PERFORMACE EVALUATION OF GIRJA TOWN WATER SUPPLY SYSTEM IN SIDAMA REGIONAL STATE, ETHIOPIA

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

HAWASSA, ETHIOPIA

MAY, 2023

PERFORMACE EVALUATION OF GIRJA TOWN WATER SUPPLY

IN SIDAMA REGIONAL STATE, ETHIOPIA

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A THESIS SUBMITTED TO THE

DEPARTMENT OF WATER RESOURCES AND IRRIGATION ENGINEERING,

HAWASSA INSTITUTE OF TECHNOLOGY, SCHOOL OF

GRADUATE STUDIES

HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE

DEGREE OF

MASTER OF SCIENCE IN WATER RESOURCES ENGINEERING AND MANAGEMENT

HAWASSA, ETHIOPIA

MAY, 2023

ADVISORS' APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

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This is to certify that the thesis entitled "PERFORMACE EVALUATION OF GIRJA TOWN WATER SUPPLY IN SIDAMA REGIONAL STATE, ETHIOPIA" submitted in partial fulfillment of the requirements for the degree of master's with specialization in Water Resources Engineering and Management the Graduate Program of the Department of WATER RESOURCES AND IRRIGATION ENGINEERING, and has been carried out by MESERET MARMARA ID. No GPWREMW/0011/12 under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by MESERET MERMERA have read and evaluated his MSc thesis entitled "PERFORMACE EVALUATION OF GIRJA TOWN WATER SUPPLY IN SIDAMA REGIONAL STATE, ETHIOPIA", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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ACKNOWLEDGMENT

First, I want to express my thankfulness to the Almighty God who has helped me in every manner and given me the stamina to finish learning.

Next, I want to express my gratitude to my advisors Dr. Tewodros Tesfaye and Mr. Petros Yohannes, for their devoted criticism, close monitoring, and supervision of the thesis work.

Finally, I would want to express my gratitude to my family for their unwavering love and support over the course of my entire life.

I am so satisfied to my classmates in all our harmonization from start to end of this M.Sc. Program in Hawassa University.

At the last, but not least, I am very proud of my lovely wife for her love, support and she is truly a special gift from God for me; and I don't forget my close friends support and encouragements.

ACRONYMS

CAD……………………………….Computer Aided Design

CSA……………………………….Central Statistical Authority

DEM………………………………Digital elevation model

ELL…………………………… …..Economic level leakage

GPS ……………………………….Global positioning system

GTP..Growth and transformation program

ILI…………………………………infrastructure leakage index

IWA……………………………….International water association

JMP……………………………….Joint Monitoring Program

MDG………………………………Millennium development goal

MoWR……………………………Ministry of water resources

NRW………………………………non-revenue water

NTU ………………………………Nephelometric Turbidity Unit

TWB……………………………….town water board

TWSSO ………………………. ….Town Water Supply Service Office

UAP……………………………….Universal Access Program

UARL……………………………......Unavoidable annual real losses

UFW………………………………unaccounted-for water

UFW………………………………unaccounted for water

UNICEF…………………………Unite nation children fund.

WASH……………………………water, sanitation, and hygiene

WDS……………………………..Water distribution system

WHO ……………………………World health organization

WPC……………………………..Water design criteria

WSSE……………………………Water supply service enterprise

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DECLARATION

I hereby declare that this MSc thesis is my original work and that has not been presented for a degree in any other university and all sources of material used for this thesis have been duly acknowledged.

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ABSTRACT

Increasing demand can be fulfilled by designing efficient water distribution networks based on advance computing systems include modern hydraulic modeling and designing software's. The main objective of this study was to model the existing water distribution system and evaluating hydraulic performance of the system. For conducting this study, both primary and secondary data were collected and tools such as WaterGEMS and GPS were used. The total average per capita consumption of the Town in the year 2015 E.C was 10.15 l/c/d which showed lower performance compared to 50 l/c/d which is set by GTP-II of the country for category 4 town and 35653 m^3/year of water is non-revenue (NRW) and the apparent losses and real losses of the town is 0.9% and 26.75% respectively. There is high gap between demand and supply in the town because the current (2015 E.C) and the future (2035 E.C) maximum daily water demand of the town was 767224.89 m^3/year and 1172509 m^3/year respectively and the current water production of the town was 128940 m^3/year which only satisfies 19.6% of the current demand (2015 E.C) and 14.4% of the future demand in year 2035. Therefore, securing additional water supplies becomes an essential issue to meet the current and future water demand of the town. The hydraulic model result showed that 2.78% for pressure value (<10m), 76.39% for pressure value (10-70m) and 20.83% for pressure value (>70m) at peak consumption and the velocity of pipe flow showed that 91.3% (<0.6m/s), 8.7% the range of 0.6-2m/s at low consumption time. The performance of the model was evaluated using model evaluation statistics. The value of the coefficient of determination (R^2) for pressure calibration was 0.98. Finally, the water quality was examined for biological, and physiochemical parameters, potential causes of water losses in the town water supply system were assessed, and improvement measures were proposed for existing water supply problems.

Keywords: Girja town, water production, NRW, Hydraulic performance, WaterGEMS,

1. INTRODUCTION

1.1. Background

Managing of water is a challenging task in developing countries. The rapidly growing population number time to time is causing an ever-increasing demand on water supply system (Maharashtra, 2014).

The major challenges facing many urban water utilities especially in sub-Saharan Africa is the high level of water losses. Nonrevenue water (NRW) is the difference between system input volume and billed authorized consumption according to the International Water Association (IWA) standard water balance and terminology, and consists of water losses (apparent losses and real losses) and unbilled authorized consumption (Lambert, 2015)

According to Mekonin (2014) access to improved drinking water source in Africa in 2006, 602 million people. This shows coverage increased from 56% in 1990 to 64%. The rate at which Africans gained access to improved drinking water sources, 245 million people since1990, falls short of that required to meet the 2015 Millennium Development Goals (MDG) drinking water target (Water sector, 2015) .

Ethiopia is one of the member countries that have adopted the Millennium Development Goals (MDG) declarations with its main objective towards poverty reduction (UNDP, 2008). As a part of the Universal Access Program (UAP), the water supply and sanitation program were ratified by the Ethiopian Parliament in 2010 (Ministry of Uraban Development, 2014). This initiatives laid the framework for planning the Water Sanitation and Hygiene measures (WASH).The MDG target was to attain 85% of National Potable Water Access in 2020 whereas, the UAP national targets was to attain 98% of Rural Potable Water Access within 1kms (25Liters/Capita/Day) and 100% of Urban Potable Water Access within 0.25km (40Liters/Capita/Day) by the end of 2020 (Water sector, 2015).

Every citizen in the country has the right to have access to potable water. Access to safe drinking water supplies and sanitation services in Ethiopia are among the lowest in Sub-Saharan Africa (Seid, 2017).

All water supply service enterprise seeks to provide customers with a reliable, continuous supply of high- quality water while minimizing costs. This water is often delivered through very large and complex distribution systems consisting of many distant of pipe. These systems are often difficult to understand because of their physical complexity and because of the large amount of data that must be managed (AWWA, 2015).

Water supply systems in urban areas are often unable to meet existing demands and are not available to everyone rather some consumers take disproportionate amounts of water, and the poor is the first victim to the problem (Asmelash, 2014). Moreover, managing and reducing losses of water at all levels of a distribution system remains one of the major challenges facing many water utilities in most developing countries including Ethiopia (World Bank, 2015). As a result of the overall shortage of water, many water utilities are faced a problem in distributing the available water impartially among the residents (Abaynesh, 2015).

The water supply coverage is evaluated based on the quantity of supply and level of connection that are related to the water loss. In this part of the analysis, the number of domestic connections per family and the average daily per capita consumption is used to analyze the domestic water supply coverage (Behute, 2016). The level of coverage was also compared with the necessary minimum quantity to meet needs for drinking and the local standard of per capita water use (Desalegn, 2015).

Access to clean water is a critical issue that affects all the Woredas in the Sidama Regional State. The Girja town is one of the developing towns in Sidama Region in which there is a growing demand for water and sanitation services in the town due to growing populations. The existing infrastructure of the town is not new and in poor condition. There are frequent interruptions to the scheme due to the breakdown of equipment, shortage of technicians, and inefficient operation and maintenance practices. This caused the population does not get adequate water due to the shortage of water and, one of the causes of this problem is that the existing water supply system has a design problem.

According to Candelieri, et al., (2013) Leakage is often a large source of unaccounted for water and is a result of either lack of maintenance or failure to renew aging systems. Leakage may also be caused by poor management of pressure zones, which result in pipe or pipe joint failure. Although some leakage may go unnoticed for a long time, detection of visible leakage also requires good reporting which includes some level of public participation. The current water supply coverage, population forecast, demand-supply balance, and supply system analysis are all included in this study.

Therefore, this study was focused on improvement of poor performance of Girja Town water supply distribution system based on the objectives of the study using Bentley WaterGEMS CONNECT Edition Update 2.

1.2. PROBLEM STATEMENT

The major challenges of urban water supply systems in developing countries are low water supply service coverage, unavailability of sufficient water always, occurrence of very high amount of water loss, due to it does not meet national or international drinking water standards, (World Bank, 2006).

The primary cause of system failure or damage is the construction of the water supply without proper provision of the established criteria of the hydraulic performance of the distribution system, sustainability, maintenance, and operation. Water that is properly maintained and operated, resulting in a plentiful supply of safe water everywhere. Poor design and lack of safe maintenance and operation for system sustainability, the issue is particularly acute in poor countries. Due to poor spring environment management and source yield, system viability, and a lack of organized (networked) infrastructure in the appropriate locations, water supply systems in the Sidama region of Girja town do not operate as intended or are not continuously accessible.

Without universal access to clean water, extreme poverty cannot be eliminated (Cruz M, 2015). It was observed that in Girja town, there is a rapid growth in the population number due to uncontrolled urban expansion of the town and immigrants. This could result in low level of water production with the existing supply system in relation to current demand of the town. As it is indicated above the shortage of water in the distribution system could be caused by wrong assumptions, like in population forecasting. Using correct data inputs and other assumptions help to achieve appropriate design that resulted in exact balancing of water demands with the water supply amounts.

Water scarcity can be accelerated by such unexpected or unaccounted population pressure within distribution systems. In addition to these different hydraulic variables design problems such as the non-uniformity pressures, water velocity in the pipe distribution, head loss in the pipeline and loss of water at the burst pipes and junction were observed in some kebeles of the town that could also aggravate the problem.

To know the level of the problem and propose a mitigation measure evaluating the problems relating to design, operation and maintenance of the distribution system is important. Therefore, this research work was evaluated the present status of distribution system performance of the town and recommend possible measures for problems in hand.

1.2. OBJECTIVE

1.3.1 General objectives

The overall objective of this study is to evaluate hydraulic performance of the existing water supply system of the Girja town by using WaterGEMS CONNECT Edition Update 2.

1.3.2. Specific objectives

The specific objectives of this study are:

- ❖ To evaluate the existing water demand as well as its supply, service coverage and forecast future water demand of the town,
- ❖ To quantify the water loss and identifying the causes of water loss in the distribution network,
- ❖ To assess the hydraulic performance of the existing water distribution network by using WaterGEMS modeling,
- ❖ To examine existing water quality

1.3. RESEARCH QUESTIONS

The study will address the following research questions:

1. Are the existing water supply adequate water requirements of this town population now?
2. Are there balance b/n demand, water supply and the water coverage adequate or not for current and future?
3. Is this water supply system flow pressure and velocity adequate to reach all parts of town?
4. Is the existing water quality safe or not?
5. Is there water loss by leakage or by any means from supply system?
6. Is water available any time within 24 hours of a day?

1.4. SCOPE OF THE STUDY

The scope of the study is to check the reliability of the existing water distribution system and water loss on the town water supply distribution network and modeling the existing system problems using WaterGEMS CONNECT Edition Update 2 software. The study is limited to model the water distribution network from a clear water reservoir to distribution endpoint of the customer’s town water supply system in the Sidama region of Ethiopia and managing the existing and enhanced system hydraulic parameters (flow, pressure, and velocity) from model simulation results.

1.5. SIGNIFICANCE OF THE STUDY

The basic aim of this study is to assess the existing situation of Girja Town water supply distribution system by using WaterGEMS to the sustainable water distribution system of the town. This could have a significant on the improvement of the existing water distribution network, though, indicating the problems in relation to the operation, maintenance activities and hydraulic performance of the water distribution systems with possible mitigation measures. It also serves as base line data for any further investigation, as useful materials to government and non-government organizations. Farther more this study will also serve as a lesson for the future development of water supply distribution schemes in other areas of similar nature.

2. LITRITURE REVIEW

2.1. GENERAL

The developing towns' one of the difficulties among the other is imbalance between demand and supply, losses of water by various ways in all levels of the distribution system and poor management of the water supply distribution network. As a result, the distribution of water among the available resource becomes unsatisfactory.

Because of the poor management, the existing aged infrastructure increases the level of losses in the water supply and results demand gap. As this research deals with imbalance between demand and supply, distribution network develop, bursting and leakage problem of pipe at Water distribution system.

2.2. WATER DISTRIBUTION SYSTEM

Water distribution system model have become widely accepted within the water utility industry, as a mechanism for similarity the hydraulics behavior in water distribution system network. The most important consideration in the planning and operation of a water distribution system is to satisfy the consumer's demands. Thus, it is important to provide all users with good quality water and adequate amount at reasonable pressure at all times to ensure a reliable water distribution network system (Salman, 2015). Water utilities facing the high level of water loss in their distribution networks, for many utilities reducing loss should be the first option to pursue when addressing low service coverage levels and increased demand for piped water system. But increasing water distribution networks without addressing water losses was only guide to a cycle of waste and inefficiency (Hussni & Zyoud, 2003). Construction operation and maintenance of water infrastructure and providing water services to communities are the responsibilities of water utility. (Aydin, 2014) States that the six functional components of water utilities are such as source development, raw water transmission, raw water storage, treatment, finished water storage and finished water distribution. Well-planned water distribution system is vital in the development of urban areas. The network is made to satisfy various consumer demands while meeting minimum pressure requirements at certain nodes (Atiquzzamn, 2004). According to this study the benefits of evaluating the existing water supply distribution system to know the problems of the hydraulic system.

2.2.1. Components of water distribution system

i. Transmission mains

According to (Tomas, 2003) transmission main were consist of device that are convey large amount of water over great distances typically between major facilities within the distribution system. In most water supply system transmission main are mainly used to transport water from the source to the service reservoirs. Whereby individual customers are usually not served from these main transitions.

ii. Distribution mains

Distribution mains are an intermediate pipeline used to delivering water from the transmission main to customers. The distribution mains are smaller in diameter than transmission main and typically follow the general topology and alignment of the town streets. Different fittings such as elbows, tees, reducers, closed and numerous other accessories are used in the main to connect pipes. While other maintenance and operation appurtenances, such as fire hydrants and valves are also connected directly to the distribution mains (Tomas, 2003).

iii. Reservoir and storage tanks

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

iv. Pumps

Pumps are devices which provide pressure and head to the water. The most common input of energy into a system is during pumping. Pumps are crucial to any distribution system that cannot supply acceptable pressures to user through the sole use of gravity flow. The most common pump used in water distribution system is a centrifugal pump because of their low cost, simplicity, and reliability (NRC, 2006). Pump selection is usually dictated by rotational speed, discharge capacity, pumping head, power input, and efficiency. Pump efficiencies influence the pump operating cost, and the higher the efficiency the cheaper the value of operation. Pump efficiency is determined by the ratio of power delivered to the water to power input to the pump.

2.3. HYDRAULIC ANALYSIS AND DESIGN OF WATER DISTRIBUTION NETWORK

The computation of the flows and pressures in networks of pipes has been of great value and interest for those involved with the design, construction and maintenance of public water distribution system and with the advent of computer network components of WDS as well as to investigate more complex issues associated with their design and operation (Ormsbee, 2006). In a water distribution system, the steady state analysis is an important component of assessing the adequacy of a network. The hydraulic problem in connection with pipe networks consists of solving for the distribution of flow and head loss in the individual elements for a given total discharge or for a total given total head loss. The supply may be from reservoirs, storage tanks or pumps or specified as in flow or outflows at some points in the network and from the known flow rates the pressure or head losses through the system is computed. Alternatively, the solution may be initially for the heads at each junction of the network, and these can be used to compute the flow rates in each pipe of the distribution system. Within the formulation individual energy equations for every pipe are combined with individual nodal equations for every junction node to provide for a simultaneous solution for both nodal heads and individual pipe flow (Ormsbee, 2006). The method can directly solve both looped and branched network is numerically stable when the system becomes disconnected by checked valves, pressure regulating valves, or modeler’s error and the structure of the extremely fast and reliable sparse matrix solves (Haestad Method, et al., 2003).

2.4. BASIC PRINCIPLES OF HYDRAULIC MODELING

The hydraulic simulation model of distribution network is taken into account to be one within which all elements are connected to every other, every element is influenced by its neighbors and every element is consistent with the condition of all other elements. These conditions are mainly controlled by two laws: law of conservation of mass and law of conservation of energy. Thus, the total mass of water living within the system should be equal to the total mass of water leaving in the system and the sum of the flows at any given node should be equal to zero. The principle of conservation of energy is principally dictated by the Bernoulli’s equation, which states that the difference in the energy between any two points should be the same regardless of the path taken (Haestad Method, et al., 2003). A typical network in hydraulic model consists of the following components: these are pipes, storage tanks, pumps, valves, and reservoirs.

The junctions are representing points having base demands. Reservoirs are those points in model, which can have a specific storage capacity that varies with time. Reservoirs in hydraulic model are assumed to be an infinite source of water (Haestad Method, et al., 2003). Pumps are energy devices which provide pressure and head to the water distribution system. Generally, there are three parameters that define the pump operation; shut off head, the design point, and the maximum point. The pump should be able to overcome the elevations differences, which is dependent on the topography of the system. The head added on the pump to overcome these differences is called the static head. Friction and minor losses also affect the discharge from beginning to end of the pump.

2.5. HYDRAULIC MODELING OF WATER DISTRIBUTION SYSTEM

There are various modeling software's developed for the purpose of design and analysis of models for a water distribution network such as water CAD V8i, EPANET and water GEMS V8i. The hydraulic model software can be used for designing, operating, and maintaining of water distribution network with an appropriate way (Sonaje & Joshi, 2015).

2.5.1. Modeling Softwares

Water CAD V8i software

Water CAD V8i is a hydraulic modeling software package comprised of wide range of functionality includes graphical and profiling advancements, flexibility, and customization. Several features like hydraulic and water quality analysis, steady state and extended period simulations are also made to function with better capabilities strong data management along Auto CAD and GIS integrations. The advantage of water CAD over other software's include simplified model building with geospatial models and tools like load Builder and TRex water quality optimization. Water CAD V8i is thus easy way to use and flexible water distribution as well as quality modeling software packages accepted for variety of applications (www.bentley.com/waterCAD-sepc as retrieved on January 6, 2015).

EPANET 2.0 Software

EPANET 2.0 software is public domain software which can be efficiently used to design any sort of network. It provides variety of advantages like water quality analysis extended period simulation, residual chlorine calculations for disinfections, etc. it can also be used to renovate or restore the existing water supply distribution system. It is available as public domain software with the relative categorization as EPANET 2.0 (www2.epa.gov/water-research/epanet as retrieved on November 6, 2014).

Modeling a system using Water GEMS

Water GEMS V8i is a flexible hydraulic modeling software package with the advancements in the optimization of networks, model building, integration with the Arc GIS and the AutoCAD functionalities, optimized model calibration, design, and its operations. It is a versatile hydraulic modeling software package with the advancements in the interoperability, geo special model-building, and optimization and asset management tools. The best part in the water GEMS V8i is giving of obtained results which is very attractive and appealing and can be presented with the variety of graphical tools include Arc Map visualization, thematic mapping, contouring, and profiling, profile with color coding. Water GEMS V8i has strong design algorithm to meet the criteria of accuracy in the design of water distribution networks, control of distribution network available like flow, pressure, and velocity along with their optimization (Sonaje & Joshi, 2015).

Water Distribution Network Model Selection

Due to the rise of advanced computing techniques and applications, there are various computer software developed for the design and analysis of water distribution networks like EPANET, Water CAD, Water GEMS, etc. Among these applications software's Bentley Water GEMS/CAD at the current time is well-known throughout the world due to its availability, functionality, user interference, compatibility, etc.

The advantages of WaterGEMS CONNECT Edition Update 2 over other software's its tools for a simplified model building with geospatial modules like water quality modeling, fire flow analysis, optimization, and scenario management, etc. WaterGEMS CONNECT Edition Update 2 is thus easy to use as a multipurpose water distribution scheme as well as quality Modeling. Also, the main advantage of WaterGEMS application is its various tools like Darwin designer for analyzing the cost of pipes and pipe catalog tools which are found to be very effective for Modeling, design, and optimization of water distribution network concerning strong data management and integration along with AutoCAD, ArcGIS and other related software packages (Bentley Systems, 2014).Moreover, the choice of software’s for Modeling distribution network is based on the overall cost of the project, data required by software’s, specificity of the software related to types of distribution networks it can handle as well as its computational requirements.

Bentley WaterGEMS CONNECT Edition Update 2

WaterGEMS CONNECT Edition Update 2 is a powerful tool for hydraulic Modeling software package with the advancements in highly competent and active Modeling software, which provides wide management of investigation and resolutions for fire-flow analysis, water quality Modeling. Many of the features and functions are common in Water CAD V8i and WaterGEMS CONNECT Edition Update 2, which modernizes the model building, integrated with the GIS and AutoCAD functionalities, and optimized model calibration, scenario management, design, and its operations (Rudolf, & Liemberger, 2010). The best part of the Water GEMSCONNECT Edition Update 2 is the presentation of obtaining results which is very attractive and appealing and can be presented with a variety of graphical tools include Arc Map conception, thematic charting, contouring, outlining with color coding and symbology. WaterGEMS CONNECT Edition Update 2 is selected due to the ease of model building and operation and is greater programming competencies as compared to water CAD V8i. The software finds the lowest allowable diameter for each pipe segment that will allow the system to function, or more specifically, to meet the minimum pressure requirements at all junctions (Shinde, et al., 2018).

Input data for assembling the model.

Brown (2007) has recognized as a water distribution system model is created using a link-node formulation that is governed by two conservation laws, namely mass balance at nodes and energy management round hydraulic nodes. The node is an idea where water drinking is allocated and defined as demand which treated as the nodal hydraulic head can be solved. This design is valid only if the hydraulic pressure at all nodes is acceptable so that the demand is autonomous of pressure. All the nodes are connected by the pipes. In practice, pipe networks consist not only of pipes but composed of various fittings, services, storage tanks and reservoirs, meters, regulating valves, pumps, and electronic and mechanical controls. For Modeling purposes, these system elements were organized into the following categories (Hussni, & Zyoud, 2003a).

Table 2.1: Input parameters and the primary purpose of water GEMS tools

Label	Type	Primary Modeling purpose	Input data
Reservoir	Node	Provides water to the system	Hydraulic Grade Line, water surface elevation
Pump	Node/Link	Provides energy to the system and raise the water pressure to overcome elevation deference and friction loss	Elevation, pump definition (characteristics of max, operation and design discharge, head efficiency)
Tank	Node/link	Store execs water within the system and release that water at the time of high usage	Base elevation, maximum elevation, minimum elevation and Diameter
Valve	Node / Link	Controls flow or pressure through a pipe and results in losses of energy in the system	Elevation, diameter, valve type
Pipe	Link	Transport water from one node to another node	Diameter, material, Pipe length and roughness coefficient
Junction	Node	Discharge the demand required or recharge the inflow water from/to the system	Elevation

(Source: Hussni & Zyoud, 2003a)

2.6. HYDRAULIC PARAMETERS OF WDS

The main hydraulic parameters in water distribution system are the pressure and the flow rate; other relevant design factors are the pipe diameter, velocities, and the hydraulic gradients (Masri M, 2005).

Pressure

According to (Aydin, 2014) the pressure at nodes depends on the adopted minimum and maximum pressure within the network, topographic circumstances, and the size of the network. The minimum pressure should be maintained to avoid water column separation and to ensure that consumer's demands are always provided. The maximum pressure constraints results from service performance requirements such fire needs or the pressure-bearing capacity of the pipes, also limit the leakage in the distribution system, especially that there is a direct relationship between the high pressure and the increasing of leakage value in the system (Thomas & Waliski, 2003)

Velocity

Velocity is also one of the important parameters in hydraulic performance evaluation of the water supply system. The result of velocity of Girja town is not desirable with response to (MoWR, 2006) of urban water supply design criteria. The minimum and maximum velocities within the distribution system are achieved per the design criteria during the peak flow condition. Velocity in distribution network is also varying with demand pattern changes. At peak hour demand the values are different as compared to minimum consumption hour.

Flow rate

Flow rate is the quantity of water pass within a certain time through a certain section. Velocity is directly proportional to the flow, for a known pipe diameter and a known velocity; the flow rate through a neighborhood is often estimated. Low velocities affect the proper supply and will be undesirable for hygienic reasons (Al-Zahrani, 2014).

2.7. ESTIMATION OF WATER DEMAND

The design and completing of any water supply scheme requires an estimate of the total amount of water required by the community. According to the (Zyoud, 2003) indicator for measuring the level of water demand is the amount of water consumed per capita per day (l/c/d). Water demand is a function of accessibility, religion, and climate conditions. The other indicator used in measuring the level of water consumption is the adequacy of distributed water. Demand estimation during a water distribution network provides crucial data for monitoring and controlling systems. Average day demands were used to estimate the baseline demand and other demand in the water distribution system including unaccounted-for water. Hence, most modelers determine the water demand analysis of a given town by applying baseline demand to a spread of peaking factors and demand multipliers. To simplify the complicated demand estimation of the current study is very vital. Because the demand was classified using the urban land use in Arc Map application to prepare overlying with existing network layout. To estimate water demand of the town have been taken the existing production and water consumption with new average daily demand design the compare with actual design report. The peak water demand for residential users implies one of the most difficult operating conditions for an urban water distribution system (Tomas, 2003).

Types of water demand

i. Domestic Demand

The domestic water demand includes drinking, bathing, washing, and cooking, lawn sprinkling, gardening, and sanitary purpose.

ii. Institutional, commercial, and public demands

This demand includes water required for other purposes public, commercial, and institutional. Besides, this category usually includes water day school, clinic, hospital, public office, shops, bar, restaurant, a cinema house, mosque, and churches. Normally, demand for such facilities are calculated according to their number or built-up areas assumed and/or projected in the town. Most of the time institutional and commercial demands will account for 15% of domestic water demand based on the degree of development of the town.

iii. Industrial Demand

The industrial demand category applies to major factories that consume a large volume of water per day. It is apparent that large scale industries consume a large volume of water, actually based on the type of industry, compared with other demands and this large demand along with the demand of the community can cause fluctuations in the water supply system of the community.

2.8. WATER DISTRIBUTION SIMULATION TYPES

The basic element of the hydraulic models is defined; further modification of the model can be done depending on its intended purpose. In our case the term simulation refers to the process of using a mathematical representation or real system called model (Bentley, 2014). Two types of simulation (steady state and extended period simulation) the model may perform, depending on what the modeler is trying to observe or predict.

Steady-state simulation

It determines the operating behavior of the system at a specific point in time. Steady-state simulation computes the state of the system (flow, pressure, pump operating attributes, valve position) assuming that hydraulic demands and boundary conditions do not change with respect to time. In general, this type of analysis was used to determine the short-term effect on demand conditions on the system.

Extended- period simulation

It determines the dynamic behavior of a system over a period, computing the state of the system as a series of steady-state simulations in which hydraulic demands and boundary conditions do change with respect to time. 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 throughout in the system in response to varying demand conditions and automatic control strategies formulated by the modeler. Then regardless of project size model-based simulation can provide valuable information to assist an engineer in making well informed decisions (Haestad Method, et al., 2003).

2.9. OPERATION AND MAINTENANCE PRACTICE

Water distribution systems are irregularly 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. Operation refers to the procedures and activities involved in the actual delivery of services, and Maintenance refers to the activities aimed at keeping existing facilities (physical assets) in serviceable conditions. Planned maintenance activities include supplies going offline (e.g., reservoir shutdown for inspection, cleaning, or repairs; installation of new pipe connections; pipe rehabilitation or break repairs; and transmission main valve repairs.) while, emergency situations include power failures, equipment failures, or transmission main failures. Therefore, all these activities can result in a reduction in system capacity and supply pressure, and changes to the flow paths of water within the distribution system (NRC, 2006).

Operation and maintenance aim to provide continuous and sustainable water supply services with the perspective that the useful life of the water supply facilities needs to be extended and their service quality enhanced; the health of the population must be maintained, and the quality of the environment must be preserved and protected. Therefore, lack of attention to the important aspect of operation and maintenance of water supply schemes led to corrosion of the useful life of the distribution systems.

2.10. WATER SUPPLY COVERAGE

Service level refer to utility`s declared dedication to deliver service of specified level in water supply institutes. Service level can be regulatory/customer related (response times, information availability, complaints etc.) or performance related (asset performance drove by faults, equipment failure etc.)

The quality of service is assessed based on service indicators consisting of coverage of service zone, service hours, metering and billing and the degree of responsiveness of service providers to consumer`s complaints.

All sources confirm that water supply coverage in Ethiopia is on a strong upward trajectory. According to official government data, water supply coverage has risen in 1990 from (11 percent rural, 70 percent urban) to in 2009 (62 percent rural, 89 percent urban). Based on the official government data, Ethiopia has already met of 60 percent. Estimates of current coverage from the international Joint Monitoring Program (JMP) are significantly more cautious, due to a range of factors. Nevertheless, the JMP data still portray a remarkable increase in coverage of over 1 million people per year (1990–2008), (AMCOW, 2015).

A municipal water supply system has the objective of providing an adequate and reliable water supply to meet the following demands:

- Residential occupancy water consumption.
- Commercial occupancy water consumption.
- Industrial occupancy consumption.
- Municipal and educational building use; etc.
- Needed Fire Flows (NFFs) that are available from a planned location of fire hydrants throughout the municipality; and
- Water for special community needs that include parks and recreation, street cleaning, decorative water fountains, sale of water to contractors through metered water from fire hydrants, etc. (Harry, 2008).

The problem of inadequate access to water and sanitation exists in both rural and urban areas, the problem is particularly pressing in cities. With internal migration and the "urbanization of poverty," cities are where an increasing proportion of the poor live. In the last three decades, growth in urban populations in developing countries exceeded that of rural areas three times more.

According to Ethiopian water sector (strategy, 2015) “As per the GTP-2 water supply service level standard, it is required to provide safe water in minimum 25 l/c/day within a distance of 1 km for rural areas while in urban areas it is required to provide safe water in minimum 100 l/c/day for category 1 towns/cities (towns/cities with a population more than 1 million), 80 l/c/day for category 2 towns/cities (towns/cities with a population in the range of 100,000-1million), 60 l/c/day for category 3 towns/cities (towns/cities with a population in the range of 50,000 -100,000), 50 l/c/day for category 4 towns/cities (towns/cities with a population in the range of 20,000-50,000) up to the premises, and 40 l/c/day for category-5 towns/cities (towns/cities with a population less than 20,000) within a distance of 250m”.

2.11. WATER LOSS AND LEAKAGE IN DISTRIBUTION SYSTEM

The amount of water loss differs from country to country, city to city, and even from network to another network in the same city. Different countries use different indicators to evaluate their states in comparison with others and to compare the distribution of water loss from one location to another location of a distribution system to take action based on the level of loss. As stated, above competition using unaccounted for water (UFW) expressed as a percentage has a limitation when used for comparison as it highly depends on the volume of water produced.

The traditional performance indicators of water losses are frequently expressed as a percentage of the input volume. However, this indicator fails to take account of any of the main local influences. Consequently, it cannot be an appropriate performance indicator (PI) for comparison (WHO, 2014).

Depend upon the consumption per service connection, the same volume of real losses/service connection/day, in percentage terms, is anything from 5% to 30%. Thus developing countries with relatively low consumption can appear to have high losses when expressed in percentage terms, percentage losses for urban areas in developed countries with high consumption can be equally misleading (Farley and Trows, 2003).

Non-Revenue Water (NRW)

According to Rudolf & Liemberger (2010) Until the early ’90s, there was no standard term to express and assess the water losses in the distribution system. The International Water

Association (IWA) has acknowledged this problem and established the Water Loss Task Force (WLTF). The WLTF examined the international best practices and developed a standard terminology as “Non-Revenue Water is the difference between the volume of water put into the water distribution system and the volume that is billed to customers.”

However, there is no simple solution to reduce water losses in the distribution system especially in the developing world, it should be involving improvements not only regard to the water system but also required a change in attitudes (WUAM, 2013). Besides‘ understanding how leakage is currently performing and collecting relevant data, and turning it into useful information for planning and good information systems’ are essential to water loss reduction polices (Farley, et al., 2008). In addition, utility managers often do not pay enough attention to NRW because of weak internal policies and procedures which contributes to rising NRW levels. Many utility managers do not have access to information on the entire network which would enable them to fully understand the nature of NRW and its impact on utility operations, its financial health, and customer satisfaction. Successful NRW reduction is not about solving an isolate technical problem, but is instead to overall asset management, operations, customer support, financial allocations, and other factors.

A. Real losses

Physical water losses known as Real losses (RL) are categorized as water losses from reported and unreported bursts, background losses, reservoir leakage and overflow and leakage from valves and pumps. There are because this water did not have the opportunity to pass through a customer’s meter, (ABOMA, 2017) indicate that these losses are incurred at the production rate. The real losses can be classified according to their size and runtime, (GIZ, 2001) .

i. Reported or visible leaks

Primarily come from sudden bursts or ruptures of joints in big mains or distribution pipes. Leaking water will appear at the surface quickly depending on water pressure, leak size as well as on soil and surface characteristics. Special equipment is not required to locate the leak (Thornton J. a., 2005)

ii. Unreported or hidden leaks

By definition have flow rates greater than of the order of 250 l/h at 50m pressure but due to unfavorable conditions do not appear at the surface (Farley M. , 2001). The presence of hidden leaks can be identified by analyzing trends in water consumption behavior within a defined water supply zone. A wide range of acoustic and non-acoustic instruments is available to detect unreported leaks (WHO, 2001).

iii. Background leakage

Comprises water losses with flow rates less than of the order of 250 L/h at 50 m pressure, which do not appear at the surface these very small leaks (seeping or dripping water from leaky joints, valves, or fittings) cannot be detected using acoustic leak detection methods. Therefore, it is assumed that many background leaks are never detected and repaired but leak until the defective part is eventually replaced. Background leaks often cause a major share of real water losses due to their great number and their long runtimes (WHO, 2000).

B. Apparent Losses

Apparent losses are losses that are not due to physical leaks in the infrastructure but are caused by other factors. According to (Thornton J. S., 2008) apparent losses can be categories based on their origin: meter inaccuracies due to broken or incorrect customer and bulk water meters data handling and accounting errors and poor customer accountability in billing systems Unauthorized consumption due to water theft and illegal connections. Summarizing the above, apparent losses comprise all water that is successfully delivered to the customer, but which is not metered or recorded accurately and thus causes an error in the amount of customer consumption.

C. Unavoidable Annual Real Losses

It is impossible to eliminate all real losses from a distribution system. Some losses are “unavoidable”. Some leakages are believed to be undetectable (too small to detect) or uneconomical to repair an estimate of Unavoidable Annual Real Losses (UARL) can help to evaluate the feasibility of real loss minimization (provides better understanding of real loss components).

Table 2.2: IWA water balance

	Authorized consumption	Billed authorized consumption	Billed metered consumption (including water exported)	Revenue water

<table>
<tr><td rowspan="8">System input volume</td><td rowspan="3"></td><td></td><td>Billed unmetered consumption</td><td></td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered consumption</td><td rowspan="7">Non-revenue water</td></tr>
<tr><td>Unbilled unmetered consumption</td></tr>
<tr><td rowspan="5">Water losses</td><td rowspan="2">Apparent losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Metering inaccuracies</td></tr>
<tr><td rowspan="3">Real losses</td><td>Leakage on transmission and/or distribution mains</td></tr>
<tr><td>Leakage and overflows at utility’s storage tanks</td></tr>
<tr><td>Leakage on service connections up to point of customer metering</td></tr>
</table>

(Source: Introduction to operation and maintenance of water distribution system JE VAN ZYL)

Factors Causing Water Loss in the Water Distribution Networks

In most of the developing regions, the design of water distribution systems is based on the assumption of direct supply, although most of these systems are intermittent systems which result in severe supply, insufficient pressure in the distribution system (pressure losses in several areas in the network), inequitable distribution of the available water and very short duration of supply (Hussni, S. & Zyoud, A.R. , 2003).

However, the purpose of hydraulic integrity in the water distribution system is to supply water at adequate/acceptable pressure and flow. The most common factors for intermittent water supply and loss of hydraulic integrity in the distribution system are described in the following sections.

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, and the internal roughness of the pipe, pipe length, gradient and diameter of the pipe. Such situations may occur 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, pipes of inadequate capacity (too small diameter), rough pipes (e.g., corroding iron pipes or pipes with a build-up of sediment) and equipment failures such as pumps and valves. In general, poor pressures tend to be caused by inadequate capacity in a pipe or pump, high elevations, or some combination of the two' (Candelieri, et al., 2013).

High pressure during low demand conditions

High pressure during low demand conditions can cause pipe bursting, leakage, and many water losses through the distribution networks. Therefore, when dealing with high pressures, PRVs should be used to reduce and regulate pressure in the system (Tomas et al., 2003). Accordingly, pipes and pumps must be sized to overcome these problems and to provide acceptable pressure in the system. Although, the sizing of control valves based on the desired flow conditions and the pressure differential is vital (NRC. 2006).

Pump capacity

A pump is a device in which mechanical energy is applied and transferred to the water as a total head, and this head is a function of the flow rate through the pump (Tomas, et al., 2003). While, 'the failure, location, size and capacity of pumps in water distribution are the major impacts for low flow or negative pressure arise in the system, and this can lead to intermittent water supply in the distribution system' (Candelieri, et al., 2013).

Demand Increase

Rising water demand because of population growth and urbanization affects the availability and reliability of existing water distribution system. Therefore, 'water demands need to be assessed based on 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).

Poor infrastructures

In most of the developing countries, it has been observed that the pipe network is very old, and which is laid many years ago. With the aging problem, there is a considerable reduction in the carrying capacity of the pipelines. Although, most of the distribution pipelines were get corroded and leakage occurred, 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 the distribution system assures and providing conditions for adequate flow through the pipelines. Incidentally, this will prolong the effective life of the pipeline and restore it carrying capacity. Some of the main functions in the management of preventive maintenance of pipelines are assessment, detection, and prevention of loss of water from pipelines through leaks, maintaining the capacity of pipelines, cleaning of pipelines and relining'(Dighade, et al., 2014).

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 offline (e.g., reservoir shut down for inspection, cleaning, or repairs; installation of new pipe connections; pipe rehabilitation or brake repairs; and transmission main valve repairs.) while, emergencies include earthquakes, power failures, equipment failures, or transmission main failures. Therefore, all these activities can result in a reduction in system capacity and supply pressure, and changes to the flow paths of water within the distribution system' (NRC, 2006).

2.12. STRATEGY FOR WATER LOSS MANAGEMENT IN DEVELOPING COUNTRIES

Knowing the magnitude and the spatial distribution of the loss greatly helps to intervene giving priority to those areas with higher magnitude of loss regarding the leakage index usually fixed based on local condition. Nevertheless, identification is not by itself an end in reducing the water loss. Identifying the causes of the losses might help where to focus with probably limited resources that the town is having. This study somehow gave an indication that the predominant causes of the water loss in the city is leakage and losses due to meter errors. Ones the spatial distribution and the characteristics of the loss are identified; it is possible to see alternative solutions to reduce the water loss. Therefore, an appropriate long- and short-term strategy is necessary. Due to time limitation all the strategy issues are not addressed, rather some of the remedial measures to be taken are discussed in this section.

The following may be considered to beremedial actions to be taken to reduce water loss an d leakage in a distribution system but not limited:

Setting leakage index

The most important aspect of any leakage strategy is setting a leakage target. Ones the spatial distribution and characteristics of the losses is identified, what level of leakage should the water authority aim for and what level should be maintained in the long term should be well addressed. There will always be a level of leakage which has to be tolerated, and which must be managed, and it depends on the economic level of the leakage reduction activities specific to that area. The estimation of the economic level of leakage (ELL) must use data, information, and policy rules specific to that area and the water supply organization. Moreover, until significant works has been conducted to reduce leakage and so collect the necessary data, it is not possible to make an accurate assumption of ELL. Therefore, the calculation of ELL will follow a staged approach & could take several years to determine accurately (Welday, 2005).

Water audit

Water audit determines the amount of water lost from a distribution system due to leakage and other reasons such as theft, unauthorized or illegal withdrawals from the systems and the cost of such losses to the utility. Comprehensive water audit gives a detailed profile of the distribution system and water users, thereby facilitating easier and effective management of the resources with improved reliability. It helps in correct diagnosis of the problems faced to suggest achievable and practicable solutions. It is also an effective tool for realistic understanding and assessment of the present performance level and efficiency of the service and the adaptability of the system for future expansion and rectification of faults during modernization. It helps in identifying problem and risk areas and a better understanding of what is happening to the water after it leaves the source point. Such investigation should provide enough information to set specific objectives for a water efficiency program.

Performance indicator and bench marking

A performance indicators (PI) system can be considered as a key assessment tool for the achievement of targets, by applying a coherent set of indicators. Performance indicators help the utility to-(a) better understand water losses (b) set targets for improvement (c) measure and compare performance (d) develop standards (e) monitor compliance and (f) prioritize investments. Water utilities should include standard performance indicators to measure performance to facilitate comparisons with other utilities. The annual volume of water loss is an important indicator of water distribution system efficiency. Expanding water networks without addressing water loss will only lead to a cycle of waste and inefficiency. High and increasing water losses are an indicator of ineffective planning and construction, and of low operational and maintenance activities. Performance Indicators (PIs) and Benchmarking are identified as the appropriate tools for water supply systems' performance evaluation. The worldwide many experts have identified PIs which may be used to measure the efficiency and effectiveness of a utility in achieving its objectives. The most widely used performance indicator in developing countries for water loss performance is Non-Revenue Water (NRW) which is expressed in terms of system input volume. Although, it is an important PI, many practitioners tend to overlook its shortcomings for properly assessing water losses because it is highly dependent on supply time, average operating pressure, and level of consumption. In developed countries NRW is used as financial indicator and not as an operational indicator, whereas the infrastructure leakage index (ILI) is used as a technical performance indicator for real losses. While using ILI in the developing world, most utilities do not have reliable information on the actual network length; Maps often show only a fraction of the existing network and hence ILI is overestimated. The pressure data and pressure loggers are not available and hence estimated average pressure usually too high, therefore ILI is underestimated. It is, therefore, the need of the hour to develop suitable performance indicators that could be appropriately used under different circumstances in various countries. Performance indicators and benchmarking efforts should lead toward the vision of water supplies for all.

Improving organizational management and provision of training

For an effective management of water supply service in general and water loss and leakage in particular, water supply providing institutions must have an appropriate organizational management. The organizational aspect related to the water loss management is well addressed in the organizational structure of TWSSO, but shortage of qualified and experienced personnel is the major problem of the country in general and TWSSO in particular. Capable management and technical staff are paramount to achieve better performance. Offering a continuous theoretical and practical training based on the need is also important. Due to the complex nature of water loss and leakage commitment of staffs at all levels is also very important. Effective leakage management an input from a number of different personnel and unless, they are all committed, the implementation of any water loss reduction programmed will not be efficient, it may then be difficult to maintain the infrastructure which has led to lower leakage levels (Welday, 2005).

Proper maintenance and renewal

One of the major causes for the increase of water loss is the usage of poor-quality materials and poor workmanship. Despite the many pipe networks in the city seem to have younger ages, the loss found from the analysis reaches up to 25% of the production. The main reason for this might be the usage of poor quality of material and poor workmanship. Therefore, care should be taken while maintaining existing networks and installation of new ones. While rehabilitation of any mains is planned, due attention should be given to maintain the service connections as well fed from the mains. Replacing an old water main with a new installation will undoubtedly reduce on the main. Most leakage occurs on service connections and, unless the service connections are also renewed, the benefit may not be a great as the first estimated (Welday, 2005).

Regular inspection of the water network

Ones the locations of highly suspected leaking networks are identified due attention should be given to inspect for these areas and any leaks should be well recorded as it will be a good base for further maintenance or replacement. Regular inspection supports to find the problematic areas and take action immediately before much water is wasted. Regular inspection should not be limited only to the network systems and supply meters but also to the customer meters.

Calibration and replacement of customer meters

One of the main causes for the water loss is the under-recording of customer meters. The usage of poor material quality also holds true for the customer meters. Unless meters are regularly calibrated and those not functioning well are either maintained or replaced the water loss reduction programmed will not be effective. Until recently, the water authority was checking the customer meters only if it is requested by the customers themselves, but this might only help the customer not to pay more as such requests are usually for over registration. Therefore, systematic checkup of the customer meters is important not only to identify the magnitude of the loss but also to maintain and replace when necessary.

2.13. Water quality

Drinking water must be tested to ensure it is safe to drink, because most contaminants are invisible to the human eye. Pathogens such as bacteria and viruses can give people diarrhea, and hazardous levels of naturally occurring minerals such as fluoride or arsenic can cause long-term health problems. Drinking water must be tested using scientific methods and the results compared with internationally accepted water quality standards. Water quality standards that are directly related to health are called “Primary Health-Based Standards for Drinking-water,” and water must meet these standards to be considered safe to drink. Water users may have preferences regarding the water they consume. For example, some groundwater has an unpleasant, salty taste or a metallic color, even though it is safe to drink, and users may prefer not to drink it if other options are available. Drinking water standards that are related to taste but not to health are secondary parameters. Water users may refuse to drink from an otherwise safe water supply and return to an unsafe, contaminated source because of the difference in the taste of the water. Tests for secondary parameters like Total Dissolved Solids and Total Iron to inform discussions with water users about aesthetic concerns. Water testing helps identify which chemical, physical, and biological characteristics are problematic so a protection or treatment solution can be identified. It is critical to develop a water source that is both acceptable to users and safe to drink. Water sources are typically tested during three stages in the intervention process: First, water sources to be rehabilitated and potential spring protection sites are pre-screened to determine whether these sources have adequate water quality and whether communities are likely to use the water. This testing helps to limit investment to the best water sources. Start-up validation testing confirms the safety of the water source following construction but before the water point has been handed over to the targeted community. To test uses nationally certified laboratories whenever possible for this stage to ensure the water meets national standards and that records are maintained. Finally, water quality testing is performed at regular intervals after the source is handed over to the community. Water quality can change over time, based on leakages depends on high pressures, low velocity case stagnant water in the system, new contamination sources, and ongoing testing helps identify the need for additional interventions to either mitigate the sources of contamination and decontaminate the water point or decommission the water point.

General Standards will ensure water quality testing is performed for water points based on the World Health Organization's published Guidelines for Drinking-Water Quality and as defined in these standards (WHO, 1993). To ensure water quality testing is performed for each water point in accordance with the relevant national standards of the country in which the water collection point is located. Timing of Water quality testing will be performed according to the following timeline.

Pre-screening water quality testing

It will be performed for existing water being considered for rehabilitation (including boreholes, wells, and protected springs) and all unprotected springs sources being considered for protection and to supply targeted population. Testing will be completed before finalization of the construction plan for town or rural community. The needed to be test water quality parameter for prescreening time:

- E. coli
- PH
- Electric conductivity
- Turbidity
- Nitrite/Nitrite
- Iron if the area there is some implication.
- Arsenic
- Fluoride

Validation Water Testing

It will be performed for all new or rehabilitated water schemes after construction and disinfection are complete. The start-up validation testing must be completed, and the water must meet national water quality standards before the water scheme is handed over to the community. (Click on this link to view national standards.) The minimum list of parameters to be tested in the start-up validation is listed in the next section. Start-up validation water sampling and testing will be performed by using the Drinking Water Test Kit. In addition, the water will be tested by a nationally certified laboratory if it is feasible to do so.

The needed to be test water quality parameter for prescreening time:

- E. coli
- PH
- Electrical conductivity
- Turbidity
- Nitrite/Nitrite
- Free chlorine residual

In water quality monitoring

It will be performed at the frequencies listed in the following table based on the water source type and number of people served. Water quality monitoring will continue throughout the duration of maintenance and will be led with increasing involvement from district-level government and local water committees. The technician will perform the sampling and the water quality testing using the Drinking Water Test Kit during this phase. The parameters to be monitored are listed in the next section.

Table 2.4: schemes ongoing water quality monitoring time

Type of Water scheme	Ongoing Water Quality Monitoring	No. Tests/Year
Borehole in confined aquifer* with on-point collection	Once yearly	1
Borehole in unconfined aquifer* with on-point collection	Twice yearly (wet/dry seasons)	2
Improved hand-dug well with on-	Twice yearly (wet/dry seasons	2

point collection		
Protected spring with on-point collection	Twice yearly (wet/dry seasons	2
School rainwater harvesting system with on-point collection	Once yearly (wet season, when tank is full of first rains)	1
Piped water supplies serving 1000 people or greater	Quarterly (at farthest point from source)	4
Piped water supplies serving less than 1000 people	Twice yearly (at farthest point from source)	2

Post-program water quality monitoring

It will be addressed as part of sustainability efforts.

The needed to be test water quality parameter for prescreening time:

- E. coli
- PH
- Electrical conductivity
- Turbidity
- Nitrite/Nitrite
- Free chlorine residual, if an ongoing chlorination system is ongoing chlorination system is being used to treat the water supply.
- Total hardness

Drinking Water Concentration Limits

The below diagram summarizes the water quality test parameters that must be evaluated during each stage of the project cycle.

Table 2.5: schemes ongoing water quality test parameters and allowable limits

Primary Health-Based Parameters for Drinking Water	Maximum Allowed Concentration
E. coli (or fecal coliform)	0 (absent)
Turbidity	5 NTU
Nitrate	50 ppm as NO_3 -
Nitrite	3 ppm as NO_2 - for short-term exposure 0.2 ppm NO_2 - for long-term exposure
Free chlorine residual (if indicated)	2.0 ppm (note: should be 0.2-0.5 ppm for acceptable taste)
Fluoride (if indicated)	1.5 ppm
Arsenic (if indicated)	0.01 ppm (WHO) Note that many countries allow up to 0.05 ppm; if a country has a 0.05 ppm maximum allowable standard, results between 0.01 and 0.05 ppm will be discussed with the regional government to determine locally appropriate actions
Secondary Parameters (to avoid technical and aesthetic issues)	Maximum Recommended Concentration
Specific Conductance (Electrical Conductivity)	1600 µS/cm (note:<900 µS/cm is most acceptable for taste)
Total Iron	0.3 ppm
Total Hardness	250 ppm
pH	6.5-7.5 is the optimum pH level for effective chlorination

Source Ethiopian Standards Agency, Drinking water specifications, 1st edition.

When the E. coli test is used for pre-screening of an unprotected spring, the result must be less than 10 in 100 milliliters as this gives reasonable assurance of a successful protection project.

The Water Quality Testing Procedures will be followed when interpreting water test results and addressing problems with water quality. The following summarizes the overarching guidelines:

Table 2.*6* summarizes of the overarching guidelines.

Pre-screening water testing	
Primary drinking water standards	Must be met prior to rehabilitation (remediation sometimes possible)
Secondary drinking water standards	If not met, the likelihood of future use must be discussed with the community
Start-up validation water testing	
Primary drinking water standards	Must be met before handing over the water point to the community. If not met, two courses of action include decommissioning or implementing appropriate water treatment
Secondary drinking water standards	If not met, the likelihood of future use must be discussed with the community
water quality monitoring	
Primary drinking water standards	If not met, disinfect and/or implement appropriate water treatment
Secondary drinking water standards	Discuss with community if there is a significant change from past tests

Source: WHO, 2011. Guidelines for drinking-water quality, 4th edition

2.14. REVIEW OF RELATED STUDIES

Shimeles (2018) conducted research titled "water Supply Coverage and Water Loss in Distribution systems with Modelling (The Case Study of Addis Ababa)". His intention was to assess the supply coverage and explore the water loss in city water supply distribution system. The researcher attempted to quantify the average water supply per person at city level and determine water loss as leakage at the city level and at the sub system level. In his findings, he found the average water supply coverage of the city as 86.59 litre/capita/day and water loss at city level and sub-city level as 39% and 37.56% respectively.

The other research titled “Water Supply Coverage and Performance Evaluation of Distribution System Using Hydraulic Simulation Software.”(The Case of Jigjiga Town) conducted by (Demelash, 2020). The intention of the researcher was to improve hydraulics performance of Jigjiga city water supply distribution system and control its operation, Water CAD software was used as tool to model water distribution system analysis. The Modelling effort included only hydraulic performance Modelling. In his findings the model analysis result shows the different problems of the system. These are aged pipes, oversized and undersized pipes, low and high pressures and shortage of water from the source.

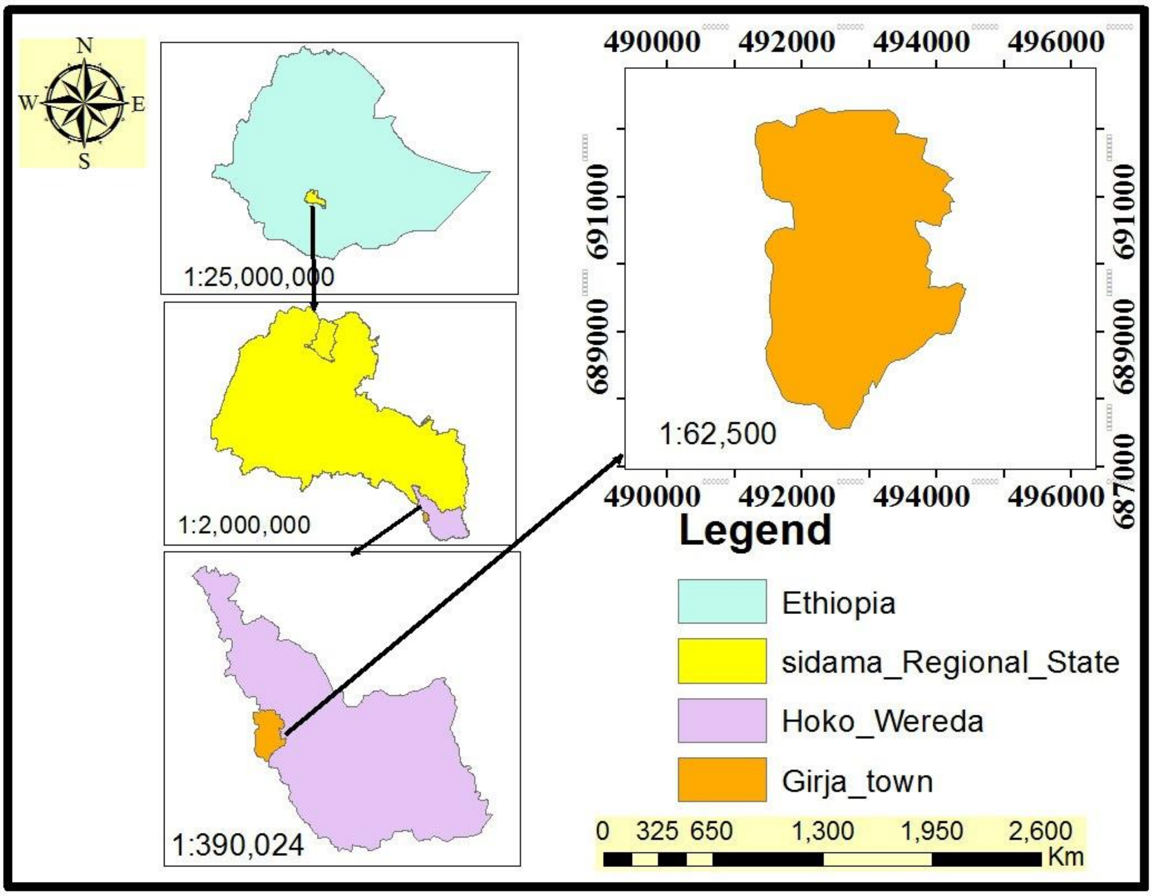
Saleamlak (2018) also conducted research titled “Hydraulic Modelling and Improvement of Addis Ababa Water Supply System (The Case of Bole Bulbula)”. His intension was to assess supply and demand gap analysis, hydraulic and water quality Modelling, water loss in water distribution system. The researcher attempted to analyse evaluating hydraulic performance of the distribution system as well as analysing issues of supply network and water quality in the distribution system in selected sub-city. In his findings, he found the Domestic water supply coverage of the sub-city by family connection (57%) and average base line demands (58 l/c/d) and 8.33% of the system’s total distribution hydraulic performance improved by resizing existing distribution mains pipes with respect to low pressure and Excessive rate of unaccounted for water is estimated (34.46%). The researcher used model to evaluate alternative scenario to improve system performance.

The other research titled “Urban Water Supply System Performance Assessment” (The Case of Holeta Town, Ethiopia) conducted by RATA (2018) His intension was to assess the problem of Holeta town water supply and distribution system. In his findings, he found the performance of Holeta town water supply system based on main performance indicators namely high-water loss, water quality, and inadequate water supply coverage, satisfaction of customers and operation and maintenance. The distribution system is evaluated by running the system of water supply by WaterGEMS V8i.

3. MATERIALS AND METHODS

3.1. Study Area Description

Girja Town is the capital of Hoko Woreda of Sidama National Regional State. Girja town located at 449 km south of Addis Ababa and 174 km 492741 Easting and 690511 Northing southeast of Hawassa the regional capital. The area has got dense green vegetation with exotic and indigenous tree, fruit specious, perennial, and annual crops. The study area is accessible with some-weather gravel road and asphalt works started and on a progress from Daye town to Girja which is 42km road. The type of vegetation found are predominantly exotic and some indigenous and other perennial crops like 'Enset and chat', maize, 'teff' and other related. It is the good trade cash cropped area.



Source own.

Figure 3.1: Location map of study area

3.2. Methods

3.2.1. General

The components of this study include a review of the literature, data collection either primary or secondary, depending on the situation analyses of the data, findings, and discussion. The methodology used to conduct the study is reviewed considering the goals and issues that were outlined in the introductory chapter. It also talks about the procedures for gathering data and preparing it. Typically, the research is split into two main sections: modeling and analysis of the current Girja water distribution network system, and recommendations for upgrading the existed network. Data on the production and usage of water on a yearly basis are used to assess water loss at all levels. The hydraulic performance matrices are then attempted to be assessed utilizing the many ideal criteria that have been identified from the water line network's features.

3.2.2. Study Work Steps

The first step of this study was evaluation of the water supply coverage, current and future water demand of the town. Evaluating the water supply coverage focused on the volume of consumption and level of water connection. The next step was evaluating and identifying the loss of water due to leakage and bursting problem of the main pipe system. The loss was evaluated by using data of water production and consumption which was collected by Girja Town Water Supply Service Office for the purpose of fee collection. To identify the bursting problem of main pipeline same part of the distribution pipeline elevation and other relevant data has been collected and used to analysis by WaterGEMS model to assess the hydraulic performance of the distribution network. Moreover, pressure data was measured and used to calibrate the model. Finally, from analyzed data, problems were identified, and possible remedial measures were suggested.

3.2.3. Materials and Tools Used

To achieve the goal of the research the materials that were used are, a Pressure gauge to measure the pressure at the different locations. Software tools that have been used are computer Zotero, Google Earth Pro, ArcGIS 10.3, Bentley WaterGEMS CONNECT Edition Update 2, etc. GPS instrument was also used to collect the required coordinate and elevation data during pressure reading. Pressure readings were done using pressure gauge which is commonly taken in the selected points of distribution system.

3.2.4. Data Collection and Source

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

The Girja water supply system has no organized data especially for old distribution network; hence all relevant primary data of main and distribution pipeline network has been collected. The secondary data of gravity main line used to compare with the surveyed data, current population, Consumption and production data and level of connection data are collected from concerned governmental institutions.

Collected Primary Data

Primary data is collected through field survey and from key personnel’s of Girja Town WSSO. The data collection process included consultation and discussion with the respective officials of various agencies and institutes such as District administration, municipality, and finance and economic office.

- By using GPS surveying instrument coordinate and elevation data of selected nodes were collected during pressure measurement on ten points by using pressure gauge.
- The type of pipe materials, fittings and valves has been collected from the site to identify whether the system have material quality problem or not.
- Pressure measurement is taken at different time and in different locations to perform calibration and validation of the hydraulic model. Pressure measurement throughout the entire day was conducted at critical times were selected while pressure gauges were taken. According to the water services recommendation, these critical times were fixed based on the peak hour demand rate of the users which covers the time between 8:00-12:00 AM, 2:00-6:00 PM and 8:00- 12:00 PM. The operating performance indicator (unavoidable annual real loss) was calculated taking the average pressure in meter during nighttime.
- Discussion with the officials and experts in the concerned government office to acquire necessary information on WSS.

Collected Secondary Data

Secondary data gathered from the available data source such as reports and projects documents, census and survey reports, books, journals, internet as well as other published and unpublished documents. Input data is collected for the analysis and modeling of distribution system should be using the type, size, diameter, discharge, age of pipe, GPS reading of service reservoirs and junctions. The collected secondary data includes:

- Hydraulic analysis of main pipeline from design document and used to compare with the model analysis result made by using primary surveyed data.
- Total number of population and some other relevant documents.
- The amount of customer data as per level of connection is collected which used to analysis the coverage.
- Three years Water production and Consumption data used to analysis the Water loss.

Computer software called WaterGEMS used to evaluate the hydraulic performance of Girja town water supply distribution system. To compute the friction had losses Hazen Williams' equation was used with the assumption with that viscosity is constant.

Table 3.1: Quantity of pipe material in distribution system

Pipe Type	Length (m)
GI	20387

(Source: Girja Town Water Supply Service Enterprise)

3.3. EXISTING WATER SUPPLY SYSTEM

The system uses spring water as its water supply. One spring is present. The source is around 11 kilometers east of the town. The current sources produce at a rate of 4.5 l/s or 388.8m^3/day. Existing water is delivered to five water stations at remote Jangalo-Tadota kebele communities after flowing straight by gravity to 100m^3 reservoirs at 1.5km. When collected, the water from this reservoir is supplied to the beneficiaries via the distribution network before flowing to another 200m^3 reservoirs that supplies water to Girja Town.

Distribution Network

The collected water from this reservoir is supplied to the beneficiaries via the distribution network after flowing into 200m^3 reservoirs that supplies water to Girja Town.

All of the old distribution pipes have been taken into account because they were excluded from the newly installed system because they are too old and have a lower hydraulic capacity, but local plumbers continue to use them to supply water to the locals because the new distribution system isn't fully functional.

Public fountains and household connections

There are 17 water points found in the study area. Among the water points 5 was found in rural area and only 2 were operational, and they are all around Jangalo-Tadota Kebeles settlements. There are 12 in Girja town, however only one is non-functional. Several home water connection lines are found in the town's water supply systems. It is assumed that there are shortages and losses in water yield in order to determine the number of extra public taps. All of the public fountains are walled in and guarded from pollution and harm from outside sources. Not enough source sanitation issues were discovered during the site visit.

Figure 3.2: Existing community water points

Reservoirs

When facilities are shut down or, in the case of urban supplies, if the source is unable to deliver the requisite capacity, to help the system meet peak demand. Storage reservoirs' principal purpose is to supply water to users. The current 2 reservoirs at Jangalo rural part and Girja town service reservoir were built in 2010 E.C. These volumes 100m3 and 200m^3 capacity respectively. Totally 300m3 serves as reservoir. On other there is also one 100m^3

existed not functional old reservoirs.

It is situated on the town's higher side, with an average height of 1545.4 meters above mean sea level. It contains a valve chamber and was constructed of reinforced concrete.

Figure 3.3: Existing 100m^3 reservoirs

Figure 3.4: Existing 200m^3 reservoirs

Operation & Maintenance Information of the Town

The system is operated by the town utility operator. A progressive mode of tariff was set by the town water board (TWB) and collection of water revenues is being carried out by the utility operator and utilizes it for operation and maintenance of the town water supply system. As reported by the utility operator all customer connections are metered including the Public Taps. The utility operator has operation & maintenance manual, 'as built' drawing, technical data sheet for electro-mechanical equipment, pipes, fittings, and accessories. But they are not updated and revised. The utility operator is being trying to update them by this time, but technical support is required. The annual water production and consumption of Girja Town was indicated below.

Table 3.2: Annual water production and Consumption of Girja Town

Year (E.C)	Production (m^3/year)	Consumption (m^3/year)
2012	120,390	79,860
2013	126,756	90,129
2015	128,940	93,287

3.4. WATER DEMAND AND COVERAGE

According to Abayneh 2015 Design of water systems require estimation of predictable water demands appropriate to size the pumping equipment, transmission and distribution pipelines and storage facilities. Assessing water demands for a certain town depends on the extent of the population to be attended, their standard of living and activities, the cost of water supply, the availability of wastewater service and the purpose of demand. It varies according to the requirement of the domestic population, institutional, industrial, and social establishments. In addition to these, demand allowances need to be included for leakage, wastage, and operational requirements such as flushing of mains.

3.4.1. Coverage of Water

According to Ethiopian water sector (Water sector, 2015)"As per the GTP-2 water supply service level standard, it is required to provide safe water in minimum 25 l/c/day within a distance of 1 km for rural areas.

In urban areas it is required to provide safe water in minimum within a distance of 250m as shown below:".

Table 3.3: Water Supply Service level Standard

category 1	100 l/c/day	towns/cities with a population more than 1 million
category 2	80 l/c/day	towns/cities with a population in the range of 100,000- 1million,
category 3	60 l/c/day	towns/cities with a population in the range of 50,000 - 100,000,
category 4	50 l/c/day	towns/cities with a population in the range of 20,000- 50,000 up to the premises,
category 5	40 l/c/day	towns/cities with a population less than 20,000 within a distance of 250m

(Source: Urban Water Supply Design Criteria by Ministry of Water Resources.

The water supply coverage of study area is evaluated based on the average per capital consumption by using yearly domestic consumption with the current population and level of connection per family by using the total domestic connection as per average family size. The whole system water supply coverage has been evaluated by considering domestic as well as non-domestic user by using Design guideline of MoWR (2006). For this study the average family size of 5 was used.

Per Capital Consumption (l/person/day) = $\frac{\text{Annual Consumption(m3)} * 1000 \text{ l/m3}}{\text{Population number} * 365 \text{ day}}$……..… (3.1)

Connection per family= $\frac{\text{Total number of connection}}{\text{(number of population of the town/Average family size)}}$ ………... (3.2)

3.4.2. Analysis of Water Demand Coverage of Girja Town

1. **Town population projection**

Several methods are used to forecast the population but, their result varies from one method to another. Selection of appropriate method for particular town needs to consider over all current situation of the targeted town. Because of town was fast growing town, where relatively high economic activities were observed at the same time continuous expansion of town due to various reasons was experienced, so that, for this study Geometric increase method of future population forecasting is used because this method is mostly applicable for emerging towns having that vast scope of expansion. It is expressed as follows:

$$Pn = Po^* (1 + r)^n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

Where: Po = Initial known population i.e., the population at the end of last known census.

Pn = population after n years

r = Annual population growth rate in %

n = number of years of the concerned period.

Therefore, the future population of Girja town was projected by using the method for period of 2015 to 2035.

i. Present and Future Demand Forecasting

For this study water demand is classified in to two major categories as domestic and non-domestic water demand. Domestic water demand is water that is required for cooking, toilet flushing, bathing, drinking, and washing of face, clothes, and utensils, etc. whereas nondomestic water demand includes industrial demand, institutional demand, firefighting demand, water lost and waste, and public demand.

2. Domestic Water Demand

Estimation of water demand per mode of service and estimation of population by mode of service was used to calculate the average per capita water demand. The average per capita domestic water demand for each year was computed by combining water demand by mode of service and population percentage distribution by mode of service for the year 2015-2035.

There are four modes of services identified for domestic water consumption of town such as, house connection user, yard connection user, yard shared connection user and public tap user. The per capital water demand for various categories of the town was adopted by taking into account the different development factors and standards used by the Ministry of Water Resources (MoWR, 2006).

i. Population percentage distribution by mode of service

The mode of service is an important element to assess the level of water coverage of the town. Based on the available data obtained from the Water Supply Service during the field visit in 2020; four major modes of service were identified for domestic water consumers. These are house tap users (HTU), yard connections users (YCU), yard shared Connections users YCU(S) and public tap users (PTU). The distribution of population for each mode of services was determined by considering socio-economic situation and living standard of the town (MoWR, 2006).

ii. Per-capita domestic demand by mode of service

The per-capita domestic water demand for various demand categories varies depending on the size of the town and the level of development, the type of water supply scheme, the socio-economic conditions of the towns and the climatic condition of the area. The per capita water demand for adequate supply level must be determined based on the basic human water requirements for various activities of demand category (MoWR, 2006).

Adjustment to climate

In addition to per-capita water demand and mode of services which influence the quantity of water consumption, the climate also affected the water consumption, and the per-capita domestic demand was adjusted by factors which are given in table 3.2.

Table 3.4: Climate Adjustment factor (MoWR, 2006)

Altitude	Factor
>3300	0.8
2300-3300	0.9
1500-2300	1
500-1500	1.3
<500	1.5

Adjustment for socio-economic activity

The domestic water demand also depends on the socio-economic situation of the area. Thus per- capita domestic water demand was modified using appropriate factor. The demand adjustment factors in socioeconomic situations were given in table 3.3.

Table 3.5: Demand adjustment factor for socioeconomic situation

Group	Description	Factor
A	Towns enjoying living standard and with very high potential development	1.10
B	Towns having a very high potential for development, but lower living standard at present	1.05
C	Towns under normal Ethiopia condition	1.00

Non-Domestic Water Demand

i. Institutional Water and Commercial Demand

The water required for schools, hospitals, health centre, government offices and services, religious institutions and other public facilities is classified as institutional water demand whereas the water required for restaurants, shopping centres, local drinks, and other commercial purposes, is classified as commercial water demand. Both water demands are termed as public water demand. This type of demand is recommended 10% of the domestic demand.

ii. Industrial Water Demand

Water required under this head depends mainly on the type of industry in the town or area. The water required by factories, paper mill, textile mills, breweries, sugar mill, etc. comes under industrial uses. This demand accounts for 5-10% of the total domestic water demands. In Girja town there are no huge industries, so for this study industrial demand was taken as 5% of domestic demand.

iii. Livestock Water Demand

Animal demand may be required if there are no water sources to the proximity of the town. From the existing information and observation made around the town there is a nearby river called Genale-Dewa River. Therefore, it is believed that the animal demand will be meeting from Genale-Dewa River.

iv. Fire Demand

Fire demand is the quantity of water required for fighting a fire that may break out at commercial centers, stores, etc. in the town. Fire demand can be expressed as a function of population, and it is estimated by using empirical formula. But, in Ethiopia, the demand is generally taken care of by increasing the size of service reservoirs by 10 % (MoWR, 2006).in this study not considered because on it is one-time sudden action and even if always not considerable for large cities like Hawassa.

v. Unaccounted water demand

This includes the quantity of water due to wastage, losses, etc. from water supply systems vary considerably according to diverse factors. System losses are a function of the quality of construction, the type and age of pipes in the distribution network and pressure within the system (MoWR, 2002). For urban schemes, unaccounted water equivalent to 25% of the total domestic, commercial, institutional, and industrial water demand was assumed. Note that the total water demand is the sum of domestic demand, unaccounted for water and non-domestic demand.

Variation of Water Use

The maximum daily water demand and peak hour demand coefficients and factor respectively figured out in table as the guidelines.

Table 3.6: Maximum daily coefficient and peak hour factor

Maximum daily coefficient	Town population	Peak hour factor
2.00	0-50,000	2

1.55	50,001-100,000	1.8
1.45	>100,000	1.6
1.35		

(Source: MoWR, 2006)

In demand analysis knowing maximum daily demand and peak hour demand are very crucial. The maximum daily demand is based on the average daily water required and peak hour demand is greatly influenced by population size.

3.5. WATER LOSS ANALYSIS

One of the major challenges of water utilities is high volume of water loss in their distribution networks. If a large quantity of supplied water is lost; it is difficult to meet the required demands, and correspondingly made challenges to keep the water tariffs in the system at a reasonable level. Whereby, water loss for town was assessed and discussed as follows.

Figure 3.5: Existing water loss by leakages

3.5.1. Quantifying Total Water Loss

To evaluate the total loss of water in the town, the total volume of water input to the network distribution system was compared with the actual water consumption. In this case, the data on consumption were collected to the entire town level. The total annual water produced and distributed to the 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. All the water consumptions in the town were metered as the authorized non-metered consumption is insignificant while compared with the total water production, the unaccounted-for water (UFW) has been used as a similar of the total water loss in this study.

A certain level of water losses cannot be avoided from a technical point of view and considered as acceptable from an economic point of view. According to AWWA leak detection and accountability committee (1996) recommended 10% as a benchmark for UFW (Sharma, 2008).

i. Water Loss by Mathematical Calculation

Water loss expressed as a percentage can be an appropriate means to show the extent of the loss within a given town, but it is not a good indicator for comparing the losses from one area to another. Water loss as % of net water production was used to quantify losses as it could be expressed by Equation 3.4 (EPA, Slums of the World: the faces of urban poverty in the new millennium, 2010).

$$\text{UFW (\%)} = \frac{\text{Total water produced} - \text{Total water billed}}{\text{Total water produced}} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

UFW levels less than 10% is acceptable and no need for monitoring action whereas UFW levels 10-25% is intermediate and could be reduced. UFW levels above 25% are very acute and it requires immediate action for water loss management.

ii. Water Loss by Water Balance Method

The AWWA Water Balance diagram shown in table 3.6 portrays all component volumes of water supplied, delivered to customers, or lost during the course of a reporting year. Each box represents an annual volume of water, and each column totals to the same amount of water. Thus, all columns "balance" as water moves across the system, and all water is accounted for. Accordingly, there is no "unaccounted-for" water, and AWWA recommends against use of the term "unaccounted-for water." Instead, AWWA recommends use of the term NRW. The water balance diagram provides accountability for water utilities by defining a clear path to quantify the loss volumes and demonstrate how those losses affect utility operations.

Table 3.7: Classification of water balanced method.

System input volume A1	Authorized Consumption A2= A4 + A5	Billed Authorized Consumption A4= A8 + A9	Billed Metered Consumption A8	Revenue Water A18 =A8+A9
			Billed Unmetered Consumption A9	
		Unbilled Authorized Consumption A5= A10 + A11	Unbilled Metered Consumption A10	Non-Revenue Water (NRW) A19 = A1-A18
			Unbilled Un metered Consumption A11	

	Water Loss A3= A1-A2	Apparent Losses (Commercial Losses) A6 = A12 + A13 + A14	Unauthorized consumption A12	
			Customer meter inaccuracies A13	
			Systematic data handling Errors A14	
		Real Losses (Physical Losses) A7 = A15 +A16 +A17	Leakage in Transmission and Distribution Mains A15	
			Storage Leaks and Overflows from water storage Tanks A16	
			Service Connection leaks up to the meter A17	

3.5.2. Unavoidable annual real losses (UARL)

UARL represents the allowable volume of real losses from the system, which estimated a volume of leak that are undetectable or would be uneconomical to repair during the year. This can help to evaluate the feasibility of real loss minimization (provides better understanding of real loss component). The total length of main pipes was 11km, number of service connections was 350 and the average pressure 39.37 m from the result of Water GEMS was used in the calculation of UARL. Based on the analysis, unavoidable annual real losses of town were determined as:

UARL= (18*Lm+0.8*NC+25*LP) *P……………………………………………… (3.5)

Where, UARL = unavoidable annual real losses (l/d)

Lm = length of main pipes (km)

Nc = number of service connections (main to meter)

Lp = Total length of private pipe property line to customer meter (km) or length of unmetered underground pipe from street edge to customer meter (km)

P=average operating pressure (m)

3.6. HYDRAULIC MODEL ANALYSIS

Modelling of water supply system

By using surveyed data of pipeline, Size of pipe, material type data of the pipeline, elevation and other relevant parameters the water supplies network was developed by using WaterGEMS model. The hydraulic analysis has been done under the conditions like average loading condition, peak loading condition and under low loading condition. Elevation, base demand, length of the pipe, pipe size and type of pipe materials were the input of WaterGEMS model and velocity and head loss at pipe and pressure at every junction was the output.

A. Data Organization

The collected primary and secondary data was organized on Micro soft excel sheet. The tabulated data includes the elevation, pipe length, pipe size, pipe material type and the demand of each junction, base, minimum, initial, and maximum elevation of the reservoirs and the maximum, average and minimum head and discharge of the pump were well organized and using Micro soft excel sheet.

B. Nodal Demand Computation & Water Demand Analysis

The regular water peak demand of this study area was distributed among the nodal nodes which applying the proportional area distribution method by using WaterGEMS CONNECT Edition Update 2. The proportional areas for each node were determined by generating Thiessen Polygon for that node using manual loading. For this purpose, at first the bounding areas for demand distribution were determined by the geo-referenced aerial image by using Global Mapper software. Then this bounding polygon was segmented into Thiessen Polygons for the model nodes.

C. Model Calibration and Validation

Model calibration is the process which lies in matching the simulated and observed pressure because of loading under various demand conditions for a specified time horizon to an established degree of accuracy. Once a water distribution model has been developed, it must be calibrated so that it accurately represents the actual working real life water distribution network under a variety of condition. This involves making minor adjustment to the input data then the model accurately simulated the pressure rate in the system. For model calibration, pressures are measured in the water distribution system at twelve points using pressure gage instrument.

There are many ways to judge on the performance of model calibration, the calibration statistics used in this study was by calculating the squared relative difference between observed and simulated pressure for each test. The results and the observation data were entered to an excel sheet and the value of squared error was calculated for every test then the mean square error and standard deviation calculated from Excel sheet: the lower values of these parameters, the higher is the accuracy of the calibration process. For this study, pressure at 12 nodes at different locations of the distribution system was measured using pressure gauge.

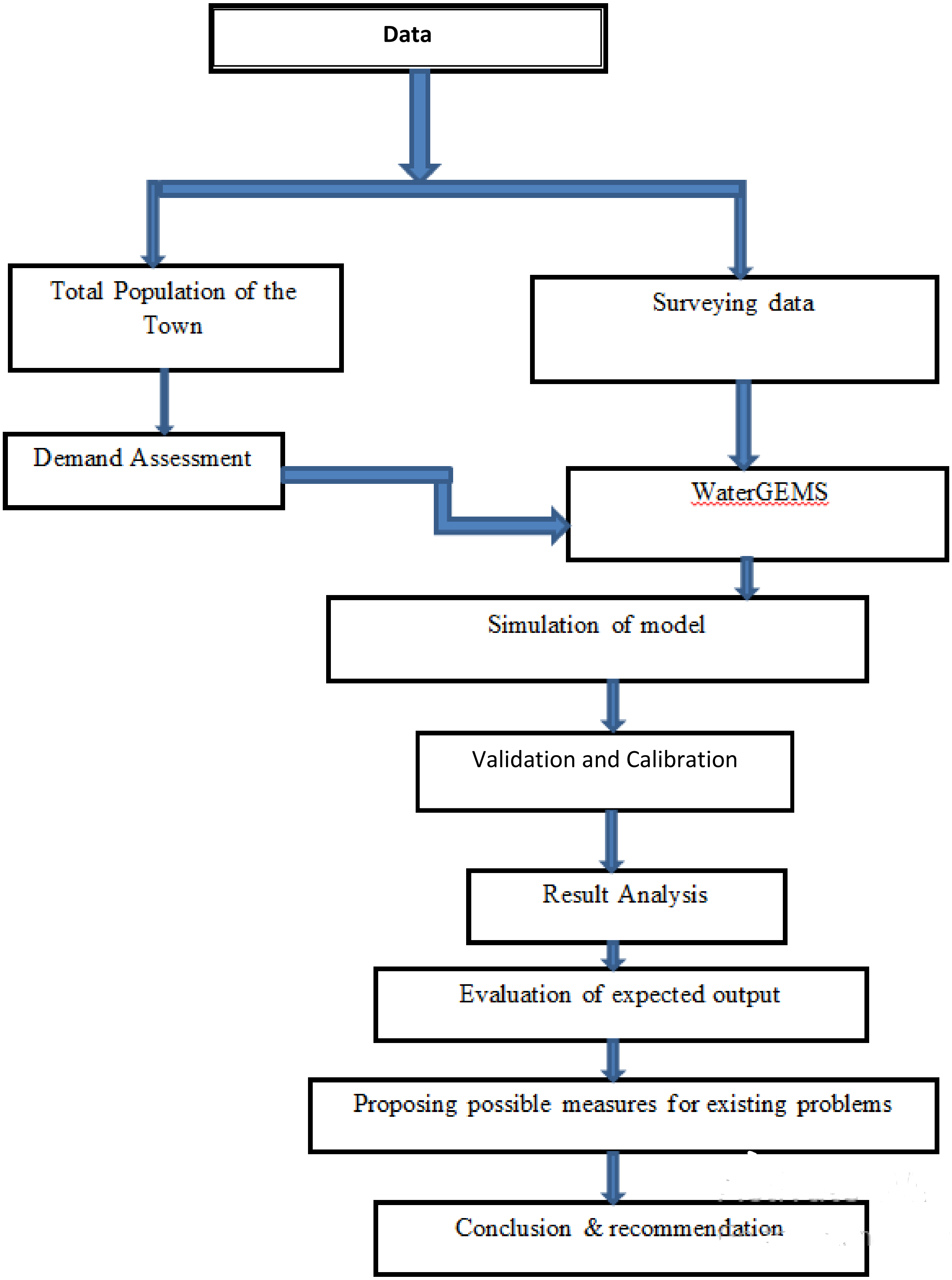


Figure 3.6: Conceptual framework of the Study

3.7. Water quality collection and analysis

Water quality data collection

It is important to analyze Water quality for the water sampling points to evaluate selected physicochemical and bacteriological parameters at water source, storage and point of use to identify the quality of potable water. The quality of water depends on the various chemical constitutes and their concentration, which are mostly induce from natural and anthropogenic activities. Water for human consumption must be free from living and non-living organisms, toxic elements and chemical substances in concentration large enough to affect health.

To examine Girja town existing water supply system quality, the sample was collected from different components of water supply system depends on sampling system by using Yemane's formula:which is $n= N/(1+N(e))^2$, where n=number of sumple size, N=the population of study and e= error in the calculation. Depends on this sample collecte+d from: (Source, reservoir, water point/public fountain/ and household water collection). $n=72(1+72(0.05))^2 =16$. However I have taken 12 points which means 75% of sample depends on collection resources problem.

The GPS data of water quality sample points was shown in table 3.8 below.

Table 3.8: Water quality Sample point*s*

Sampling place	Easting	Northing	Elevation
Source	496935	696875	2141
Jangalo 100m^3 reservoir	496151	695654	1879
Jangalo rural part water supply community fountain	494230	693019	1618
Girja 200m^3 reservoir	493348	691850	1555
Girja Water point 1	493170	691653	1529
Girja household water	492862	691369	1486

collection 1			
Gudumale community wp-2	492741	690511	1464
Household collection 2	494330	692772	1503
community wp-3	493006	691671	1503
Household collection3	494081	692321	1505
Water point 4	492266	690289	1442
Household collection 4	492781	690443	1468

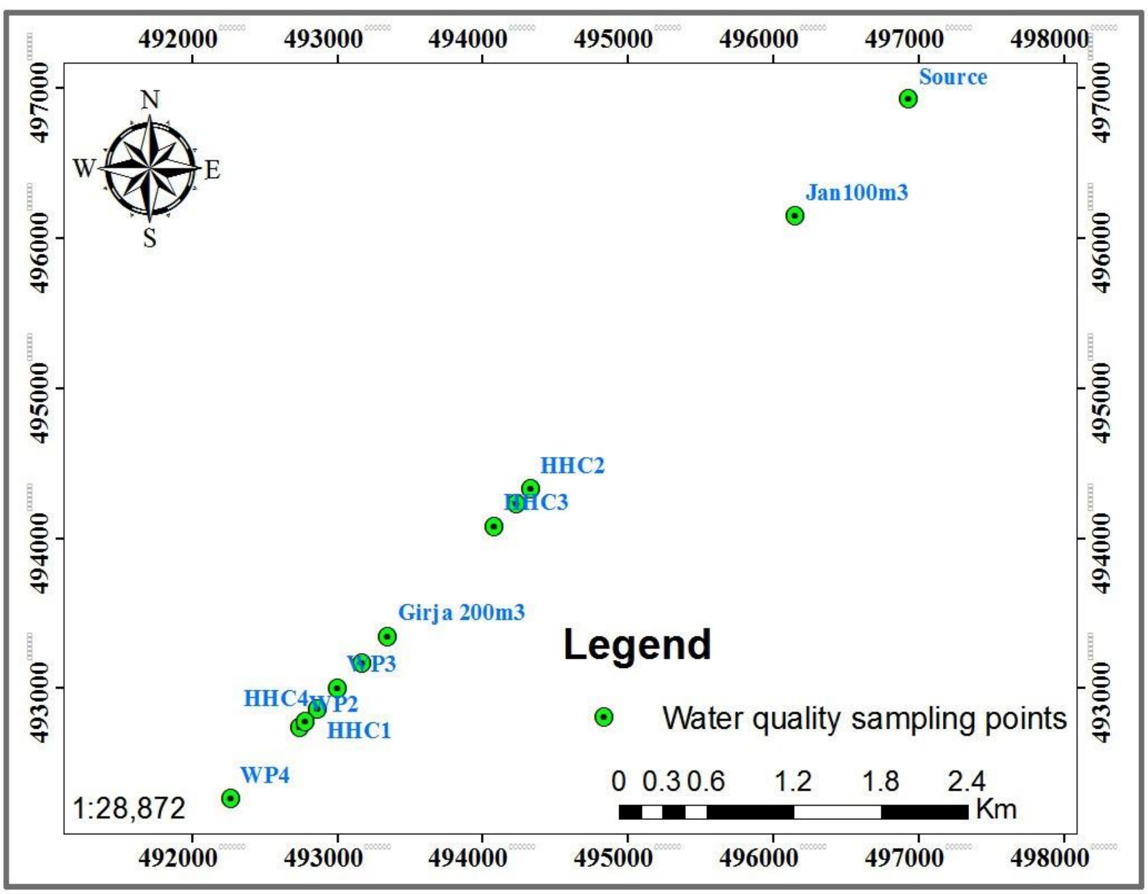


Figure 3.7. water quality sample map

Water Sampling Procedure

Water sampling and preservation techniques followed the standard methods of water sampling and preservation techniques (APHA, 1998; Hutton, 1996). Before collection, bottles were washed with concentrated nitric acid and distilled water to avoid contamination.

A separate sample was collected at the source where the household obtains the water. If households accessed the same source of water at different points, such as using different taps of one piped network, each tap was considered a unique source and was tested. In this study, sample was taken from source (Buche spring), reservoir, households and water points located at different locations to test and compare the quality of water at source and in distribution network. The household sample was taken to test the quality of the water being consumed by household members to account for any contamination after the water was collected.

The water samples collected from 12 sampling points separately in 1000ml polyethylene plastic bottles to test physicochemical and bacteriological parameters were handled carefully in sterile glass bottles, labeled and kept in an ice-box during transportation to the laboratory of Faculty of Bio-systems and Water Resources Engineering Hawassa University. Finally, water samples from each sampling sites were analyzed for selected physiochemical and bacteriological parameters.

Water quality Analysis

To analyze the physicochemical parameters, the collected water samples were measured by digital turbidity meter 2100A instrument, in which international standard samples with different turbidity ranges were observed from the reading instrument and were measured and the measuring instruments were calibrated. Total solids and total dissolved solids (TDS) were determined by putting 50ml water sample to the crucible and put on the oven to vaporize the collected water and measuring the remaining solids on the crucible. Determination of total hardness and free residual chloride were carried out by titration methods by which 0.02N of H_2SO_4, $AgNO_3$, or EDTA used as a titer. Nitrate and Fluoride amount of the collected water sample was analyzed calorimetrically. A colorimetric method was used to determine free chlorine in water at concentrations of 0.1–10 mg/l.

For the analysis of Bacteriological parameters, Escherichia coli (or, alternatively, thermo tolerant coliforms) were generally measured in 100-ml samples of water. The procedures include membrane filtration followed by incubation of the membranes on selective media at 44°C to 45°C and counting of colonies after 24 hours. Composite samples were used to improve the precision of the estimated average contaminant concentrations. In the laboratory, the samples from each site were mixed into one and a composite sample is subjected for membrane filter analysis of fecal coliforms. The composite samples were mixed thoroughly by shaking and filtered under laboratory hood. Finally, the water quality parameters result was compared with Ethiopian standard and WHO guideline.

4. RESULTS AND DISCUSSION

4.1. WATER SUPPLY AND DEMAND COVERAGE

4.1.1. Water Supply Coverage Analysis

To identify the gap between demand and supply three ways are followed, first by using annual domestic consumption identifying the level of per capital demand per person, second computing the per capital demand by level of connection and third by following the design criteria calculating the overall demand coverage. The current i.e., 2015 E.C population number of Girja Town is 25,193 and the annual consumption was 93,287 m^3. To evaluate the amount of water consumption, the annual water consumption is converted to average daily per capita consumption using the population data of the town and the number of domestic connections per family has been also used to analyze the level of connection. The volume of water consumed for domestic purpose has been distributed for all beneficiaries of the town to analyze the distribution of the water supply coverage.

$$\text{Per Capital Consumption (l/person/day)} = \frac{\text{Annual Consumption}(m^3) * 1000\ \text{l}/m^3}{\text{Population number} * 365\ \text{day}} \ldots\ldots\ldots\ldots \ (4.1)$$

$$= \frac{93{,}287(m^3) * 1000\ \text{l}/m^3}{25{,}193 * 365\ \text{day}} = 10.15\ \text{l/c/d}$$

By using the above expression, the average daily per capita consumption became 10.15l/c/day. According to WHO (2008), the minimum quantity of domestic water required in urban areas of developing country is taken as 20 l/c/day. Regarding to this value, the domestic water supply of Girja Town only satisfies 50.75% of the standard value. In addition, according to GTP-II (Ethiopian Water Sector Strategy, 2015); the per capita consumption standard set for category-4 town like Girja is 50l/d. But the current water supply coverage is only satisfying almost 20.3% of the demand.

Level of water connection per family is one mechanism to evaluate the level of water coverage. The total number of connection or water meter within the town are about 890 that among these 540 are for domestic users, according to the census of the 2007, average family size of 5 is used for calculating the average number of connections per family using the following expression.

Connection per family= $\frac{\text{Total number of connection}}{(\text{number of population of the town/Average family size})}$........... (4.2)

$= \frac{890}{(25{,}193/5)} = 0.18$

The level of water connection as per the above expression became 0.18; this implies that the current connection coverage is only 18%.

4.1.2. Analysis of overall Water Demand Coverage

A water supply system capable of supplying enough portable water is necessary for city or town. To estimate as correcting as possible, the total demand of a particular community, all demands must consider. Generally, speaks in design of water supply scheme for a town, it is necessary to determine the total quantity of water required for various proposes. This is done as follows.

Present and Future Domestic Water Demand

i. Population Forecasting

The water demand of a particular town is proportionally related with the population to be served. According to Woreda Administration office, the current (2015E.C) population of Girja Town is 25,193 and it was used as base population for current estimation. According to CSA, the regional level annual growth rate of urban population and applying geometric increase method, the estimated number of populations from 2015 to 2035 E.C of the town was presented in table 4.1 below.

$P_n = Po*(1+r)^n$ -- (4.3)

Where: Po = Initial known population at time zero or base population the population

Pn = projected population after n years

r = annual growth rate

n = number of years or time horizon.

As part of this project applying the below growth rate in the geometric increase method, the population of Girja town is projected up to year 2035.

Table 4.1: Girja town Population growth rate

Population Projection	Year			
	2020 -2024	2025 - 2029	2030 - 2034	2035 – 2039
CSA Growth Rates (%)				
Urban	2.26	2.26	1.93	1.71
Rural	3.16	3.16	2.9	2.86

Table 4.2: Jangalo kebele Population Projection (2015 - 2030)

Jangalo kebele	Projected Population	
Year	2015	2030
Population	8583	13178

Basin line population Source*: - Direct counting of woreda administration*

Table 4.3: Girja town Population Projection (2015 - 2035)

Girja town population projection			
	Baseline	Phase – I	Phase – II
Year	2015	2025	2035
Population	25,193	30500	35363

4.2. Projected Water Demand

Design of water systems require estimates of expected water demands applicable to size the pumping equipment, transmission and distribution pipelines and storage facilities. Estimating water demands depends on the size of the population to be served, their standard of living and activities, the cost of water supplied, the availability of wastewater service and the purpose of demand. The demand varies according to the requirement of the domestic population, institutional, industrial, and social establishments, etc. In addition to these, demand allowances need to be included for leakage, wastage, and operational requirements such as flushing of mains.

Accordingly, the water demand of study area is calculated with due consideration of actual conditions of the area and pertinent to available data. Where gaps are observed in acquiring of data, estimates are made from general experiences of the country utilized for similar towns.

Domestic Water Demand

Domestic water demand includes water used for basic needs such as drinking, cooking, ablution, washing clothes and utensils and cleaning houses. The average amount of water used per person per day varies from country to country as well as from place to place within a country. The major important factors for these variations are:

- Level of water supply services
- Per-capita per day water consumption
- Climatic conditions
- Level of socio-economic development
- Affordability and willingness of people to pay for water supply services.
- Water Quality Standard and etc.

Level of Water Supply Services

As mentioned above the level of a water supply service greatly affects the water demand of the users. If the level of service is excellent like house connection, the demand for water is also very high due to its multipurpose such as toilet flushing, laundry machines and bathing rooms. The water demand of the users decreases as the level of the water supply service decreases and vice versa. Consequently, the following common three types of service levels have been adopted in the study area.

a) House Connections (HC);

b) Yard Connections (YC); And

c) Public Fountains

Per Capita Water Demand

The amount of water used per person per day for daily life and activity is known as Per capita water demand which uses as a base for estimating the domestic water demand of customers. The domestic water consumption varies according to the mode of service, Per capita water demand and Population. The researcher considered the three modes of service namely Public Taps (PT), Yard Connections (YC), at premise shared (YCP) and House Connections (HC). In Ethiopia Water Development Commission guideline (2021), the following proportion (Table 4.4) is proposed for rural area of the country for estimation and used by this project.

Table 4.4: Percentage of population served by Service Type

Service Types	Year	
	2015 E.c	2035 E.c
HC	4	7
YCP	25	37
YCS	31	22
PT	40	34

Table 4.5: Per capita water demand with mode of service

Per Capita Water Demand (lit/day)	Year	
	2015 E.c	2035 E.c
YCS	35	40
PT	25	30

In the same manner, the daily domestic water demand of the Girja town is calculated based upon Urban Water Supply Design Criteria developed by MoWR (2006).

Table 4.6: Summary of Jangalo rural Kebele Domestic Demand

Description	Unit	Year	
		2015 E.c	2030 E.c
Populations	No	8583	13178
% of population served by Service Type			
YCO		0.05	0.2

PT		0.95	0.7
Population served by			
YCO	No	429	2636
PT	No	8154	9225
Domestic Demand			
YTS	l/c/d	35	40
PT	l/c/d	25	30
Total Domestic demand	l/d	218864.3	382175.9
	l/s	**2.53**	**4.42**

Table 4.7: Girja Town Domestic Water Demand

Description	Unit	2015 E.c	Phase-I (2025 E.c)	Phase-II (2035 E.c)
Population	No.	25,193	30500	35363
% of population served by Service Type				
HC		4%	5.50%	7%
YCP		25%	31%	37%
YCS		31%	26.50%	22%
PT		40%	37%	34%
Population served by				
HC	No	1008	1678	2475

YCP	No	6,298	9,455	13,084
YCS	No	7,810	8,083	7,780
PT	No	10,077	11,285	12,024
Demand by Service Type				
HTC	l/c/d	80	80	80
YTO	l/c/d	60	60	60
YTS	l/c/d	50	50	50
PT	l/c/d	40	40	40
Total Domestic Demand	l/d	1252092.1	1557026.038	1853037.72
	l/s	**14.5**	**18.0**	**21.4**

Climatic and Socio- Economic Adjustment Factors

Climatic factors

Water demand per person varies and depends on the climatic and socioeconomic conditions of the area. This means water is more used at hot areas than cold ones. The study area is hot but not too hot a year around. It has rainfall from march to October and its dry season start from half of November to end February. Its annual rainfall between 600 to 900mm. climatic Condition Adjustment Factors are presented in the following two tables:

Table 4.8: Climatic adjustment factors

Group	Mean annual precipitation	Factor
A	<600	1.1
B	600-900	1.0
C	>900	0.9

Socio- Economic Adjustment Factors

In addition, rich people consume more water than the poor ones. These are adjusted by multiplying the adjustment factors with total domestic demand. Socio economic condition of this town is under development and its development advanced rural towns. Socio- economic Condition Adjustment Factors are presented in the following two tables:

Table 4.9: Socio-economic adjustment factors

Group	Description	Factor
A	Towns enjoying high living standards and with high potential for development	1.1
B	Towns having a very high potential for development, but lower living standards at present	1.05
C	Towns under normal Ethiopian conditions	1
D	Advanced rural towns	0.9

Source: 9/25 Towns Water Supply Feasibility Study and Engineering Design Report (Oromia Towns)

Socio-economically, Girja town can be grouped under "Advanced rural towns, D" and the climatic factor will be categorized under group B. Beside the result of both Socio-economic and Climatic adjustment factors will be 1. Hence, for both rural kebele and town, the factor of 1 is used.

Institutional and Commercial Water Demands

Commercial demand includes water requirement for restaurants, cinema houses, railways, bus stations, shopping centers, local drinks etc whereas public demand includes water required by schools, hospitals, public offices, military camps, public parks, dispensaries, and day-care centers and so on. In case where exhaustive estimation of the public and commercial institutions is not possible it is recommended to take percentage of the domestic water demand, depending on the size of population. Therefore 10% of total domestic demand is considered as institutional and commercial water demand.

Table 4.10: Institutional and commercial Water Demands of the Girja town.

Name of town	2015	2025	2035
Girja Town(l/s)	1.45	1.8	2.14

Industrial Water Demand

In this study area there is no concrete industrial development plan soon or designs period. And if comes in effect it is expected to consider 5% of total domestic demand.

Table 4.11: Industrial Water Demands of the area.

Name of town	2015 E.c	2025 E.c	2035 E.c
Girja Town(l/s)	0.73	0.90	1.07

Livestock Water Demand

The livestock water demand is considered where there are no traditional sources such as rivers and streams available within a radius of 10km from the town. In the study area there are a nearby river (Genale River) and seasonal streams that can suffice demand of the livestock.

Non-Revenue Water (NRW)

All water leakages in the system and unauthorized connections are categorized under NRW. The Criteria developed for non-revenue water estimation by Ministry of Water and Energy, Ethiopia Water Development Commission (2021) has been used for calculation.

Table 4.12: Recommended percentage of NRW

Water supply system size	Planned beneficiaries	NRW at the project start up	NRW at the end of design period
On spot schemes	Up to 500	5%	5%
Rural pipe system up to 15 KM system network	Up to 10,000	20%	15%

Water supply system with more than 15KM system network	More than 10,000	25%	15%

Water Demand for Fire Fighting

For assuring public safety, the provision of adequate fire demand is quite important. However, unless there is a specific national and/or local regulation, water required for firefighting shall be met by stopping supply to customers for the required time of fire suppression due to economic reasons. Since the project is undertaken in most rural parts of the country, no firefighting water demand is considered.

Water Demand Factors

The consumption patterns of different users of water supply services vary on hourly, daily, and annual basis. Keeping records of these variations can help in developing standard peak factors for a given locality, which is the basis for the design of different water supply components. Poor estimation of these factors can lead to under or over design of water supply systems. To design the different elements of a water supply scheme, the following demand type must be considered.

Average Daily Demand

The total water demand summed up from all demand categories including the specified NRW per time is the average day demand and expressed with the following formula.

$$\mathbf{Q_{total} = Q_{Dom} + Q_{Inst} + Q_{Com} + Q_{Ls} + Q_{Ind} + Q_{NRW}}$$

Where Q_{total} is total water demand, Q_{dom} domestic water demand, Q_{Inst} Institutational water demand, $Q_{Com\ Commercial}$ water demand, $Q_{Ls\ Livestock}$ water demand, Q_{Ind}= Institutional water demand, and $_{QNRW}$ is non-Revue water demand. The Average Daily demand is presented in Table 4.13 below.

Table 4.13: Average daily demand of Girja Town

Description	Unit	Years		
		Base line (2015 E.c)	Phase-I	Phase-II (2035 E.c)

			(2025 E.c)	
Population	No	25,193	30500	35363
Domestic demand	m^3/day	**1252.1**	**1557.03**	**1853.04**
Livestock Demand	m^3/day	**0**	**0**	**0**
Institutional (with 10% growth)	m^3/day	125.2	155.7	185.5
Industrial (5%)	m^3/day	62.6	77.9	92.7
Total Demands	m^3/day	1439.9	1788.5	2131.24
Non-Revenue Water (NRW)	%	25%	20%	15%
Average Day Demand	m^3/day	1798.98	2101.99	2450.93
	l/s	**20.82**	**24.33**	**28.37**

Table 4.14: Jangalo rural Kebele Average daily demand

Description	Unit	Year	
		Baseline (2015)	End of design period (2030 E.c)
Population	No	8583	13178
Domestic demand	m3/day	218.86	382.18
Total Demands	m3/day	218.86	382.18
Non-Revenue Water (NRW)	%	25%	15%
	m3/day	54.715	57.327
Average Day Demand	m3/day	273.575	439.507
	l/s	3.17	5.09

Maximum Daily Demand/Seasonal Peak Factor

It is the highest demand of any one 24-hour period over any specified year. It represents the changes in demand with season and some special events happening in any specified year. The maximum day demand is obtained by multiplying the average day demand with the maximum day peak factor recommended by Ethiopia Water Development Commission (2021). For this project the value of 1.3 is used.

Table 4.15: Demand conditions with recommended factor values

Demand parameters	**Demand factors**
Minimum day Demand	0 to 0.3 of the average day demand
Average day Demand (ADD)	1.0
Maximum Day Demand (MDD)	1.1 to 1.5 of ADD
Peak hours demand (PHD)	1.5 to 2.0 of ADD(>15,000population)
	2.0 to 2.5 of ADD (<15,000 population)

Peak Hour Demand

The peak hour demand is the highest demand of any one hour over the maximum day. It represents the diurnal variations in water demand resulting from the behavioral patterns of the local population. The peak hour demand is obtained by multiplying the maximum day demand with the peak hour factor. The factor recommend by rural water supply design criteria of WDC (2021) is used for the estimation (factor of 1.9) and the result of rural kebele is determined as Table 4.16.

Table 4.16: Average, Maximum and Peak Hour Demand of Jangalo rural kebele

Kebele	2015 E.c	2030 E.c
Population	8583	13178
Average Day Demand(l/s)	3.17	5.09
Maximum Day Demand(l/s)	**4.12**	**6.62**
Peak Hour Demand(l/s)	**6.34**	**10.18**

Table 4.17: Average, Maximum and Peak Hour Demand of Urban town (Girja)

Description	Unit	Years		
		Base line (2015 E.c)	Phase-I (2025 E.c)	Phase-II (2035 E.c)
Population	No	25,193	30500	35363
Average Day Demand	l/s	20.85	24.84	28.6
Maximum Day Demand	l/s	**27.11**	**32.3**	**37.18**
Peak Hour Demand	l/s	**39.62**	**47.20**	**54.34**

The existing system can supply a total of 4.5l/s which is very less when it compared with the theoretical average day demand of the systemfor current 20.85l/s, 24.84 l/s required in 2025 & in 2035 which is 28.6 l/s. Therefore, another source of water is needed.

4.3. WATER LOSS ANALYSIS

4.3.1. Non-revenue Water

Non-revenue water is the difference between the volumes of water put into a water distribution System and the volume that is billed to customers. NRW comprises three components: physical (real) losses, commercial (apparent) losses, and unbilled authorized consumption.

- ❖ Physical losses comprise leakage from all parts of the system and overflows at the utility's storage tanks. They are caused by poor operations and maintenance, the lack of active leakage control, and poor quality of underground assets.
- ❖ Commercial losses are caused by customer meter under registration, data handling errors, and theft of water in various forms.
- ❖ Unbilled authorized consumption includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer.

The water loss analysis has made by using expression in terms of percentage of (UFW), loss per kilometer of main pipes and loss per number of connections. To compute the level of apparent loss due to limitation of data, the real loss is calculated as per level of connection and length of pipe and the apparent loss became the different between total loss and real loss.

A. Total Water loss Computation

Three-year production and consumption data of the study area used to compute the total loss as shown in table 4.8 below by using this expression.

$$NRW\ (\%) = \frac{(production - metered\ use)*100\%}{Production} \quad \ldots\ldots (4.3)$$

Table 4.18: Computed Total Water Loss

Year	Production (m^3/year)	Consumption (m^3/year)	Loss (m^3/year)	Loss (%)
2012	120,390	79,860	40,430	33.66
2013	126,756	90,129	36,627	28.89
22015	128,940	93,287	35,653	27.65

B. Water loss expressed as per number of connections.

The total number of connections in the study area is 890; the water loss per connection computed by using this expression.

Water loss = Annual total loss *1000/ (Number of connections*365)

For year 2015 computed total annual water loss value of 35,653 m^3 is used.

Water loss =35,653*1000/ (890 *365) = 109.75 lit/connection/day

C. Water loss expressed as per length of pipes.

Expressing water loss as per km of main pipe is one way to indicate the loss. The total length of pipes is 20.4 Km, and this total pipe length is used to express the water loss.

Water loss = Annual loss/ (Length in Km *365)

Water loss =35,653/ (20.4km *365) = 4.8m^3/km/day

4.3.2. Determining the water balance and Water Loss components

Annually water produced and distributed to the supply system and the water billed that was aggregated from the individual customer meter readings of one-year 2015E.c was used to quantify the total water loss for the entire town. The entire annual production and billed water consumption of scheme are shown below table 4.9.

Table 4.19: Water balance method

<table>
<tr><td rowspan="9">System input volume
128,940</td><td rowspan="4">Authorized Consumption
93,287 m^3
72.35 %</td><td rowspan="2">Billed Authorized Consumption
93,287 m^3</td><td>Billed Metered Consumption
93,287 m^3</td><td rowspan="2">Revenue Water
93,287m^3</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)
35,653 m^3</td></tr>
<tr><td>Unbilled Un metered Consumption</td></tr>
<tr><td rowspan="5">Water Loss
35,653 m^3
(249,571 birr fiscal year loss)
27.65 %</td><td rowspan="3">Apparent loss (Commercial Losses)
0.9%
1,160 m^3
8,120birr</td><td>Unauthorized consumption
0.1% 128.94 m^3 902.58birr</td></tr>
<tr><td>Customer meter inaccuracies
0.3% 386.82 m^3 2,707.74birr</td></tr>
<tr><td>Systematic data handling Errors
0.5% 644.7 m^3 4,512.9birr</td></tr>
<tr><td rowspan="2">Real loss (Physical Losses)
26.75%
34,493 m^3</td><td>Leakage in Transmission and Distribution Mains
(Not broken down)</td></tr>
<tr><td>Storage Leaks and Overflows from water storage Tanks</td></tr>
</table>

		241,451birr	(Not broken down)	
			Service Connection leaks up to the meter (Not broken down)	

i. Apparent loss

This component of the total water loss volume includes the loss due to unauthorized consumption, customer metering inaccuracies and data handling errors and is aggregated to 1,160m^3/year. This loss amount covers 0.9% of the total system loss. This result signifies less of the loss in the system as real loss which is mainly caused due to deterioration of the existing distribution system.

ii. Unauthorized Consumption

This volume of water includes theft and illegal connections. As there is not any means to determine this quantity of water, its volume is estimated based on the system input volume. Accordingly, the unauthorized consumption amounts to 128.94 m^3/year which is 0.1% of system input volume.

iii. Customer Metering Inaccuracies

The total volume of loss due to meter in accuracy in the system is 386.82 m^3/year. This apparent loss of water accounts for approximately 0.3% of the system input volume for the fiscal year and translates to lost revenue of approximately 2,707.74 ETB. Generally, in the case of Girja the main reason for this high meter under registration is the deterioration of water meters with age, resulting in inaccurate readings. This is highly influenced by the lack of water meter testing and replacement programme and unlimited service year for meters in the distribution system.

Real loss

This category includes the volume of water lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering. In this specific study the real loss volume is found to be 34,493m^3/year. This apparent loss of water accounts for approximately 26.75% by breakdown the two Loss categories) of the system input volume for the fiscal year and translates to lost revenue of approximately 241,451 ETB. So, in this figure indicates the deterioration of water supply system, water supply management problem and urgent need of a leakage of main and distribution (transition lines) and overflows in tanker area control program.

4.3.3. Possible Causes of Water Loss

There are several reasons for the high level of water loss in Girja town. These factors are given below, and some-advise solutions were concisely proposed in next sections.

a. Poor and Unscheduled maintenance of network

The water services of Girja town had no scheduled program for inspection and maintenance of networks, rather, they repair when the customer report. There was also a lack of finance to buy proper materials and construction.

b. Customer Meter inaccuracies

Metering losses are frequently the most common form of apparent losses. Experience shows that the high percentage of water is not metered or metered incorrectly due to measuring errors or creeping losses in water meters made in Poland water meters. This affects both customer meters and bulk water meters, and may be caused by selecting unsuitable meters, oversized meters, incorrect installation as well as many meters' deteriorating performance over time. In Girja town utility the water readers check-up the water meters every month and they report the suspected meters. Accordingly, the main reason age of water meter water in this case the utility test, replace and reuse meters which are passed the testing. According to water meter testing result 1,193.7 m^3 in 365 days of the year due to customer meter inaccuracy.

c. Data Handling Error

Meter-reading personnel may make meter-reading errors. Water consumption data may get lost or changed due to systematic errors in data processing and billing procedures. Unmetered consumption may be underestimated while unmetered production may be overestimated. Flat-rate tariffs may cause excessive domestic water consumption that by far exceeds the budgeted amount. In the case of Girja town data handling error the additionally this case happen by carelessness of water meter readers and meter inaccuracies covers their own percentages of apparent loss.

d. Poor record keeping

The requirement for good maintenance records is often overlooked. System maps, designs of the network and reservoirs and historic records of the equipment installed in the distribution system are often not available, whereas minimum information is required to operate and maintain the system efficiently. The top-down audit cannot be performed without maintaining the accurate data. Awareness can be created among the managers of water supply system about the importance of good maintenance of record.

e. Community Behavior

Water loss is not only just an engineering problem but also reflects a socio-cultural situation that requires changes in community behaviour, awareness gap and attitudes toward water usage. Many utilities that have been successful in addressing Non-Revenue Water have gone beyond technical measures to address community behaviour that drives illegal connections and thief the water material infrastructures. Technical measures have been complemented by efforts to address illegal connections by walk-through surveys and authorizing illegal connections by legitimizing them and adding them to the network and to create awareness to communication with the community.

f. Operation and maintenance

It has been observed that lack of attention to the important aspect of Operation and Maintenance (O&M) of water supply schemes in Girja town often leads to deterioration of the useful life of the systems necessitating premature replacement of many system components. Some of the key issues contributing to the poor Operation & Maintenance have been identified as follows.

- Lack of assets and inadequate data on Operation & Maintenance
- Inappropriate system design and poor workmanship
- overlapping responsibilities
- Inadequate training of personnel

- Inadequate emphasis on preventive maintenance
- Lack of operation manuals
- Lack of real time field information

4.3.4. Possible Water Loss Reduction Strategies

An analytical approach strengthened by the implementation of solutions which are practicable and possible, can be applied to water distribution system in Girja town, to develop water loss minimize strategy.

I. Effective maintenance

In Girja town water supply system there was a poor and unscheduled maintenance of networks. Therefore, the water services should establish a scheduled maintenance program targeted toward minimizing a leakage through proactive action. Once a distribution system has been properly constructed and placed in service, routine maintenance should be conducted to monitor the system's performance and identify repairs/rehabilitation as needed. Continuing maintenance will maintain the public water system operating at optimal performance and maximize the full life expectancy of the system.

II. Water Balance check-up

Water audit determines the amount of water lost from a distribution system due to leakage and other reasons such as theft, unauthorized or illegal withdrawals from the systems and the cost of such losses to the utility. Comprehensive water audit gives a detailed profile of the distribution system and water users, thereby facilitating easier and effective management of the resources with improved reliability. It helps in correct diagnosis of the problems faced in order to suggest achievable and practicable solutions. It is also an effective tool for realistic understanding and assessment of the present performance level and efficiency of the service and the adaptability of the system for future expansion and rectification of faults during modernization. It helps in identifying problem and risk areas and a better understanding of what is happening to the water after it leaves the source point. Such investigation should provide enough information to set specific objectives for a water efficiency program.

III. Assessing meter testing and replacement

In Girja town water services meters are key components for obtaining funds required to operate and maintain a public water service. Therefore, maintaining a meter assessment testing and replacement are very obligatory to optimize revenues and aids in locating losses in any operation and maintenance program. According to IWA water Balance result, Repair, or replacement of meters outside of ±2% of accuracy is required. Water loss in Girja town can be prevented by effective and pro-active infrastructure management. The water service will reduce real water losses by: maintaining proper inventory and inspection of new water mains and main breaks to repair.

IV. Improving Organizational Management and Provision of Training

For an effective management of water supply service in general and water loss and leakage in particular, water supply providing institutions must have an appropriate organizational management. The organization aspect related to the water loss management is well addressed in the organization structure of SWSS, but shortage of qualified and experienced personnel is the major problem of the country in general and SWSS. Capable management and technical staff are paramount in order to achieve better performance. Offering a continuous theoretical and practical training based on the need is also important. Due to the complex nature of water loss and leakage commitment of staffs at all levels is also very important. Effective leakage management requires an input from several different personnel and unless, they are all committed, the implementation of any water loss reduction program will not be efficient; it may then be difficult to maintain the infrastructure which has to be lower leakage levels.

4.4. HYDRAULIC PERFORMANCE EVALUATION

Pressure analysis

The analysis of the pressure distribution is a decisive parameter in water distribution network modeling. The water distribution network was designed based on pressure criteria and the existing criteria on the minimum and maximum pressure in the network. The operating pressures in the distribution network according to the (MoWR, 2006), urban water supply design criterion shall be 15m to 70m ranges. Accordingly, this study result of the pressures distribution networking is avail in within these ranges. Minimum pressures at peak hour consumption: appropriate to assist the maximum supply idea in the system classically mains, pressures not less than 15 m would be required (MoWR, 2006). Maximum pressure during low consumption hour: The maximum pressure in mains is considered not to exceed 70 m to limit leakage and stress on pipes (MoWR, 2006). Considering the Pressure reducing valve requirement at source site, a small system with no zones and distribution mains close to reservoir the exceptional condition is taken as the pressure range to be 10mH_2O and 70 mH_2O (MoWR, 2006). As a result of simulations carried out in the existing models, it was found that it is possible to reconstruct the actual working conditions water supply network. Most of the pressures are distributed in the range of 10 mH2O to 70 mH2O, with some nodes with pressures greater than 70 mH2O and with few nodes with pressures less than 10 mH2O (Fig. 4.1). The result of simulation run was obtained after model constricted from the input data of existing data a total node of 72 was reported from the study inventory dialog box software. As described in Table 4.20 below, 76.39 % of consumption nodes have acceptable pressure limits between (10 –70) mH2O. During hydraulic modelling of the distribution system of town, 72 nodes were identified and regarding current simulation the result of pressure at distribution system summarized in table blow.

Table 4.20: Simulated result of pressure of Girja town

Pressure (m of H2O)	Number of nodes	Percentage
<=10	2	2.78%
10 -70	55	76.39%
>70	15	20.83%
	72	100%

Table above indicates that 2.78% of the distribution system was with pressure of less than the minimum recommended level, 20.83 was with pressure of greater than the maximum recommended level and the rest 76.39% is within recommended level (10 -70 m H20).

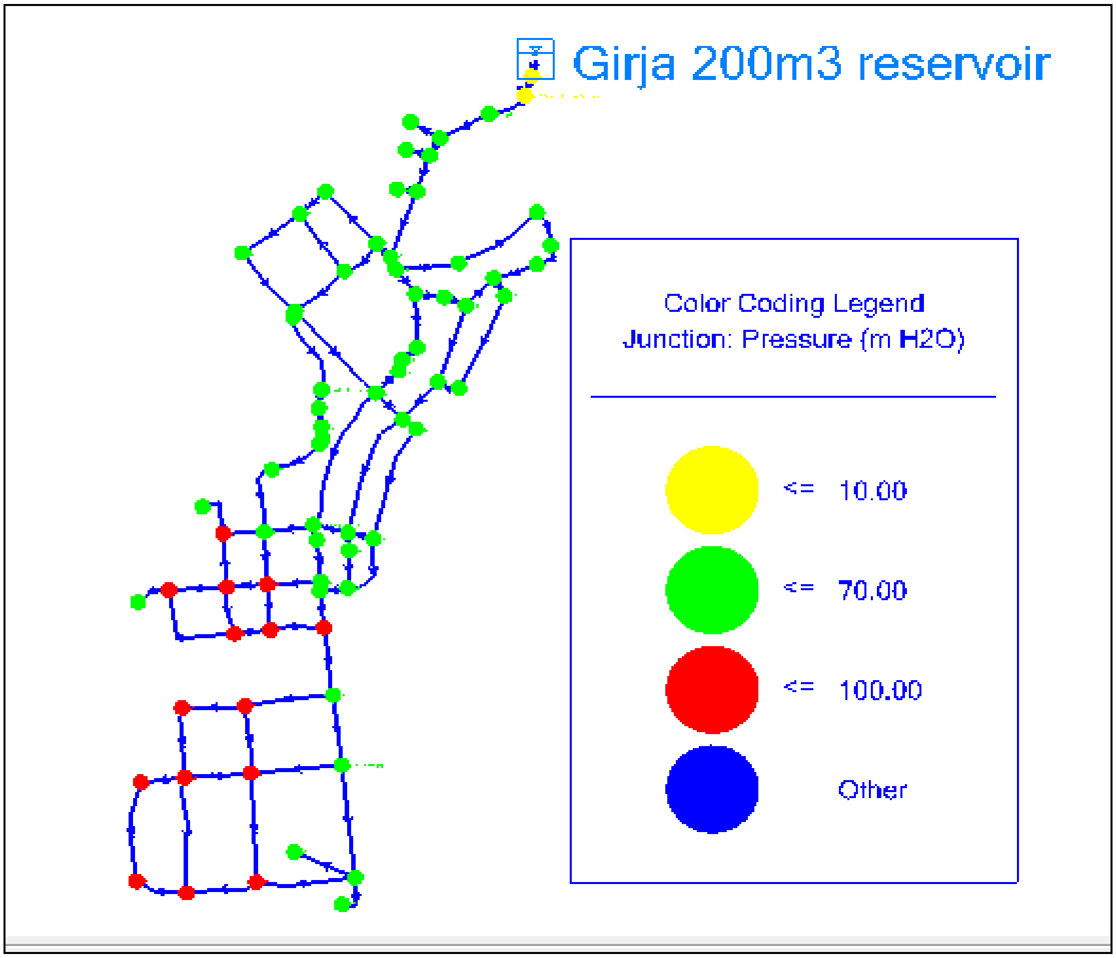


Figure 4.1: Pressure variation at junctions in the distribution system

As described in this Figure 4.1 above, green color indicates with pressure value between 10-70 mH2O, which was within permissible range. The junctions below permissible range of pressure were indicated with yellow color, and it carries low pressure due to the high elevation levels. The pressure above permissible range indicated by red color. The pressure at node depends on the adopted minimum and maximum pressure within the network, topographic circumstances, source position, storage elevation and the size of the network.

Developing pressure zone boundaries

A pressure zone is a geographic area that serves customers within a water distribution system that is bounded by a lower and upper elevation. The pressure is strongly linked to the topography. The nodes with a lower ground are subjected to higher pressure and the nodes with a higher elevation are subjected to lower pressure. The integrated system can generate accurate, smooth contours for any variable including pressure, hydraulic gradient, and elevation with a defined contour interval. In existing system there is no pressure zone classification. But based the current study hydraulic modelling, the entire distribution system of the town has three pressure zones (low-pressure zone, medium pressure zone and the high-pressure zone). The elevation with magenta colour is the area of low elevation and high-pressure zone which is represented by red coloured junctions carries the pressure greater than 70mH2O. The elevation represented with blue colour is the area of medium elevation and medium pressure zone which is represented by green coloured junctions carries the pressure between 10 mH2O to 70mH2O. The elevation with red colour is the area of high elevation and low-pressure zone which is represented by yellow coloured junctions carries the pressure less than 10mH2O.

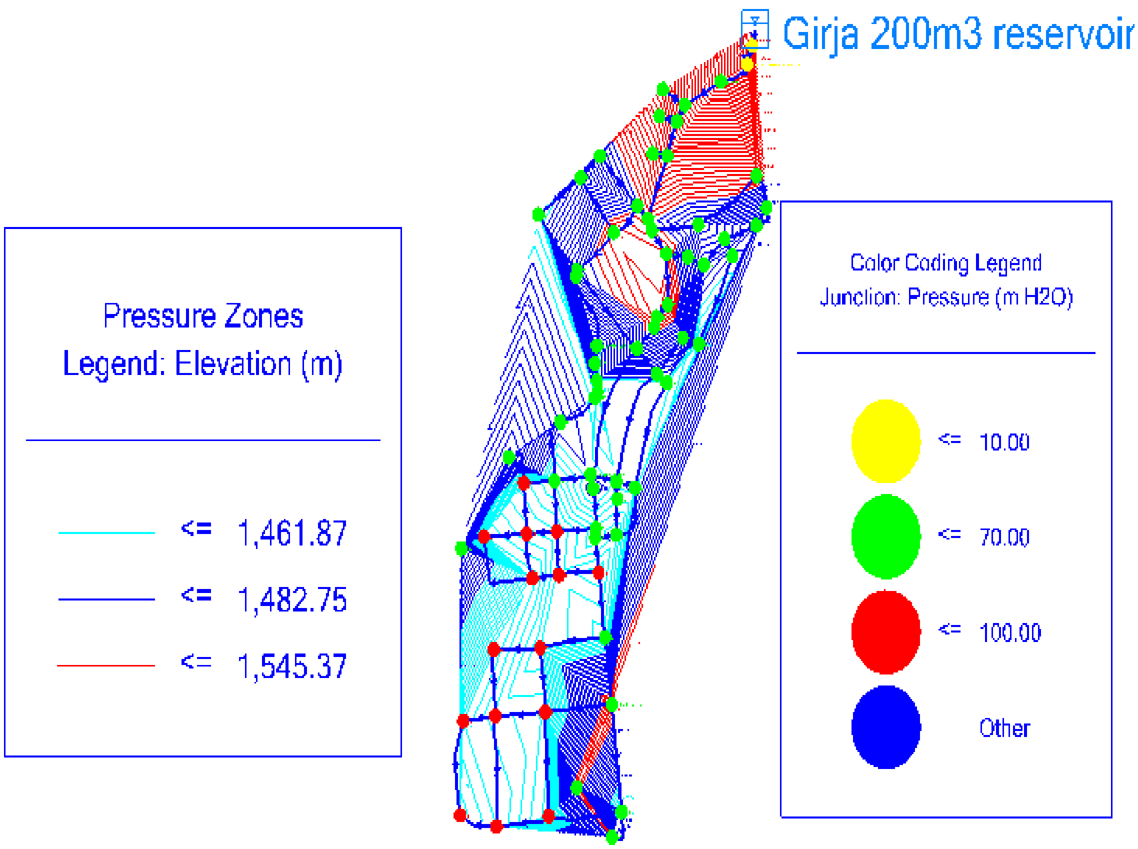


Figure 4.2: Pressure Zone contour map of the Girja Town

Velocity analysis

The velocity of water flow in a pipe is one of the important parameters in the hydraulic modeling, performance evaluation of the efficiency of water supply distribution and transmission line. Velocity distribution also varies with demand pattern changes. Water velocity should maintain at less than 2m/sec, in the distribution system and not more than 2.5 m/s in a transmission system. According to MoWR, (2006) the velocity ranges can also be adopted as the design criteria, low velocities for hygienic, while too high-velocity cause exceptional head loss reason are not preferred velocity distribution is also varying with demand pattern changes. There are specific standards for velocity and head loss in WDS. According to (MOWR, 2006). velocity of flow in the pipe below 0.6m/s causes" water stagnation, sediment accumulation and bacteriological growth in the pipe, on the other hand velocity of flow in the pipe above 2m/s causes head loss as well as water hammer. Velocity in water distribution system was varied with the demand pattern change. At peak consumption time the values are different as compare low consumption time. The analysis of the speed distribution made on the existing state models of all tested water supply networks showed that most pipes, its value are lower than the recommended. The result of velocity distribution show that up to 91.3% of the network have low which may causes low water quality due to water stagnation, increase age of water, sediment accumulation and bacteriological growth in a pipe network. This is 84 out of 92 pipes which had a velocity lower than 0.6m/s. A total of 8 pipes out of the 92 pipes accounting for 8.7% presented velocity between 0.6m/s to 2m/s, which is recommended range for water distribution network. According to the velocity result at table 4.21 and Fig 4.3., the velocity percentage between pipes divides into two intervals. As indicated on the figure 4.3 below, almost all pipes carry small velocity which is below 0.6m/s which has its own water quality implication. Since discharge is a function of velocity and velocity is a function of pipe size, the results of discharge and velocity is used for the judgment in solving the distribution network problems related to pipe size. Inadequate water supply, oversized service pipe diameter and topography are the major problem which causes low velocity of water in the pipe system. Topography of Girja town is characterized as rugged and inclined. At low elevation and oversized service pipe diameter, the velocity of water is low, and the pressure is high.

Table 4.21: Velocities for distribution system

Velocity (m/s)	Number of pipes	Percentage
<0.6	84	91.3%
0.6-2	8	8.7%
Total	92	100%

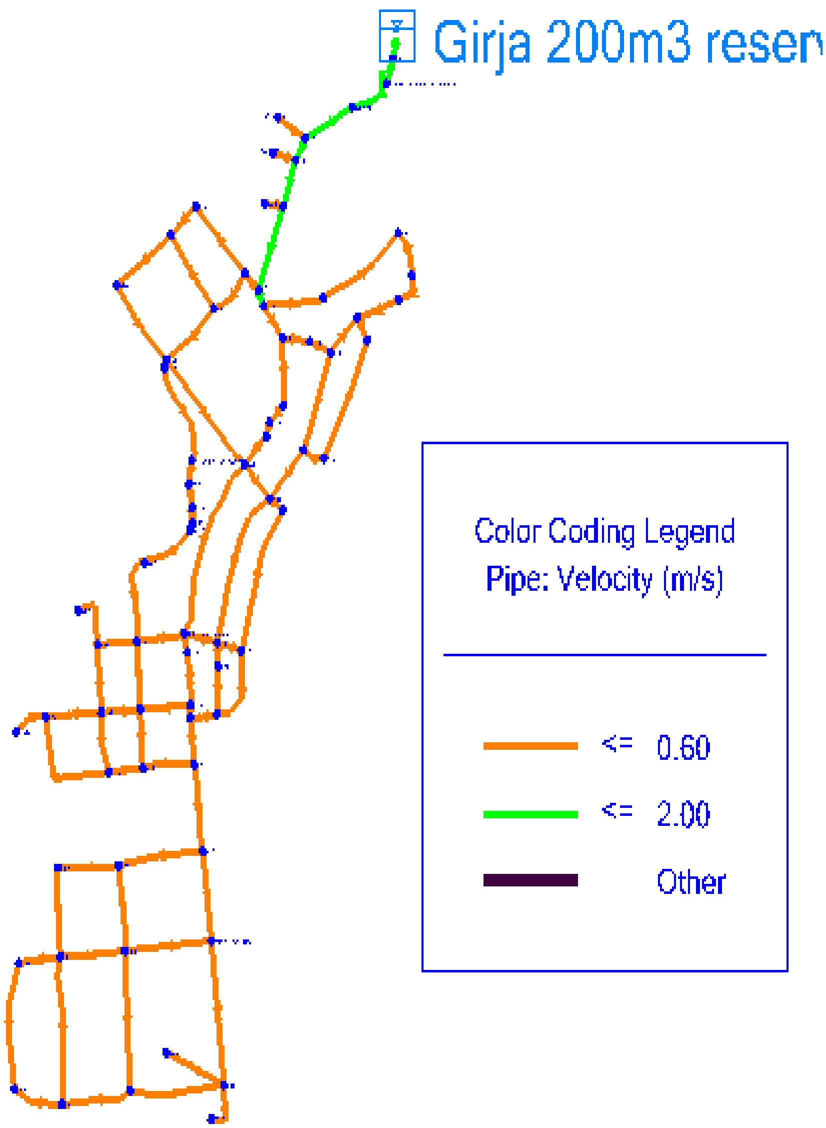


Figure 4.3: Velocity variation in the distribution pipe network

Head loss analysis

Generally, undersized pipes would lead to increased head losses due to increased friction. However, oversizing pipes beyond reasonable limits would increase the contracting cost. As the length of the network increases and the number of pipes, valves, fittings, and other obstructions in the system increase, both major and minor losses increase. As indicated in table 4.22 below, 4.57% of the pipes are below the recommended minimum head loss range of 1m/km, 43.48% are within the recommended head loss range (1 to 5m/km) and the rest of pipes, 11.95% head loss is above the recommend range based on Ethiopia urban water supply design guideline criteria.

Table 4.22: Head loss for distribution system

Head loss gradient (m/Km)	Number of pipes	Percentage
<1	41	44.57%
1-5	40	43.48%
>5	11	11.95%
Total	92	100%

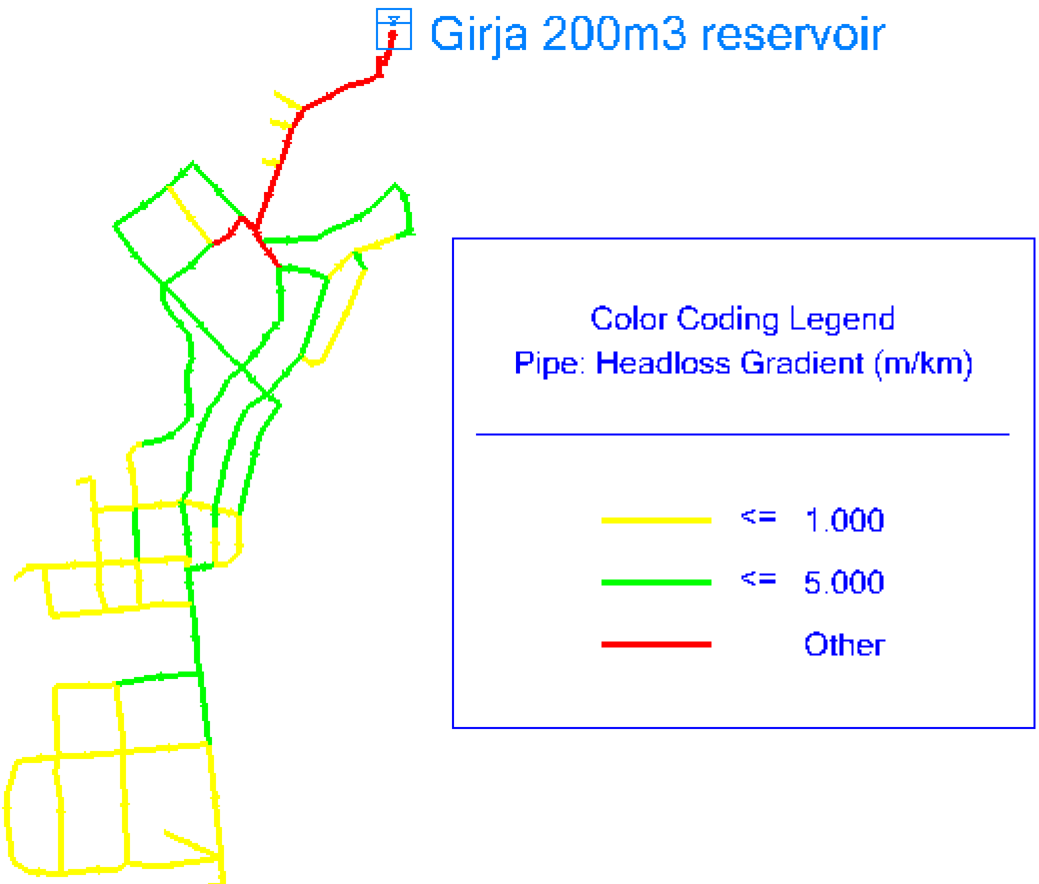


Figure 4.4: Head loss gradient in the distribution network

Jangalo rural water supply hydraulic analysis

Jangalo rural villages are the villages nearest to the source which is Jangalo Buche spring. The topography of the village is characterized by very steep slope and the 100m^3 Jangalo service reservoir is located at higher elevation nearest to the villages. The water distributed from these reservoirs following this steep slope until it gets the delivery points. Due to this, all distribution pipes are under very high pressures which is greater than a pressure head of 100m of water column.

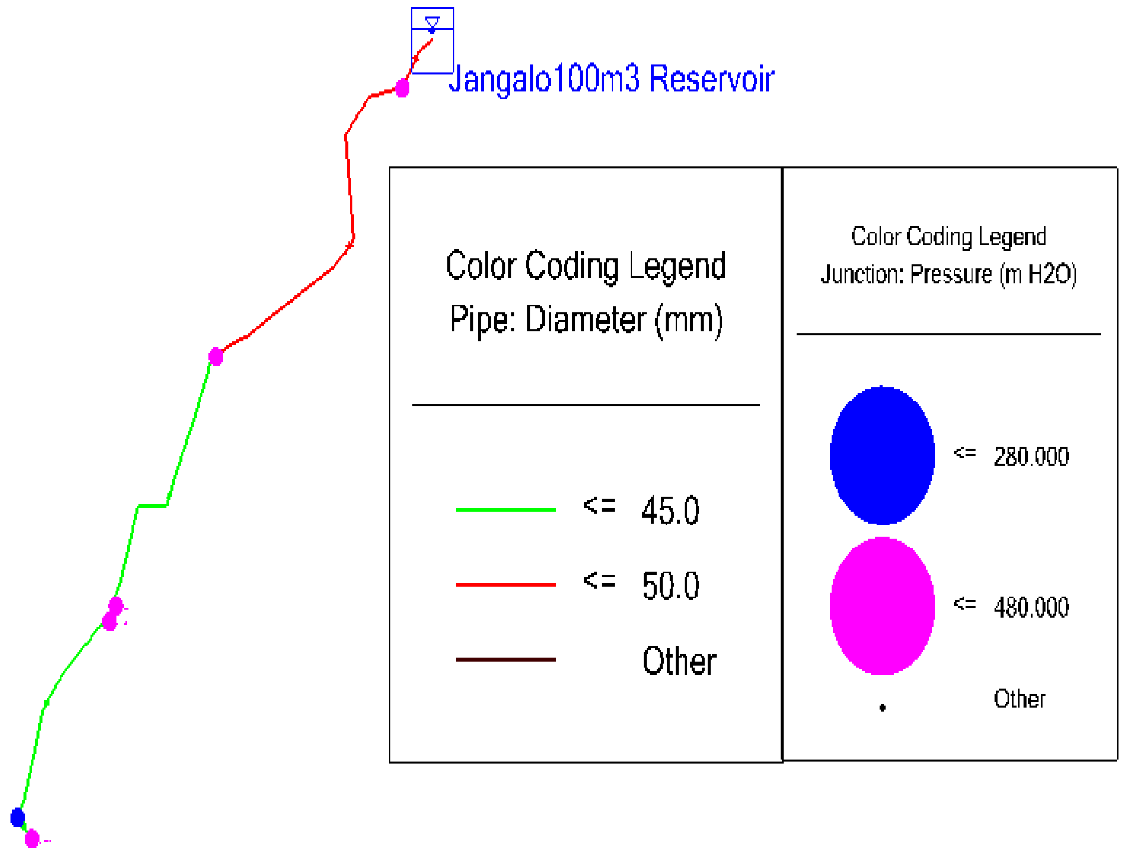


Figure 4.5: pressure variation of Jangalo kebele in the distribution network

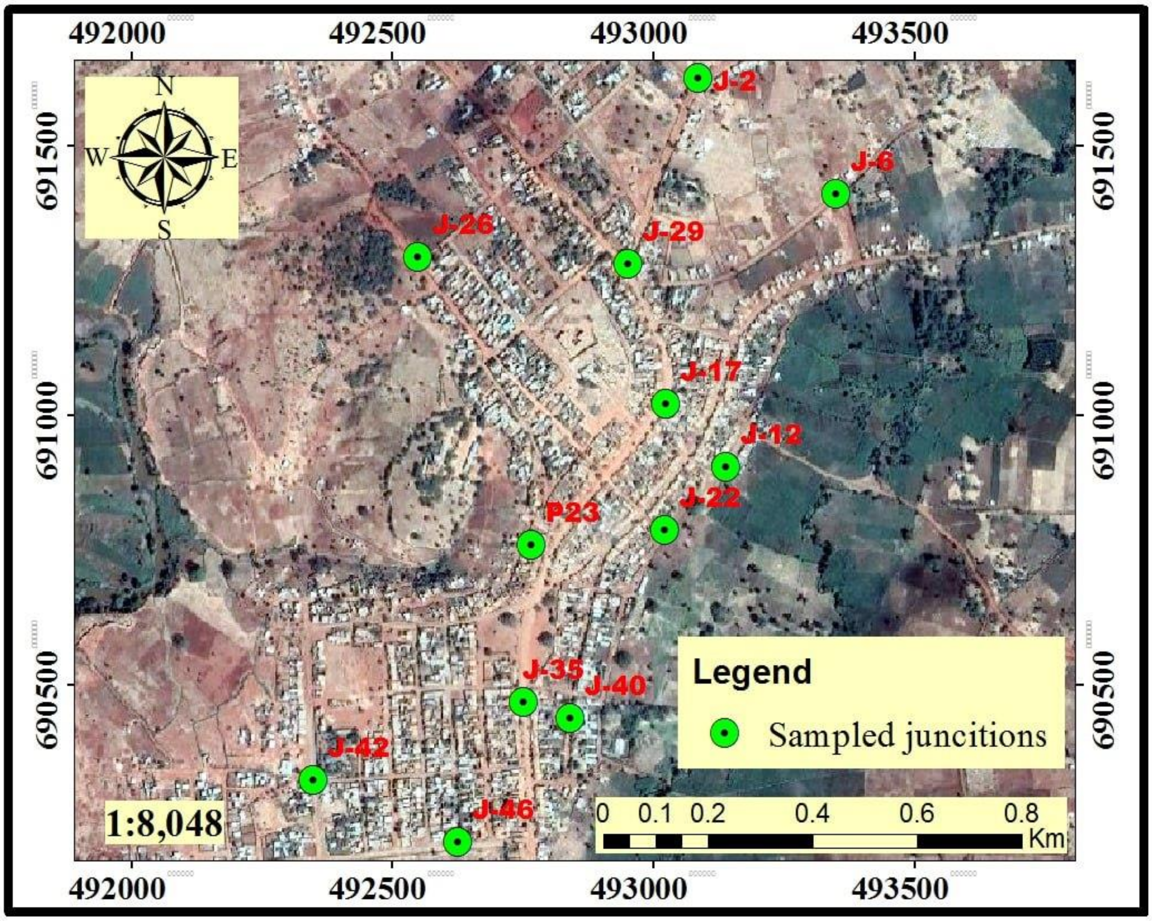
4.5. Model Calibration and Validation

The hydraulic model calibration was made by comparing simulated value with measured values in the field. The pressure was measured in the distribution networks using a portable pressure gauge at public fountain and different end users tap. The model performance measure such as the degree of accuracy (error of difference) and the coefficient of determination (R^2) are two techniques to be considered for the calibration of model check as mentioned below the results.

The observed and simulated pressure giving a correlation coefficient of determination which ranges between 0 and 1, describes the proportion of the variance in the measured data which is explained by the model with higher values indicating less error variance.

The diagonal line on the plot represents the line of perfect correlation as indicated in figure 8 generally, all the points should align themselves on this line, and all observed pressure should be equal to computed pressure giving a relationship coefficient of 1 that is the best correlation between observed and simulated (Tsegay, 2019) All observed pressures were equal to the simulated pressures, giving a link coefficient of one that is the best correlation between observed and simulated.

Sample Location	Observed pressure (m H2O)	Simulated pressure (m H2O)	Difference in pressure error	Measured time	X (m)	Y (m)	Elevation (m)
J-2	23.95	24.1	-0.15	7:30 AM	493085	691625	1513
J-29	35.6	33	2.6	8:15 AM	492951	691281	1484
J-17	33.58	32.19	1.39	9:00 AM	493023	691022	1492
J-6	34.39	35.63	-1.24	9:45 AM	493348	691411	1489
J-12	69.55	67.89	1.66	10:30 AM	493137	690904	1456
J-22	63.01	63.21	-0.2	11:15 PM	493020	690787	1460
J-26	74.9	66.37	8.53	12:00 PM	492549	691294	1458
P23	64.5	66.74	-2.24	12:45 PM	492766	690760	1456
J-35	61.5	58.39	3.11	1:30 PM	492750	690468	1464
J-42	79.2	77.99	1.21	2:15 PM	492349	690324	1444
J-40	66.24	64.46	1.78	2:45 PM	492839	690438	1458
J-46	74.88	71	3.88	3:30 PM	492624	690209	1451
		Average	**1.69**				



Source Own

Figure 4.7: Pressure observation sampling map

The coefficient of determination (R^2) value was 0.98, it indicates that observed and simulated relation is strong as values tend to one. The observed and simulated pressure relationship plot is shown in the figure below.

Table 4.23: Junction pressure calibration based on degree of accuracy criteria.

As shown in table above the computed pressure values within an average error of 1.69m pressure from simulated to observed values. Hence the model is acceptable calibrated which is satisfied the criteria that pressure calibration under average level (average ±1. 5m to maximum ±5m).

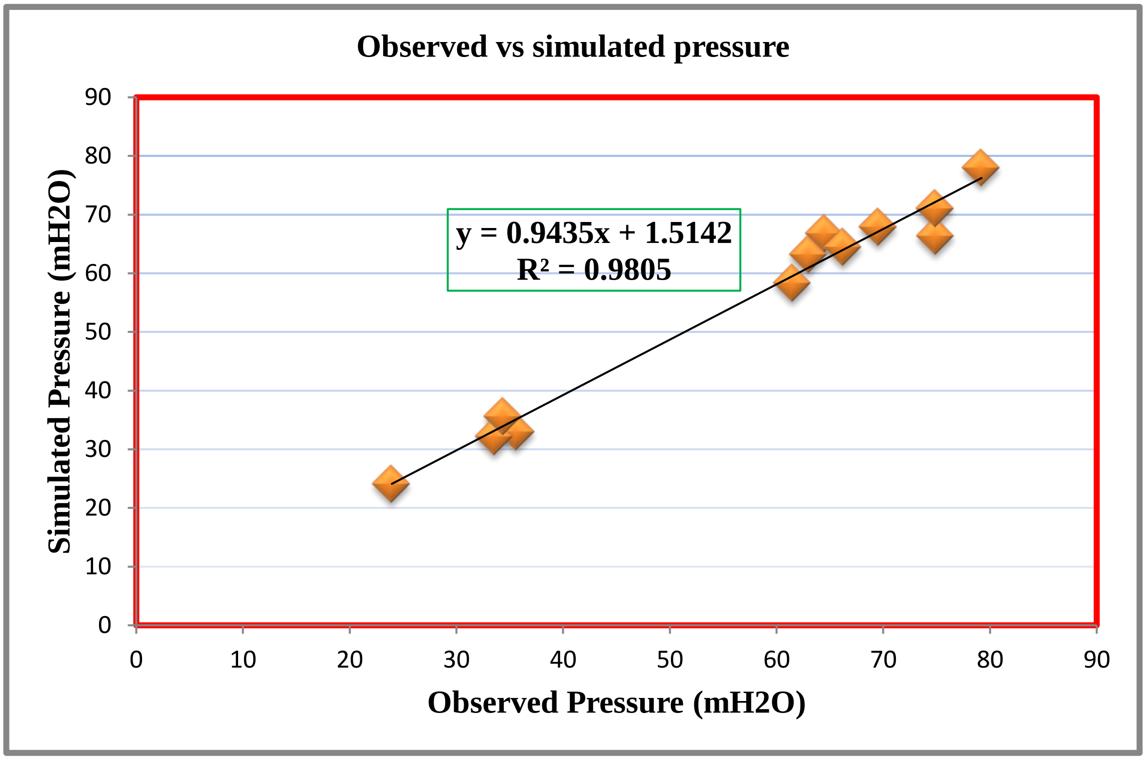


Figure 4.6: Correlation between observed and simulated pressure relationship plot.

4.6. Water Quality Analysis

Comparison of Water quality Parameters with standards

Water quality testing should be done to ensure that water meets relevant standards. For drinking water quality standardization many countries base their own standards based on the standard of world health organization (WHO) guidelines (WHO, 2004). The World Health Organization (WHO) drinking water quality guidelines provide international norms on water quality and human health be used as the basis for regulation and standard setting in developing and developed countries as worldwide. These guidelines adopted by many countries as national guidelines to follow. These countries including Ethiopia set drinking water quality guidelines based on the WHO guidelines but may modify the standard based on what is achievable in the country. The most common national requirements are suitability of water quality for drinking and domestic purpose. In this research the samples were taken from different sampling points such as from sources, reservoirs, water points and at household (point of use) and the quality of water was examined in Environmental Laboratory of

Hawassa University. Then, the results of each parameter were compared with the Ethiopia and WHO drinking water quality standards as indicated below. From table 4.24, it is concluded that almost all the parameters couldn't meet the standards.

Table 4.24: Physicochemical and biological parameters water quality result

Physicochemical Parameters	**Units**	**Samples from different sources**						**Standards**	
		Source		**Water containers in home before consumption**		**Point of use**		**Ethiopian Standard**	**WHO guideline**
		Mean	Std	Mean	Std	Mean	Std		
Temp.	°C	22.07	1.71	21.21	1.94	20.79	2.18		<15
EC	µs/cm	166.75	64.3	165.9	64.65	165.58	64.79	1500	1000
PH	-	6.89	0.69	6.76	0.64	6.74	0.63	6.5-8.5	6.5-8.5
Turbidity	NTU	5.96	4.99	5.48	4.83	4.74	4.66	7	5
TDS	mg/l	110.78	40.96	110.11	40.91	109.29	40.54	1000	1000
TH(CaCO3)	mg/l	76.72	11.59	76.30	11.60	76.01	11.59	300	300
Nitrate	mg/l	4.12	1.62	3.91	1.45	3.77	1.40	50	50
Chloride	mg/l	7.29	1.28	6.91	1.41	6.65	1.42	250	250
Fluoride	mg/l	0.51	0.21	0.48	0.19	0.47	0.19	3	1.5
Iron	mg/l	0.07	0.008	0.06	0.008	0.05	0.009	0.4	0.3
Magnesium	mg/l	33.72	18.22	33.38	18.28	33.23	18.13	50	50
Phosphate	mg/l	0.26	0.16	0.24	0.14	0.22	0.12	0.02	0.005

Total coliform	CFU/ 100ml	6.65	6.07	8.46	5.58	10.03	6.56	0	0

4.7. Major Problems Identified on Existing Water System of the Town

The following are the main problems of the water supply system as reported by the town's WSSE and field observations.

(a.) Technical capacity is constrained due to lack of equipment and tools, as there are few pipe cutters, pipe traders, and a welding machine. Leakage detection instrument, laboratory kits, water meter tests, digital multi meter, electrician hand tool sets, mechanics hand toolbox, and other required for technical supports are lacking.

(b.) Office automation such as computerized billing, local area networking, and installation of specialized software for financial and technical management are also lacking. The manuals and procedural guidelines such as administration, management, organizational, technical, financial etc. are either outdated or not available.

(c.) Too large diameter of pipes to transmit the required water flow, Frequent breakage of pipes and failure pressure reducing valves.

(d.) Lack of skill and equipment for periodic maintenance, Lack of appropriate office building, workshop, store,

(e.) Lack of awareness of record keeping Poor billing systems

In general, frequent interruptions due to breakdown of equipment, lack of spare parts, shortage of technicians, and inefficient operation and maintenance practices are the major constraints of town Water Supply system.

The following are the main problems of Existing Water Supply System of the Town based on the analysis results.

(a.) The Existing Water Supply System of the Town has been modeled with the help of WaterGEMS in which the result of the analysis showed that the overall technical performance of existing water distribution of the town was poor which is reflected by low water production rate, low water consumption, and high level of non-revenue water, low service coverage, not velocity and pressure in permissible range.

(b.) Hydraulic performance evaluation result indicated that acceptable minimum pressure value has not been met. During peak hour flow, parts of the distribution system receive water with low pressure and under some circumstances risk of obtaining no water because of the pressure in the distribution system is beyond permissible minimum requirements.

(c.) Most parts of the central network being suffered by lower flow velocities of less than 0.5m/s due to unnecessarily congestion of pipe network. This is to the extent of occurring zero (no) flow conditions in some of the pipes.

In general, the simulated hydraulic result indicated that the current hydraulic performance of town distribution system is not satisfactory. But it doesn't mean that the system is not functional. Rather the frequency of service interruption is relatively high. This interruption is partly contributing for the current water shortage in the town.

4.8. Measures taken to improve the existing water system of the Town.

Adding pressure reducing valve in the network

The best operational practice to optimize the operation of water distribution system was controlling the pressure in the network. This management of pressure has been reflected in the aspect of reducing excessive pressure by installing pressure reduced valve. By controlling the pressure, it is possible to reduce the amount of water loss from the system, the occurrence of internal damage and power consumption related to high pressure. At minimum hour demand pressure was high at lower elevation area. Installing pressure reduced valve at links which have maximum pressure was used to reducing excessive pressure to the desired allowable values.

Using higher PN class of pipe in the network

The excessive pressure in the system (pressure head greater than 70m) can be solved by two methods (1) to use pressure reducing valve or (2) use higher PN class of pipe which can resist the maximum pressure. Therefore, the best recommendable option is to use higher pipe class for those pipes where the pressure head greater than 80m water column in order to withstand the excessive pressure.

Improving pipe size

Increasing in the diameter of the pipe in water distribution model results in a corresponding decrease in velocity and increase in pressure. At peak hour consumption the velocities out of the design range are modified by resizing pipes diameter.

Improving water quality

The result of town's water supply system showed that water is not safe and there are E-coli/ faecal coliform and other parameters. These was happened because of high pressure there is many leakages, it has not well scheduled chlorination time and in the down part of town there is low velocity that makes stagnant water in the pipe system. To improve water quality:

- Timely follow up maintain and manage leakages.
- Reducing pipe size to increase water velocity in the pipe to make no stagnant water at the low velocity areas.
- Disinfecting by using chlorine within the regular time.
- Protecting 100m radius spring source environment to free from any contamination sources.
- Fencing all community water points.

5. CONCLUSION AND RECCOMENDATIONS

5.1. CONCLUSIONS

This study aimed to assess and update the local status regarding the coverage of the water supply and water loss in the water supply system. For the purpose of reducing and controlling non-revenue water, the study has also suggested suitable tactics and techniques. Multiple noteworthy findings came from this investigation. To provide us a better knowledge of the state of the water distribution network system at the moment, pressure, flow velocity, and nodal discharges were modeled. Following the discovery of ways to make the issue better, helpful recommendations were made. But it is advised that future works concentrate on the following for a more thorough and detailed understanding. Impacts of various development activities on performance of water distribution system. In this water supply system, inadequate operation of water distributing components, weak management system and absence of inspection largely contribute to inefficient hydraulic performance which as a result create poor level of service to the satisfaction of user community in this study. Some the fundamental performance challenges identified and taken as cases to be considered on the system are insufficient availability of water on some of water points, uneven distribution, evaluation indicated that acceptable minimum and maximum pressures have not been met. During the service hour of the system, parts of the distribution receive water with low pressure and under some circumstances on some of points water is not observed because of the pressure and velocity in the distribution system is contradicting to the permissible minimum requirement.

Despite the low water supply coverage, the total water loss in the focused area is up to 27.65% of the total system input volume. This is the main issue that Girja water supply system is presently struggling with because of this most of the customers are not satisfied in the level of service of the system. Malfunctioning of taps and valves, frequent disconnection of joint is observed. Poor workmanship and lack of supervision on the construction brought the pipe type and dimension installed different with recommended type and size on some portion of the system, poor management, absence of inspection and O&M. Therefore, about the satisfaction level of service, the system was observed in poor performance which deliver fluctuating amount of water to various demand categories within the user community.

5.2. RECOMMENDATIONS

Based on the findings, the researcher has made the following recommendations:

- The system must be maintained as a closed system, which means all taps and gate valves should be replaced. Conservation must be prioritized above all other uses of resources in order to ensure future consumption.
- In order to prevent pressure variations, pressure-sustaining valves or regulating valves must be put on the distribution system between two consecutive connections. These valves begin automatically closing and manually opening to maintain the minimum necessary pressure and prevent pressure fluctuations.
- In addition to the technical advice mentioned above, it is advisable to consider creating an asset management plan, especially to limit water loss.
- The system is not new and it serves 5 years, so depends on the service year other than the disconnection of joints and the breaking of valves and taps, the pipes have not deteriorated. Therefore, by increasing the reservoir's capacity, changing the pipe's diameter, using reservoir overflow water by connecting with providing additional storage of by maintaining old 1oom3 reservoir by maintain and installing pressure-reducing valves, the future demand can be met, and the design period could be increased to 25 years.
- It is necessary to create a utility or satellite water office in the heart of the user community because the system is large enough to be managed by water service.
- Having an as-built drawing of the layout will help the maintenance team be directed and will save time by preventing them from having to inspect the pipe size and placement in the field.
- As researcher data collecting time observed there is unprotected large yield onother spring source at nearby Buche spring source, so disconnecting Jangalo rural part supply and construct for rural community another source.
- In order to supply water for the reservoir like other water points, it must be looped back to the original pipe. These significantly alter the downstream water flow rate.
- If population increment become high, looking to propose Genale river as another source because it is at the near distance less than 5km far from the Girja town.

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APPENDIX

APPENDEX A: Hydraulic Modeling Analysis of Junctions flex table for distribution network

Label	**X (m)**	**Y (m)**	**Elevation (m)**	**Hydraulic Grade (m)**	**Pressure (m H2O)**
100m3 Reservoir-2 not functional	493315	691746	1541.82	1547.7	5.86
Girja p22	492992	691591	1498.17	1534.98	36.74
Girja wp1	493218	691694	1528.69	1541.86	13.14
Girja wp2	493006	691671	1502.82	1536.81	33.92
Household collection	492763	690899	1459.14	1523.23	63.96
J-2	493085	691625	1512.67	1536.82	24.1
J-3	493057	691575	1505.94	1534.99	28.99
J-4	493023	691471	1497.75	1531.72	33.9
J-5	493135	691264	1475	1525.17	50.07
J-6	493348	691411	1489	1524.71	35.63
J-7	493386	691316	1470	1524.56	54.45
J-8	493348	691262	1464	1524.47	60.35
J-9	493231	691221	1470	1524.39	54.28
J-10	493156	691142	1466	1524.42	58.3
J-11	493079	690923	1473	1523.99	50.88
J-12	493137	690904	1456	1524.03	67.89
J-13	493261	691170	1462	1524.31	62.18
J-14	493097	691166	1475	1524.67	49.57
J-15	493019	691176	1487	1525.02	37.95
J-16	492966	691246	1484	1525.55	41.46
J-17	493023	691022	1492	1524.26	32.19
J-18	492983	690986	1489	1524.03	34.96
J-19	492973	690954	1486	1523.9	37.83
J-20	492912	690891	1480	1523.63	43.54
J-21	492984	690814	1464	1523.45	59.33
J-22	493020	690787	1460	1523.34	63.21
J-23	492904	690472	1460	1522.66	62.53
J-24	492836	690490	1460	1522.64	62.52
J-25	492691	691126	1479	1524.13	45.04
J-26	492549	691294	1458	1524.5	66.37
J-27	492774	691471	1477	1525.12	48.02

J-28	492912	691320	1482	1525.65	43.57
J-29	492951	691281	1484	1525.94	41.86
J-30	492704	691406	1465	1524.92	59.79
J-31	492825	691241	1488	1524.92	36.85
J-32	492686	691108	1479	1524.05	44.96
J-33	492608	690492	1455	1522.51	67.37
J-35	492750	690468	1464	1522.51	58.39
J-36	492760	690349	1456	1522.34	66.2
J-37	492616	690340	1450	1522.26	72.11
J-38	492496	690486	1451	1522.15	71.01
J-39	492506	690333	1448	1522.16	74.01
J-40	492839	690438	1458	1522.59	64.46
J-41	492835	690330	1453	1522.51	69.37
J-42	492349	690324	1444	1522.14	77.99
J-43	492758	690321	1456	1522.33	66.2
J-44	492770	690216	1449	1522.05	72.9
J-45	492527	690199	1443	1522.15	78.99
J-46	492624	690209	1451	1522.15	71
J-47	492794	690021	1454	1521.13	66.99
J-48	492854	689496	1452	1520.15	68.02
J-49	492555	689990	1450	1520.36	70.22
J-50	492385	689985	1441	1520.25	79.09
J-51	492391	689784	1446	1520.19	74.04
J-52	492573	689797	1446	1520.26	74.11
J-53	492273	689770	1441	1520.16	79
J-54	492261	689485	1445	1520.15	74.99
J-55	492396	689451	1441	1520.15	78.99
J-56	492587	689483	1448	1520.16	72.01
P23	492766	690760	1456	1522.88	66.74
P24 Girja gudumale	492741	690511	1462	1522.59	60.47
Wp 5	492819	689419	1484	1520.14	36.07
Wp3	492969	691477	1492	1531.71	39.63
Wp4 not functional	492819	689820	1489	1520.41	31.35
Wp6	492690	689569	1486	1520.13	34.06
Wp7	492440	690563	1480	1522.5	42.41
Wp8	492629	690669	1464	1522.67	58.56
Wp9	492764	690793	1460	1522.94	62.82
Wp10	492757	690743	1460	1522.85	62.72

Wp11	492756	690847	1460	1523.07	62.95
Wp12	492266	690289	1479	1522.14	43.05
p21	493334	691802	1543	1548.84	5.83

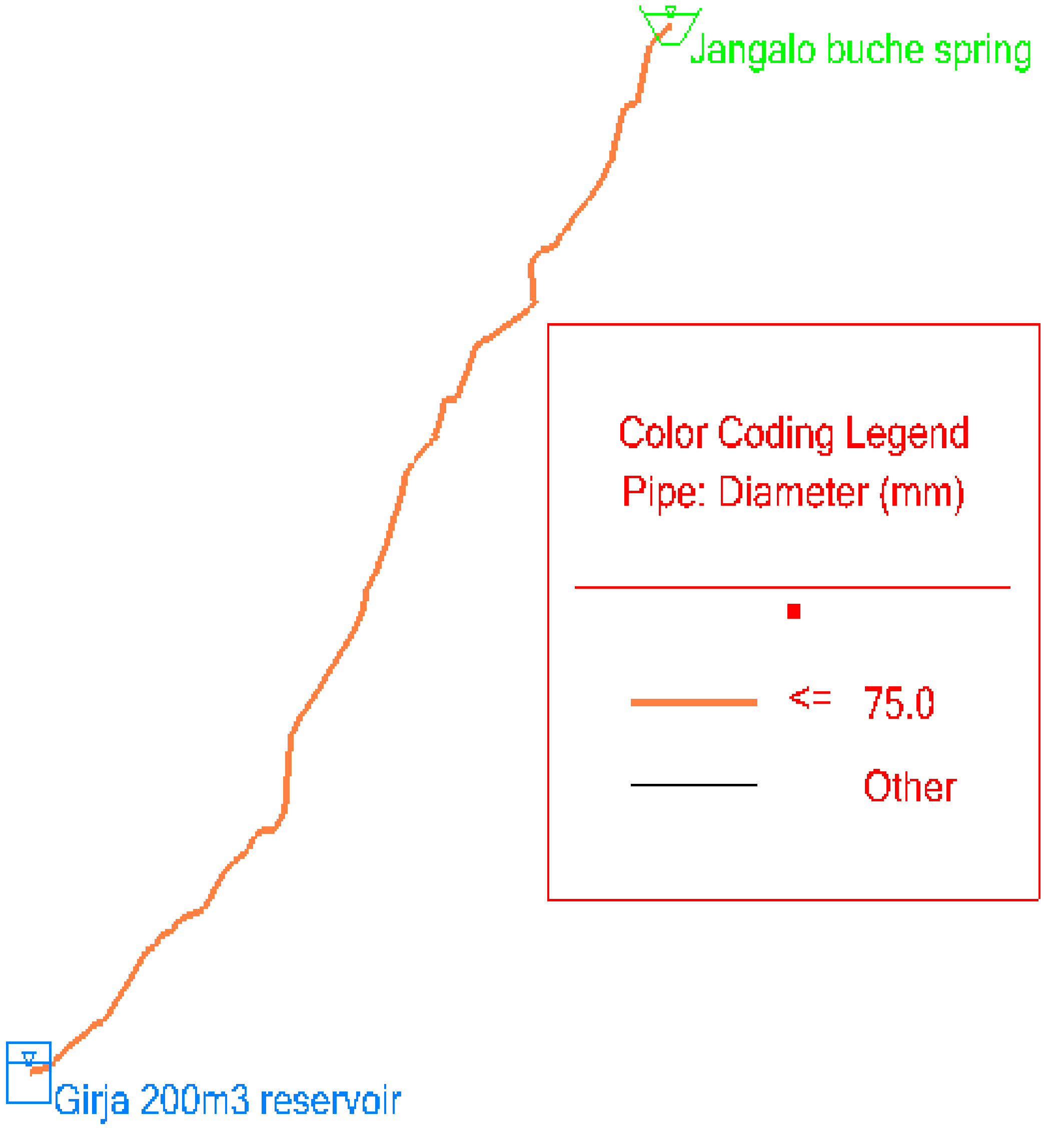
APPENDEX B: Hydraulic Modeling Analysis of Pipe flex table for Girja town distribution network

Label	**Length (Scaled) (m)**	**Diameter (mm)**	**Material**	**Hazen-Williams C**	**Flow (L/s)**	**Velocity (m/s)**	**Head loss Gradient (m/km)**
P-29	50	63	Galvanized iron	120	4.2	1.35	42.076
P-30	59	63	Galvanized iron	120	4.141	1.33	40.997
P-31	179	63	Galvanized iron	120	4.083	1.31	39.935
P-32(1)	150	63	Galvanized iron	120	4.025	1.29	38.885
P-33(1)	58	63	Galvanized iron	120	3.908	1.25	36.823
P-34(1)	109	63	Galvanized iron	120	3.791	1.22	34.814
P-35(1)(1)	204	63	Galvanized iron	120	3.675	1.18	32.856
P-35(1)(2)	38	63	Galvanized iron	120	2.147	0.69	12.146
P-48	154	50	Galvanized iron	120	0.782	0.4	5.773
P-98	197	50	Galvanized iron	120	0.758	0.39	5.447
P-67	178	50	Galvanized iron	120	0.739	0.38	5.188
P-49	54	50	Galvanized iron	120	0.724	0.37	5
P-69	18	50	Galvanized iron	120	0.703	0.36	4.738
P-50	34	50	Galvanized iron	120	0.666	0.34	4.28
P-115	237	50	Galvanized iron	120	0.645	0.33	4.039
P-51	88	50	Galvanized iron	120	0.607	0.31	3.613
P-70	53	50	Galvanized iron	120	0.587	0.3	3.388
P-90	106	50	Galvanized iron	120	0.558	0.28	3.084
P-54	45	50	Galvanized iron	120	0.538	0.27	2.89
P-71	54	50	Galvanized iron	120	0.528	0.27	2.791
P-88	77	50	Galvanized iron	120	0.511	0.26	2.625
P-35(2)	172	50	Galvanized iron	120	0.505	0.26	2.567
P-55	340	50	Galvanized iron	120	0.48	0.24	2.335
P-72	34	50	Galvanized iron	120	0.47	0.24	2.248
P-41	233	50	Galvanized iron	120	0.46	0.23	2.156
P-78	44	50	Galvanized iron	120	0.458	0.23	2.143

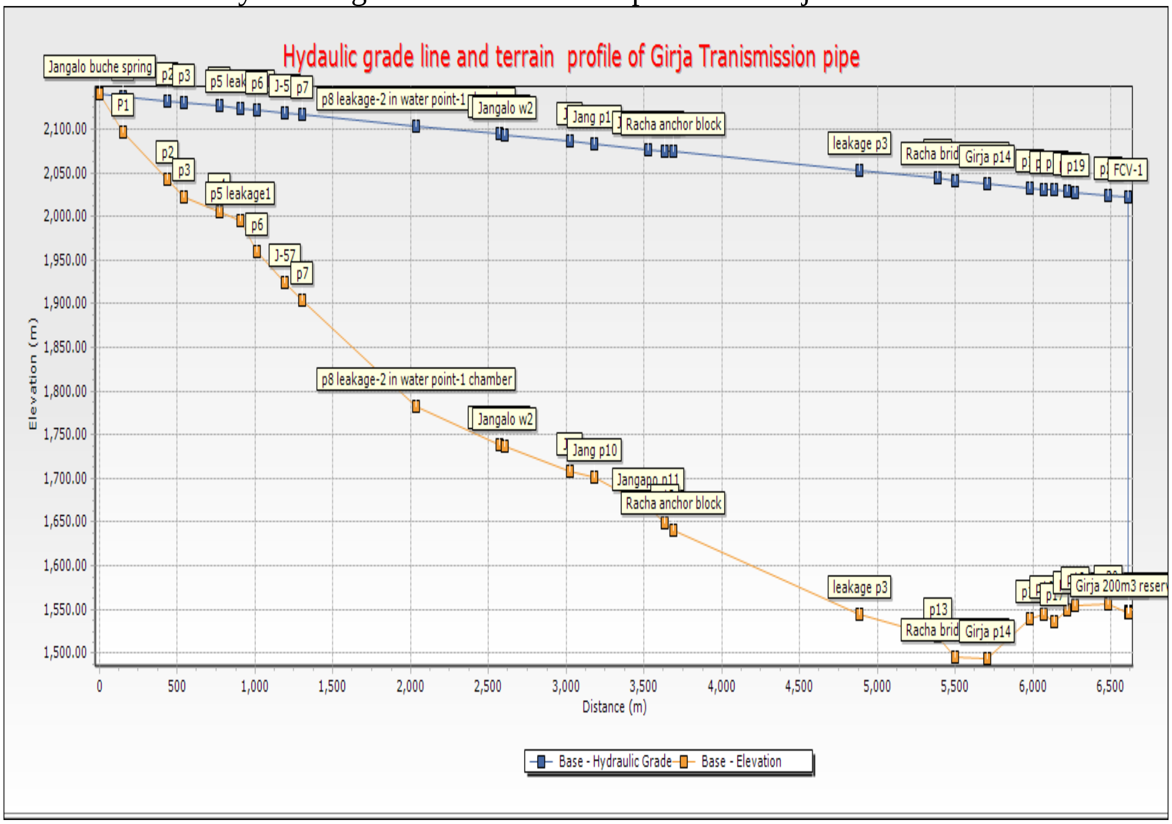
P-36	262	50	Galvanized iron	120	0.447	0.23	2.045
P-52	105	50	Galvanized iron	120	0.434	0.22	1.936
P-73	19	50	Galvanized iron	120	0.412	0.21	1.757
P-79	120	50	Galvanized iron	120	0.4	0.2	1.665
P-37	107	50	Galvanized iron	120	0.388	0.2	1.579
P-99	203	40	Galvanized iron	120	0.361	0.29	4.079
P-74	154	50	Galvanized iron	120	0.353	0.18	1.325
P-84	52	50	Galvanized iron	120	0.339	0.17	1.229
P-102	243	40	Galvanized iron	120	0.339	0.27	3.642
P-38	86	50	Galvanized iron	120	0.33	0.17	1.169
P-92	110	50	Galvanized iron	120	0.308	0.16	1.029
P-75	205	50	Galvanized iron	120	0.295	0.15	0.949
P-85	108	50	Galvanized iron	120	0.281	0.14	0.867
P-39	124	50	Galvanized iron	120	0.272	0.14	0.814
P-57	98	50	Galvanized iron	120	0.237	0.12	0.633
P-80	145	50	Galvanized iron	120	0.237	0.12	0.632
P-100	326	40	Galvanized iron	120	0.162	0.13	0.922
P-103	170	40	Galvanized iron	120	0.151	0.12	0.813
P-56	70	50	Galvanized iron	120	0.133	0.07	0.217
P-89	28	50	Galvanized iron	120	0.105	0.05	0.143
P-104	202	40	Galvanized iron	120	0.093	0.07	0.329
P-108	119	40	Galvanized iron	120	0.089	0.07	0.308
P-32(2)	93	40	Galvanized iron	120	0.058	0.05	0.14
P-33(2)	67	40	Galvanized iron	120	0.058	0.05	0.141
P-34(2)	54	40	Galvanized iron	120	0.058	0.05	0.14
P-82	250	50	Galvanized iron	120	0.058	0.03	0.047
P-94	96	50	Galvanized iron	120	0.058	0.03	0.046
P-101	122	40	Galvanized iron	120	0.058	0.05	0.14
P-119	180	40	Galvanized iron	120	0.058	0.05	0.14
P-109	290	40	Galvanized iron	120	0.031	0.02	0.043
P-96	97	50	Galvanized iron	120	0.017	0.01	0.005
P-112	270	40	Galvanized iron	120	0.013	0.01	0.009
P-95	298	50	Galvanized iron	120	-0.021	0.01	0.008
P-110	143	40	Galvanized iron	120	-0.027	0.02	0.034
P-111	198	40	Galvanized iron	120	-0.029	0.02	0.038
P-113	335	40	Galvanized iron	120	-0.057	0.05	0.132
P-83	153	50	Galvanized iron	120	-0.058	0.03	0.047
P-65	205	50	Galvanized iron	120	-0.06	0.03	0.05

P-87	157	50	Galvanized iron	120	-0.095	0.05	0.117
P-97	137	50	Galvanized iron	120	-0.096	0.05	0.118
P-114	314	40	Galvanized iron	120	-0.101	0.08	0.385
P-105	182	40	Galvanized iron	120	-0.112	0.09	0.464
P-107	194	40	Galvanized iron	120	-0.13	0.1	0.616
P-106	247	40	Galvanized iron	120	-0.141	0.11	0.714
P-40	109	50	Galvanized iron	120	-0.167	0.08	0.33
P-76	136	50	Galvanized iron	120	-0.252	0.13	0.707
P-91(1)	147	50	Galvanized iron	120	-0.259	0.13	0.745
P-42	65	50	Galvanized iron	120	-0.264	0.13	0.768
P-86	190	50	Galvanized iron	120	-0.289	0.15	0.911
P-91(2)	132	50	Galvanized iron	120	-0.301	0.15	0.982
P-43	293	50	Galvanized iron	120	-0.322	0.16	1.114
P-44	59	50	Galvanized iron	120	-0.38	0.19	1.517
P-60	323	50	Galvanized iron	120	-0.416	0.21	1.79
P-81	152	50	Galvanized iron	120	-0.43	0.22	1.908
P-61	221	50	Galvanized iron	120	-0.439	0.22	1.979
P-62(2)	95	50	Galvanized iron	120	-0.495	0.25	2.477
P-62(1)	192	50	Galvanized iron	120	-0.497	0.25	2.493
P-58	370	50	Galvanized iron	120	-0.502	0.26	2.538
P-59	428	50	Galvanized iron	120	-0.531	0.27	2.817
P-63	204	50	Galvanized iron	120	-0.554	0.28	3.043
P-53	145	50	Galvanized iron	120	-0.665	0.34	4.27
P-45	64	50	Galvanized iron	120	-0.685	0.35	4.507
P-46	78	50	Galvanized iron	120	-0.743	0.38	5.246
P-66	124	50	Galvanized iron	120	-0.857	0.44	6.835
P-64	55	63	Galvanized iron	120	-1.469	0.47	6.015
P-47	88	63	Galvanized iron	120	-1.584	0.51	6.914

APPENDEX C: Girja Town Existing Water Supply Transmission Line



APPENDEX D: Hydraulic grade line and terrain profile of Girja town Transmissions line



APPENDEX E: Junctions table of Transmissions line of Girja town

Label	X (m)	Y (m)	Elevation (m)	Hydraulic Grade (m)	Pressure (m H2O)
Girja p14	493996	692429	1493.44	1843.71	349.566
J-1	495396	694536	1707.58	1892.04	184.091
Jang p10	495346	694388	1701.12	1889.23	187.731
Jangalo p9	495623	694907	1738.33	1900.15	161.491
Jangalo w2	495609	694879	1737	1899.58	162.256
Jangapo p11	495216	694069	1667.34	1882.95	215.174
P1	496818	696778	2097	2139.77	42.688
Racha anchor block	495136	693932	1640.73	1880.09	238.879
Racha bridge acho 2	494156	692546	1495.86	1847.43	350.864
leakage p3	494588	692953	1543.96	1858.55	313.956
p2	496747	696504	2043.56	2137.94	94.194

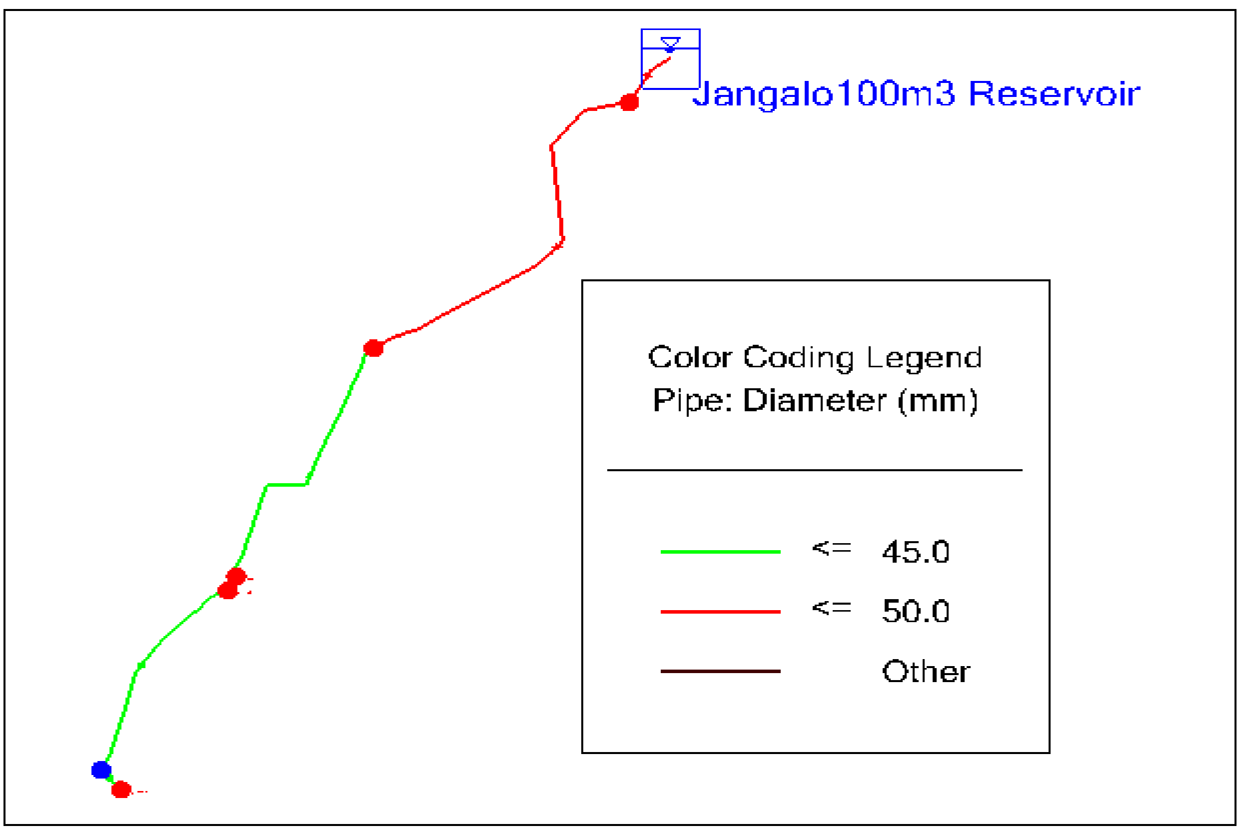
p3	496664	696449	2023.26	2137.24	113.755
p4	496604	696231	2005.83	2135.78	129.69
p5 leakage1	496537	696115	1995.17	2134.92	139.465
p6	496468	696029	1960.6	2134.2	173.255
p7	496284	695811	1904.04	1922.99	18.914
p8 leakage-2 in water point-1 chamber	495854	695342	1782.1	1909.87	127.512
p12	495169	693977	1649.36	1881.09	231.266
p13	494247	692607	1519.33	1849.49	329.495
p15	493844	692207	1538.39	1838.87	299.87
p16	493792	692130	1544.08	1837.19	292.523
p17	493738	692090	1536.28	1835.96	299.081
p18	493673	692045	1548.38	1834.47	285.509
p19	493631	692017	1554.16	1833.55	278.825
p20	493473	691882	1556.62	1829.73	272.562

APPENDEX F: Hydraulic Analysis of Girja town Transmissions pipe table

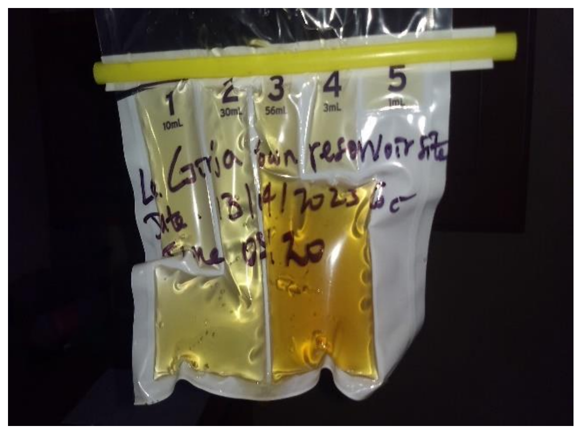
Label	**Length (Scaled) (m)**	**Diameter (mm)**	**Material**	**Hazen-Williams C**	**Flow (L/s)**	**Velocity (m/s)**	**Head loss Gradient (m/km)**
P-1	152	75	Galvanized iron	120	4.5	0.63	6.466
P-2	283	75	Galvanized iron	120	4.5	0.63	6.467
P-3	108	75	Galvanized iron	120	4.5	0.63	6.467
P-4	226	75	Galvanized iron	120	4.5	0.63	6.466
P-5	134	75	Galvanized iron	120	4.5	0.63	6.467
P-6	110	75	Galvanized iron	120	4.5	0.63	6.466
P-7(1)(1)	169	75	Galvanized iron	120	4.5	0.63	6.467
P-7(1)(2)	8	75	Galvanized iron	120	4.5	0.63	6.464
P-8	112	75	Galvanized iron	120	4.2	0.95	18.001
P-9	729	75	Galvanized iron	120	4.2	0.95	18
P-10	540	75	Galvanized iron	120	4.2	0.95	18
P-11	31	75	Galvanized iron	120	4.2	0.95	18.001
P-12(1)	419	75	Galvanized iron	120	4.2	0.95	18
P-15	156	75	Galvanized iron	120	4.2	0.95	18.001
P-16	349	75	Galvanized iron	120	4.2	0.95	18
P-17	103	75	Galvanized iron	120	4.2	0.95	18

P-18	56	75	Galvanized iron	120	4.2	0.95	18
P-19	1197	75	Galvanized iron	120	4.2	0.95	18
P-21	207	75	Galvanized iron	120	4.2	0.95	18.001
P-22	269	75	Galvanized iron	120	4.2	0.95	18
P-23	93	75	Galvanized iron	120	4.2	0.95	17.999
P-24	68	75	Galvanized iron	120	4.2	0.95	18.001
P-25	83	75	Galvanized iron	120	4.2	0.95	18.001
P-26	51	75	Galvanized iron	120	4.2	0.95	18.001
P-27	212	75	Galvanized iron	120	4.2	0.95	18
P-117	503	75	Galvanized iron	120	4.2	0.95	18
P-20	114	75	Galvanized iron	120	4.2	0.95	18
P-28(1)(1)	126	75	Galvanized iron	120	4.2	0.95	18.001
P-28(1)(2)	6	75	Galvanized iron	120	4.2	0.95	18

APPENDEX G: Jangalo rural Existing Water Supply Transmission and distribution Line



APPENDICES H: Water quality sampling, packing, transporting, quality perfomed procedures and result photos

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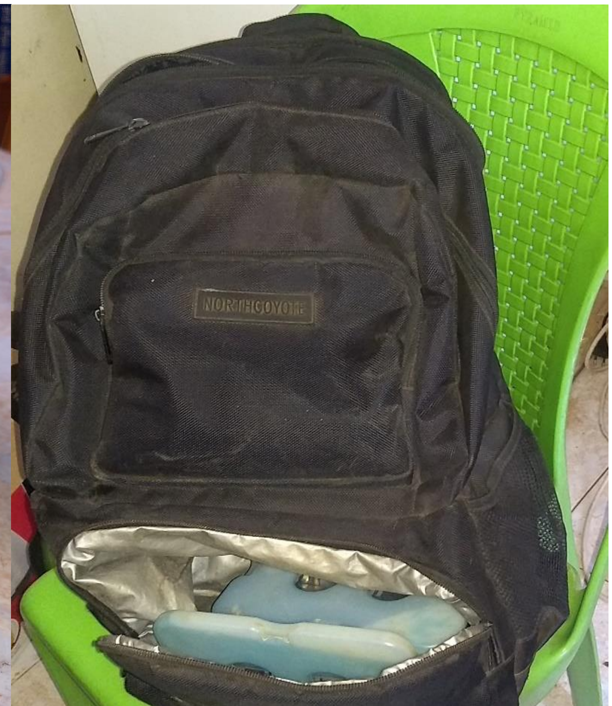


Jangalo NS