant drop in the hydraulic grade line should be registered at the place of obstruction.

2.3 Components of water distribution network

2.3.1 Transmission and distribution mains

In the water distribution system, piping system is often categorized as transmission/ trunk mains and distribution mains(Tomas, *et al*., 2003);

2.3.1.1 Transmission mains

Transmission mains were consist of components that are convey large amounts of water over great distance typically between major facilities within the distribution system. In most water system, transmission main are mainly used to transport water from treatment plant to service reservoirs tanks. Where by, individual customers are usually not served from these mains. The general topology alignment of the town streets. Different fittings such as elbows, tees, reducers, crosses and numerous other accessories are used in the main to connect pipes. While, other maintenance and operational appurtenances, such as fire hydrants and valves are also connected directly to the distribution mains. Further, services also called service line were laid and transmit water from the distribution mains to end customers.2.3.1.2 Distribution mains

Distribution mains are an intermediate pipe line used to delivering water from transmission main to customers. The mains are smaller in diameter than transmission mains, and typically follow.

2.3.2 Reservoir and storage tanks

In the watre distribution system, reservoir and storage tanks are mainly provided inorder to meet. The fluctuations of water demand and to stablize pressure within the distribution system. Similarly, these components were reserve water for emergency requirements. Accordingly, the common reservoirs established in the water supply system are circular and/or rectangular type which build either from concrete or steel materials. And, the recommended location of such facilities are mainly in elevated area beyond the center of service area (NRC, 2006).

2.3.3 Pump Stations

Pumps are used for convey energy to the water in order to boost water at higher elevation. Most pumps used in the water supply systems are centrifugal in nature, and are installed to improve the water distribution, if gravity is insufficient to supply water at an adequate pressure. So that, to control the operational condition of pumps swich board were providing in the station (NRC, 2006; Chambers,*et al*., 2004).

2.3.4 Accessory Equipments

The accessory equipment in the water distribution pipe lines can be classified as fittings, valves (such as; control valves, air release valves, pressure reducing valves, etc), hydrants, drainage facility, flow meters, and etc. All these accessories has been installed at places were necessary for connecting the network, controlling and management of the system, and for maintenance purposes during failure (Bhadbhade, 2009).

2.4 Factors causing loss of hydraulic integrity in water distribution network

In most of the developing regions, the design of water distribution system is based on the assumption of direct supply, although most of these systems are intrmittent systems which result in suvere supply, insufficient pressure in the distribution system (pressure losses in several areas in the network), inequatable distribution of the available water and very short duration of supply (Hussni & Zyoud, 2003). However, the purpose of hydraulic integrity in the water distribution system is to supply water at adequate/accptable pressure and flow. But, according to (Chambers, et al., 2004; NRC,2006). (Tomas, *et al*.,2003; Marta & Rudolf, 1987; Hickey, 2008; Dighade, *et al.*,2014) the most common factors for intermittent water supply and loss of hydraulic integrity in the distribution system are;

2.4.1 Low pressure

However, there is pressure loss by the action of friction at the pipe wall and its magnitude also dependent on the water demand, properties of the fluid that is passing through the pipe, the speed at which it is moving, the internal roughness of the pipe, pipe length, gradient and diameter of the pipe. Such situation may occure where there are: properties on high ground, remote properties at the end of long lengths of pipe, demands that are greater than the design demand, pipe of inadequate capacity (to small diameter) rough pipes (e.g. corroding iron pipes or pipes with a build – up of sediment) and equipment failures such as pump and valves. In general, poor preessure tend to be caused by inadequate capacity in a pipe or pump, high elevations, or some combination of the two (Chambers, *et al*., 2004).

Therefore, one of the most hydraulic integrity is maintaining adequate water pressure inside the pipe. Hence, the water utilities should be achieve a high degree of hydraulic integrity through a combination of proper system design, operation, and maintenance along with good monitoring.

2.4.2 High pressure during low demand

High pressure during low demand conditions can cause pipe bursting, leakage and large amount of water losses through the distribution networks. Therefore, when dealing with high pressure,

PRVs should be used to reduce and regulate pressure in the system (Tomas, *et al*., 2003). Accordingly, pipe and pumps must be sized to over come these problem and to providea cceptable pressure in the system. Although, sizing of control valves based on the desiredflow conditions and pressure differential is vital (NRC, 2006).

2.4.3 Pump capacity

A pump is device in which mechanical energy is applied and transferred to the water as total head, and these head is a function of flow rate through the pump (Tomas, *et al*., 2003). While the failurity, location, size and capacity of pumps in water distribution are the major impacts for low flow or negative pressure arised in the system, and this can lead to intermittent water supply in the distribution system (Chambers, *et al*., 2004).

There are many reasons and factors why a pump is not performing well in a certain situation of water distribution system. But, as per Marta & Rudolf, 1987; the important and possible reason to less performing of pumps were identified as below;

- When the pump is of poor design and quality,
- If it is not suitable for the given situation and does not work in its optimal range,
- If the pump is not being used properly and maintained regularly (cleaning, greasing, etc.
- If the pump is excessively exposed to sun, rain, dust, etc,
- If it is overused and was not repaired properly after a break-down and
- If supply of spare parts is difficult.

2.4.4 Demand increase

Rising water demand as a result of population growth and urbanization has an effect on the availability and reliability of existing water distribution system. Therefore, water demand need to be assessed on the basis of considering the year and date supplying water through the distribution system. The primary objective is to make sure that the community is being serviced adequately. If there are deficiencies in meeting current or future goals because of population growth, this needs to be identified for the areas of the community where there may be inadequate flows to meet customers consumption during peak hour water demand of the day (Hickey, 2008).

2.4.5 Poor infrastructure

In most of the developing countries it has been observed the pipe network is very old which is laid many years ago. With aging probem there is considerable reduction in carrying capacity of the pipe lines. Although, most of the distribution pipe line were get corroded and leakage were occur, since resulting in loss of water and pressure reduction. Hence, all these materials suffer from degradation over time and result in leakage in the network. It is, therefore, preventive maintenance of distribution system assures and providing conditions for adequate flow through the pipe lines. Incidentlly, this will prolong the effective life of the pipe line and restore its carrying capacity. Some of the main functions in the managment of preventive maintenance of pipe lines are assessment, detection and prevention of loss of water from pipe lines through leaks, maintaining the capacity of pipe lines, cleaning of pipe lines and relining (Dighade, *et al*., 2014)

2.4.6 Operation and maintenance activities

Water distribution systems are occasionally subject to emergencies or planned maintenance activities in which certain components become not workable and the system can no longer provide the minimum level of service to customers. Planned maintenance activities include supplies going off line (e.g. reservior shut down for inspection, cleaning, or repairs; installation of new pipe connections; pipe rehabilitation or break repairs; and transmission main valve repairs). While, emergency situations include earth quakes, power failures, or transmission main failure. Therfore, all these activities can result in a reduction in system capacity and supply pressure, and changes to the flow paths of water within the distributionsy stem' (NRC, 2006). Therefore, lack of attention to the important aspect of operation andmain tenance of water supply schemes were leads to deterioration of the useful life of the distributi on systems. Further, as per (Dighade,*et al*.,2014) some of the key issues contributingto the po or operation and maintenance have been identified as follows;

- Lack of funds, operation manuals and real time field information
- Inappropriate system design and poor workmanship,
- Overlapping responsibilities and inadequate training of personnel,
- Inadequate emphasis on preventive maintenance,

Whereby,there is a need for clear policies,legal framework and decision of responsibilities an d mandates within the water supply authority.

2.5 The effects of head loss in water distribution system

(Sodiki, 2013) in his study available pressure at any point in a fluid flow conduit is progressively reduced away from the pressure source (such as the elevated storage in water distribution systems) due to frictional losses through fittings such as elbows, tees, reducers and

valves. The latter loss is some times called separation loss. Thus, extensive runs of would result increased frictional loss while multiplicity of fittings would result in increased separati on loss.The effects of head loss in the distribution system are; the capacity of the pump was increase due to high head of pressure line and as result the investment cost and operation and maintenance cost of pump is high. The flow rate of the water in the distribution system is not uniformly reach each nodes or the juctions of the tap. To prevent high head losses in water distribution system optimum an engineering design is required which is all hydraulic parameters like pressure, velocity and optimum pipe diameters should be in thedesign criteria of water system design.

2.6 Types of water distribution system

2.6.1 Branching system

This type of distribution network is the most economical system and common in the develo ping countries due to its low cost. In this system, when there is need for developing the networ k, new branches follow that development and new dead ends should be constructed.The br anchingsystems have some disadvantages such as the following.

- ✓ The dead ends cause accumulation of sediments, which result in increasing contamination and health risks.
- ✓ The maintenance operation upstream of the network was prevent water to reach the down stream due to the interruption of the whole area of maintenance.
- ✓ The fluctuating demand causes high-pressure oscillations.

2.6.2 Gride system

There are no dead ends in this type of distribution networks. The maintenance operation did not affect the interruption on the whole area as in the branching system, this type of lay out is highly desirable because, for any given area on the grid, water can be supplied from more than one direction. This results substantially lower head losses than would other wise occur and, with valves located properly, allows for minimum in convenience when repairs or maintenance activities are required the whole area is covered with mains that form the grid sy stem.

2.6.3 Ring system

The mains form a ring around the area under service, secondary pipes connecting the mains and delivering the water to the consumers.

2.6.4 Radia system

The area under service in the radial system is divided in to sub areas, and a storage tank is placed in the center of each subarea to supply water to the consumer.

2.6.5 Water distribution system modeling

Analysis of water distribution network provides the basis for the design of new system, the extension, and control of existing systems. The flow and pressure distributions across a network are affected by the arrangement and sizes of the pipes and the distribution of the demand flows. WaterCADv8i could show pressure, demand and hydraulic grade in different nodes as well as flow, velocities, gradient and pressure different pipes through out the distribution system.

2.7 Water supply mode in distribution system

2.7.1 Continuous system

This is the best system and water is supply for 24 hours. This system is possible when there is adequate quantity of water for supply. In this system sample of water is always available for fire fighting and due to continuous circulation, water always remains fresh. In this system less diameter of pipes are required and rusting of pipes would be less. Losses was more if there are leakage in the system.

2.7.2 Intermittent system

If plenty of water is not available, the supply of water is dividing in to zones and each zone is supply with water for fixed hours in a day or on alternate days. As the water is supply after intervals, it is all intermittent system. The system has disadvantages, such as pipe lines are likely to rust faster due to alternate wettingn and drying, increases the maintenance cost, polluted water through leaks during non- flow periods and more wastage excess to collect fresh water each time. In this water supply system the high elevated area, get adequate pressure by dividing the city in zones. The repair work can easly do in the non- supply hours. Depending up on the level of the source of water and the city, topography of the area, and other local conditions and considerations, the water forced in to the distribution system in the following three ways:

Gravitational system: This method is the most economical and reliable since no pumping is involved at any stage. However, it needs a lake or a reservoir as a source of supply. Such as a system can adopt for cities, which are situating at the foothills, and the source of supply is available some were in the hill at sufficient elevation of the city. High pressure for fire fighting may require use of motor pumping trucks, and low- lying areas may need to be isolated to prevent excessive pressure

Pumping without storage system: The treated water is directly pumping in to the distribution mains with out storing it any where. High lift pumps are required in this system, which have to operate at variable speeds to meet the variable demand of water. Therefore, generally not use as a distribution system. It is the least desirable method of distribution, since it provides no reserve flow in the event of power failure and pressure was fluctuate substantially with variations in flow. Since the flow must be constantly, vary to match an unpredictable demand, sophisticated control system are required. Systems of this kind have the advantage of permitting increased pressure for firefighting.

Combined gravity and pumping system: The treated water is pumping at a constant rate and stored in to an elevated distribution tank, to distribute with action of gravity to customer. Some times the entire water is first pump into the distribution reservoir and then distributed among the consumer. Many times it is pump into the distribution mains and tanks simultaneously. The excess water during low demand period gets stored in the reservoir and is supply during high demand periods. The pumps work at a costant rate, which is adjusting in such away that the excess quantity of water stored in the reservoir during low consumption nearly equals the extra demand during high consumption (Shimelis and Tamirat 2012).

2.8 Pump

The most common input of energy into a system was through pumping. Pumps are crucial to any Distribution system that can not supply acceptable pressure to consumer through the sole use of gravity flow. A pump is an element that adds a head to the system as water passes through it. Pump is an integral of much pressure system and add energy to head gains to the flow to counteract head losses and hydraulic grade differences within thesystem.

2.9 Water demand

When designing the water supply scheme for a town or city, it is necessary to determine the t otal quality of water required for various purposes by the town. In fact, the first duty of the engineer to determine the water demand of the town and then to find suitable water sources from where demand can be meet. However, as there are so many factors involved in demand of water, it is not possible to accuretely determine the actual demand. Certain empirical formula and thumbe rules are employing in determining the water demand, which is very near to the actual demand (Rao, 2005). The various types of water demands are domestic water demand, industrial water demand, commercial water demand, demand for public uses, fire demand and demand for losses.

2.9.1 per capital demand

Whento find out not only the total yearly water demand but also assess the required average rates of flow and the variation in rates. Then to calculate it total annual volume (V), annual average rates liter per day (V/365) and annual average demand per person (per capital demand) fluctuating rates of demand in flows is expresses with percentage ratios of maximum or minimum yearly, monthly, daily or hourly rates average values.The total quantity of water required by various purposes by a town per year and population of town, the per capital demand should be per capital demand = Q/ (P x 365) liters/day. Per capital demand of the town depend on various factors like standard of living, numbers and type of commercial places in a town etc. (Rao, 2005).

2.10 Population forecasting methods

The water distribution systems design for a predefined time horizon generally called design period. When the design period is fixed the next step is to determine the growing of population or water demand of a town depends upon the factors like births, deaths, migration and annexation. The future development of the town mostly depends upon trade expansion, development industries and surrounding country, descoveries of mines, construction of railway station etc. May produce sharp rises, slow growth, and stationary conditions or even decrease the population. For a static population, the system can be designed either for a design period equal to the life of the pipes sharing the maximum cost of the system. On the other hannd, for a growing population or water demand, it is always economic to design the system in stages and strengthen the system after the end of every staging period (Rao, 2005). The Ethiopianst atistic authority uses the formula p n=p o x (1+r) ^n for most water supply project in the coar get year or design period Pp = present population, r = Annual growth rate, n= design period, in year (ADSWE, 2036).

2.11 Water distribution network simulation

The term simulation generally refers to the process of imitating the behavior of one system through the functions of another. It can be used to predict system responses to events under a wide range of conditions with out disrupting the actual system. Problems can be anticipated in proposed or existing systems, and can be evaluated before time, money, and materials are invested in a real world project (Tomas, *et al*., 2003). In water distribution network the most basic type of model simulations are either steady - state or extended-period simulation.

- **Steady state simulations:** represent a particular view of point in time and are used to determine the operating behavior of a system under static conditions. It compute the hydraulic parameters such as flows, pressure, pump operating characterstics, and other by assuming that demands and boundary conditions were not change with respect to time. In general, this type analysis was used to determining the short term effect of demand conditions on the system (Tomas, *et al*., 2003).
- **Extended period simulations:** are determine the dynamic behavior of a system over a period of time, and it analyze the system on assumption that the hydraulic demands and boundary conditions were change with respect to time. Hence, extended period analysis used to evaluate system performance over time and allows the user to model pressures and flow rates changing, tanks filling and draining, and regulating valves opening and closing through out the system in response to varying demand conditions and automatic control strsegies formulate by the modeler. Therefore, regardless of project size, model based simulation can provide valuable information to assist an engineer in makin well -informed decisions' (Tomas, *et al*., 2003).

2.12 Water CAD: Modeling Capabilities

WaterCAD provides and allowing modeling practically for any distribution system aspect. Therefore, working with Water CAD used as for decision support tool for water infrastructures and were help to assess and/or operate (Dawe, 2000; Water CAD: User mannual);

- The hydraulic analysis at a steady-state or an extended-period simulation
- Pressure, flow and demands in the system and to see how behaves over time,
- The size of pipes, pump and computer system head curves,
- Tank, pump and valve behavior in the system,
- Leakage and water loss from the network,
- Calibration the model either manually or use the Darwin Calibrator methods
- And, generate fully customizable in graphs, charts and reports form.

2.12.1 Input data for assembling the model

In practice, pipe networks not only of pipes, but composed of vary fittings, services, storage tanks and reservoirs, meters, regulating valves, pumps, and electronic and mechanical controls. For modeling purposes, these system elements were organized in to the following categories (Water CAD: User mannual):

Table 2.2: Input parameters and primary purposes of water CAD tools

Element	Type	Primary modeling purpose	Input data
Reservoir	Node	Provides water to the system	Hydraulic grade line (water surface
Tank	Node	Stores excess water within the system and releases that water at	Base Elevation, Max. Elevation, Min. Elevation, and Diameter
Junction	Node	Discharge the demand required or recharge the inflow water	Elevation
Pipe	Link	transport water from one node to another	Elevation, Diameter, Material and Roughness coefficient
Pump	Node/ Link	provide energy to the system and raise the water pressure to overcome elevation differences	Elevation, Pump definition (Characteristics of max. operation and design discharge and head

Valves	Node/ Link	Controls flow or pressure through a pipe and results in a	Elevation, Diameter, Valve type,

(Source; Water CAD: User mannual)

2.13 Water demand modeling

The question in the design and operation of WDN is; how much water is needed? The answer to this question is difficult because the required water is a function of various factors. While,s ome of the factors are completely independent and time varying. Therefore, water demandm odel in is one of the most important challenges in the design of WDN, since it reflects the changes in population, climate, land use, the number of service connections and customer life style (Jalal, 2008)

2.13.1 Demand modeling approaches

In the water distribution system, there are two main approaches for water demand modeling(Jalal, 2008).

Deterministic water demand estimation: In this approach, the actual water demand for all users is estimated based on predicted water consumption over the service time. One simple approach for deterministic water demand is estimating individual needs based on type of customers and their activities and finally adding these lead to get total water demand. For example, the water demand can be estimated on the basis of per capital demand in small urban areas(Jalal, 2008).

Stochastic demand forecasting: This method mostly considers and adopt the uncertain fluctuations on demand over time and location spans. Risks and sensitivity of forcasts such as the consequence of total loss of supply and the effect of variations in rates income should be considered and included. Hence, demand estimation based on historical consumption per user category (domestic, industrial or comercial) and expected changes (increasing or decreasing) in user category over the forecasting period is good example of stochastic demand forecasting (Jalal,2008).

2.13.2 Variations in water demand

The per capital demand of a particular town is the average consumption of water for a year. In practice it has that this demand does not remain uniform through out the year, but it various from season to season, even hour to hour (Venkateswara, 2005).

2.13.3 Baseline demands

The most common method of allocating baseline demands is a simple unit loading method. This method involves counting the number of customers (hectares of a given land use, number of fixture units, or number of equivalent dwelling units) that contribute to the demand at a certain node, and the multiplying that number by the unit demand (for instence, number of gallons/ liters per capital per day) for the load classification (Tomas,*et al*., 2003).T herefore, average day demand were used to estimate the baseline demand and other demand un the water distribution system including unaccounted for water. Hence, most modelers determine the water demand analysis of a given town by appling baseline demand to variety of peaking factors and demand multipliers (Bhadbhade,2009)

2.13.4 Demand diurnal pattern and multipliers factors

The variations in water usage for water supply system typically follow a 24 hour cycle. However, in reality, water demand varies over time and for extended period simulation to reflect the dynamics of the real system, these demand fluctuations must be incroporated in to the model and it requires both baseline demand data and information on how demands vary over time. These demand can be determined by applying a multiplication factors or a peaking factor. Multiplication/ peaking factors from average day to maximum day tend to range from 1.2 to 3.0, and factors from average day to peak hour are typically between 3.0 and 6.0. Of course, these values are system- specific, so it must be determined based on the demand characterstics of the system at hand (Tomas, *et al*., 2003).

Therefore, when more than one demand type is served by a particular junction, the total demand for a junction at any given time is equal to the sum of each baseline demand times with its respective pattern multiplier, and it is used in most software packages to assign a different pattern to the different components of the composite demand as per below(Tomas, *et al*., 2003).

CHAPTER THREE
METHODS AND MATERIALS

3.1 Study Area

Ambo town is the capital city of west shewa zone is located in the west of Addis Abeba at a distance of 120km. specifically it is located in the Oromia regional state, west shewa zone. The town is located at 8^0 43' to 8^0 59' N latitude and 37^0 41' to 37^0 51' E longitude and its average elevation of 2110 meters above sea level. It has moderate temperature. Its Annual temperature is 18.5^{0}C, mean annual rain fall is 1200 mm and existing wind direction is from nort to south.

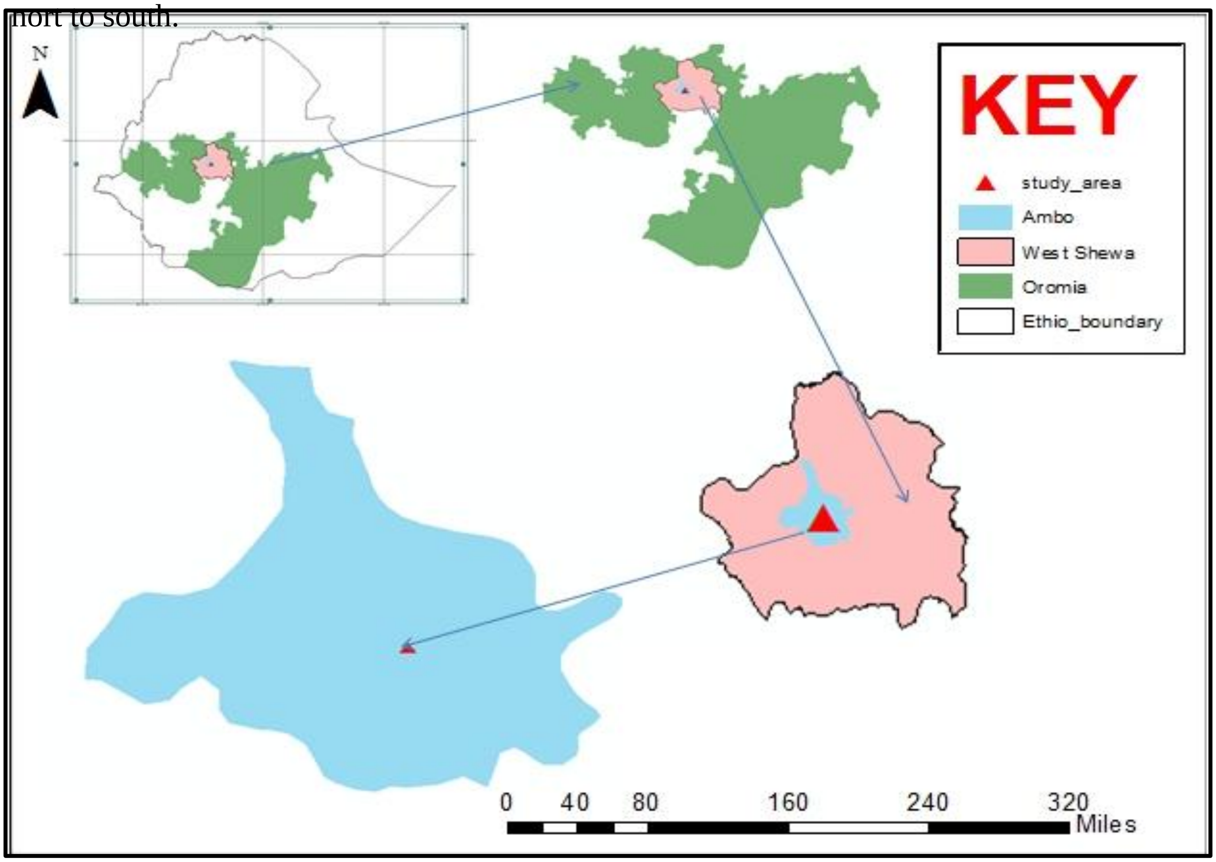

Figure 3.1 Map of thestudy area

3.1.1 Climate

Despite its proximity to equator, Ambo enjoys a mild, afro alpine temperature and warm temperate climate. The lowest and highest annual average temperature are between 13 and 27oc. April and May are the driest months. The main rainy season occurs between mid-June and mid-September, which is responsible for 70% of the annual average rainfall of 1100mm. It is characterized by intense rainfall of short duration. During the dry season the days are pleasantly warm and the night are cool. During rainy season both day and nights are cool. The infrastructure of the Ambo town has road connections Addis Ababa and Dembidollo and is accessible all the year for transporting system, Ambo enjoys the benefits of a digital automatic telephone system. Mobile telephone and postal service are also available. Ambo receives a 24-hourelectric supply from the country's hydro electric grid system. There is a growing demand for water and sanitation services in the town due to growing populations, rising standards of living and per capital incomes, and rising awareness of health benefits of improved water and sanitation. However, the demand for water in the town is growing much faster than the supply, a considerable portion of Ambo town is habited by urban poor living in low and small housing where supply facility is not adequate. Furthermore, some of the rural areas around the town also have limited water supply access.

3.2 Potential source water

Ambo area is characterized by high rainfall regime, due to this there are streams with adequate flow in the area that can be utilized as a source of water supply for the town. The potential surface

water source used for Ambo town water supply system is Huluka River. Huluka River which starts from Dendi Lake near wonchi town, 39 km from Ambo, and flows from the southern pole of Ambo towards the northern part of the town. The water content of the river varies from season to season with a mean flow of about 15,000 and 75,000 m3 during the dray and rainy seasons, respectively.

3.4 Water supply coverage

3.4.1 Mode of services

According to the town water service office reports, there are four major modes of services fordomestic water consumers of Ambo town. These are; house connection (HC), yard connection private (YCP), yard connection shared (YCS), and public foundation (PF). But, those populations not served from any of these modes of services are categorized as traditional source users.

3.4.2 Population distribution by mode of services

The percentage of population served by each mode of service is varying with time. This variation is caused because of the changes in living standards, improvement of the service level, changes in building standards and capacity of the water supply service to expand. According to 2017 Ambo water supply and sewerage enterprise repot shown, the over all domestic water supply coverage of Ambo town was indicate 88.8%, of this only about 8.1% of the population were house connection users. The great number of the populations was served their water need from both shared yard taps and public fountations found in different villages of the town are covers 31% and 12.5% respectively. The remained 37.2% of the population were obtained water from their bounded privet yard connections. While, remain 11.2% of the population was got water for their day to day activates from the unprotected surface water (river and streams), and rain water harvesting technique which come duringthe rainy seasons.

Table 3.1: Summarized Ambo town domestic water supply coverage

User	Total Number of Population served	Percentage
Public Tap(PTU)	12,454	12.5%
YTU (Private)	37,064	37.2 %
YTU (Neighboring)	30,887	31 %
House Connection	8,070	8.1%
Total	88,475	88.8%

(Source CSA, 2007 statistical census document and the town water service office)

3.5 Study Period

The study period was done from Jully- November 2017 within the specific period of time the required research planning, preparation of ground work, building of scaffolding, data collection,sampling and analysis and writing up

3.6 Study Variables

The study variables assessed in this research are both independent and dependent variables. Which variables express about impact of water loss in water supply system.

3.6.1 Independent variables

These independent variables are more relating with specific objectives but each specific objective is affecting another. The independent variables that are to be measure and manipulate to determine its relationship to observe phenomena are select and list below.
Intermittent water supply, high water demand and population for water use in distribution system.

3.6.2 Dependent variables

In other case, the dependent variable, which is the output and its result depend on the independent variables, which directly related to the general objectives. On the other hand, dependent variable is measure to determine the effect of the independent variables is list below.

- Hydraulic integrity the distribution system
- The Scarcity of Water source

3.7 Materials

3.7.1 Source of data

The source of data was involved both primary and secondary data. For the study, the primary data were obtained from pressure reading, elevation surveying and by made of discussion with water utility staff members to obtain additional relevant information on thesubjectmatter. While, secondary data were collected from different litrature reviews, design report, the town water supply service office existing documents and annual reported paper.

3.7.2 Equipments Used

GPS instrument as used to collect the required elevation data during pressure reading. Pressure reading, readings were done using pressure gauge which is commonly taken in the selected point of distribution system

3.7.3 Hydraulic Model: Water CAD

Model is some thing that represents things in the real world. Computer model uses mathematical equation to explain and predict physical events. Modeling of water distribution system can allow determining system pressure and flowing rate under a variety of different conditions with out having to go out and physical monitor the system (Dawe, 2000). Water CAD is a state of the – art software tool and primarily uses in the modeling and analysis of hydraulic and water quality modeling application of water distribution system. But the methodology is applicable to any fluid system with different characteristics, such as steady or gradually-varying turbulent flow (Water CAD: User manual).

3.7.4 Additional software

ArcGIS, was used to display the overlapped shape file of the distribution network on the topographic map of the town. While, Microsoft Excel sheet were used to organize data, to calculate a repeated work of nodal base water demand requirement of distribution network simulation and for manual pressure validation work.

3.8 Methods

3.8.1 Preliminary data collection

The field data collection consisting of data gathering from different nodes/junctions, reservoir, source and pipe layout related to the water distribution system in the study was investigated using different data collection instruments. Field observations would the other method which was help in this study. During the field visit different users such as privet tap and public fountation uses including the sites and infrastructures was visited to collect different information and data should be recorded. The study was focus on the following key consideration of the town areas: Remote areas in the town most residents living in rented hous es very suppressed water supply service areas commercial centers of the town proportion of the house hold using different types of facilities. The lowest or depression and peak point or areas of town at field level the data hydraulic parameters of pressure, flow rate and velocity was measured and conducted with the data collecting instruments. The elevations and directions of existing nodes, water sources and service reservoir and length of pipe links would be collected that was used for analysis of pressure at nodes and velocity of links. The type and diameter of pipe the capacity of reservoir and itsshape.

3.8.1.1 Elevation data

Setting elevation is one of the significant requirements to simulate the hydraulic characteristics of water in distribution system. Most of elevation data was obtained from the town water service office which was prepared as the design report of Ambo town water supply system (existing document). But elevatioin data for expansion area in the town were served in the field using surveying instrument global position system (GPS).

Table 3.1 Elevation data for source of water and service reservoir site

Description	**Coordinates**		
	X	**Y**	**Z (Elevation, masl)**
Source (Huluka River)	378536	988493	2299
Raw Water Tank	378329	997184	2268
Clear Water Tank	378048	999290	2257
Exesting service Reservoirs	376448	992399	2168

3.8.2 Secondary Data Collection

3.8.2.1 The Town Water Supply Networks

The entire town water supply network including their attibute like the length, material types, pressure capacity of the pipes, reservoir and tank section has been collected from the town water supply service office. The collected pipe network mainly comprises of main pipes and secondary pipes that covers the major part of the town. Extension networks are also included in the existing network during the site observation. The length of the entire network was summed up according to their diameter of further determination of unavoidable annual real loss.

3.8.2.2 Rising main and distribution pipeline network

The transmission and distribution main line consists of branching system with a total sum length of 39217.07m, and supplying water through gravity means.

Table 3.2: Summarized quantity of pipe material in distribution system

Pipe type	Length (m)	Coverage in system (%)
DCI	8050.39	20.53
Rigid PVC	31166.68	79.47
Total	39217.07	100

(Source: Ambo town water supply service office)

3.8.2.3 Reservoirs

There are two circular RC type reservoirs with the capacity of (500 m^3) and internal diameter of 11.70 m were used in the town water distribution system, which used as clear water tank(point of disinfection) and service reservoir. Water is pumped simultaneously in to the distribution network and service reservoir, thus the part of the town that is locatedabove the treatment plant is served from the service reservoir and the pumping line. But, the part of the town that is located below the treatment plant site is served from the clearwater reservoir found at treatment plant.

Figure 3.2 Clear water reservoir

3.8.2.4 Source

Huluka river is usually transported to a water treatment plant where it is processed to produce treated water and stored in to the service reservoir the water is chemically treated and fed into the distribution system by gravity, Water distribution systems are designed to adequatelysatisfy the water requirements for a combination of domestic, commercial, industrial, and fire fighting purposes.

Figure 3.3 Huluka River

3.8.2.5 Pipes

Every pipe is connected to two nodes at its ends. In a pipe network system, pipes are the channels used to convey water from one location to another. The physical characteristics of a pipe include the length, inside diameter, roughness coefficient, and miner loss coefficient.The pipe roughnes coefficient was associated with the pipe material and age. The miner losscoe fficient is due to the fitting along the pipe. Pipe length and diameters are then inputted as roughness. A roughness of 150 was selected the PVC pipes.

3.8.2.6 Nodes

Nodes are the locations where pipe connected. Two types of nodes exist in a pipe networks system. All nodes should have their elevation specified above sea level. Nodes, besides representing the connection point between pipes, can represent the following components in a network: demand nodes, Source nodes and Storage nodes.

3.8.2.7 Pumps

A pump is an element that adds energy to the system in the form of an increased hydraulic grade. Since water flows to down hill (that is from higher energy to lower energy) pumps are used to boost the head at desired locations to over come piping head losses and physical elevations differences unless a system is entirely operater by gravity. Pumps an integrated part of the distribution system.

3.8.2.8 Tanks

A storage tank is also a boundary node. But unlike a reservoir the hydraulic grade line of a tank fluctuates according to the in flow and out flow of water. The 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) storage tanks are presented in most real world distribution systems and the relationship between an actual tank and its mode l counter part is typically straight forward.

(a)

(b)

Figure 3.4 Raw water tankFigure 3.5 Clear water tank

3.9 Data quality management

In order to increase the quality of the data, the research prepared a field work manual to check every day progress and assistant was selected and trained to make the data handling good. The researcher has checked the reliability and accuracy of the data.

3.10Analysis data by WaterCADv8i

1. Develop water distribution network scenarios. The water distribution system lay out would be prepared using the surveyed data of base demand, elevation and direction of Northing and Easting of Junction, source and tanker but also pipe data is links using water CADv8i software. The existing water supply design network was evaluated in reality depending on the existing situation of operating the different parts of thenet work.
2. Determine head loss, velocity of the flow and pressure in water distribution using water CADv8i software.
3. Estimation of distribution parameter/pressure, velocity, discharge, time variation/and procedure.
4. Check the nodal pressure at the point of lower and higher elevation areas of the distribution system.
5. The water supply system of Ambo will be redesigned as continuous supply depending on fixed pattern, assuming the availability of water sources, and the using of pressure reducing valves to reduce the high pressures in the system if the pressure of the distribution system is above from the permissible limit or if these design parameters may be above the design criteria.
6. Provide the solution of the hydraulic water hammer or develop scenario to reduce pipe system failure by providing the design of surge tank at the outlet of the pump andinstallation of pressure breaks tank or reducing valve in the distribution system.
7. Finally, the recommendation and conclusion was done based on the results and discussions ofthis study researches.

CHAPTER FOUR

RESULTS AND DISCUSIONS

4.1 Domestic water supply coverage

Access to water supply may be evaluated using the amount of water consumed and by mode of service for evaluating the annual water consumption which is converted to average daily per capital consumption using the population data of town. Besides population distribution by mode of service has been also used as elaborated below.

The design and execution of any water supply scheme requires an estimate of the amount of water required by the community. The total amount of water is affected by expected citydevelopment, presence of industries, quality of water and its cost. Generally, in designing the water supply scheme for town or city, it is necessary to determine the total quantity of water required for various purposes.

The demand for various purposes is divided under the following categories of water demand: Domestic, non-domestic, institutional, commercial water demand, industrial and firefighting. Loss and waste of from all these type of water demands depending on such factors as climate, geographical location of what population size, living standard of the community, degree of industrialization, water cost and water quality, water policy and water resources regulatory bodies.

Table 4.1 Water demand of Ambo town

	Item	Unit	Water demand
1	Domestic demand	m^3/day	1920
2	Non - domestic	m^3/day	1013
3	Public school	m^3/day	780
4	Commercial	m^3/day	520
5	Ambo University	m^3/day	436
6	Industrial	m^3/day	210
7	Other public government	m^3/day	621

4.1.2 Average Daily per Capital Consumption

The level of water consumed for domestic purpose has been aggregated to town so as to analysis the distribution of the water coverage among different localities. Evaluating the domestic water supply coverage using volume of consumption may not allow realizing the distribution comparison among the town. For this reason, the annual consumption data has been converted to average daily per capital consumption using the number of population

Table 4.2 Water production and consumption of Ambo town.

Year	Production m^3/ year	Consumption m^3/ year	Total population	Consumption l/person/year	Consumption l/person/day
2013	950,355	722,436	87,165	8288.1	22.71
2014	834,048	680,477	90,129	7550.3	20.68
2015	1,427,290	1,065,767	93,193	11436.1	31.33
2016	1,765,264	1,274,656	96,362	13227.7	36.24
2017	1,816,918	1,373,230	99638	13782.2	37.73

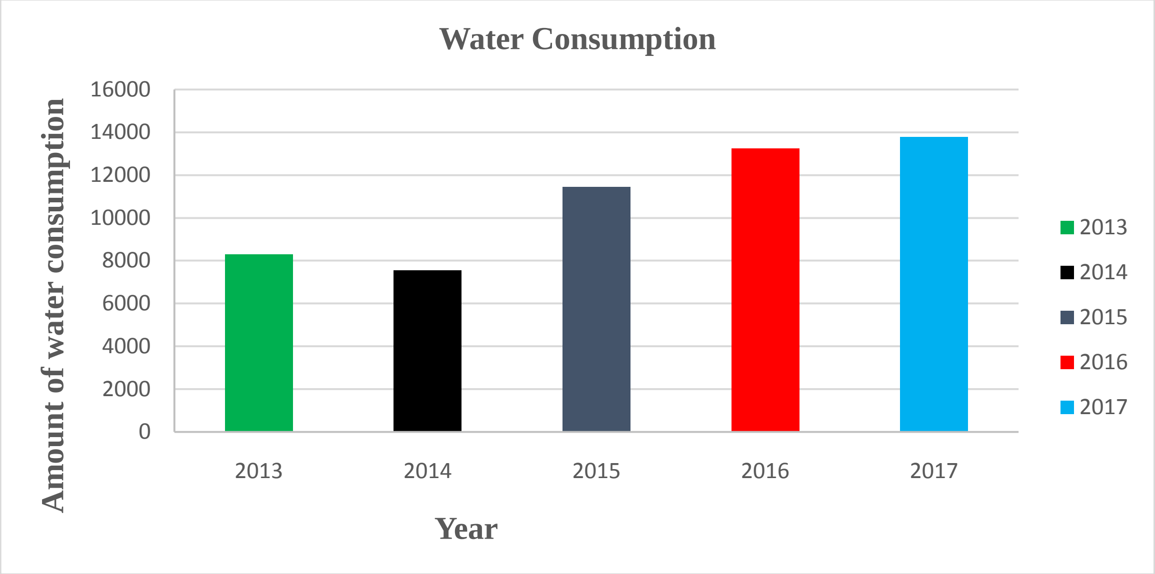

Figure 4.1 Water consumption

The distribution of average domestic water supply coverage of the town is found to be 29.73 l/capital/day. This average per capita consumption is almost close to the minimum design value low while compared with the country standard used for design purpose (30 to 60 l/capital/day). According to some literatures, a minimum quantity of 25 l/capita/day domestic water supply categorized as basic level of service (Wallingford 2003) which is lower than the average domestic consumption of the town.

4.1.3 Water demand by mode of service

Domestic water demand is the daily water requirement for use by human being for different domestic purposes like drinking, cooking, bathing, gardening, etc. the domestic water demand required by human being can be supplied or obtained through different modes of services depending on the economic level and facilities owned by the individual. The use of water for domestic purposes may be sub divided in various categories drinking, food preparation and cooking, cleaning, washing and personal hygiene, vegetable garden watering and other uses including waste disposal. Generally, for Ambo town piped system, the models and levels can be categorized as Public Tap (PT), Yard connection Own (YCO), Yard Connection Shared (YCS), and House Connection (HC).

Table 4.3Projected Service Level

	2010 (%)	2014 (%)	2019 (%)	2024 (%)	2029 (%)
HC	3.7	6.9	10.9	14.8	18.8
YTU (Private)	33.8	36.1	39.0	41.9	44.8
YTS	33.8	32.0	29.7	27.5	25.2
PF	12.8	12.5	12.1	11.6	11.2
	84.1	87.5	91.7	95.8	100

4.1.4 Population Distribution by Mode of Service

Mode of service is an important element on the one hand for evaluating the level of water coverage that was the focus of this section and on the other hand it has a direct impact on the water loss that was dealt separately. The adopted per capita water demands of each of the modes of services.

Table 4.4 population percentage distribution by mode of service

User	Total Number of Population served	Percentage
Public Tap(PTU)	12,454	12.5%
YTU (Private)	37,064	37.2 %
YTU (Neighboring)	30,887	31 %
House Connection	8,070	8.1%
Total	88,475	88.8%

Source: CSA (2007) Statistical Report

The socio-economic household survey analysis identified the surveyed households who have access to safe water supply by mode of services. The survey indicates that, the majority of the inhabitants (about 12.5%) get their water from a tap outside their compound (i.e. from public fountains and vendors). About 37.2% have a private yard connection, 31% neighboring yard connection and 8.1% have house connection. The rest of the inhabitants about 11.2% use traditional water sources (like protected well/spring, unprotected well/spring, rivers and ponds) for their day to day water use.

Figure 4.2 Photo taken during field observation showing collecting water from water leakage

4.1.5 Population Forecasting

In order to forecast the current population (2017) of the study area based on last population census report population and housing census report of 2007 which was prepared by Ethiopian Central Statistical. Growth rate of 4.5% which was reported by CSA for town of Ambo was used for the current projection**.** Moreover, the exponential growth rate model has been used.

Table 4.5 population growth rates

Year		**Growth rate**
2005	2010	4.6%
2010	2014	4.4%
2015	2019	4.3%
2020	2024	3.8%
2025	2029	3.6%

Source: CSA (2007) National census figures

Applying the growth rate in the exponential model, the urban population of Ambo is projected up to year 2029.

4.1.6 Evaluation of the Distribution of the Water Supply Coverage

In this section the distribution of the consumption in relation to number of population. In areas where water supply coverage is sufficient, volume of domestic's water consumption is expected to be linear related to the level connection. Areas having better level of connection are expected to consume more water as they can easily get it within their building or compound.

4.1.6.1 Correlation between Population and Billed Consumption

It is necessary to evaluate consumption with population. This has been evaluated using the correlation between the water billed consumption and number of population. Plotting water consumption by number of population graphically illustrates R-squared values for regression models.

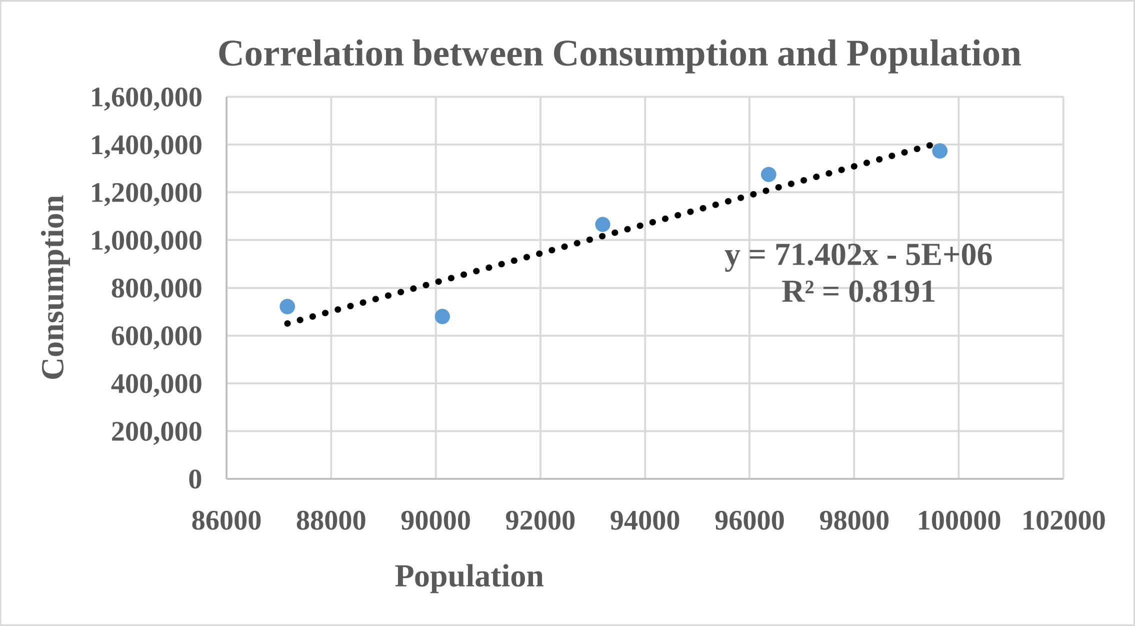

Figure 4.3: Scatter plot for volume of water consumption and number of population

Year	Population	Billed Consumption
2013	87,165	722,436
2014	90,129	680,477
2015	93,193	1,065,767
2016	96,362	1,274,656
2017	99638	1,373,230

The coefficient of determination (r is 0.82 indicates that the regression model account for 82% of water consumption is explained by population size.

4.2 Water Loss Analysis

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water loss for the town. The water production and consumption of the water supply service are assessed based the past five years' record. The production figures are taken from the water meter installed at the source and the consumption is read from the water meters installed for the customers and public fountains. The five years' actual production and consumption figures obtained from the town water supply service.

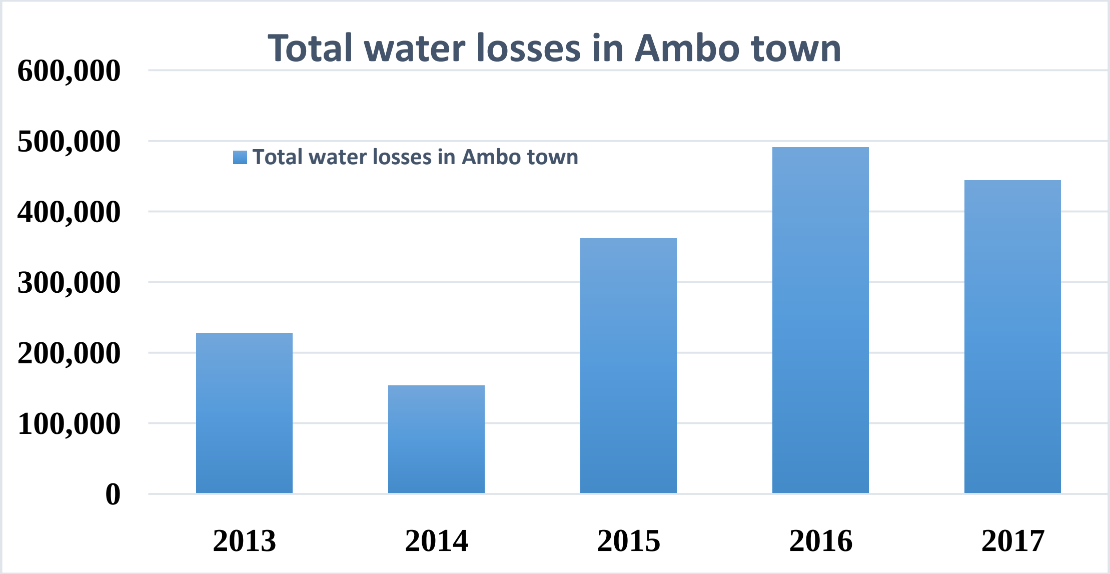

Figure 4.4: Annual water losses of the town

Annual water produced and distributed to the system within specified year was 1,816,918 $m^3$and annual water loss as derived using the above expression was 443,688 m^3which account to 24.41% of the total production.

Thus unaccounted for water is already on the higher side for a town size of Ambo. Decreasing the existing losses must be considered as part of the immediate rehabilitation plan of the town water supply system.

Table 4.6 Percentage of Non- Revenue water

Year (G.C)	Production(m^3 / year)	Consumption(m^3 /year)	NRW	
			(m^3)	**(%)**
2013	950,355	722,436	227,919	23.98
2014	834,048	680,477	153,571	18.41
2015	1,427,290	1,065,767	361,523	25.32
2016	1,765,264	1,274,656	490,608	27.79
2017	1,816,918	1,373,230	443,688	24.41

(Source:Ambo town water supply service office, existing document)

Due to the costant production/supply of water to the system, and accordingly the increases of water consumption in the town were the reason for reduction of total total volume of NRW in recent years.

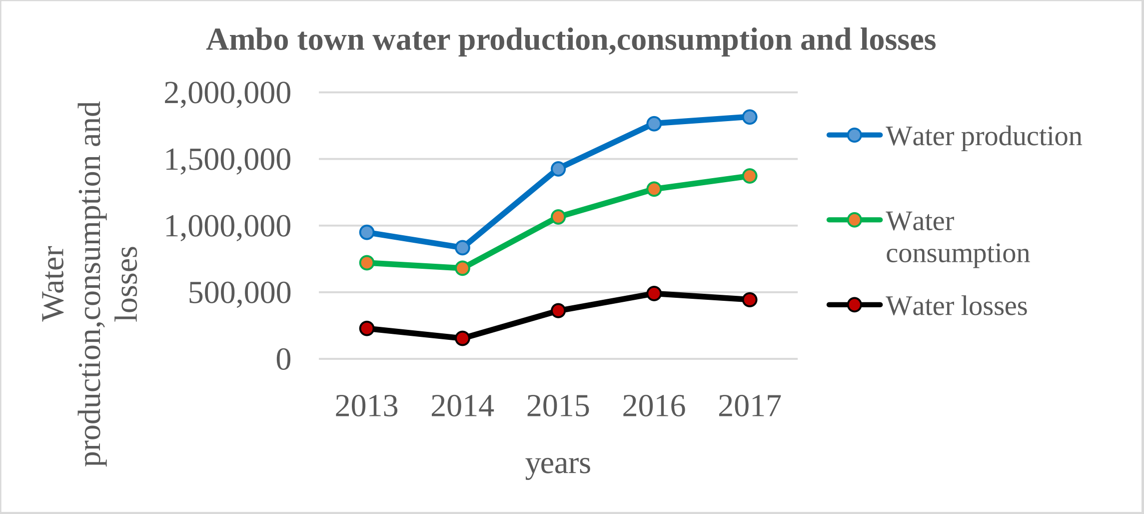

Figure 4.5 Annual water production, consumption and loss trends

4.2.1 Category of water loss

The total Non- Revenue water loss during 2017 was recorded as 443,688 m^3. These amounto f waterloss were categorized as physical/real and apparent loss. unavoidable annual real loss (UARL) or the minimum achieveable annual physical losses was adopted as the total physical loss in the system and it was analyzed as; total apparent losses in the system were determined from the town water balances as;

Apparent loss = Total NRW -UARL = (443,688-142,007.94) m^3/year = 301,680.06m^3/year ap parent loss was large in volume, and it cover 16.6% of total volume of water losses in Ambo town water distribution system. While, physical losses were also contribute a cosiderable volume of loss in the system and it cover 7.82% of total NRW.

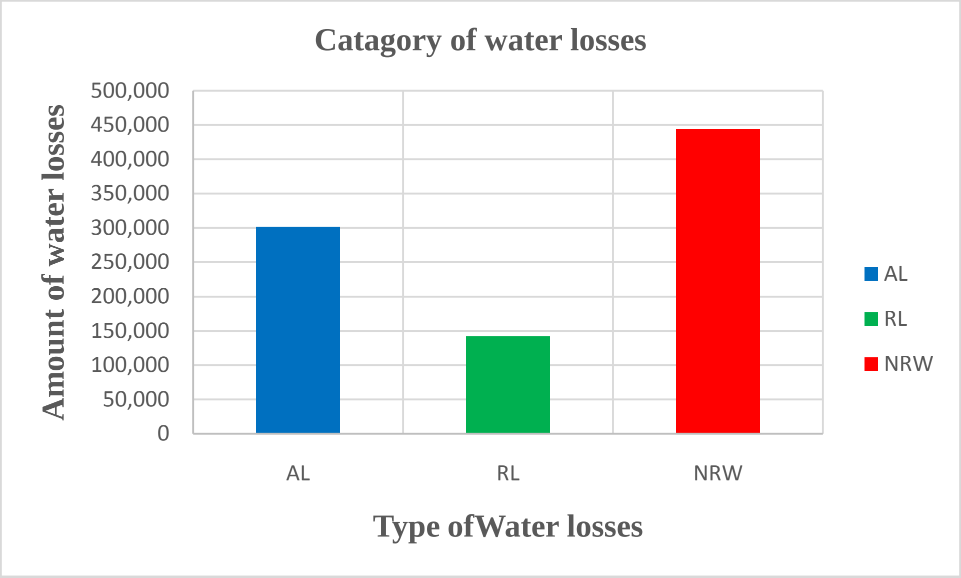

Figure 4.6 Category of water loss

4.2.1.1 Water Loss Expressed as per Number of Connection

Water loss expressed as a percentage could be an appropriate means to show the extent of the loss within a given environment, but it is not a good indicator for comparing the losses from one area to another. According to some literatures, comparison of water loss between different areas is recommended to be done using the water loss per service connection per day. Taking the total number of connection in the town as 11,014 the water loss per connection for the similar duration was derived as, Water loss = 443,688 x 1000 ÷ (11014×365) = 110.37liters/connection/day. This figure shows as litters per service connection per day increase water losses also increases.

4.2.1.2 Water Loss Expressed as per Length of Pipes

Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non- densely populated areas. The total length of pipes of greater or equal to 50mm diameter have been used to evaluate total water loss of the entire town is 39.23km. Using total pipe length of the entire town, the water loss per kilometer length of main pipes was derived to be 443,688 ÷ (39.23 km×365days) = 30.99 m^3/km/day**.** This figure shows that as length of the pipe increases the amount of water losses per day increases.

4.2.2 Financial analysis

The main financial source of Ambo town water service office is the government budget and regional contribution. Accordingly, the financial plan and polices of in the town water service system of was assessed as below.

4.2.2.1 Water tariff policies

One of the leakage management strategies in the water utilities is the water tariff carried out in the system. The major objective of water tariff is to make financial sustainability and cost recovery, with the consideration of low income groups. Accordingly, the water tariff structure for Ambo town water system was reviewed and applied based on the regional water, mineral an energy bureaure commended value, and the expected capital benefit of the waterut ility. As per the town water service office, the tariff structure is adopted as flat and graded rate. Table 4.6 below show that; public fountain uses are charged flat rate i.e. the same rate for all consumtion while, house and yard connection users are charged progressive rate poli ces i.e.the tariff rate increases with the consumption volume of water.

Table 4.7 Water tariff policies

Block	Consumption range m^3/month	Tariff (ETB/ m^3
1	0-4	4
2	4-7	5.5
3	7-10	7
4	>10	9
PF		9

(Source: Ambo town water supply service office, existing document)

From the above table the total annual water produced and distributed to the system within the specified year has been 1,816,918 cubic meters and the annual total water loss as derived using the above expression was 443,688 cubic meter that accounts to 24.41% of the total water production. Taking the average tariff of water in the city as 6.25 birr/m^3, the water loss is estimated to be 2,773,050 birr every year. Therefore, from this figure it was discussed that; the general leakage management trends of Ambo town water service system were in poor status, and the utility was given less attention for water loss.

4.3 Major factors contributing to water loss in Ambo town

There are several reasons for the high level of water loss in Ambo town. These factors are given below.

4.3.1 Age and size of pipe

It has been observed that how old pipe were laid in Ambo town water distribution network,and as shown in table 4.7 below nearly 20.53% of the pipe were served with out any replacement for the last 30 Years. Where by these pipe materials suffered its quality due to long services time, water carrying capacity and environmental conditions. Therefore, age and pipe size are the main factors for frequent pipe bursting and real losses in the town waterdistribution network. Accordingly, the water utility were lost 5.46 m^3/day of water from the system, and these mainly were occur in the transmission main, and distribution line served around treatment plant and in center of the town.

Table 4.8 pipe length by age and size category

Description	Age category	Dameter (mm)	Length (m)	Length (%)
Ductile iron	30 years and above	400- 450	4233.97	10.79
Galvanizing iron	30 years and above	150- 200	3816	9.74
Polyvinyl chloride	10 years and below	100- 250	31167.1	79.47
Total			39217.07	100

4.3.2 Illegal connection

As a developing town; there are a significant number of illegal users of water within Ambo town water distribution network and were contribute the reduction in service level to authorized water distribution network, and were contribute to the reduction in service level to authorized consumers. The town water utility were not known the actual figure of residences that do not pay water tariffs but received water from the distribution system.But as per the feed back from the water utility;construction sectors,different enterprises and hotels in the town are mainly contributing in large number. Due to limitation of data, water losses as result of illegal connections were analyzed from the water balance. And the town water service office to loss expected of 25,228.26 m^3/ year of water illegally (unauthorized consumption).

Therefore, illegal connected users have also contributed large volume of water loss in Ambo town.

4.3.3 Pressure

The pressure needed to supply water through the pipe network itself cause water loss in several ways through increased leakage because of increased pressure. Increased burst frequency as a consequence of increased pressure; pressure cycling from frequent on/off switching by pumps of fauulty pressure reducing valves can cause fatigue in plastic pipes. On the other hand, higher pressure will result in more water leaking through damaged pipe line. All pipe have specific Pressure within which they should serve; once the pressure is exceeded, the pipes naturally give way. This is worsened if the fitting were lower pressure rating as well. Excessive pressure should be avoided, if possible serve water under minimum aceptable residual pressures.

4.3.4 Poor construction and back filling

Faulty laying of pipes and in correct back filling will cause rapid pipe failure. Storage of plastic pipe in the sun and damage during handiling will shorten their durability. On the custemers, side there will be faulty tap washers, ball valves, poor seals as cause loss. To compliment a good design quality worker should inspect if not significant leaks at joints and fitting become evident.

4.3.5 Unaccounted for water

Not all the water that goes in the distribution pipe reaches the consumers. Some portion of this water wasted in the pipe line due to defective pipe joints, cracked and broken pipes, flood hazards, fault valves and fittings. On the other hand, Ambo town is severely suffering from seasonal floods. There is no enough drainage system in the city. Besides, to this some quantity of water was lost due to unutilized and illegal connections. The losses, or uncontrolled for water are expressed as a percentage of the total production.

4.3.6 Data handling error

Data handling error in the meter reading and billing process were contributed for apparent losses. Customer meter reading practice; especially unbilled metered trends were the common problem of Ambo town water service office. Where by, recording of under or overestimated figure lead the water utility to improper collection of revenue, and at the end of month the authority was lost money. According, as per the authority 2017 annual report; the town water authority has lost 3118m^3/ year of water due to poor data handling process.

4.3.7 Poor maintenance practice

Many water utilities have less attention for water loss as a result of their poor maintenance capacities. In Ambo water service it was observed that; there are no enough budget, proper instrument, accessories, and strong policies for suitable leakage management. But these have a considerable impact for physical losses in town water distribution system.

4.4 Water Distribution System Modeling

Analysis of water distribution network provides the basis for the design of new systems,the extensions, and control of existing systems. The flow and pressure distributions across a network are affected by the arrangement and size of the pipes and the distribution of thedemand flows. The objective of this modeling was not to predict the exact time at which different uses get water, But to develop a simplified model, node demand is dependent on the pressure at the junction nodes to reduce the water loss and maximize the flow rate at the tap. WaterCADV8i could show pressure,demand,and hydraulic grade in different nodes as well as velocities, head loss gradient and head loss in different pipes through out the distribution system.

4.4.1 Existing reservoirs capacity

The capacities of reservoirs in the water supply system were determined using different methods. The most appropriate and economical approach of determining storage volume of reservoir is the 24- hours supply demand simulation mass curves. In order to develop such type of curves, it requires reliable recorded historical data of hourly water demand figuresof the town. But, in the absence of such type of data, to determine the size of reservoirs, it wasadopted the commonly practiced in many water supply systems and based on the urban watersupply design criteria of the ministry of water resources; it was used for sizing the reservoir volume as one third of the maximum daily demand. Therefore, as per the design criteria of the FDRE; MOWIE, the maximum day factor usually varies between 1.0 and 1.3. Hence, a maximum day factors of 1.15 was adopted for assessing the maximum day water demand and reservoirs capacity for Ambo town and applied it corresponding to the total average day demand of a particular year (2017).

Maximum day demand = 1.15 * average day demand =1.15 * 5500 = 6325 m^3/d

Accordingly, the current required reservoirs volume capacity for water demand of Ambo tow nwas estimated as;

Reservoir capacity = maximum day demand *1/3= 6325*1/3 = 2108m^3

Hence, from the above finding to satisfy the current water demands of Ambo town; the clear water reservoir was sized as a 2100m^3 volume capacity of standard reservoir. But, in the existing water supply system of Ambo town service reservoir had a capacity of 1000m^3. This indicate, the existing reservoirs capacities were very small in size comparing with the current water demand of the town, and it was one of the major factors of the dayto day intermittent water distribution in the town. Therefore, in order to provide as a wet well for the elevation of a continues supply of clear water, for Ambo town the existing 1000 m^3 reservoirs can be incorporated to the system and an additional 1200 m^3 capacity new reservoir should be constructed to deliver adequate water in the distribution network.

4.4.2 Distribution main line

Regards the topography of Ambo town, the locations of nodes in the water distribution line is in close proximity to each other. The maximum and minimum water pressure in the distribution system was 225.3m and 3.05m head around treatment plant and service reservoir, respectively. According to the design criteria of the FDRE; MoWIE, the maximum and minimum water pressure in the distribution system is 80m and 15m, respectively. Beside these comparision; the current Ambo town existing water distribution network was operating out of the recommended limitation. This is because of; water is delivered to the distribution main simultaneously by gravity means, and the system were served beyond its design life.

4.4.3 Pressure variation in the distribution system

Variation of water pressure in the distribution system is mainly because of hourly fluctuation of water demand. The water pressure in Ambo town water distribution system were a function of this factor. Variation of elevation difference in most part of the town also an impact for the rising and reduction of water pressure in the network. Therefore, during peak demand time most part of the network was disconnected from the system and wide residential area of the town were not getting water. While, most of the residences were get and collect water at night flow during low demand time. However, residences found around treatment plant area, down stream of treatment plant and low part of the town were get water continously.

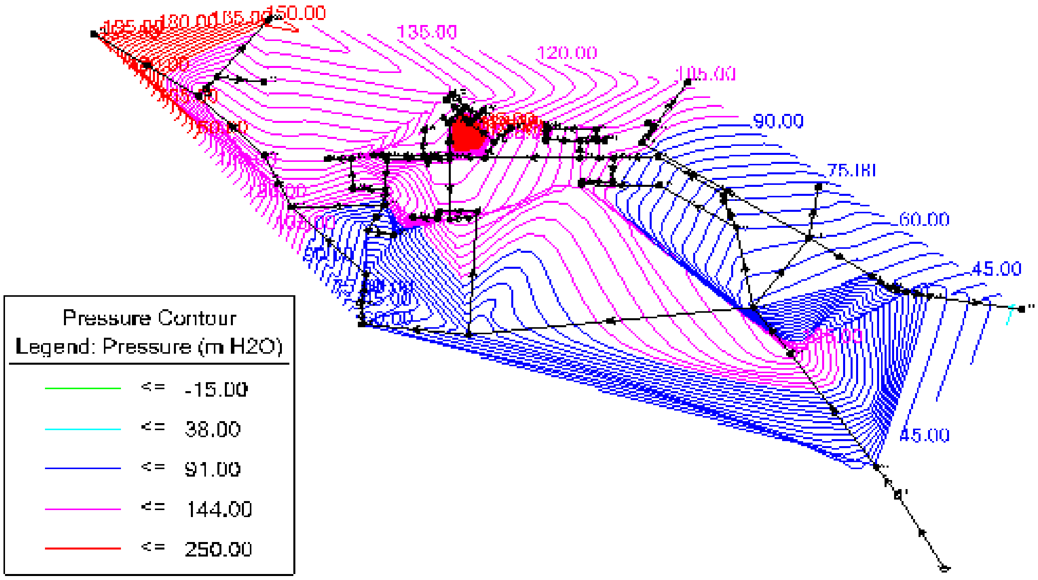

Figure 4.7 Pressure variation in distribution system

4.4.4 Flow

The flow arrow symbol on the pipe in the plan view always indicates the direction of flow, and the “start node” and “stop node” fields in the pipe properties indicate the orientation of the pipe itself. If water is flowing from the “start node” to the “stop node” the flow arrow was point thatway and the flow result value should be positive. If water is flowing from “stop node” to the “start node” the flow arrow was point that way and the flow result value was negative. A negative flow indicates orientation of flow with regard to the orientation of the pipe itself. Thereason why this behavior occur is because in some system (mainly water distribution), flow can often reverse direction over the course of a day. Showing the negative sign in front of the calculated flow value is one way for the user to distinguish the current direction of flow.

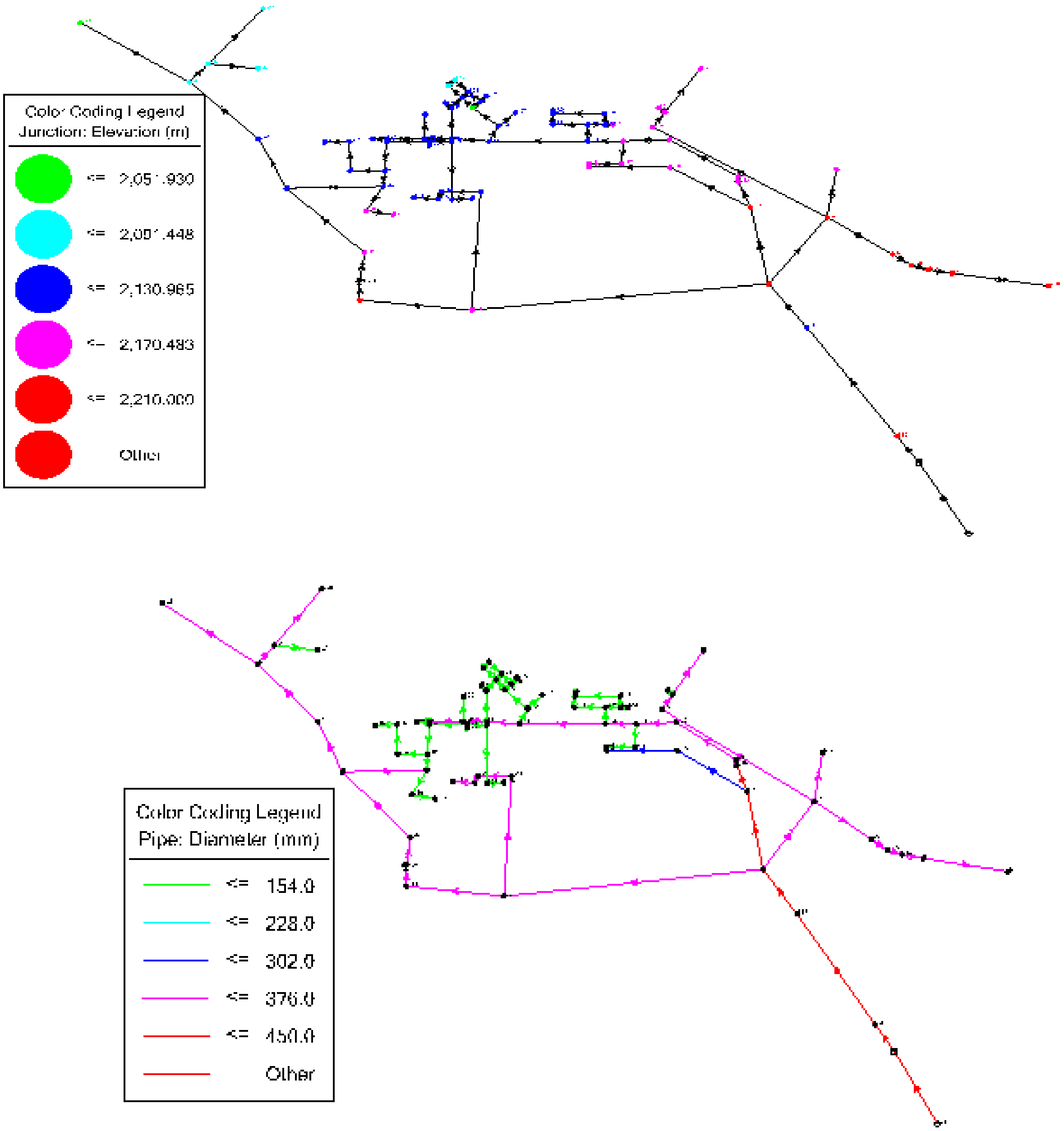

Figure 4.8 Water distribution network analysis of flow, junction, pipe diameter and elevation

4.4.5 Model Calibration and Validation

Model calibration is the process of comparing the results of model simulation to actual field data and making corrections and adjustments to the model in order to achieve close agreement between models predicted values and field measurements. Typical comparison values include pressures, flow rates and service reservoir water levels. Model parameters that may require correction during the calibration process include system connectivity, node ground elevations and control valve settings. Estimated model parameter values that may require adjustment include pipe roughness coefficients and nodal demand allocation and peak factors.

4.4.5.1 Hydraulics Calibration and Validation

Even though the required data have been collected and entered into a hydraulic simulation software package, the modeler cannot assume that the model is an accurate mathematical representation of the system. The hydraulic simulation software simply solves the equations of continuity and energy using the supplied data. Thus, the quality of the data will dictate the quality of the results. The accuracy of a hydraulic model depends on how well it has been calibrated, so a calibration analysis should always be performed before a model is used for decision-making purposes.

4.4.6Nodal demand

Nodal distribution demand for towns with the order of magnitude of Ambo does not show appreciable difference amongst demand categories. The fact that the topographic situation has dictated the provision of only one pressure zone further strengthens the logic for using a uniform demand through out the nodes. But as the demand is done differently the domestic and non- domestic demand is considered differently therefore the node near the commercialin stitution and the other node are seen as per their own demand. Hence this deduction givesroo m for developing the town in all directions, as the municipality is not very clear about the futu re industrial zone and development area of the town at this moment.

4.4.7 Network lay out

The prevailing topgraphy of Ambo town has dictated the consideration of one distinct pressure zone, which is eventually feed by the gravity system. The elevation ranges from

2168m begning of the service reservoirs up to 2080m above mean sea level at the west of the town. The primary distribution network route has already constructed.

4.4.8 Network analysis

The revised distribution network is now redesigned in such a way that it economical and efficiently conveys the peak hour demand of year 2029. As the size, routs and conditions of pipes in the existing distribution network are inadequate to accommodate the pressure and flow magnitudes ofthe new system; no part of the existing distribution network is included int he analysis of the revised distribution network as mentioned above. However it is obviousthat since all the existing house and yard connections can not be switched over night to thenew distribution system, they are assumed to be in use for some time in the future. The water service is adivised to gradually change house connections to the new distribution line and at the same time abandon old and leaking pipes. The distribution network has been carried by using the waterCADv8i computer programming and the frictional head losses in the distribution network are computed using the Hazen- Williams formula. As expressed in the design parameter the frictional head losses should less than 5.86m/km but in the design there are very few pipes. Which have frictional head loss between 5 and 12m/km.

The available head in the nodes ranges from 64 to 135m. about 74% of the total nodes have a head greater than 100m and the rest have less than 100m. however, taking in to account that the house connections are usually of small diameter ½” there should be considerable headloss between the nodal and the actual house fixtures, there by the resulting residual head at the point of fixtures would be within the 100m limit. The analysis for peak hour’s demand and maximum velocity is checked for nodes with minimum residual head and maximum velocity. As shown in the output of WaterCADv8i analysis table there is no node with minimum head of 15m. At the same time the maximum velocity is 1.13m/sec, which is acceptable .

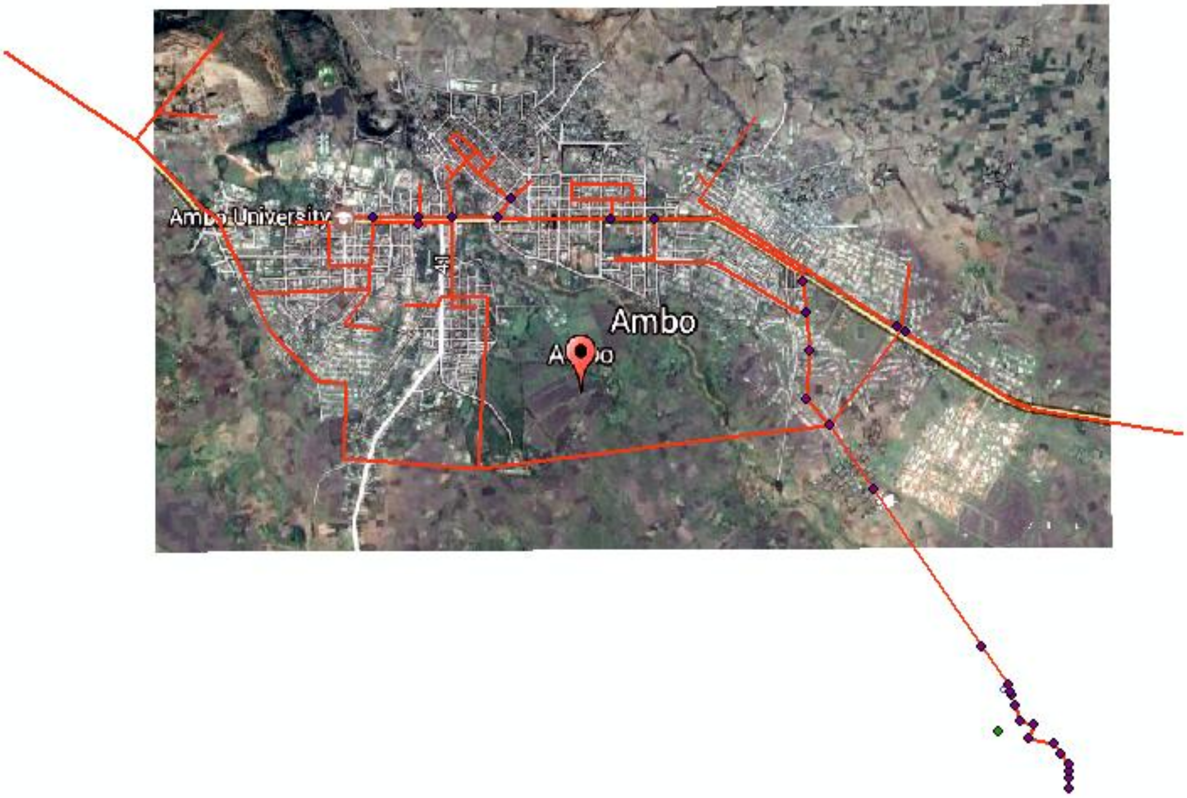

Figure 4.9 System distribution network map imposed over town map

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The existing water distribution system of Ambo town was established for an estimated population of 50,000. But as compared with the current population figure of 99,638 it was served beyond the life and low coverage in the town. For various demand categories, the current average percapital water consumption of Ambo town was found as 79 l/c/d. besides comparing the maximum water demand of the town (5500 m^3/day), in constrast the size of existing infrastructural components such as clear water reservior and distribution pipes were found small in capacities and leads to supplying water intermittently. There by water pressure in the distribution network observed that were not performing within the proposed maximum and minimum design criteria set by FDRE, MoWIE.

The standard of service reservoir is the volume of one third of the maximum day demand based on this the size of service reservoir for Ambo town water supply is currently 1000 m^3 only so this is very low on the standards, the current time the maximum day demand of Ambo town is very high biased on this the current time the new service reservoir will be 1200 m^3 after subtracting the existing reservoir volume must be cube red domestic water supply coverage,
nodal distribution demand for towns with the order of magnitude of Ambo does not shows appreciabledifference amongst demand categories.
Accordingly, the water distribution network were faced a frequent pipe bursts and failure during low demand time and exposed to large volume of water loss especially in high pressure zone areas, while during high demand time mostly residences found in dense population and higher level of the town were not received and/served continuous water from the system.

Although with low water distribution in the town, water loss analyzed from recorded annual production and consumption figure. Where by during 2017 the town water balance indicated that 24.41% of treated water was lost as a total Non Revenue water. Thus, 7.61% of total losses were within the distribution network and accounted as physical loss, while 16.6% % is lost as a result ofapparent loss. Further water loss was examined based on the infrastructure leakage index method, any however there is physical losses and contribute considerable volume of water losses in the distribution system. While, apparent losses are more significant and the major sources of water losses in Ambo.

In general, aging and size of pipe material, metering in accuracies (under registration), illegal connection, systematic data handling errors and poor maintenance practicies were found as the major sources of water losses in Ambo water distribution networks.

Gaps related with financial limitations, lack of professionals experts, and less attention towards water loss management are the major problems of Ambo town water utility.Whereby, the overall maintenance and leakage controlling practices of the authority were found in poor performance. In general, it was conclude that the current water distribution network of Ambo town was in poor performance and were not conducted adequate water to the various demand categories of the town.

5.2 Recommendations

In order to improve the water supply services of town in terms of coverage, water demand and reducing water loss the following actions should be under taken. The first and actual information should be collected and assessed the problem. Because, this study work specifically investigated the water supply and demand, the existing water supply quantity, reducing water loss; the gap associated with water scarcity and suggested possible measure.

The predominantapproach towards meeting increasing water demand of the town is towards supply augmentation schemes.This includes developing new sources or expanding existing sources. Therefore,the town water supply and sanitation office have to be look seriously into water demand management. To satisfy continuous rising of water demand several measures should be taken and for the existing situation of Ambo town water supply distribution system and the resources take a seriously such as the following.

- Increase reservoir at list one third of the maximum day demand of the town
- Proper sized pipes during the implementation of the distribution system.
- Awareness creation to the society

The Ambo town futurity water distribution system network route should be determined through thereconnaissance work that involve surveying of the network areas in line with then ew master plan of town. Both the municipality and ambo town water and sewerage service are in all directions of the pressure and future industrial zone and developmenttarget areas of the town considered in the design must be review were also reviewed through discussions with the relevant administrative and executive bodies of the town.

The water supply system of Ambo should be redesigned as continuous supply depending on fixed and extended pattern, assuing the availability of water sources, and the using of pressure reducing valves to reduce the high pressure in the system if the pressure of the distribution

system is above from the permissible limit or if these design parameters may beabove thedesi gn criteria. Following the determination of the route along with topographic data like elevation, the analysis of the revised distribution network has taken the recent available land-use and urban development master plans of the city into consideration as mentioned above.

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APPENDICES

Water supply mains- Ambo town

Appendix 1; - Pipe line input data

pipe name	Node 1	Node 2	Length(m)	Diameter(mm)	Roughness Coeff
GWM 1	CWT	J-001	151.79	450	130
GWM2	J-001	J-002	67.06	450	130
GWM3	J-002	J-003	108.51	450	130
GWM4	J-003	J-004	113.69	450	130
GWM5	J-004	J-005	306.32	450	130
GWM6	J-005	J-006	317.6	450	130
GWM7	J-006	J-007	1539.24	450	130
GWM8	J-007	J-008	235.61	450	130
GWM9	J-008	J-009	220.68	400	130
GWM10	J-009	J-010	481.58	400	130
GWM11	J-010	J-011	123.44	400	130
GWM12	J-011	J-012	175.56	400	130
GWM13	J-012	J-013	48.77	400	130
GWM14	J-013	J-014	102.11	450	130
GWM15	J-014	J-015	198.42	400	130
GWM16	J-015	BPT	43.59	400	130
P-Conn	BPT	EXT-WT	11.89	250	130
EXT-1	EXT-WT	J-EXT-1	37.19	250	120
EXT-2	J-EXT-1	J-EXT-2	69.19	250	120
EXT-3	J-EXT-2	J-EXT-3	539.8	250	120
EXT-4	J-EXT-3	J-EXT-4	86.56	250	120
EXT-5	J-EXT-4	J-EXT-5	43.59	250	120
EXT-6	J-EXT-5	J-EXT-6	70.41	250	120
EXT-7	J-EXT-6	J-CN-ext-1	221.89	250	120
EXT-8	J-CN-ext-1	J-EXT-7	252.98	200	120
EXT-9	J-EXT-7	J-EXT-8	344.42	200	120
EXT-10	J-EXT-8	J-EXT-9	252.37	200	120
EXT-11	J-EXT-9	J-EXT-10	334.67	200	120
EXT-12	J-EXT-10	J-EXT-11	660.5	150	120
EXT-13	J-EXT-11	J-EXT-12	259.08	150	120
EXT-14	J-EXT-12	J-EXT-13	522.73	150	120
EXT-15	J-EXT-13	J-CN-ext-2	121.31	150	120
ACU-01	J-CN-ext-2	J-085	353.57	200	150
ACU-02	J-085	J-084	596.49	200	150
ACU-03	J-084	J-083	864.72	200	150

GR-01	J-083	J-086	160.02	100	150
GR-02	J-086	J-087	715.67	100	150
GR-03	J-087	J-088	122.22	100	150
GR-04	J-088	J-089	104.85	100	150
GR-05	J-089	J-090	458.72	100	150
GR-06	J-090	J-091	80.16	100	150
GR-07	J-091	J-092	89.92	100	150
GR-08	J-092	J-093	114.6	100	150
GR-09	J-093	J-094	314.86	100	150
GR-10	J-094	J-095	743.41	100	150
GR-11	J-095	J-096	181.05	100	150
GR-12	J-096	J-097	568.45	100	150
AR-01	J-008	J-034	280.11	250	150
AR-02	J-034	J-035	520.9	250	150
AR-03	J-035	J-036	1050.34	250	150
AR-04	J-036	J-037	331.01	250	150
AR-05	J-037	J-038	562.66	250	150
AR-06	J-038	J-039	75.9	250	150
AR-07	J-039	J-040	663.55	250	150
AR-08	J-040	J-041	438.3	250	150
AR-09	J-041	J-042	300.5	250	150

Pipe Name	Node-1	Node-2	length(m)	Diameter(mm)	Roughness Coeff
HS-01	J-042	J-055	8.53	200	150
HS-02	J-055	J-056	346.86	200	150
HS-03	J-056	J-057	1098.5	200	150
HS-04	J-057	J-058	12.5	200	150
HS-05	J-058	J-059	37.19	200	150
HS-06	J-059	J-060	16.15	200	150
HS-07	J-060	J-061	485.24	200	150
HS-08	J-061	J-062	423.98	200	150
HS-09	J-062	J-063	291.08	200	150
HS-10	J-063	J-064	316.69	200	150
ACU-04	J-064	J-082	431.9	150	150
ACU-05	J-082	J-081	402.64	150	150
ACU-06	J-081	J-080	348.08	150	150
ACU-07	J-080	J-079	266.09	150	150
ACU-08	J-079	J-078	58.83	150	150
ACU-09	J-078	J-077	82.91	150	150
ACU-10	J-077	J-076	74.07	150	150

ACU-11	J-076	J-075	381	150	150
ACU-12	J-075	J-074	177.39	150	150
ACU-13	J-074	J-073	348.35	150	150
ACU-14	J-073	J-072	920.8	150	150
ACU-15	J-072	J-071	420.93	150	150
ACU-16	J-071	J-070	193.24	200	150
ACU-17	J-070	J-069	510.24	200	150
ACU-18	J-069	J-068	388.62	200	150
HS-11	J-064	J-065	178.92	200	150
HS-12	J-065	J-066	201.17	200	150
HS-13	J-066	J-067	78.33	200	150
CNT-01	J-014	J-043	488.59	200	150
CNT-02	J-043	J-044	188.06	200	150
CNT-03	J-044	J-045	381.91	200	150
CNT-04	J-045	J-046	87.78	200	150
CNT-05	J-046	J-047	364.24	200	150
CNT-06	J-047	J-048	238.05	200	150
CNT-07	J-048	J-049	1263.7	200	150
CNT-08	J-049	J-050	223.42	150	150
CNT-09	J-050	J-051	410.26	100	150
CNT-10	J-051	J-052	65.23	100	150
CNT-11	J-052	J-053	208.48	100	150
CNT-12	J-053	J-054	382.83	100	150
ES-01	J-008	J-016	206.65	250	150
ES-02	J-016	J-017	15.54	250	150
ES-03	J-017	J-018	1023.21	250	150
ES-04	J-018	J-033	1513.33	200	150
ES-05	J-032	J-033	142.95	200	150
ES-06	J-031	J-032	566.93	200	150
ES-07	J-030	J-031	252.68	200	150
ES-08	J-029	J-030	71.63	200	150
ES-09	J-028	J-029	536.14	200	150
ES-10	J-027	J-028	249.33	200	150
ES-11	J-026	J-027	833.63	200	150
ES-12	J-026	J-025	389.53	200	150
ES-13	J-023	J-024	668.12	250	150
ES-14	J-018	J-023	831.49	250	150
ES-15	J-018	J-019	997.92	250	150
ES-16	J-019	J-020	151.49	250	150
ES-17	J-020	J-021	99.36	250	150
ES-18	J-021	J-022	147.22	250	150

Water supply mains- Ambo town

Appendix 2; - Pipe LineResult

pipe Name	Node 1	Node 2	Length (m)	Diameter (mm)	HWC	Flow rate(l/s)	Head loss(m)	velocity (m/s)	HL/1000 (m/m)
GWM 1	CWT	J-001	151.79	450	130	109	0	0.69	2.24
GWM2	J-001	J-002	67.06	450	130	109	0.187	0.69	2.24
GWM3	J-002	J-003	108.51	450	130	109	0.082	0.69	2.24
GWM4	J-003	J-004	113.69	450	130	109	0.133	0.69	2.24
GWM5	J-004	J-005	306.32	450	130	109	0.14	0.69	2.24
GWM6	J-005	J-006	317.6	450	130	109	0.377	0.69	2.24
GWM7	J-006	J-007	1539.24	450	130	109	0.39	0.69	2.24
GWM8	J-007	J-008	235.61	450	130	101.6	1.66	0.64	2.24
GWM9	J-008	J-009	220.68	400	130	101.6	0.451	0.81	3.15
GWM10	J-009	J-010	481.58	400	130	101.6	0.422	0.81	3.15
GWM11	J-010	J-011	123.44	400	130	101.6	0.922	0.81	2.36
GWM12	J-011	J-012	175.56	400	130	101.6	0.236	0.81	2.36
GWM13	J-012	J-013	48.77	400	130	101.6	0.336	0.81	2.36
GWM14	J-013	J-014	102.11	450	130	101.6	0.093	0.81	2.36
GWM15	J-014	J-015	198.42	400	130	101.6	0.195	0.81	2.36
GWM16	J-015	BPT	43.59	400	130	95.3	0.324	0.76	2.36
P-Conn	BPT	EXT-WT	11.89	250	130	95.32	0.073	0.76	8.41
EXT-1	EXT-WT	J-EXT-1	37.19	250	120	25.17	0.05	0.51	1.41
EXT-2	J-EXT-1	J-EXT-2	69.19	250	120	25.17	0.1	0.51	1.41
EXT-3	J-EXT-2	J-EXT-3	539.8	250	120	22.95	0.64	0.47	1.19
EXT-4	J-EXT-3	J-EXT-4	86.56	250	120	22.95	0.1	0.47	1.19
EXT-5	J-EXT-4	J-EXT-5	43.59	250	120	22.95	0.05	0.47	1.18
EXT-6	J-EXT-5	J-EXT-6	70.41	250	120	22.95	0.08	0.47	1.19
EXT-7	J-EXT-6	J-CN-ext-1	221.89	250	120	22.95	0.26	0.47	1.19
EXT-8	J-CN-ext-1	J-EXT-7	252.98	200	120	22.95	0.89	0.73	3.52
EXT-9	J-EXT-7	J-EXT-8	344.42	200	120	22.95	1.21	0.73	3.52
EXT-10	J-EXT-8	J-EXT-9	252.37	200	120	18.34	0.59	0.58	2.32
EXT-11	J-EXT-9	J-EXT-10	334.67	200	120	18.34	0.78	0.58	2.32
EXT-12	J-EXT-10	J-EXT-11	660.5	150	120	18.34	6.23	1.04	9.43

EXT-13	J-EXT-11	J-EXT-12	259.08	150	120	14.18	1.52	0.8	5.85
EXT-14	J-EXT-12	J-EXT-13	522.73	150	120	14.18	3.06	0.8	5.85
EXT-15	J-EXT-13	J-CN-ext-2	121.31	150	120	11.57	0.49	0.65	4.02
ACU-01	J-CN-ext-2	J-085	353.57	200	150	11.57	0.23	0.37	0.65
ACU-02	J-085	J-084	596.49	200	150	11.57	0.39	0.37	0.65
ACU-03	J-084	J-083	864.72	200	150	11.57	0.57	0.37	0.65
GR-01	J-083	J-086	160.02	100	150	1.8	0.1	0.26	0.61
GR-02	J-086	J-087	715.67	100	150	1.8	0.44	0.26	0.61
GR-03	J-087	J-088	122.22	100	150	1.8	0.07	0.26	0.61
GR-04	J-088	J-089	104.85	100	150	1.8	0.06	0.26	0.61
GR-05	J-089	J-090	458.72	100	150	1.8	0.28	0.26	0.61
GR-06	J-090	J-091	80.16	100	150	1.8	0.05	0.26	0.61
GR-07	J-091	J-092	89.92	100	150	1.8	0.06	0.26	0.61
GR-08	J-092	J-093	114.6	100	150	1.8	0.07	0.26	0.61
GR-09	J-093	J-094	314.86	100	150	1.8	0.19	0.26	0.61
GR-10	J-094	J-095	743.41	100	150	1.8	0.46	0.26	0.61
GR-11	J-095	J-096	181.05	100	150	1.8	0.11	0.26	0.61
GR-12	J-096	J-097	568.45	100	150	1.8	0.35	0.26	0.61
AR-01	J-008	J-034	280.11	250	150	45.51	0.78	0.93	2.79
AR-02	J-034	J-035	520.9	250	150	42.62	1.29	0.87	2.47
AR-03	J-035	J-036	1050.34	250	150	42.62	2.59	0.87	2.47
AR-04	J-036	J-037	331.01	250	150	42.62	0.82	0.87	2.47
AR-05	J-037	J-038	562.66	250	150	42.62	1.39	0.87	2.47
AR-06	J-038	J-039	75.9	250	150	42.62	0.19	0.87	2.47
AR-07	J-039	J-040	663.55	250	150	42.62	1.64	0.87	2.47
AR-08	J-040	J-041	438.3	250	150	33.74	0.7	0.69	1.6
AR-09	J-041	J-042	300.5	250	150	33.74	0.48	0.69	1.6

pipe			Length	Diameter		Flow	Head	velocity	HL/1000
Name	Node 1	Node 2	(m)	(mm)	HWC	rate(l/s)	loss(m)	(m/s)	(m/m)
HS-01	J-042	J-055	8.53	200	150	19.2	0.01	0.61	1.67
HS-02	J-055	J-056	346.86	200	150	19.2	0.58	0.61	1.67
HS-03	J-056	J-057	1098.5	200	150	17.17	1.49	0.55	1.36
HS-04	J-057	J-058	12.5	200	150	17.17	0.02	0.55	1.36

HS-05	J-058	J-059	37.19	200	150	17.17	0.05	0.55	1.36
HS-06	J-059	J-060	16.15	200	150	15.81	0.02	0.5	1.16
HS-07	J-060	J-061	485.24	200	150	15.81	0.57	0.5	1.17
HS-08	J-061	J-062	423.98	200	150	15.81	0.49	0.5	1.17
HS-09	J-062	J-063	291.08	200	150	15.81	0.34	0.5	1.17
HS-10	J-063	J-064	316.69	200	150	15.81	0.37	0.5	1.17
ACU-04	J-064	J-082	431.9	150	150	11.74	1.18	0.66	2.73
ACU-05	J-082	J-081	402.64	150	150	11.74	1.1	0.66	2.73
ACU-06	J-081	J-080	348.08	150	150	11.74	0.95	0.66	2.73
ACU-07	J-080	J-079	266.09	150	150	11.74	0.73	0.66	2.73
ACU-08	J-079	J-078	58.83	150	150	11.74	0.16	0.66	2.73
ACU-09	J-078	J-077	82.91	150	150	11.74	0.23	0.66	2.73
ACU-10	J-077	J-076	74.07	150	150	11.74	0.2	0.66	2.73
ACU-11	J-076	J-075	381	150	150	11.74	1.04	0.66	2.73
ACU-12	J-075	J-074	177.39	150	150	11.74	0.48	0.66	2.73
ACU-13	J-074	J-073	348.35	150	150	11.74	1.05	0.66	2.73
ACU-14	J-073	J-072	920.8	150	150	9.03	1.55	0.51	1.68
ACU-15	J-072	J-071	420.93	150	150	9.03	0.71	0.51	1.68
ACU-16	J-071	J-070	193.24	200	150	9.03	0.08	0.29	0.41
ACU-17	J-070	J-069	510.24	200	150	9.03	0.21	0.29	0.41
ACU-18	J-069	J-068	388.62	200	150	5.62	0.07	0.18	0.17
HS-11	J-064	J-065	178.92	200	150	4.07	0.5	0.52	2.77
HS-12	J-065	J-066	201.17	200	150	4.07	0.56	0.52	2.77
HS-13	J-066	J-067	78.33	200	150	4.07	0.22	0.52	2.77
CNT-01	J-014	J-043	488.59	200	150	8.88	0.2	0.28	0.4
CNT-02	J-043	J-044	188.06	200	150	8.88	0.08	0.28	0.4
CNT-03	J-044	J-045	381.91	200	150	8.88	0.15	0.28	0.4

CNT-04	J-045	J-046	87.78	200	150	8.88	0.04	0.28	0.4
CNT-05	J-046	J-047	364.24	200	150	8.88	0.15	0.28	0.4
CNT-06	J-047	J-048	238.05	200	150	8.88	0.1	0.28	0.4
CNT-07	J-048	J-049	1263.7	200	150	8.88	0.51	0.28	0.4
CNT-08	J-049	J-050	223.42	150	150	8.88	0.36	0.5	1.63
CNT-09	J-050	J-051	410.26	100	150	8.88	4.81	1.13	11.73
CNT-10	J-051	J-052	65.23	100	150	8.88	0.76	1.13	11.73
CNT-11	J-052	J-053	208.48	100	150	8.88	2.45	1.13	11.73
CNT-12	J-053	J-054	382.83	100	150	8.88	4.49	1.13	11.73
ES-01	J-008	J-016	206.65	250	150	14.54	5.86	1.85	29.23
ES-02	J-016	J-017	15.54	250	150	32.64	0.31	0.66	1.51
ES-03	J-017	J-018	1023.21	250	150	32.64	0.02	0.66	1.51
ES-04	J-018	J-033	1513.33	200	150	32.64	1.54	0.66	1.51
ES-05	J-032	J-033	142.95	200	150	15.97	1.8	0.51	1.19
ES-06	J-031	J-032	566.93	200	150	15.97	0.17	0.51	1.19
ES-07	J-030	J-031	252.68	200	150	15.97	0.67	0.51	1.19
ES-08	J-029	J-030	71.63	200	150	15.97	0.3	0.51	1.19
ES-09	J-028	J-029	536.14	200	150	15.97	0.09	0.51	1.19
ES-10	J-027	J-028	249.33	200	150	15.97	0.64	0.51	1.19
ES-11	J-026	J-027	833.63	200	150	15.97	0.3	0.51	1.19
ES-12	J-026	J-025	389.53	200	150	15.97	0.99	0.51	1.19
ES-13	J-023	J-024	668.12	250	150	15.97	0.46	0.51	1.19
ES-14	J-018	J-023	831.49	250	150	4.58	0.08	0.15	0.12
ES-15	J-018	J-019	997.92	250	150	4.58	0.1	0.15	0.12
ES-16	J-019	J-020	151.49	250	150	12.09	0.24	0.27	0.24
ES-17	J-020	J-021	99.36	250	150	12.09	0.04	0.27	0.24
ES-18	J-021	J-022	147.22	250	150	12.09	0.02	0.27	0.24

Water supply mains- Ambo town

Appendix 3; - End node result average day

Node name	external Demand(l/s)	Hydraulic Grade(m)	Node Elevation (m)	Pressure Head (m)	Node Pressure (kpa)
J-001		2250	2250	8.096	79.4
J-002		2245	2245	11.725	115
J-003		2235	2235	19.501	191.2
J-004		2222	2222	30.167	295.8
J-005		2209	2209	36.922	362.1
J-006	6.77	2202.5	2202.5	36.373	356.7
J-007		2184.6	2184.6	23.708	232.5
J-008		2179.9	2179.9	23.726	232.7
J-009		2177	2177	20.823	204.2
J-010		2172.5	2172.5	12.665	124.2
J-011		2169.1	2169.1	12.816	125.7
J-012		2167.4	2167.4	9.9	97.1
J-013		2166.6	2166.6	8.748	85.8
J-014		2167	2167	6.837	67.1
J-015		2163.3	2163.3	5.129	50.3
J-016		2183.8	2183.8	19.523	191.5
J-017		2184	2184	19.3	189.3
J-018		2169	2169	32.731	321
J-019		2187.8	2187.8	13.731	134.7
J-020		2181.9	2181.9	19.583	192
J-021		2180.2	2180.2	21.255	208.4
J-022	12.09	2187.5	2187.5	13.935	136.7
J-023		2156.7	2156.7	44.909	440.4
J-024	4.58	2159	2159	42.535	417.1
J-025	15.97	2143.8	2143.8	52.475	514.6
J-026		2142.5	2142.5	54.234	531.9
J-027		2131.5	2131.5	66.201	649.2
J-028		2117.4	2117.4	80.569	790.1
J-029		2132.4	2132.4	66.235	649.2
J-030		2131.8	2131.8	66.919	656.3
J-031		2113.7	2113.7	85.282	836.3
J-032		2151.8	2151.8	47.931	470.1
J-033		2155.5	2155.5	44.409	435.5
J-034	2.89	2175.5	2175.5	27.337	268.1
J-035		2173.4	2173.4	28.15	276.1
J-036		2176.1	2176.1	22.867	224.3

J-037		2171	2171	27.141	266.2
J-038		2128.3	2128.3	68.368	670.5
J-039		2126.7	2126.7	69.778	684.3
J-040	8.88	2160.5	2160.5	34.411	337.5
J-041		2170.7	2170.7	23.531	230.8
J-042		2158.9	2158.9	34.827	341.5
J-043		2157.7	2157.7	16.314	160
J-044		2152.7	2152.7	21.379	209.7
J-045		2143.3	2143.3	30.913	303.2
J-046		2140.8	2140.8	33.443	328
J-047		2131.5	2131.5	42.87	420.4
J-048		2122	2122	52.446	514.3
J-049		2110.5	2110.5	64.428	631.8
J-050		2113.5	2113.5	61.797	606
J-051		2117.2	2117.2	62.907	616.9
J-052		2129.7	2129.7	51.195	502.1
J-053		2129.6	2129.6	53.735	527
J-054	5.66	2148.1	2148.1	39.753	389.9
J-055		2158.6	2158.6	35.112	344.3
J-056	2.03	2134.6	2134.6	58.485	573.5
J-057		2105.7	2105.7	85.836	841.8
J-058		2074.9	2074.9	116.557	1143
J-059	1.36	2071.7	2071.7	119.7	1173
J-060		2070.3	2070.3	121.078	1187
J-061		2079.3	2079.3	111.531	1093.7
J-062		2108.7	2108.7	81.697	801.2

Node name	**Node Title**	**External Demand(l/s)**	**Junction Elevation(m)**
J-001		0	2250
J-002		0	2245
J-003		0	2235
J-004		0	2222
J-005		0	2209
J-006		6.77	2202.5
J-007		0	2184.6
J-008		0	2179.9
J-009		0	2177
J-010		0	2172.5

J-011		0	2169.1
J-012		0	2167.4
J-013		0	2166.6
J-014		0	2167
J-015		0	2163.3
J-016		0	2183.8
J-017		0	2184
J-018		0	2169
J-019		0	2187.8
J-020		0	2181.9
J-021		0	2180.2
J-022		12.09	2187.5
J-023		0	2156.7
J-024		4.58	2159
J-025		15.97	2143.8
J-026		0	2142.5
J-027		0	2131.5
J-028		0	2117.4
J-029		0	2132.4
J-030		0	2131.8
J-031		0	2113.7
J-032		0	2151.8
J-033		0	2155.5
J-034		2.89	2175.5
J-035		0	2173.4
J-036		0	2176.1
J-037		0	2171
J-038		0	2128.3
J-039		0	2126.7
J-040		8.88	2160.5
J-041		0	2170.7
J-042		0	2158.9
J-043		0	2157.7
J-044		0	2152.7
J-045		0	2143.3
J-046		0	2140.8
J-047		0	2131.5
J-048		0	2122
J-049		0	2110.5
J-050		0	2113.5
J-051		0	2117.2

J-052		0	2129.7
J-053		0	2129.6
J-054		5.66	2148.1
J-055		0	2158.6
J-056		2.03	2134.6
J-057		0	2105.7
J-058		0	2074.9
J-059		1.36	2071.7
J-060		0	2070.3
J-061		0	2079.3
J-062		0	2108.7

Node Name	Node Title	External Demand(l/s)	Junction Elevation(m)
J-063		0	2104
J-064		0	2149.3
J-065		0	2113.2
J-066		0	2106.3
J-067		4.07	2117.5
J-068		5.62	2078.6
J-069		3.41	2055.7
J-070		0	2052.5
J-071		0	2047.5
J-072		0	2013.4
J-073		2.71	2003.6
J-074		0	1987
J-075		0	1975
J-076		0	2035
J-077		0	2043.4
J-078		0	2058.4
J-079		0	2069.1
J-080		0	2112
J-081		0	2129.5
J-082		0	2136
J-083		8.88	2111.1
J-084		0	2068
J-085		0	2074.9
J-086		0	2112
J-087		0	2086.1
J-088		0	2086.9

J-089		0	2094.1
J-090		0	2052
J-091		0	2045.6
J-092		0	2033.5
J-093		0	2002.7
J-094		0	1992.9
J-095		0	1970.1
J-096		0	1952
J-097		1.64	1922
J-CN-Ext-1		0	2139.9
J-CN-Ext-2		0	2089.6
J-EXT-1		0	2164.1
J-EXT-2		2.02	2162.4
J-EXT-3		0	2157.1
J-EXT-4		0	2155.8
J-EXT-5		0	2154.2
J-EXT-6		0	2152
J-EXT-7		0	2122
J-EXT-8		4.19	2132.3
J-EXT-9		0	2127.5
J-EXT-10		0	2116.9
J-EXT-11		3.78	2086.3
J-EXT-12		0	2084.2
J-EXT-13		2.37	2087.4