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INVESTIGATION OF WATER SUPPLY COVERAGE AND WATER LOSSES IN DISTRIBUTION SYSTEM (A CASE STUDY OF WOLKITE TOWN)

MSc IN WATER RESOURCE ENGINEERING AND MANAGEMENT THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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INVESTIGATION OF WATER SUPPLY COVERAGE AND WATER LOSSES IN DISTRIBUTION SYSTEM (A CASE STUDY OF WOLKITE TOWN)

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A THESIS SUBMITTED TO HAWASSA UNIVERSITY DEPARTMENT OF WATER RESOURCE AND IRRIGATION ENGINEERING, INSTITUTE OF TECHNOLOGY, SCHOOL OF GRADUATE STUDIES, HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE PROGRAM OF MASTER OF SCIENCE
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APPROVAL SHEET

Hawassa University Institute of Technology School of Bio system and Environmental Engineering, The Research Entitled "Investigation of Water Supply Coverage and Water Losses in Distribution System (A Case Study of Wolkite Town)" has been approved by the school of Bio system and Environmental Engineering for partial fulfillment of the requirements for the degree of Master's with specialization in Water Resource Engineering and Management.

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We the undersigned members of the Board of Examiners the thesis open defense by Abdrezak Kedir Ahmed Have read and evaluated his/her Thesis “Investigation of Water supply Coverage and Water Losses in Distribution System (A case study of Wolkite Town)" and examined the candidate. This is, therefore to certify that the thesis/dissertation has been accepted in partial fulfillment of the requirements for the MSC.

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Approval and acceptance of the thesis is contingent upon the submission of the copy of the dissertation to the school of Graduate Studies through the Department/School Graduate Committee of the candidate's department.

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DEDICATION AND STATEMENT OF OUTHOR

I hereby declare that this MSc thesis is my original work and 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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LIST OF ABBREVATION

ADD	Average Day Demand
AWWA	American Water Work Association
BMJ	British Medical Journal
CSA	Central Statistical Agency
DWD	Domestic Water Demand
GTP	Growth Transformation Plan
ILI	Infrastructure Leakage Index
IWA	International Water Association
KM	Kilo Meter
MDG	Millennium Development Goal
MDD	Maximum Day Demand
MHD	Maximum Hourly Demand
MERV	Main Ethiopia Rift valley
MOWR	Ministry of Water Resource
MoWIE	Ministry of Water Irrigation and Electricity
MDGS	Millennium Development Goals
NMA	National Metrological Agency
NGO	Non-Governmental Organization
NRW	Non-Revenue Water
PHD	Pak Hourly Demand
UNDP	United Nation Development Program
UNICEF	United Nations Children's Emergency Fund
UFW	Unaccounted For Water
WDM	Water Demand Management
WHO	World Health Organization
WDS	Water Distribution System
WTAEO	Wolkite Town Administration Education office
WTAHO	Wolkite Town Administration Health office
WTWSSE	Wolkite Town Water Supply and Sewerage Enterprise
YCS	Yard Connection Shared

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ABSTRACTS

Water consumption has been increasing significantly in most town due to increasing number of population economic development and expansion of towns. This study evaluate the wolkite town water supply system based on the methods used to study was by main performance indicators;- namely demand and supply, water coverage, water production, water consumption, distribution system ,water loss, customers satisfaction and operation and maintenance. To conduct this research, data was collected from primary and secondary source. Data of water production and consumption, some water supply system data were obtained from the water utility records, other data not found in the water utility records is collected using instruments (pressure, coordination .elevation and interviews) others from governmental organization. The Data was analyzed in different methods. The result shows that the annual total was 349,625m^3 which accounts of 33% the total water production and higher than the generally accepted value of 25%, the average domestic water production of the town is found to be 26.3 l/per/day, average daily per capita water consumption of the town is 18.61L/person/day, the average connection per family for the entire town is found to be 0.61. This implies that at average two families and or eleven persons are sharing one connection or water tap. From 2019- 2021 the average water demand for town was calculated to be 3,418.3 m^3/d and the total demands are 6,596.6 m^3/day. Coverage based on demand in 2021 is 44%. The maximum day demand of the town is 7915.92 m^3/day (91.6 L/s), Peak Hour Demand is 11873.8 m^3/day (137.4L/S). The main distribution line water does not reach to the town service reservoir because between balancing reservoir and town service reservoir 30 km length away from the town, in this area there is high loss, leakages. Due to this reason shortage of water in the town is series problems. In conclusion, the town's water supply system is poor in managing water loss, water access, operation and maintenance with the continuous generation of water from sources continuously in to balancing reservoir. It is recommended that the water utility develop a strategy and work hard on the indicate system deficiencies especially on operation and maintenance to improve the water supply system performance and provide customers with good quality service.

KEY WORD*: water loss, water coverage, operation and maintenance, hydraulic WATER CAD, Wolkite town Ethiopia.*

CHAPTER 1. INTRODUCTION

1.1. Background of the Study

Access to safe water is one of the fundamental human rights, and an essential step towards improving living standards to maintain and improve health, human growth and development. Unimproved sources of drinking water and sanitation facilities are responsible for increased risks of various infectious diseases such as; cholera, typhoid, infections of the respiratory systems, skin and eye. The currently available evidences also indicate that to prevent the novel coronavirus disease outbreak, the provision of safe water, sanitation and hygienic conditions is crucial (BMJ Open, 2021).However, between 2000 and 2020, the global population increased from 6.1 billion to 7.8 billion people. During this period, 2 billion people gained access to safely managed drinking water services, and the number of people lacking safely managed services decreased by 342 million. The 2 billion people who still lacked safely managed drinking water in 2020 included 1.2 billion people using basic services, 282 million using limited services, 367 million using unimproved sources, and 122 million drinking surface water. Half of the 771 million people still lacking even a basic drinking water service in 2020 lived in sub-Saharan Africa (UNICEF, 2021). In the world unsafe water is responsible for 1.2 million death each year (Ritche Hannah and Max Roser, 2021).Today 6% world does not have access to an improved water source, One-in four people don't have access to safe drinking water (Ritche Hannah and Max Roser, 2021).

Worldwide and in Ethiopia significant number of children are dying each day because of lack of safe drinking water (MoWIE, GTP-II, 2017 Report). In the world fresh water that has been used for household purpose is not more than 3% of the natural available. Ethiopia has an estimated 2.6 - 6.5 billion m^3 of ground water potential, with 12 river basins that generate an annual runoff volume of 122 billion m^3 of water and makes an average of 1575 m^3 of physically available water per person per year, a relatively large volume. However, due to lack of water storage infrastructure and large spatial and temporal Variations in rainfall, there is not enough water for utilization. Though the country possesses a substantial amount of water resources little has been developed for drinking water supply, hydropower, agriculture and other purposes (MoWR, 2012).

To improve this situation, and the international community adopted the Millennium Development Goal (MDG) and committed to reduce by half the proportion of people without sustainable access to safe water and basic sanitation. (MoWIE, GTP-II, 2017 Report).In the (GTP-II) plan that has an objective to provide 25 l/c/day within a distance of 1 km from the water delivery point for 85% of the rural population of which 20% are provided with RPS. Provide urban water supply access minimum service level of 100 l/c/day for category-1 towns/cities, 80 l/c/day for category-2 towns/cities, 60 l/c/day for category-3 towns/cities, 50 l/c/day for category-4 towns/cities, up to the premises and 40 l/c/day for category-5 towns/cities within a distance of 250m with piped system for 75% of the urban population. The National water supply coverage (middle of GTP-II) 54.7%, 68.5%, and 65.7% urban, rural and national respectively (MoWIE, GTP-II, 2017 Report).

Due to its unreliability and non-sustainable nature, the existing service level in different parts of Ethiopia is lesser than the required levels. The poor water supply and sanitation facilities along with other infrastructure services, bear a high level of impact on national and regional development, inclusive of both urban and rural communities. In developing countries worldwide face significant challenges in managing increasing demand for urban water because of industrialization, urbanization and the potential impacts of global warming on fresh water supply (Araral & Wang, 2013). Moreover, not all water produced reaches the customers to generate revenue for water companies. Instead, a significant portion of it is lost, due to leakage from water mains and unauthorized water use (Wu et al., 2010).

The loss of treated water occurs by leakages and overflows from the pressurized pipes and fittings in water undertaker distribution systems and customers 'private supply pipes (Lambert, 2003). Increasingly, water loss via leakage is acknowledged as one of the primary challenges facing water distribution system operations. The consideration of water loss over time as systems age, physical networks grow, and consumption patterns mature should be an integral part of effective asset management (Giustolisi et al., 2008) Drinking water supply arrangements in urban areas are typically complex. There was often a large piped supply with household and public connections and a range of alternative drinking water supplies, including point sources and vended water (UNICEF/WHO, 2012).

Urban population numbers and water use patterns mainly determine the management of water supply system. Water supply systems in urban areas 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. Even though distributing the available water and water loss from a utility's distribution system is a growing management problem in Ethiopia, there are few studies conducted on the existing water utilities in the country related to water loss and coverage. (Asmelash, 2011).

Wolkite is the capital town of Gurage zone of Southern Nation Nationality people regional state. The water supply system of the town first established in 1989 when a borehole was drilled in the town and connected to a 30 m^3 elevated steel tank. Almost over nine boreholes have been drilled since the first one and most of them were abandoned due to decrease in discharge. To solve the problem of the town water supply system, the Federal Government at the year 2007 implemented a project by developing "Bojebar" large spring which is located at 30 km away from the town. These project aims to supply water for Wolkite town and that would satisfy the demand of the targeted beneficiaries and raise the water supply service level until the end of design period. Even if the project planned to solve the problem definitely and permanently, after implementation, technical and management problems came out. For example, bursting of main pipe line, leakage along the old distribution pipe system and poor operation and maintenance are some of the problems of the town water supply system.(source Wolkite Town Water Supply and Sewerage Enterprise and related document). The town is dominantly known by high population growth and urbanization developments. Currently wolkite town has faced water shortage due to the shortfall supply, increasing water demand and large expansion of urbanization. This studies mainly focus on the status of water supply coverage, losses and distribution systems in the town.

1.2. Statement of the Problem

Access to safe drinking water is a global concern, at present sub-Saharan countries and in general Ethiopia has low water supply coverage, at most its rural area has shortage of potable water coverage (MoWR, 2011).The scarcity and low coverage of water in urban area is the major problem in many developing countries. Due to increasing Urbanization, Population growth, aging infrastructure, and coupled with unsustainable conventional water management, water loss ware facing huge challenge now a day. Leakage is often a large source of unaccounted for water and is a result of either lack of maintenance or failure to renew ageing systems and also poor management of pressure zones, which result in pipe joint failure. Water shortage and frequent service interruption is not only as a consequence of the shortfall between demand and supply but also as result of unidentified leakage and complicated network systems (Farley., 2010).

The existing source of the wolkite town water from “Bojebar” large spring which is located at 30 km away from the town. The water supply implemented to give service for the people of the town. However, throughout time, the town water supply system encountered major problems. Hence, the water supply system doesn’t provide the intended service effectively. The rapid spatial extension of the town has not been fully supported by infrastructural developments. While the town grew spatially, expansion of water supply service didn’t. Moreover, during implementation of the town water supply system from “Bojebar” large spring the distribution pipe system of town’s not improved. Hence, water service has been giving by using the old (20-30) year small size distribution pipe network. Thus design and implementation of water supply projects have been unsuccessful and inefficient as well as the old distribution system have bursting and leakage problem. Moreover, as the entire town water network system are interconnected to each other without separating which system is serving which area and how much water is distributed to which area, this makes difficult the identification and the distribution of water losses at different spatial location. The problem of water supply in the town is not only the problem of distribution and reliability but also it has the problem of water production. The level of water production with the existing power system is not proportional with the town demand. This along the 30 km gravity main pipe line a lot of unplanned connections are made directly from the line without separate storage due to new settlement and construction of different institutions and companies. Therefore, during the time of low production and peak water consumption ,much of the produced water consumed on gravity main pipe line before reaching to Wolkite town service reservoir. As a consequence, the towns‟ people suffer due to shortage of potable water. Source WWSSE & (Metaferia C. , (2007).In addition, Wolkite town water supply and sewerage enterprise, the legitimate body to supply water for the town, had many problems as an institution to ensure a sustainable water supply. Some of them are, have no well-equipped technically qualified technicians, has poor administration of the water supply system, Moreover, the involvement of the main causes for the loss of water, this research focus and measures should be taken, As the entire town water supply network systems are interconnected to each other without separating which system or which area is serving and how much water is distributed to which area, this makes the identification and distribution of the water losses at different spatial locations. As a cause of limited resources that the town water service has great difficulty to identify where and how much water is lost and what are the problems.

1.3. Objective

1.3.1. General Objective

The main objective of the research is to evaluate the domestic water supply demand, coverage and water loss in in the town distributions system and suggest a method to better identify and reduce the loss.

Based on the main objective as mentioned above, the following specific objectives are expected to be achieved:

1.3.2. Specific Objective

- To evaluate the domestic water supply demand coverage and estimate demand project it for the next 20 years.
- To evaluate the total loss of water at town level.
- To investigate the causes of water losses and possible solutions.
- To know the level of customers satisfaction towards the existing water supply service.

1.4. Research Question

The general and specific objectives of the study would be achieved by way of seeking answers to the following questions:-

1. How much water is consumed by domestic consumers?
   - What is the level of water connection and Per capita demand of the town?
2. How much water is produced and distributed to the network system?
   - How much water is lost comparing with the water produced?
3. What are the possible causes of water losses in wolkite town water distribution system?
   - What are the possible solutions to reduce the loss?
4. Are customers satisfied with the service?

1.5. Significance of the Study

Water is one of vital things to our life. And studying on water supply is very important for providing clean and safe water for the community that helps to achieve sustainable development in every circumstance. Therefore, from this research the wolkite town was benefitted through:-

- Modern management system that can improve the water supply distribution system by revising operational system.
- Upgrading the existing water supplies system evenly for those low water coverage areas.
- Initiate to plan future water demand & loss control that can alert concerned governmental office.
- The paper is important for Wolkite town water supply and sewerage enterprise (WTWSSE) as well as Non-governmental organizations (NGOs) which have interest with financial and technical support in the area can use the research outcomes as reference for their objective.

1.6. Scope of the Study

The scope of study was to evaluate the current status of the existing drinking water distribution system of Wolkite Town and recommend changes if any in the existing system. This study is limited to existing water supply system and do not include the sanitation part and rural kebele water connection. Besides targeted to the assessment of the water supply system and conducted the evaluation of the existing distribution system of Town.

1.7. The Thesis Content

This thesis comprises five chapters, which are organized as follows.

- Chapter one: Contains general background, the problem statement, the research objective, research question, significance of the research.
- Chapter two: Review of other related Work.
- Chapter three: Discussion about the methodology the data collection and preparation
- Chapter four: Results and discussion
- Chapter five: Conclusion and recommendation.

CHAPTER. 2. REVIEW OF LITERATURE

Water is an invaluable source not only for human life but also for all the living forms in this universe. The water supply utilities should fulfill the water condition quantitatively and qualitatively. One of the main problems affecting water supply systems in developing countries is the problem of water losses, which includes apparent water losses and real water losses (M.E.Fontana, 2016). Leakage can be defined as unintentional or accidental loss of water from the pipe distribution network. Leaking pipes are a major concern for water utilities around the globe as they constitute a major portion of water losses. One of the primary reasons for leakage in pipes is aged and deteriorated networks. Leakage rates are also related to length of pipes and number of connections (Melaku, 2015).

A water distribution system consists of a complex combination of components, including pipes, fittings, pumps, reservoirs, valves, hydrants, meters and backflow preventers that are all critical in maintaining physical integrity. At the same time, the distribution system is constantly changing through aging, replacement of components and the addition of new extensions (Krynauw, 2014). Improper connections can sometimes result in continuous escape of water from the distribution pipes. 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. The developing cities have great difficulty both financial and technical to develop and expand water supply projects and one of the difficulties among the others is managing and reducing losses of water at all levels of a distribution system. As a result of the overall shortage of water many cities are faced a problem in distributing the available water impartially among the residents. Beside to this poor management of the existing infrastructural asset increases the level of water losses in water supply system (Mebet, 2007). As this research deals with over all coverage of water supply and water losses and distribution systems, issues related to water loss and leakage like identifying and reducing was reviewed in this chapter.

2.1. Project History of Wolkite Water Supply Network

The water supply system of Wolkite town was established in 1989 when a borehole was drilled in the town and connected to a 30 m^3 elevated steel tanks. However, the present daily water yield of Wolkite town from the spring source (Bojebar) is estimated to be 150 L/s in dry season and it reaches 200 L/s in wet season. The Wolkite water supply, which is the major tap water Supplier in Wolkite town and the neighboring Woreda, provides the current production 3801.6 m^3/day in 18 h pumping. The drinking water supply system serves about 54,946 for Wolkite town and the rural areas. The current water supply system in Wolkite town comprises the following major components: Bojebar spring source, rising and gravity mains, pumps and electro-mechanical equipment, treatment facilities, service reservoirs, distribution network to newly developed and future expansion areas, operation buildings at intake, pump station, guard house and fences (Solomon, 2011).

2.2. Urban Water Supply Demand and Coverage

2.2.1. Urban Water Demand

Water demand is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water consumption, although conceptually the two term do not have the same meaning (Wallingford, 2007).In most developing countries, that theoretical water demand considerably exceeds the actual consumptive water use. Urban water demand is classified in to different category that domestic water demands that included in-house-use and out-of -house-use is among the others. In-house-use includes demands for cooking sanitation, house cleaning, laundry and car washing while out-of-house-use includes like garden watering, swimming pools, public stand pipes for public uses and fountains etc.

Urbanwater demand is usually quoted in terms of liter per capita per day(l/capita/day).Despite the variation in residential indoor water use from household to household, a typical pattern (referred to as the water use profile) can be developed to provide a reasonable representation of indoor water use, based on the different indoor water use components (kitchen, bathroom, laundry, and toilet) and household occupancy (Kanakoudis, 2011).

2.2.2. Urban Water Coverage

Water supply coverage provides a picture of the water supply situation of one specific country or city and helps to compare one country with others and the inter and intra city distribution with in specific country. The percentages of population with or without piped water connection are a relevant indictor to compare the coverage of water supply in urban areas. Although the water supply coverage is better in urban areas while compared with the rural, the actual water supply coverage in cities of developing countries in general and African cities in particular is very low while compared to the demand. According to the Global Water Supply and Sanitation assessment 2000 Report, the African capital cities are having 43% house connection or yard tap,21% served by public tap while 31% of the populations are un-served (WHO, 2011). A household is considered to have access to improved drinking water if it has sufficient amount of water (20 liters/person/day) for family use, at an affordable price (less than 10% of the total household income), available to household members without being subject to extreme effort (less than one hour) a day for the minimum sufficient quantity, especially to women and children (Habital, 2003). During 2019/20, the proportion of people having access to potable water supply improved to 79.3 percent (82.7 percent rural and 66.5 percent urban population); relative to 75.9 percent (78.7 percent rural and 65.5 percent urban people) a year earlier (Table 2.1).In the other words, rural areas had relatively better access to water than urban areas.

Table.2.1. National water supply coverage

Regions	2018/19			2019/20		
	Rural	Urban	Total	Rural	Urban	Total
Tigray	60.5	60.0	60.4	60.2	69.7	62.9
Afar	62.9	51.1	60.6	70.1	57.2	67.5
Amhara	90.1	71.1	86.7	94.8	70.8	90.3
Oromia	66.5	64.6	66.2	72.6	63.8	71.2
SNNPR	58.4	81.0	62.3	59.8	81.5	63.6
Somali	80.1	81.5	80.3	83.1	84.4	83.3
B.Gumuz	67.1	48.7	63.0	68.1	50.2	64.0
Gambella	75.6	61.2	70.6	76.7	68.4	73.7
Harar	85.2	64.1	73.4	87.2	63.5	73.9

D. Dawa	82.7	86.2	84.9	87.2	83.5	84.8
AA	-	63.5	63.5	-	63.9	63.9
Total	78.7	65.5	75.9	82.7	66.5	79.3

Source: Ministry of Water, Irrigation and Energy and NBE Staff Computation 2020 report

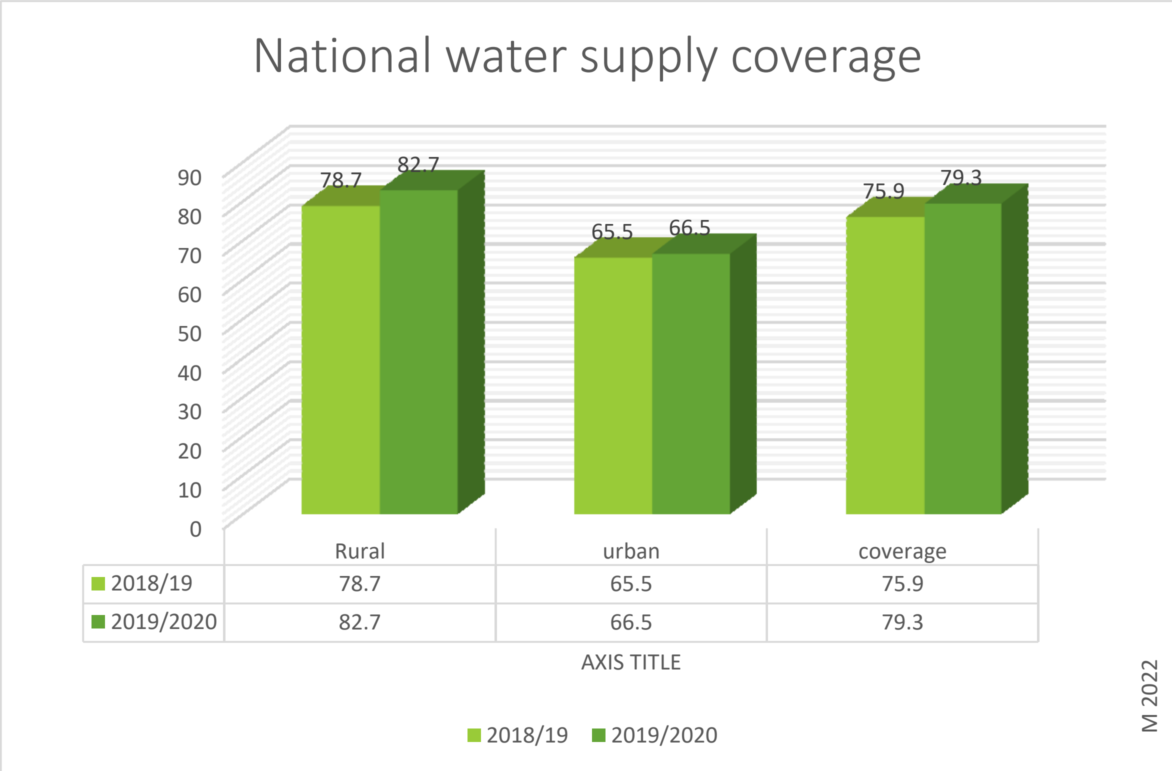

Figure .2 .1. National water supply coverage

2.2.3. Water demand Management

Water demand management is to contribute to more efficient and equitable provision of water and sanitation services and to reach this objective a number of instruments have developed (Mebet, 2007).To manage the demand by controlling waste or loss from pipe leakage and consumption through the use of meters and tariffs that is set in accordance with volume of water consumption (Delesho, 2006) Water demand management is the adaptation and implementation of a strategy by an institution to influence the water demand and usage in order to meet any of the following objectives: economic efficiency, social development, social equity (Mckenzie, 2013). In many African cities urban water demands are often non-homogeneous owing to a range of levels of service occurring within the same urban area.

Levels of service can vary from household connections to standpipes or to no service at all (Wallingford, 2003).Different literatures like (Santosh, 2012) and (Willem, 2009) state that in assessments quantity of water demand for the public in the town the demand was classified in to the following branches:-

2.2.4. Domestic Water Supply Coverage

Domestic water demand:

The quantity of water required for various domestic usage such as bathing, drinking, cooking, food preparation, washing clothes etc. And the estimation of the total domestic water consumption usually to 50-60% of the total water consumptions (Santosh, 2012). Domestic water supply coverage provides a picture of the water supply situation of one specific country or town and helps to compare one country with others and the inter and intra town distribution with in specific country. The percentage of population with or without piped water connection is relevant indicator to compare the coverage of water supply in urban areas. Although the water supply coverage is better in urban areas while compared with the rural, the actual water supply coverage in developing countries in general and African cities in particular is very low while compared to the demand (Mebet, 2007).

Institutional water demand:-

It include the quantity of water required for various public utilities purpose. The estimation of the total institutional water consumption usually about 10% of the total water consumption (Santosh, 2012).

Industrial water demand:-

It depends mainly on the types of industry in the town or area. Normally it is estimated that 25 to 40% of total water demand.

Fire demand: -

Is the quantity of water required for fighting a fire out –break According to the recommendation of American insurance association the fire water demand expressed as:-

$$Q= 64\sqrt{p}(1 - 0.01)\sqrt{p})\ \text{lettr/second} \ldots\ldots 2.1$$

Where Q = Rate of flow of water

P = population in thousands

Losses and wastes (unaccounted water):- this includes the quantity of water losses in leakage due to bad plumbing or damage meters, stolen water due unauthorized connections. Normally this quantity should not exceeded 20% of the total of total water supply for a well-managed water work (Santosh, 2012).However it cannot be less than 15%.

Domestic water demand for the following categories of consumer:

	Stage 1	Stage 2
House connection (HC)	50 l/c/day	70 l/c/day
Yard connection, own (YCO)	25 l/c/day	30 l/c/day
Yard connection, shared (YCS)	30 l/c/day	40 l/c/day
Public tap supplies (PT)	20 l/c/day	25 l/c/day

2.2.5. Factors Affecting Per Capita Demand

Per capita demand is the annual average amount of daily water required by one person and including domestic uses. According (Santosh, 2012) to per capita demand depends on the fowling factors:-

Pressure in distribution system: -The rate of water consumption increase in the pressure of the building and even with the required pressure of the farthest point, the consumption will automatically increase.

Size of the city: - per capita demand for big city is generally large as compare to the smaller town because of in big cities huge quantity of water required for different purpose.

Climate conditions:-the quantity of water required in hotter and dry places are more than cold places because of the uses of air coolers, air conditioners, sprinkler of water in lawn garden washing of rooms etc.

Types of gentry and habits of people:-rich and upper class community generally consume more water due to their affluent living standards. Middle class community consume average amount while the poor slum dweller consume very low amounts therefore, (Santosh, 2012) states that the amount of water consumptions is directly depend up on the economic status of the consumers.

Industry and commercial activities:-the pressure of industry and commercial activities at a particular place increases the consumption by amount. Many industry requires really huge amount of water and as such increase a water demand considerably.

Cost of water:-The cost of water directly affects its demand. If the cost of water is more, less quantity of water will be used as compared when the cost is low.

Policy of metering and charging methods: - water tax is charged in two different ways, on the bases of meter reading and on the bases of certain fixed monthly rate. Water demand varies seasonally with the lowest usage in winter months and the highest usage during summer month. Variations in demand also occur with respect to time of a day. Diurnal peaks typically occur during the morning early evening periods, while the lowest usage occurs during night time hours (Willem, 2009).

2. 3. Water Loss and Leakage

The term "water loss" is generally adopted to indicate the difference between the overall amount of water supplied in the network and the sum of the water volumes corresponding to the customer consumption recorded by the flow-meters (Lambert, , 2009). The first and foremost cause of water loss is leakage. Water put to inappropriate or excessive uses may also be considered as loss. Water that is unaccounted for because of measurement errors, including inaccurate meters, forgotten users, and unmeasured uses, are also some of the causes for evaluating the water losses. Leakage can be defined as unintentional or accidental loss of water from the pipe distribution network. Improper connections can sometimes result in continuous escape of water from the distribution pipes. These water losses can be divided into two groups: the apparent losses, which consist of water volumes actually consumed but not accounted for, and the Physical (real) losses, that are caused by large damages that may have occurred to the network pipes or by the deterioration of the pipe junctions or the hydraulic devices (Malcolm, 2008).

Regardless of the magnitude that greatly varies from town to town or from one area to another area, water loss is a problem experienced in all water distribution systems. The first and foremost cause of water loss is leakage. Water put to inappropriate or excessive uses may also be considered as loss. Water that is unaccounted for because of measurement errors, including inaccurate meters, forgotten users, and unmeasured uses, are also some of the causes for water losses. Unaccounted for water (UFW) is one of the commonly used methods for evaluating the water loss that is usually defined differently by different writers that some of the definitions indicated here: There is no universally applied or accepted definition of unaccounted-for water. Water losses in the water supply distribution system, illegal connections, over flow from reservoirs and improper unaccounted for water. Metering (meter err), poor maintenance, etc. are referred to as unaccounted for water.

Table.2.2.Components of Water Loss

Water Loss	
Physical loss (Real loss)	Commercial loss (Apparent loss)
Pipe breaks and leaks	Metering Errors
Storage overflows	Water Theft
House connection leaks	Billing Anomalies

2.3.1. Commercial Losses (Apparent loss)

Commercial losses, sometimes called „apparent losses", include water that is consumed but not paid for by the user. In most cases, water has passed through the meters but is not recorded accurately. In contrast to leaks or reservoir overflows, the lost water is not visible, which leads many water utilities to overlook commercial losses and concentrate instead on physical losses. Commercial losses can amount to a higher volume of water than physical losses and often have a greater value, since reducing commercial losses increases revenue, whereas physical losses reduce production costs. Commercial losses can be broken down into four fundamental elements and those are :-(1) customer meter inaccuracy, (2) unauthorized consumption, (3) meter reading errors and (4) data handling and accounting errors (Malcolm, 2008).

1. Customer meter inaccuracy

Inaccurate meters tend to under-register water consumption leading to reduced sales and therefore reduced revenue. Only very rarely do meters over-register consumption. Utilities should focus initially on large customers, such as industrial or commercial users, since they consume a larger volume of water and often pay a higher tariff. Using data from accurate meters to bill customers, rather than charging them based on an assumed per capita basis, ensures that customers are charged according to their actual consumption and encourages them to preserve water (Malcolm, 2008).The paragraphs below discuss common problems with customer meter accuracies and solutions for utilities. The common possible solutions to address customer meter inaccuracy are describing as below;

a. Installing meters properly

Meters should be installed properly according to the manufacturer's specifications. For example, some meters require a specific straight length of pipe upstream and downstream of the meter. Therefore a standard meter stand should be designed and constructed onsite. Utilities should purchase the meters on the customers‟ behalf, so that only standard, high quality meters are used. Meters should also be installed where meter readers can easily read them, and where it is easy to identify each property's meter.

b. Sizing meters properly

Customer meters work within a defined flow range, with the maximum and minimum flows specified by each manufacturer. Large meters will not register low flows when the flow rate is lower than the specified minimum. Therefore, utilities should conduct customer surveys to understand the nature of each customer's water demand and their likely consumption. This information helps to determine the proper meter size for households and businesses. For customers with a high demand, checking the flow pattern and the newly installed meter verifies whether the correct meter size is used. Problems with low flows can occur when a storage tank, with the water flow controlled by a ball or float valve, is installed on the customer's premises. These valves operate by slowly closing as the water level in the tank rises, which has the effect of reducing the flow through the meter, often below the minimum flow specification. This problem is compounded even further if the size of the storage tank is large in comparison to the customer's consumption because the ball or float valve will never fully open and the flow through the meter was continually low.

c. Using the appropriate class and type of meter

Choosing the appropriate meter helps to ensure the accuracy of customer consumption data. Class B meters are a good choice where water quality is low, as the sediments will not greatly affect the meter. Class D meters are more preferable where roof tanks are used and water quality is good, since they have a lower minimum flow specification and will measure the roof tank inflow more accurately. Class C meters are a suitable compromise in most situations, since they can measure low flows better than Class B meters and are not as expensive as Class D meters. Common types of meters include positive displacement (PD), multi-jet, single-jet, turbine, and electromagnetic. The most common type of meter for domestic and small commercial installations is the 15 mm and 20 mm PD meter. Single-jet and multi-jet meters are more accurate for small commercial and industrial installations that require 20 mm to 50 mm sizes. Electromagnetic meters are the best choice for sizes 100 mm and above.

d. Maintaining and replacing meters properly

All meters should be installed above ground and located where they can be audited easily, Including by the meter readers during their regular rounds. The utility should replace the meters systematically, beginning with the oldest meters and those in the worst condition. Poor maintenance will not only encourage inaccuracy but may shorten the life span of the meter. Meter servicing is essential, especially in areas of poor water quality. The accuracy of mechanical meters changes over time as the mechanical bearings wear down, causing friction to increase and thus the meters to under-register. These changes will occur over a number of years, depending on the quality of manufacture. The water utility should regularly test a sample of its customer meters, including a range of meter brands and ages, using a calibrated meter test bench. This testing will determine the optimum age at which customer meters should be replaced.

2. Unauthorized consumption

Unauthorized consumption includes illegal connections, meter bypassing, illegal use of hydrants, and poor billing collection systems Illegal connections involve the physical installation of a connection to water distribution pipelines without the knowledge and approval of the water utility. The common problems and possible solutions are describing as below.

A. Finding and reducing illegal connections

Illegal connections can occur during the installation of a new supply connection, or sometimes the customer's supply is cut off after non-payment and the customer cannot afford, or does not want to pay, to be reconnected. During customer awareness programmers, customers should be encouraged to report illegal connections, and regulations should be in place to penalize the water thieves. Meter readers should also report cases of direct connections without accompanying meters that they see during their rounds.

B. Tackling meter by passing

Some customers try to reduce their water bills by using a meter bypass, which is an additional pipe installed around the meter. This type of unauthorized consumption is usually committed by industrial and commercial premises, where only a small volume of the consumption goes through the meter and the rest through the bypass pipe. Because large customers tend to steal large volumes of water, the discrepancy will show up when the utility conducts a flow balance analysis.

C. Preventing illegal use of fire hydrants

Although the only legal use of fire hydrants is for firefighting, some use them illegally to fill tankers (normally at night) or to provide water supply to construction sites. The utility staff can detect these flows, often high volume over a short period of time, through appropriate flow measurements at DMA meters. Such high flows are not only incidences of water theft, but also a detriment to the pipe network and water quality, which affects the service to the customer. Through customer awareness programs, the utility staff should encourage customers to report cases of illegal uses of fire hydrants. In addition, the utility manager needs to cooperate with relevant local agencies or departments to identify owners of tankers suspected of drawing water illegally and without proper permission. Developing and enforcing regulations to penalize water thieves together with local agencies will also deter unauthorized consumption.

D. Actively checking the customer billing system

Sometimes connections are made legally, but the billing department is not notified of the new connection; therefore, the customer is never billed. These unregistered customers can be detected during the regular meter reading cycle when diligent meter readers find meters that are not in their reading book. However, this process may not identify all of the errors in the billing system.

E. Avoiding corrupt meter readers

Corrupt meter readers can significantly impact a utility's monthly billed consumption. For instance, the same meter reader who walks the same route for an extended period of time, thus becoming familiar with the customers and their monthly billed consumption, may collude with those customers to record lower meter readings in exchange for a monetary incentive. To reduce this risk, the utility manager needs to rotate meter readers to different routes on a regular basis.

3. Meter reading errors

Errors can be easily introduced through negligence, aging meters, or even corruption during the process of reading the meters and billing customers. Incompetent or inexperienced meter readers may read the meter incorrectly or make simple errors, such as placing a decimal in the wrong place (Malcolm, 2008). The ages of pipes. Ages of meters also has an impacts of the increase of water loss. Customer meter errors include errors due to under or over registration of the meter (Lambert, 2003). Dirty dials, faulty meters, and jammed meters can also contribute to meter reading errors. The meter readers should immediately report any observed problems, and the maintenance team should take action to remedy the problem immediately. If remedial action is too slow, meter readers may become demoralized and less inclined to report problems. Because meter readers are the utility's frontline in liaising with customers, their activities have an immediate impact on cash flow. Utility managers should therefore invest in training and motivating.

2.3.2. Physical loss (Real Losses)

Real losses are water volumes lost within a given period through all types of leaks, bursts and overflows. Physical losses, sometimes called real losses or leakage includes the total volume of water losses minus commercial losses. However, the water balance process indicates that commercial losses are estimated and therefore the resulting leakage volume may be incorrect (Malcolm, 2008). Can be classified according to **(a)** their location within the system and **(b)** their size and runtime.

A. Based on Location

1. Leakage from the Transmission and Distribution Mains

May occur at pipes (bursts due to extraneous causes or corrosion), joints (disconnection, damaged gaskets) and valves (operational or maintenance failure) and usually have medium to high flow rates and short to medium runtimes. And causes of leaks will vary depending on the nature of the soil, the quality of the construction, the materials used, the pressure levels and the utilities.

2. Leakage from service connections: - up to the point of the customer meter: service connections are sometimes referred to as the weak points of water supply networks, because their joints and fittings exhibit high failure rates. Leaks on service connections are difficult to detect due to their comparatively low flow rates and thus often have long runtimes.

3. **Leakage and overflows from storage tanks:-**are caused by deficient or damaged level controls. In addition, seepage may occur from masonry or concrete walls that are not watertight. Water losses from tanks are often underestimated and, though easy to detect, repair is usually elaborate and expensive.

B. Size and runtime

1. 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.

2. Unreported or hidden leaks by definition have flow rates greater than of the order of 250 l/h at 50 m pressure but due to unfavorable conditions do not appear at the surface (WHO, 2011).The presence of hidden leaks can be identified by analyzing trends in water consumption behavior within a defined water supply zone.

3. 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 ripping 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.

2.3. 3. Non - Revenue Water (NRW)

Nonrevenue water (NRW) in a water distribution network is the water lost from unbilled authorized consumption, apparent losses, and real losses compared to the total system input volume (Yang, 2018)**.** Nonrevenue water is an important parameter for prioritizing water distribution network improvement intervention planning, and it is necessary to identify the affecting parameters. A factor classification system has been developed based on the factors suggested by major institutions and researchers to propose an effective NRW classification system in a water distribution network. Factor classifications used include physical, operational, and socioeconomic factors that could affect NRW. Appropriate standards are required when classifying water main parameters. It must be possible to quantify selected parameter data. Whether the collected data are numerically valid and whether it can be used as a standard for assessment or comparison between regions must be examined. Quantification portion of the qualitative data in managing NRW is important and needs to be used in accordance with reasonable standards. A case study was conducted by Metaferia Consulting Engineers for Water Aid Ethiopia in 2010 in seven towns which reveals the extent of leakage of each town. Summary of the study result is shown in table below.

Table.2.3. Level of Non-Revenue Water in Towns of Ethiopia

S/N	Town	Level of leakage
1	Assosa	48%
2	Burayu	23%
3	Butajira	22%
4	Hossaena	51%
5	Miza-Aman	61%
6	Sebeta	21%
7	Wolkitie	43%

Source. Case Study Report of Water Aid Ethiopia (2010**)**

2.4. Causes of Water Losses

There are multiple causes for loss of water in transmission pipelines which include leakage, metering errors, public usage such as firefighting, and theft (El-Abbasy, 2016)**.**The most critical route for losses is a leak, as they are considered to contribute an estimated of 70% of water loss in water transmission systems, this value is expected to become higher in undermanaged networks (Clayton, 2007). Comparatively, gas pipeline networks suffer from similar fates, yet the outcomes of leaks in gas pipelines can be more Water losses occur in every water distribution network (WDN) in the world. For economic and technical reasons, it has to be accepted that real water losses cannot be entirely eliminated. Nevertheless, there has been a large increase in the knowledge and development of state-of-the-art equipment, allowing us to manage water losses within economic limits. According to the WHO leakage management manual (2010). Leakage is usually the major components of water loss in developed countries, but this not always the case in developing or partial developed countries, where illegal connections, meter error or an accounting error are often more significant (Farley., 2010).The other components of total water loss are non-physical losses, e.g., meter under registration, illegal connections and unknown use (WHO, 2010). Four key factors influence the degree of leakage within a utility's pipe network these are:-

- Availability of water, financial and personnel resources
- Infrastructural conditions regarding materials, system pressure and renewal policy
- Leakage control policy: activity, perception, technical expertise
- Institutional attitude with respect to structure, regulation, politics

2.4.1. Causes of Real (Physical losses)

Pipes and fittings of different dimension, material and age are installed below ground, where they are subject to a multiplicity of factors which cannot be registered and controlled on a regular basis. Additionally, specify four key system-specific factors for real water losses, namely the length of the mains, the number of service connections, the location of the customer's meter and the average operating pressure in the system (when the system is pressurized). These factors vary from system to system (Lambert a. T., 2010). The multitude of active and passive interactions between pipes and their environment frequently lead to damage and leaks. In simple terms, the assets of water distribution networks comprise (a) pipes and joints, (b) valves and fittings and (c) storage tanks and pumps. The causes and factors influencing water losses thus can be classified according to the type of asset.

a) Defective pipes and joints

❖ **Material, condition and age of the pipe**

1. **Material:-** Besides material failures caused during manufacturing (insufficient wall thickness, absence of corrosion protection on steel pipes, poor reinforcement cover on concrete pipes), damage is also brought about by inappropriate use of certain materials: soft water (especially untreated water from dams) with a high carbonic acid (CO_2) content and low calcium concentrations, or with high sulphate concentrations are known to affect concrete aggressively. Reinforced concrete pipes as well as the internal and external cement mortar lining of cast iron pipes are affected.
2. **Condition:-** All metallic pipes are exposed to physical and electro-chemical corrosion. Corrosion will reduce the wall thickness and decrease the pipe's ability to withstand water pressure and external stress. The most common causes of corrosion are aggressive water and soil as well as stray current.
3. **Age of pipe:-** Many factors influencing leakage are age-dependent. Consequently, the age of a pipe section can appear to be the most significant factor for leakage. Nevertheless, age is not necessarily a factor, if the pipe has been carefully designed and installed, maintenance is carried out at regular intervals and external conditions are favorable. Pipes age and material are important factors contributing to the burst probability of pipes that as a result cause of loss of water loss.

❖ **Design and installation, workmanship**

1. **Design:-**Mistakes made during the planning phase may influence leakage from pipes, such as the incorrect material choice, insufficient dimensioning for the actual pressure, inadequate corrosion protection measures or incorrect alignment (e.g. along slopes prone to landslides or adjacent to tree roots).
2. **Storage and laying of pipes: -**improper storage may damage pipes even before installation. Grass roots can penetrate the bituminous coating of steel pipes. Dragging PE pipes over concrete surfaces or stones was cause chamfers which are more susceptible to future leakage. Extended sunlight exposure causes PE pipes to become brittle. Heavy machinery used for transport and installation may also cause damage.
3. **Bedding:-**the selection of inappropriate material for pipe bedding is a frequent cause of damage: Course or rocky bedding material spoil external coatings on steel or cast iron pipes and support corrosion. Longitudinal and spiral cracks may appear in PE and PVC pipes as a result of stony bedding materials. Insufficient backfill and compaction of the pipe trench may cause subsidence. These uncontrolled soil movements can also trigger socket disconnection or pipe ruptures.
4. **Joints:-**Unprofessional execution of pipe joints is a further reason for leakage. Welded steel pipes often lack proper internal and external corrosion protection along the weld seam. If unskilled or poorly trained welders execute the relatively new technique of welding PE pipes, it frequently contains defects due to insufficient heating and pressing of the pipe ends. Leakage can also occur if socket pipes exceed the maximum permitted angular bending or if water hammer and high pressures affect joints that are not force locked.

❖ **Pressure**

1. **High pressure:-**Increasing pressure was result in a higher flow rate from existing leaks and an augmented occurrence of new pipe bursts and leaks. Aged valves and fittings may lack sufficiently robust dimensioning for high pressures.

2. **Poor pressure:-** Poor pressure may complicate leak detection efforts because the water is less likely to reach the surface. Furthermore, decreased noise levels from the leak impede acoustic leak location methods and may cause longer leak runtimes.
3. **Pressure variations:** marked variations in pressure within the system may lead to material fatigue and thus to leakage, mainly in plastic pipes.
4. **Pressure surges:** pressure surges (water hammer) mainly arise from inappropriate control mechanisms and can cause pipe fractures, disconnect joints and damage valves and fittings, hence leading to leakage.

- **Soil and groundwater**

1. **Soil type:** The prevailing soil type has significant effect on the runtime of leaks. While water escaping into cohesive soils (e.g. clay or silt) may soon appear at the surface, leaks into non cohesive soils (e.g. sand or gravel) tend to drain away below ground, making leaks more difficult to detect.
2. **Soil Aggressiveness:** most non-cohesive soils are not aggressive. Cohesive soils may negatively affect the external corrosion of metallic pipes due to differing levels of dissolved salts, oxygen, moisture, pH and bacterial activity.
3. **Soil movement:** soil movement is caused by changes in the temperature and moisture content (changing groundwater levels cause cohesive soils to contract or expand), heavy frost as well as subsidence prompted by incorrect pipe bedding, mining activities or earthquakes. Construction work, increased surface loads or pipe repair works may also trigger soil movement. Soil movement may cause pipe joints to disconnect and pipes to rupture.

❖ **Traffic**

1. **Traffic load:** many pipes that were originally laid underneath pavements are now situated under the roads as traffic and road widths have increased. More vehicles and the high axle loading of modern trucks place an additional burden on the pipes.
2. **Pavement:** the water outlet may appear far away from the damage due to concrete and tarmac pavements, thus hampering leak location efforts.
3. **Stray current:** 1 ampere erodes approximately 10 kg of iron each year. Stray currents from DC-powered railway systems (trams) and reinforced concrete foundations thus aggravate the external corrosion of metallic pipes. (Oppinger P., 2009)

(a).Third-party influence:-the absence of infrastructure documentation (e.g. as-built drawings) or improper execution of construction work may damage pipes, either directly through excavators or indirectly through vibrating construction machines or heavy vehicles. Damage may be detected instantly or after a delay, making the cause harder to detect.

(b) Defective valves and fittings:-Leaks from valves and fittings include breakage, deformations or material failures at the valve body as well as leaking gaskets at joints, bonnets or stems. Rough handling or an absence of maintenance often causes these leaks. Defective valves and fittings may contribute significantly to real water losses in spite of rather low leak rates. These deficits often remain undiscovered for a long time without a regular servicing program. Considerable water losses may also occur from defective fire hydrants and public water standpipes.

(c) Defective storage tanks and pumps:-Water losses from storage tanks are caused both by structural damage and by operational failures, such as faulty or lacking system controls which may result in overflow. Structural damage involves cracks, holes or delamination at tank walls or floors, leakage due to inferior concrete quality, as well as sealing's and pipe penetrations that are not watertight. Water losses from tanks are often underestimated and, though easy to detect, repairs are usually elaborate and expensive. Water losses from pumps are usually caused by defective pump shaft seals. The amount of leakage is negligible in most cases, but flooding pump chambers and electric equipment is a nuisance and should be avoided by undertaking proper maintenance.

2.4.2. Reasons for Commercial loss (Apparent losses)

Apparent water losses are caused by (a) water meter inaccuracies, (b) data handling errors and (c) any form of unauthorized consumption. Apparent losses should not be underestimated, because they do not generate revenue for water that has already been produced, treated, transported and delivered to the customer. Reasons for apparent losses can be grouped as described on the next: (Thornton, 2008.)

(a) Meter Inaccuracies:-Metering losses are frequently the most common form of apparent losses. Experience shows that a small percentage of water is not metered or metered incorrectly due to measuring errors or creeping losses in water meters.

(b) Data Handling Errors:-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 (own needs and free supplies for firefighting, watering of greens, street cleaning, etc.) 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.

(c) Unauthorized consumption:-Unauthorized water extraction represents a considerable source of losses in many countries and appears in many different ways, for example illegal connections, vandalized, manipulated or bypassed customer meters, illegal water abstraction from fire hydrants as well as bribery and corruption of meter-readers or other utility personnel.

2.5. Water Loss Management

Water loss reduction should be the aim of every water utility since it leads to improved economic and ecological efficiency and better service for clients. (Thornton, 2008.) Before developing a water loss reduction strategy, decision-makers should be aware of why it makes sense to provide financial and personnel resources to reduce water losses. From the perspective of a water utility, there are at least ten reasons that may justify increased expenditure on water loss management:

Operating cost efficiency:-A well-maintained water distribution system was require fewer repairs, lower production costs and prevent compensation payments.

Capital cost efficiency:-A lack of maintenance and intermittent operation increase wear and tear on pipes, valves and meters. Improved supply will extend the service life of the system components and lead to lower fixed costs for the water utility in the long run.

Improved metering and billing:-Fewer leaks and an improved supply situation may also have positive effects on apparent water losses because air inside the distribution system can cause metering errors.

Reduced health risks: Sewage and other pollutants can infiltrate the pipe system through leaks and trigger water-borne diseases in low-pressure systems or in the case of intermittent operation.

Increased security of supply: A well-maintained system with fewer leaks and bursts will increase the supply guarantee.

Less infrastructural damages: Leakage might create voids below ground which can lead roads and buildings to collapse.

Reduced loads on sewers: Infiltration of water lost to sewers places an additional load on sewer pipes and wastewater treatment plants.

2.6. Consequences of Water Loss &Leakage

Improved consumer satisfaction:- In addition to poor water quality, inadequate quantity and health risks, leakages also decrease the pressure at customers' appliances. Enhancing the supply service will improve customer satisfaction and willingness to pay.

Publicity and willingness to pay:

Fewer bursts, increased security of supply and hygienic conditions was enhance the public's perception of the water utility. This may also positively affect the consumers' willingness to pay.

Reduced ecological stress:-Finally, the development of a water loss reduction strategy makes sense from an ecological point of view. In the case of scarce or over-exploited water resources, water losses should be reduced to decrease the stress on these resources.

The primary consequence of leaks in distribution system is financial. Reduction in water loss enables water utilities to use existing facilities efficiently. Alleviate shortage of water supply. When it comes to operating water supply systems, water losses are a clear obstacle to sustainability, as the following list of potential impacts shows:

- **Economic impacts:** Costs for exploiting, treating and transporting water which is lost on its way to the customer without generating any revenue for the water utility. Pipe bursts and leaks necessitate expensive repair works and may also cause considerable damage to nearby infrastructure.
- **Technical impacts:** Leakage leads to reduced coverage of the existing water demand, possibly so much so that the system can no longer operate continuously. Intermittent supply will cause further technical problems by air intruding into the pipes and will tempt customers to install private storage tanks.
- **Social impacts:** Water losses result in customers being adversely affected by supply failures, such as low pressure, service interruptions and unequal supply, but also by health risks which may arise from the infiltration of sewage and other pollutants into pipe systems under low pressure or intermittent supply.
- **Ecological impacts:** Compensating water losses by further increasing water extraction places additional stress on water resources and requires additional energy and thus causes carbon

dioxide emissions that could have been avoided. These few examples impressively demonstrate that water loss impairs all aspects of operating a water supply system sustainably. Water utilities worldwide should thus strive to analyses, quantify, combat and reduce physical and apparent water losses from their water supply systems. A successful and sustainable reduction in water losses requires a political and financial framework that encourages water loss reduction activities by means of binding regulations, incentives, benchmarking and setting leakage targets.

2.7. Leakage Monitoring and Control

The losses of water are inevitable in the process of supplying thousands of customers spread over a large area started from reservoirs at the treatment plants. Through a complex network to the individual customer. It is there for important to ensure that leakage monitoring and control is given the attention it deserves by all waters supply authorities and consumers (MULafu.et al., 2003).

2.7.1. Identifying Leaks through Visual Inspection

In this method a leak may be self-evident because of water shows on the surface or may become so upon investigation flowing consumer complaints such as poor pressure or noise in the plumbing system (Walling ford HR., 2003).

2.7.2. Identifying Leaks through Using Detection Equipment

Most of the water is lost through numerous small holes, which are very difficult to locate, as the pipes are laid underground that usually need special equipment to locate the leak and repair. The leak noise detected will depend upon the position at which a sounding is made

2.7.3. Location of Large Leaks by Pressure Control

A large leak in a small network can be located by measuring the pressure during the time of minimum water supply especially during the night. This can be done by shutting of the valves in successive election of the distribution starting from the supply. Pressure control is a necessary tool for the technical management of the system and combined with any other methods of water loss estimation could give very useful information in order to identify the cause of water loss through leakage (Walling ford HR., 2003).

2.8. Distribution Network

The distribution network is responsible for delivering water from the source or treatment facilities to its consumers at serviceable pressures and mainly consists of pipes, pumps, junctions (nodes), valves, fittings, and storage tanks. Water distribution networks play an important role in modern societies being its proper operation directly related to the population's well-being. A completely satisfactory water distribution system should fulfill its basic requirements such as providing the expected quality and quantity of water during its entire lifetime for the expected loading conditions with the desired residual pressures (Misirdali, 2003).Water distribution systems can be either looped or branched. Looped systems are generally more desirable than branched system because, in the looped system, breaking of pipe can be isolated and repaired with little impact on consumers outside the immediate area. On the other hand, in the branched system, all the consumers downstream from the break will have their water supply interrupted until the repairs are finished (Atiquzzaman, 2004). Water supply and distribution systems serve many critical functions and play a large part in achieving human and economic health. Despite this, the performance of these systems often goes unnoticed until there is a major disruption or operational failure. While failure events are likely inevitable, often dramatic and costly, day- to-day, inefficient performance of WDS also entails great economic, social and environmental burdens. The most common challenges in water distribution networks include water quality degradation, capacity shortages, infrastructure aging and increasing demand (Jalal, 2008).

2.8.1. Water Distribution

For efficient distribution, it is required that water should reach end use with required flow rate with needed pressure in the piping system. There are three main types of distribution system that can be adopted in villages/towns:

Gravity Fed Distribution:-When the ground level of water source/storage is sufficiently raised than the core village/town area, such system can be utilized for distribution.

Pumping System in such system, water is supplied by continuous pumping. Treated water is directly pumped into the distribution main with content pressure without intermediate storing. Supply can be affected during power failure and breakdown of pumps. Hence, diesel pumps also in addition to electrical pumps as stand by to be maintained. Such system works only in condition where there is continuous power supply, reliable water source and where intermediate storage system cannot be installed.

CHAPTER. 3. MATERIALS AND METHODS

Focused on the objectives and questions of this research stated in the chapter one part 1.3 and 1.4 the method how the research carried out is discussed in this part. The methods of data collection and data preparation are also discussed in this chapter. Generally, the research is divided in to two major parts, analyzing the water supply coverage and the water loss analysis. The monthly water production and consumption data was used to evaluate the water loss at all levels. After evaluating the water loss, the causes for the loss was tried to be identified using the different factors that have an impact to the water loss like the pipe ages, the ground elevation (topography) and customer meter records.

3.1. Description of the Study Area

3.1.1. Location and Relief

Wolkite is the Capital city of Gurage Zone of Southern Nation Nationality People Regional State of Ethiopia. The town is located on the main road of Addis Ababa to Jimma town at distance of 157 kilo meter (km) south-west of Addis Ababa. This town has a latitude and longitude of 8°17′N 37°47′E and an elevation between 1910 and 1757 meters above sea level diversified topographic features. The town is situated in the south-west plateau about 80 km to the west of the main Ethiopia Rift Valley on a water divide of “Rebu”, “Megecha” and “Wabe” rivers. The town stretches some 12 km towards south west direction of Gubere sub city which is recently being part of Wolkite town and the place of Wolkite University.

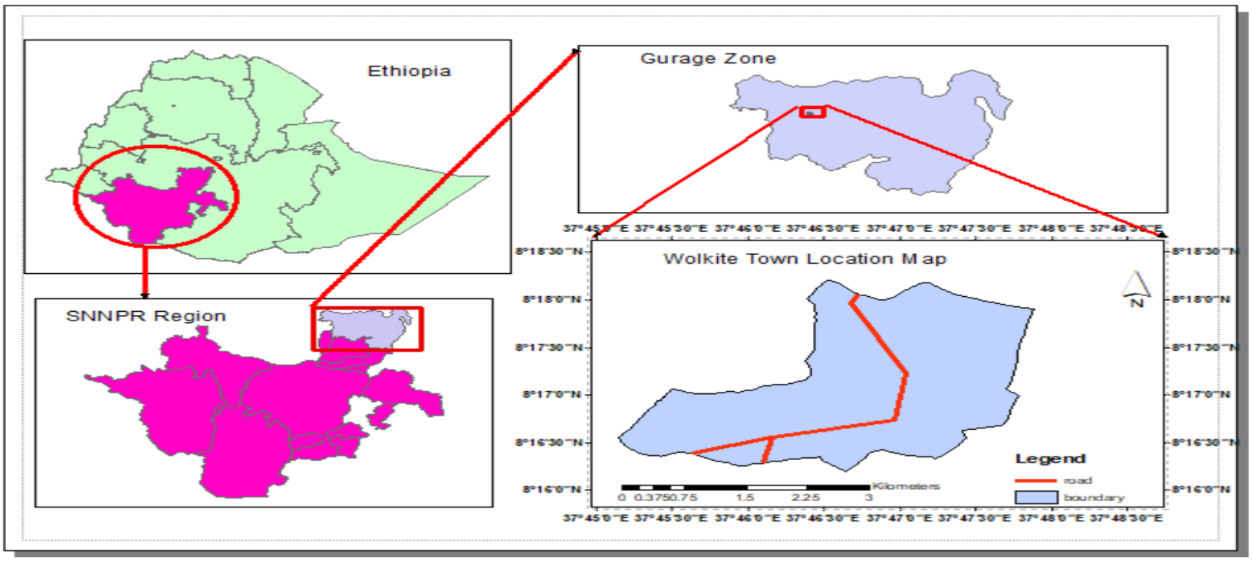

Figure.3.1. Map of the Study Area

3.1.2. Climate

The climate is tropical with a mean annual precipitating of 1310mm, mean minimum precipitation with 11mm in the month of December during the dry season and mean maximum precipitation with 278mm in the month of July during the wet season. Temperature varies between 12^0C in winter to 28^0 C in summer.

3.1.3. Population

According to CSA (2007), the total population of Wolkite Town is about 28,866. Out of this, 15074 are men and 13,792 are women. But in 2018 CSA population projection editing because the master plan of the town expand and included rural kebles around the town due to this the federal house of agency the approved additional number of populations send to the wolkite town Plan and development office in 2018, based on this the current projection populations of town are (2018) 92,517, (2019)96,957, (2020) 101,611, (2021)106,488 and (2022) 111600 the growth rate was 4.8. (Wolkite town plan and development commission office 2022).

3.1.4. Economy and Infrastructures

Wolkite town is fast growing commercial center and transit polite for an estimated 10,000 visitors per day according to Wolkite town administration culture and tourism office .These visitors pass through the town on their way to western part of Ethiopia or come from this part of the country of Addis Ababa. Trading is the most predominant economic activity in the town, according to municipal of town there are some small scale agricultural practice like garden crop production is also common in the town. There are seventeen elementary and junior schools with 24,310 number of students, and five high school with 9395 students a total 33,705 students attending day school (WTAEO, 2022).

In Wolkite there is one University and Collage the maximum number of student's trainee staff and supporting staff around 17,000. Health institution there is one hospital, three health center r and sixteen medium and seven primary totally 23 private clinics with a total of about 200 beds and number of public toilets 6 (WTAHO, 2022).

3.2. Materials and Methods

This research was mainly conducted to evaluate existing water supply distribution system in wolkite town. To achieve the goal of the research, the materials used are:-

- ARC Map version 10.1: For delineate of boundary map and location of the study area.
- Water GEMS for Arc Map and Water CAD Software for Hydraulic Origin for Drawing and Hydraulic analysis.
- Excel Spreadsheet 2013: For data preparation, analysis and interpretation of results.
- Discharge measuring and pressure gaging instrument.

First evaluated the water supply coverage of the town before analyzing the water loss. In evaluating the water supply coverage based on the volume of consumption and level of water connection as these are highly related to the issue of water loss. The stages of the study was divided in to three. The first stage of the study was desk study concentrating on literature review and development of data gathering methods. The second stage involved data gathering from legal organizations, field data collection from selected area of the wolkite town and discussions with the local experts of the town water supply authority or Wolkite water supply and sewerage enterprise (WWSSE).The third stage is to analyze the collected data, identify problems towards answering the research questions. The activities in each of these phases are described in the consecutive sub-sections .finally, from analyzed data problems identified and remedial measures was suggested.

❖ The major factors considered during the selection of sample study areas was:-
  - The zone of which there is a serious problem is found.
  - Topography
  - Data availability
  - Suitability to identify the problem

By taking the above criteria in to consideration the main pipe line between the balancing reservoirs around the source area to the town service reservoir was selected to identify the bursting problem and at different points the level of pressure measured. The losses of water were expected in the process of supplying thousands of customers spread over large areas. Water leak detection was systematic method of locating visible and non- visible leaks in distribution system through visual inspection and identify leak sound and pinpoint the location of non-visible underground leaks. Starting from treated water reservoirs, through the complex network to the farthest customer, water is lost through leakage or taken without authorization.

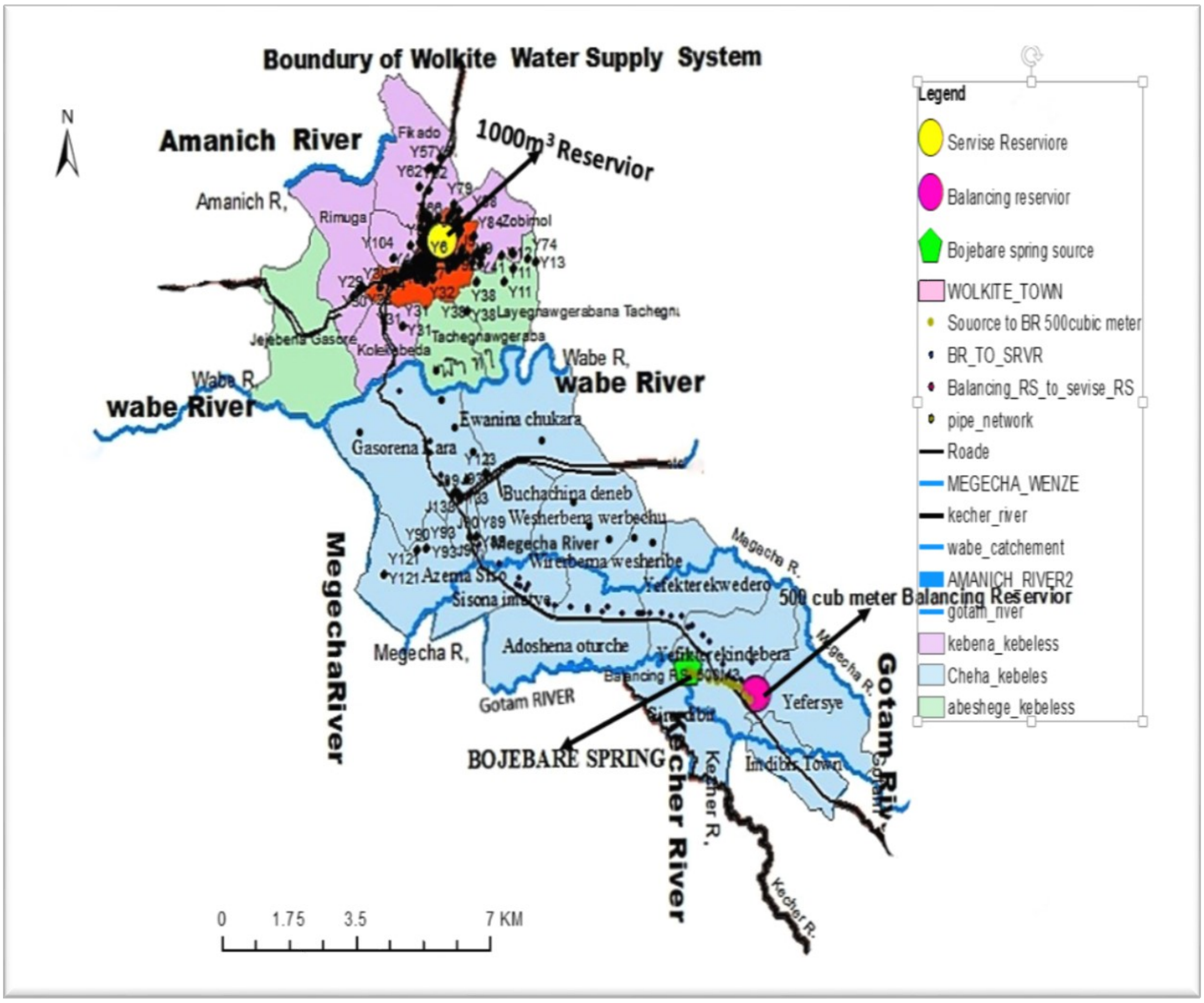

Figure.3.2. Boundary map of wolkite water supply system

3.3. Data Collection and Preparation

Based on the work plan of the study both primary and secondary data was collected. Secondary data was collected from the regional Water Resource Bureau, The zonal water mine and energy office, the town administrative municipality office, the town water supply service and at the field from the distribution system, some supplementary information was also collected from Metaferia Consulting Engineers (MSC) design report and also Interviews from the town three sub city.

During the field visit, other secondary data includes various published and unpublished documents, annual reports and project or design documents etc. This information include source wells, water reservoirs, mains length of pipes , number of service connections, customer meter, average pressure, system input volumes, authorized and unauthorized consumption, tariff, population data, and other related data and information.

3.3.1. Primary Data Collection

The primary data gathering technique include household survey, field visit, questionnaires, key information interviews, customer satisfaction, focus group discussion, and personal observation and informal discussion.

3.3.1.1. Pressure measurements

Pressure measurement throughout the entire day was conducted at different zones in the distribution system. A Pressure gauge is used to determine the line pressure and the size of the leak hole is measured, though error may be introduced due to irregularity of the shape of the hole. Depend on easy to identify the problem, topography and technical point of view all the pipe network system divided in to three zones:-Zone-one from balancing reservoir(Bojebare) to1000m^3 service reservoirs(Wolkite),Zone-two from 1000m^3 ground reservoir to the down part of the reservoir and Zone-Three from 15m elevated 100m^3 reservoir to upper part of the reservoir. At location where pressure gauges were installed, elevation readings were also taken. Critical times were selected while pressure gauges were taken. These critical times were fixed based on the peak hour demand rate of the users which covers the time between 8:00-12:00 (early mid noon), 2:00-6:00 (after noon), 8:00- 12:00 (early mid night) and 2:00-4:00 (early morning: (Lambert and McKenzie, 2001).From the sample measured average maximum pressure is 129.7 m and average minimum pressure is 31.3m.

Zone name	Elevation avg (m)	Pressure day avg.(m)	Pressure night avg.(r
Zone 1	2310	129.3	130.1
Zone 2	1878	30.5	32
Zone 3	1804	48.5	49
Average pressure		69.4	70.36

- **Field survey data**

Source (spring) to balancing reservoir ($500m^3$)

Site	X	Y	Z	Diam(Inch)	Village
Spring	376857	901168	1924	0	Bojebare minch
pump house	376801	901198	1921	12	
	376898	901225	1944	12	Tedey water
	377138	901130	1947	12	
	377348	901094	1949	12	
	377744	900954	1960	12	
	378117	900891	1974	12	Yterek Eden water branch
	378471	900871	1988	12	Joinig with emedeber pipe lines
	378686	900784	1982	12	
	378879	900702	2014	12	
	379068	900658	1941	12	Asephalet crossing area
	379330	900369	2012	12	
B Reservoir ($500m^3$)	379525	900190	2024	12	Emedeber Tekutenee village

From the balancing reservoir to service reservoir and all distribution line survey data shown in appendix 7.

3.3.1.2. Population Forecasting

Direct population count and projection based on pre-counted population are two possible approaches to collect population data. However, since direct population count at any time requires a great deal of resource and time, it is not usually preferred. Different population forecasting methods are in fact available and can be used for population projection. But their result varies from one method to another. For fast growing city, where relatively high economic activity is observed and at the same time continuous expansion of city due to various reasons is experienced, exponential method population forecasting is preferably used (MoWR, 2012).

Exponential population forecasting method is expressed as follows;

$Pn = Po\ e^{Rn}$……………………………………………………………………………….…3.1

Where: - Pn = population at n years

R = growth rate

Po = base year population

e = constant

n= number of year

- The Wolkite town Population projection analysis data shown in appendix.9.

3.3.2. Secondary Data Collection

Secondary data was collected from legal organizations, agencies, and literatures, the following secondary data include:-

3.3.2.1. Hydraulic analysis

Hydraulic analysis of main pipe line from design document and used to compare with the hydraulic analysis result made by using primary surveyed data. Hazen William formula the head loss due to pipe friction (hf) computed the result.

$$H= \frac{10.675*L*\left(\frac{Q}{1000}\right)^{1.85}}{C^{1.85}(D*0.0254)^{4.78}} \text{……………………………………………………...3.2}$$

Where H= head loss (m)

Q= flow rate (m^3/sec), L= length of pipe (m)

C= Hazen William's coefficient of the pipe material, D=diameter of pipe

$$V= \frac{Q}{\frac{(\pi D)^2}{4}} = \frac{Q/_{1000}}{\frac{(\pi * D * 0.0254)^2}{4}} \text{………..………………………………………………………3.3}$$

Where V= velocity,

Q= flow rate (m^3/sec), D = diameter of pipe

$$L= \sqrt{(X2-X1)^2+(y2-y1)^2+(Z2-Z1)^2} \text{…………………………………………3.4}$$

3.3.2.2. Existing water source and pump

Table.3.1. Existing water source, **(**Source:-WTWSSE)

Name source	Types of sources	Q(l/s)	Constr. Year	Pump position(m)	GPS location			current condition
					X-	Y-	Z(m)	
Bojebare	Spring	80	2003	5	376857	901169	1934	Good
Rekboka	Borehole	2	1982	90	365073	916376	1887	Good
Rebu	Borehole	5	1996	102	366626	921101	1767	Poor
Tatesa	Borehole	2.5	1989	132	369146	915951	1845	Poor

Figure.3.3. Bojebare spring source

3.3.2.3. Per capita demand and some other relevant standards.

Table.3.2. Average Demand

S/N	Connection Type	Per Capita demand(l/c/day)	Number of population per service(2021)	Average Demand(l/c/day)	Average Demand(m^3/day)
1	Private house connection	60	3,195	159732	159.732
2	Private yard	30	93,709	2811283	2811.2832
3	Private yard shared	40	9,584	383357	383.3568
Total					3,386.4088

3.3.2.4. Customer data as per level of connection

These data were collected which used to analysis the coverage. From wolkite town water supply and sewerage enterprise yearly report collected the four year consecutive customer data are shows in the following table.

Table.3.3. customer data as per level of connection.

Type of customers	Year			
	2010	2011	2012	2013
Domestic	8225	9112	10334	11651
Commercial	1112	1278	1284	1291
Institutions	121	156	152	156
Industries	3	3	3	3
Total connection (costumer)	**9461**	**10549**	**11773**	**13101**

3.3.2.5. Number and type of customers

The number and type of customers with their corresponding meter type has been collected from the town water supply service office that can be used in the determination of real and apparent loss. The length of service connections are also summed up as it is required for the determination of real loss in the distribution system. Meters according to their size and type were also identified.

3.3.2.6. Town Water Reservoir

The reservoir's data including their capacity, years of construction & material of construction were also collected.

Figure.3.4. Wolkite town Water Reservoir

- Water supply storage (Reservoir)

Table.3.4. Reservoir data

Reservoir Name	Capaci (m^3)	Construction material	Constr. Year	GPS Location			Kebele	Specific Locality name
				Z(m)	X-	Y-		
Balancing	500	Concrete	2002	2022	379525	900190	Yefek terek	Cheha
Elevated Tanker	100	Concrete	2002	1911	365884	916797	Menaheria	Wolkite
Service Reservoir	1000	Concrete	2002	1905	365787	916601	Menaheria	Wolkite

Source:-Field survey and WTWSSE

Table.3.5. the design aspects of reservoir and valve chamber

Parameters	Balancing reservoir	Service reservoir	Valve chamber
Area $A = \pi r^2$	200.6 m^2	254 m^2	27.75 m^2
Type	Circular concrete structure	Circular concrete structure	Rectangular structure
Height(depth)	3.0 m	8 m	3 m^2
Diameter	16 m	18 m	
Volume V= hπr^2	602.88 m^3	1498.6m^3	74.25 m^3
Finished water storage		1498.6 and 1000 m^3	

Source: - Design Document

3.3.2.7. Water production and Water consumption

Table.3.6. Water production and Water consumption

Year	Total production(m^3)	Total Billed data (m^3)
2018/10	1171119	701276
2019/11	1170259	716376
2020/12	1095627	656001
2021/13	1022454	725483

Source:-WTWSSE

3.3.2.8. Population data

According to CSA (2007), the total population of Wolkite Town was 28,866. But in 2018 population projection editing because the master plan of the Wolkite town expand and included rural Kebles in to the town. The federal agency of house the current population growth rate of the town send to the wolkite town Plan and development office in 2018, based on this the current projection populations of town are (2018) 92,517, (2019)96,957, (2020) 101,611, (2021)106,488 and (2022) 111,600 the growth rate was 4.8. (Wolkite town plan and development commission office 2022**).**

Table.3.7. Current population number of Wolkite Town

No.	Year	Male	Female	Total
1	2018	45333	47184	92517
2	2019	47509	49448	96957
3	2020	49789	51822	101611

3.4. Water Supply Coverage Analysis

The domestic water supply coverage of the town was evaluated based on the average per capita consumption and level of connection per family. The average per capita consumption has been derived from the yearly consumption that was aggregated from the individual domestic water meters.

Average Demand by mode of service using this expression.

Average Demand for Town=Number of Population *Per Capita Demand……………...3.5

Water coverage = quantity of water supply/quantity of demand *100………………..…3.6

3.4.1. Average Daily Per Capita Consumption

The average daily per capita consumption of the town was computed using this expression.

$$\text{Aversge Per capita consuption}\left(1 \Big/ \frac{\text{person}}{\text{day}}\right) = \frac{\text{Annual billed data }(\text{m}^3) * 1000\text{L/m}^3}{\text{Populaton Number of each keble.} * 365\text{day}} \text{………..3.7}$$

3.4.2. Level of Connection per Family

Level of water connection per family is one mechanism to evaluate the level of water coverage.

$$\text{Level of Connection per family} = \frac{\text{Total number of annual Connection by each kebee}}{\text{Number of Populaton by keble/Average family size}} \ldots\ldots\ldots\ldots..3.8$$

3.4.3. Factors Affecting Per Capita Demand

Per capit demand is the annual average amount of daily water required by one person, and include the domestic uses, industrial uses, public use, wastes, thefts it was expressed as:-

$$\frac{(\text{Total yearly water requirement of the city in liter}(\mathrm{m}^3)}{\text{design population} * 365} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.9$$

Per capita demand depends on, size of the city, climate conditions, habits of people, industrial and commercial activities, quality of water, pressure in distribution system & cost of water (Santosh K, 2012).

- **Water demand:-**The water use/demand in the distribution network classified in to three:- Domestic, Industrial and Other use (Alkhatib, 2012).

- **Domestic water use** is the quantity of water required for various domestic usage such as bathing, drinking, cooking, food preparation, washing clothes etc. Expressed as:-

$$D = \quad dn \times N \times 365 \times \ 10^{-9} Mm^3/\text{year} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.10$$

Where D = domestic use dn = per capita consumption (L/cd), N = population served

- **Industrial water demand**: –

$$\mathrm{I} = Av \times N \times 365 \times \ 10^{-9} Mm^3/\text{year} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

Where N = Total population served at n^{th} yea

Av = average industrial consumption

- **Other use** :-the water demand for other use (O) is computed as :-

$$\mathrm{O} = On \times N \times 365 \times \ 10^{-9} Mm^3/\text{year} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.12$$

Where N = Total population served at n^{th} yea

$On =$ Average other use consumption L/c.d at n^{th} yea

- **The total water demand** (WD) in to the distribution network is given by:-

$$\text{WD} = \text{D+I+O} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.13$$

Where WD = water demand

D = domestic water demand

I = Industrial water dema O = other uses

3.5. Water Loss Analysis

3.5.1. Statistical Analysis of Water Losses

1. Evaluation of water loss (unaccounted for water) analysis at town level

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water loss for the entire town. The 12 months water production and consumption was derived using the following expressions (Mebet, 2007).

$$\text{Total water loss\%} = \frac{\text{Total water produced} - \text{Total waterbilled)}}{\text{Total water produced}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.14$$

2. Water loss as per number of connection

Water loss expressed as a percentage could be an appropriate means to show the extent of the loss within a given environment, but it is not a good indicator for comparing the loss from one area to another. According to some literature comparison of water loss between different areas is recommended to be done using the water loss per service connection per day. Taking the total number of connection in the town and annual consumption for the similar duration was derived the following expiration, (Mebet, 2007).

Water loss = Annual total loss *1000/ (Number of connection*365)…………..…3.15

3. Water loss expressed as per length of pipes and age

Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non-densely populated areas using the total pipe length of the entire city, the water loss per kilometer length of main pipes will be derived to be evaluated for the following expiration (Mebet, 2007).

$$\text{Water loss Per pipe age } \left(\frac{\frac{m^3}{Km}}{day}\right) = \frac{\text{Annual Consumption}(\,m^3)}{\text{tota piplength of each year(km)}*365} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.16$$

3.5.2. Analysis of Water Loss Components and Performance Indicators

3.5.2.1. Water Loss Components

1. Water loss (Real and Apparent losses)

This volume of water lost in the system was evaluated by taking the difference of the system input volume and the authorized consumption.

1.1. Unavoidable Annual Real Losses (UARL)

UARL can be assessed using a formula developed by the IWA water losses task force. Data required for this assessment are the number of service connections (Nc), the length of mains (Lm in km), the length of private pipes (Lp in km) between the street: property boundary and customer meters, and the average operating pressure (P meters).

UARL values have now been calculated for several hundred diverse systems worldwide. The general equation for UARL is:

UARL (liters/day) =18xLm+0.8xNC+25xLP) x P……………………………………3.17

Where Lm= Mains length (km) NC= number of service connection

Lp = total length of private pie, property boundary to customer meter (km)

P = average pressure (m).

1.2. Apparent losses

Apparent loss = Total NRW – UARL…………………………………………………3.18

1.3. Customer Metering Inaccuracies

Customer metering inaccuracies are defined as the discrepancy between the amount of water actually consumed and the amount of water reportedly consumed due to under or over registering meters (Sarah, 2006). This type of error can be beneficial or detrimental to the utility, although typically meters tend to under-register more often than over-register. A general expression for estimating this metric is:

M Error =V (1-A)……………………………………………….…3.19

Where M, error=Apparent losses due to meter errors (m^3/year).

V = Billed metered consumption (m^3/year),

A = Average meter accuracy

I. Infrastructure Leak Index (ILI)

It is the ratio of the current annual real losses (CARL) to the unavoidable (technical minimum) annual real losses (UARL). It is calculated as follows (Liemberger & Farley, 2004)

$$ILI=\frac{CARL}{UARL} \quad \text{……………………………………………}3.20$$

II. Performance indicator Assessment

There are different measures for assessing the water supply system performance yet they have not been subjected to comparative interpretation over a range of different water utility condition worldwide (Mutikanga et al., 2010).

1. Financial Performance Indicators (FPI)

1.1. Non-Revenue Water: as % of system input volume

This volume was described as the water which does not provide any revenue to the utility. It should not be used for assessing any aspect of operational performance management of water losses (Liemberger & Farley, 2004). It is given by the Expression:

$$NRW\ (\%) = \frac{\mathbf{Qin-Qrevenue}}{\boldsymbol{Qin}} * \mathbf{100\%} \quad \ldots\ldots 3.21$$

Where Qin = annual system input volume

Q revenue = annual billed volume

1.2 Non-Revenue Water: as % of cost of running system:-the detailed financial PI for non-revenue water is based on the percentage by value of the water, rather than the percentage by volume (Mutikanga et al., 2010). A general expression for estimating this metric is:

$$NRW\ (\%) = \frac{\text{cost of Non Revenue water}}{\text{cost of oprating system}} * 100\% \quad \ldots\ldots 3.22$$

2. Operational efficiency Performance Indicators (OPI)

2.1. Apparent loss per service connection

The purpose of this operational indicator was to evaluate the volume of apparent losses per service connection in the utility system. This is a useful indicator to compare between utility systems (Sarah, 2006). It is calculated as equation:

Apparent loss (L/Connection)/day=V Apparent/Nc……………………………………3.23

Where: V Apparent = Volume of apparent loss per day (m^3/day)

NC = Number of service connections

2.2. Real Losses per service connection

The objective of this performance indicator is to measure the efficiency of the water supply system (Mebet, 2007) it is given by the expression:

$$\text{Real loss (l/con/day)} = \frac{\mathbf{VReal}}{\mathbf{Nc}} \quad \ldots\ldots 3.24$$

Where V Real is the volume of real loss per day (m^3/day

3.6. Assessment of Customer Satisfaction

To assess customer satisfaction evaluation of town water supplies are the following steps.

- 250 page questionnaires 12 questions in each page are prepared and printed.
- Distributed the questionnaires in to the 3 sub cities of the town (Addis, Bekur and Gubure-sub cities).

- The random sampling is used to distribute the questionnaires but the total subsystem area is considered.
- Based on Wolkite town water utility customer's connection type Distributed from the total questionnaires private yard connection79%, Institutional 13%, and industrial customers 8%.
- To distributed questionnaires from house to house & interview the customers by using 1st degree engineer friends and using daily labors have water maintenance profession paying per diem.
- Collect data's from 240 customer's take target samples and try to cover the whole but to take above 240 sample have financial problem because there is not any external financial support from other covered by myself.
- Excel chart is used to analyze the questionnaires and the output is analyzed.

3.7. Summary of Methods Followed

The water supply coverage of the town was evaluated before analyzing the water loss. In evaluating the water supply coverage focused on the volume of consumption and level of water connection as these are highly related to the issue of water loss. Analyzing the actual water production rate with the design document variability was stated. The overview of the summary of methodology flow chart is described by Figure 3.5 below;

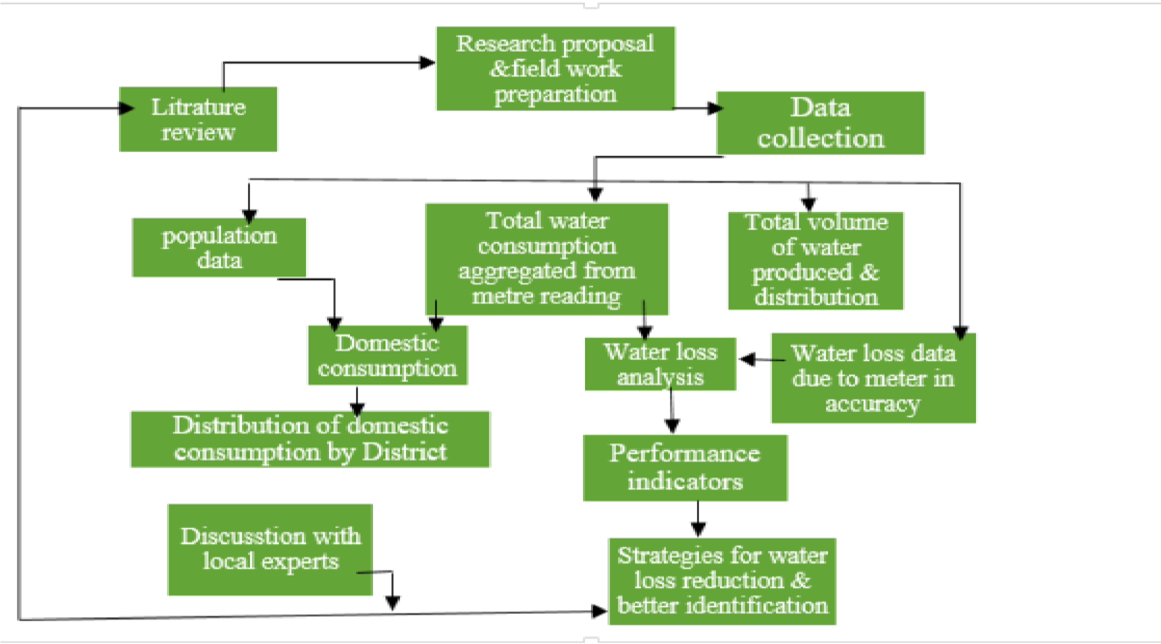

Figure 3.5. Summary of Methods Followed

CHAPTER. 4. RESULTS AND DISCUSSIONS

4.1. Water Supply Demand and Coverage in Distribution system

Problems in provision of adequate water supply to the rapidly growing urban populations are increasing dramatically. Water demand in the domestic sector of developing town including wolkite town increases through time that as a result demands for additional water sources and infrastructure. Despite to these the financial capacity of the city is low to satisfy the growing demand. In this research is to evaluate related to the quantity of supply and level of connection that 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 for the town. The level of coverage has been also compared with other cities of developing countries. Beside to the statistical analysis for the entire city the distribution of the average daily per capita consumption and connection per family has been evaluated.

4.2. Analysis of Water demand

A water supply system capable of supplying sufficient quantity of portable water is necessary for town. In order to estimate as correcting as possible, the total demand of a particular community, all demands must consider. Generally speaks in design the water supply scheme. For a town, it is necessary to determine the total quantity of water required for various proposes.

4.2.1. Population Forecasting

Direct population count and projection based on pre-counted population are possible approaches to collect population data. However, since direct population count at any time requires a great deal of resource and time, it is not usually preferred. Different population forecasting methods are in fact available and can be used for population projection. But their result varies from one method to another. For fast growing city, where relatively high economic activity is observed and at the same time continuous expansion of city due to various reasons is experienced, exponential method population forecasting is preferably used (MoWR, 2012).Exponential population forecasting method is expressed as follows;

CSA's Country Level urban Population Growth Rates 2007 report

Year	Urban Growth rate %
2022	4.8
2023	4.06
2025	3.95
2030	3.72
2035	3.42
2040	3.07
2045	2.68

Table.4.1. Forecasting of wolkite town population

Year	Projected population
2021	106,488
2023	115,496
2025	124,990
2030	150,541
2035	178,615
2040	208,249
2042	219,716

4.2.2. Domestic water demand

It includes water finished to in- house purpose such as drinking, cooking ablution washing utensil washing clothe, washing toilets, watering animal. The amount of water used for domestic purpose varies depending on the life style living standard, climate mode of service and all the price of water and affordability of users.

4.2.2.1. Demand Computation by mode of service

The following are the most common model of domestic service in Ethiopia and are used in Wolkite town.

Table.4.2. Demand Computation by mode of service

S/N	Connection Type	% of Population By mode of Service	Number of population per service(2021)
1	P H C	3	3,194.64
2	Private yard	88	93,709.44
3	Private yard shared	9	9,583.92
Total		100	106488

4.2.2.2. Average Demand by Mode of Services in the Town

According to the current standard of the country the third level towns like Wolkite have the following per capital demanded and the calculated average demand is shown in table below.

Average Demand for Town=Number of Population *Per Capita Demand

Table.4.3. Domestic water demand categories of consumer:

	Stage 1	Stage 2
Private House connection (HC)	50 l/c/day	70 l/c/day
Private Yard connection, own (YCO	25 l/c/day	30 l/c/day
Yard connection, shared (YCS)	30 l/c/day	40 l/c/day
Public tap supplies (PT)	20 l/c/day	25/c/day

Source .Design criteria of MoWR (2006)

4.2.2.3. Analysis of Average Domestic Demand

According to the MoWR standard the Wolkite town was third level towns, it has the following per capital demanded and the calculated average demand is shown in table below.

Table.4.4. Analysis of Average Domestic Demand

Connection Type	Per Capita Demand(l/c/day)	No.of population perservice(2021)	Average Demand(l/c/day)	Average Demand(m^3 /day
Private house connection	50	3,195	159732	159.732
Private yard	30	93,709	2811283	2811.2832
Private yard shared	40	9,584	383357	383.3568
Total				3,418.3

4.2.2.4. Level of Domestic Water Supply Coverage

Access to water supply may be evaluated using the amount of water consumed and the level of Connection. For evaluating the amount of water consumption, the annual water consumption is converted to average daily per capital consumption using the population data of the city. The number of domestic connection per family has been also used for analyzing the level of connection as elaborated below. Taking the total number of connection in the town and annual consumption for the similar duration was derived the following expiration**,** (Mebet, 2007).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. The average daily per capital consumption of the town was computed using this expression.

From the analysis of average per capita consumption of the wolkite town found to be 17.6 and 18.6 L/person/day, while an overview of GTP-2 Provide urban water supply access with minimum service level of 60 l/c/day for category 3 towns with a population in the range of 50,000 -100,000), according to the standard set by MoWR wolkite town was third level and average per capital consumption is lower while compared with the minimum requirement of domestic demand which is 25 l/c/day set by Wallingford HR. Based on the above results wolkite town water supply consumptions are very less.

4.2.3. Non-Domestic Water Demand

Non-Domestic demand is a quantity of water required for various non- domestic needs, Non – domestic demands are:-

S/N	Institutions	Consumption
1	Restaurants	10 l/Seat
2	Boarding school	60 l/Pub
3	Day schools	5 Lit/Pub
4	Public offices	5 l/employee
5	Workshop/shops	5 l/employee
6	Mosques & Church	5 l/worshipper
7	Abattoir	150 l/cow
8	Hospitals	50-75 l/bed
9	Hotels	25-50 l/bed
10	Public Bath	30 l/visitor
11	Public latrines	20 lit/seat

Source: Design Criteria Guide Line of MoWR (2006)

4.2.3.1. Institutional demand

• The water demand for educational institutes

In the Wolkite town there are seventeen elementary and junior schools with 24,310 number of students, and five high school with 9395 students a total 33,705 students attending day school (WTAEO, 2022). Based on the analysis results of educational institutional demands of wolkite town is 168.525 M^3/day or 61,511.625 M^3/year.

- **University and collage**

In Wolkite there is one University and Collage the maximum number of student's trainee staff and supporting staff around 17,000.based on the data the results of the demand is 1020m^3/day or 372,300 m^3/year.

- **Health institutes**

Health institution there is one hospital, three health center and sixteen medium and seven primary totally 23 private clinics with a total of about 200 beds and number of public toilets 6 (Wolkite town health office, 2022).based of the data the result is 10m^3/day or 3650m^3/year.

- **Public and governmental offices**

According to CSA about 51% of the population of Wolkite town is economically active and 7% of the population of Wolkite is employed in public or government offices. And their consumption is recommended as 5 l/c/d. The results of the demand is 37.27 m^3/day or 13,603.842 m^3/year.

4.2.3.2. Commercial demand

Wolkite town is the most commercial center and transit polite for an estimated above 10,000 visitors per day. Wolkite town is a centers visitors passing through the town come from part of the country of to western parts of Ethiopia (Jimma,MizannTapy,Bonga,Agaro,kefa,Gamebela ,Bedele) and to Easter parts of the Country(Butajera, Shashemene,Hawassa,Hosana,wolayta ,Areba Minch and other parts of Ethiopia. The water demand of the hotels, bars and restaurants estimated as by taking the consumption in 2021 is 250m^3/day or 91250 m^3/year.

4.2.3.3. Industrial water demand:-

Industries in small to medium size Ethiopian towns are in most cases light industry with a demand of some 5 m^3/ha/day. In case of larger industries, the demand will have to be assessed individually for each industry through detailed interviews. Considering the development opportunity of the town in the future 5% of the average domestic demand is taken. There are three Industries in Wolkite town at present which have a total land area of about 71.773m^2. The estimated industrial demand is 170m^3/day.

Table.4.5. Non-Domestic Demand

S/N	Institutions	Demand (M^3/day)
1	Day School	168.525 m^3/day
2	University and Collage	1020m^3/day
3	Health Institution	10m^3/day
4	Public and Government office	37.27 m^3/day
5	Commercial demand	250m^3/day
6	Industrial Demand	170.9 m^3/day
Total Sum		**1,656.7 m^3/day**

Table.4.6. Domestic and Non-Domestic Demand (2021)

S/N	Item	Demand (M^3/Day)
1	Domestic	3,418.3 m^3/day
2	Non-Domestic	1,656.7 m^3/day
	Subtotal	5,072 m^3/day
3	30% loss(for scheme having 10 year service)	1521.6 m^3/day
Total Sum		6596.6 m^3/day

- **The total water demand** (WD) in to the distribution network is 6,596.6 m^3/day.

4.2.3.4. Average water demand

There are several mathematical methods of estimating the water demands of a given town; including extrapolating historical trends and correlating demand with the socio economic variables of the town. But, the most common means of forecasting future water demand is estimating current per-capital water consumption, and multiply this by the projected population figure. Therefore, the average water demand for Wolkite town (2021) was calculated to be 3,418.3 m^3/d and the total demands are 6,596.6 m^3/day.

4.3. Evaluating the distribution of Water Supply Coverage

The water supply coverage of the Town has been evaluated based on the average per capita consumption and level of connection per family. The average per capital consumption has been derived from the yearly consumption of the town that has been aggregated from the individual domestic water meters. Beside to the average per capital water consumption, the distribution number of domestic's connection per family has been also evaluated.

4.3.1. Water Production and Water Consumption

The annual water supply production for wolkite town is obtained from 3 boreholes (Tatesa ,Rukabuka and Rebu) and springs located Bojebare around 30 km away from the Wolkite town. The annual water production from the water supply service is collected on the monthly base and then converted to yearly base for the evaluation purpose. The production of the water for distribution purpose is from the boreholes and the spring sources. Here below are presented the production for the year 2021 both in tabular and in chart form.

Table.4.7.Monthly Consumption and production Year 2021

Month (2021)	Production (m3)	Total Billed data (m^3)
January	85325	55575
February	87267	55688
March	65881	55605
April	85462	74883
May	84086	66089
June	94897	69583
July	98453	50808
August	99453	64968
September	86342	64216
October	68470	58124
November	80768	56050
December	86050	54894
Total	1022454	725483

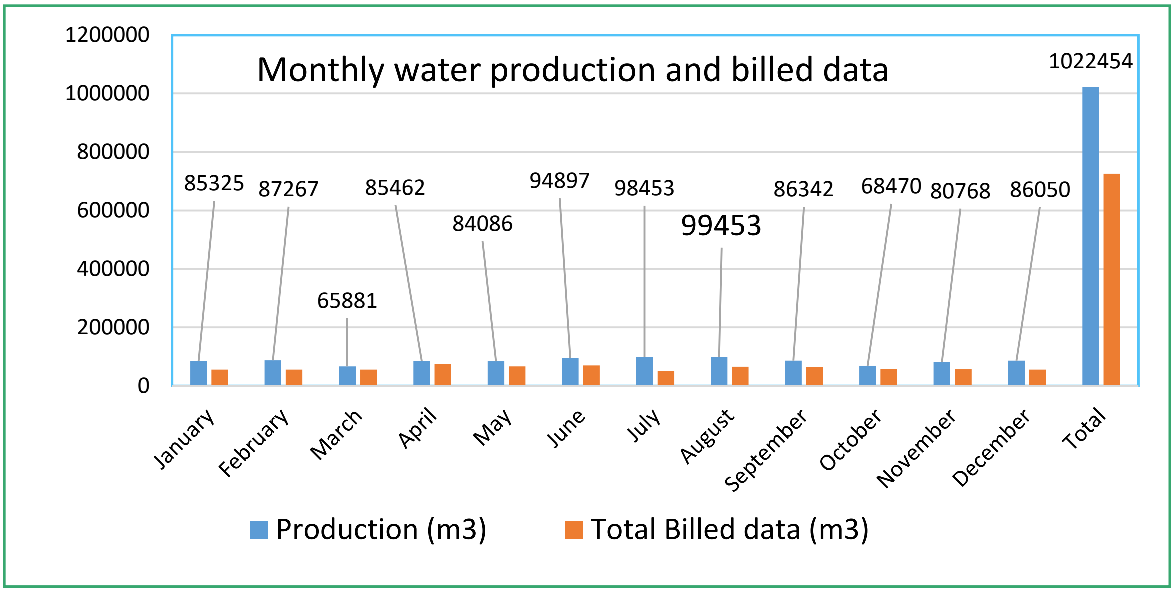

Figure. 4.1. Water production and consumption comparison

As shown in the Table 4.7 and Figure 4.1 above the lowest water production in 2021 was recorded in March and highest production in August .The lowest water consumption in 2021 was recorded in July and highest consumption in April. Generally, the water production shows seasonal variation with highest production in summer (Kiremt) and lowest production in winter (Bega) and spring (Tseday).From the data analysis the highest production in August above 34% of the production does not reach to the consumers. Analysis shows there is high loss in water supply system.

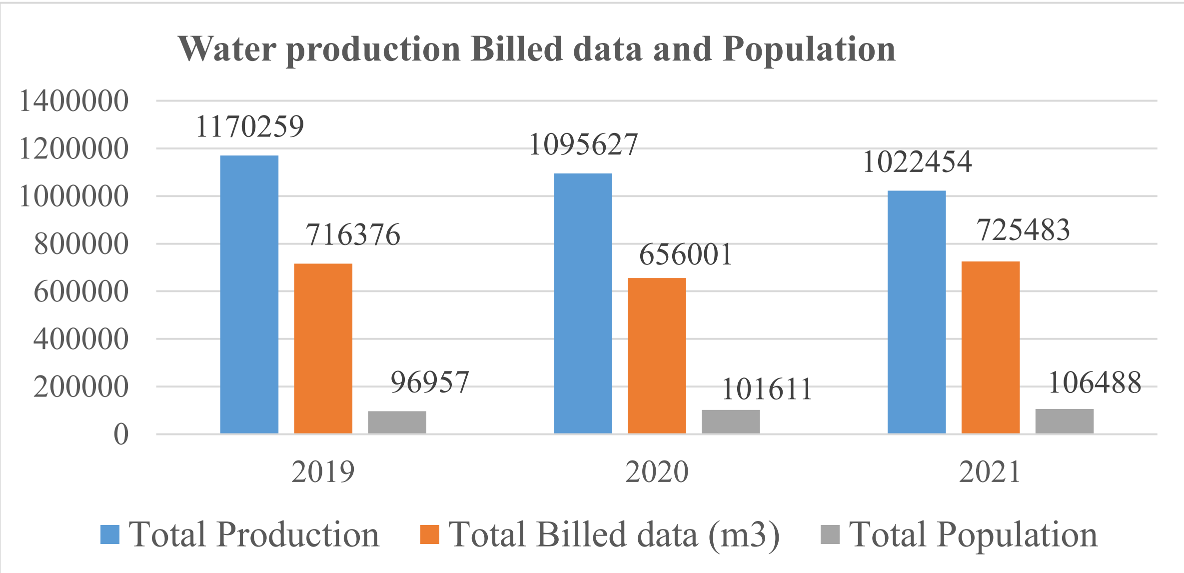

Figure. 4.2. Water production and population relation (2019-2021)

The annual water production rate in 2019-2021 was 1170259m^3, 1095627 and 1022454 m^3 respectively and the annual population number in 2019-2021 was 96957,101611,106488 respectively. The water produced and number of population in the three year as shown in the above figure 4.2.The water production of the wolkite town shows a decreasing trend from year to year but the number of population was increase from year to year. From 2019-2021 the town population was increased by above 9% but the water production of the wolkite town was deceased by 13% from 2019-2021. Reasons the production of water decreases and population number increase, pumps and electric power problems, and the expansion of the town.

To increase the water production reduce losses, reduce unplanned connection and to balance water production and number of population create additional source.

4.3.2. Comparison between Population and Billed Consumption

It is necessary to evaluate consumption with population. This has been evaluated using the correlation between the water billed consumption & number of population. Water consumption by number of population graphically illustrates are shown below Figure 4.3 volume of water consumption increase and number of population also increase.

Year	2019	2020	2021
Total Billed data (m^3)	716376	656001	725483
Total Population	96957	101611	106488

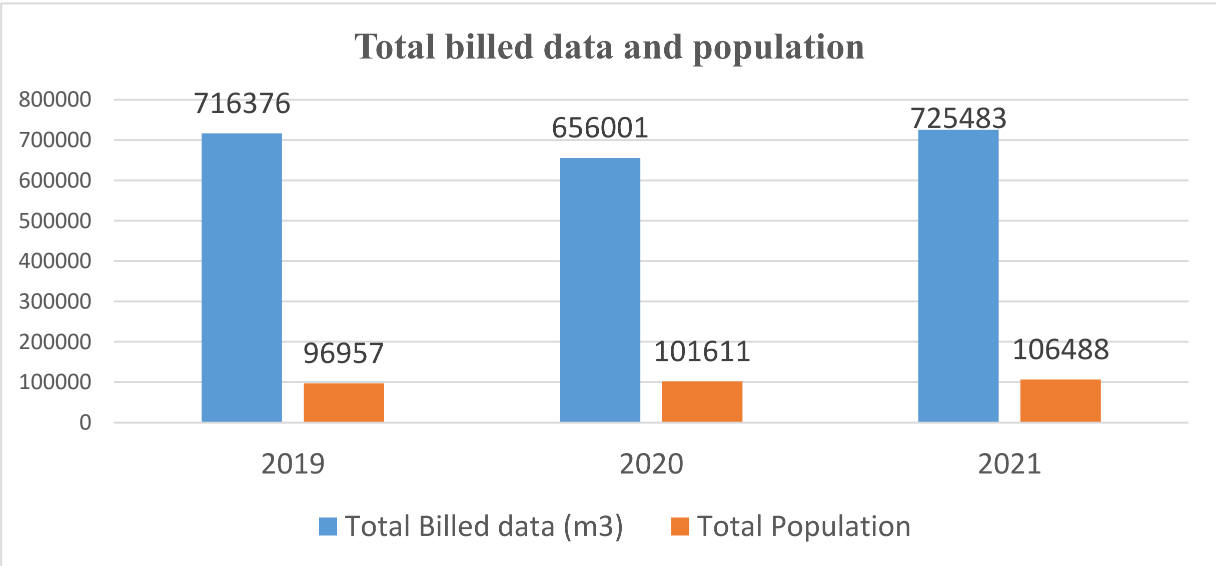

Figure. 4.3. Yearly water consumption vs population

Table.4.8. water production, Billed data and Population

Year	Total production(m^3)	Total Billed data (m^3)	Total population
2018/10	1171119	701276	92517
2019/11	1170259	716376	96957
2020/12	1095627	656001	101611
2021/13	1022454	725483	106488

4.3.3. Average Daily per Capita Consumption

The level of water consumed for domestic purpose has been aggregated to the town so as to analysis the distribution of the water coverage. Statistical analysis was used to evaluate the distribution of the supply coverage of the town. Evaluating the domestic water supply coverage using volume of consumption may not allow realizing the distribution comparison. For this reason the annual consumption data has been converted to average daily per capital consumption using the number of population. The average daily per capital consumption of the town was derived using the following expressions.

Table.4.9. Average Daily per Capita Consumption of the Town

Year	Total production(m^3)	Total Billed data (m^3)	Total population	production $\left({}^{l}\!/\!\frac{\text{person}}{\text{day}}\right)$	Consumption $\left({}^{l}\!/\!\frac{\text{person}}{\text{day}}\right)$
2018	1171119	701276	92517	34.6	20.7
2019	1170259	716376	96957	33.1	20.2
2020	1095627	656001	101611	29.5	17.6
2021	1022454	725483	106488	26.3	**18.6**

The distribution of the domestic water coverage has been evaluated using the above statistical tools. The distribution of the production has been first reviewed using the descriptive statics. Taking the mean production as shown in above the average domestic water production of the wolkite town is found to be 26.3 l/per/day and the consumption of the towns are 18.6l/per/day in 2021. The average daily per capital production of the town is low b/c from this production more than 30% are loss before reach to costumer, while an overview of GTP-2 Provide urban water supply access with minimum service level of 60 l/c/day for category 3 towns according to the standard set by MoWR, wolkite town was third level town. Based on the above results wolkite town water supply consumption and productions are very less.

4.3.4. Level of connection per family

Level of water connection is an important element on the one hand for evaluating the level of water coverage that was the focus of this section and on the other hand it has a direct impact on the water loss that was detail separately. The total numbers of connection or water meter in the Wolkite town water supplies are 13,101 connection among those, for domestic 11,651 use. In order to compare the distribution of the water connection among the different parts of town, the total numbers of connection are converted to connection per family using the population data. According to the census of the 2010, average family size of 5.5 is used for calculating the average number of connection per family using the following expression. Similar to the per capital consumption, and the connection per family has been evaluated.

Table.4.10.Level of Connection per family

Year	Total population	Average family size	Total number of connection	Level of connection
2018/10	92517	5.5	9461	0.56
2019/11	96957	5.5	10549	0.6
2020/12	101611	5.5	11773	0.63
2021/13	106488	5.5	13101	**0.67**

In this analysis the per capital consumption after evaluating for outliers, the average connection per family for the entire wolkite town is found to be 0.61. This implies that at average two families and or eleven persons are sharing one connection or water tap. In other words the average in-house or yard connection of the town is about 61%. Similar to the per capita consumption, the distribution of the level of connection per family shows variation among districts and this has been evaluated using the above table.

Table.4.11.Domestic Water Supply Coverage

Year	consumption (m^3)	Population	consumption m^3/pers/year	consumption ($^l/_{\frac{person}{day}}$)	Production (m^3)	Annual demand	% of coverage
2019	716,376	96,957	7.4	20.2	1170259	2,249,561.8	52
2020	656,001	101,611	6.45	17.6	1095627	2,318,667.98	47.2
2021	710,483	106,488	6.81	18.6	1,060,108	2,407,759	44

The analysis of water coverage as per domestic and non-domestic demand.

The result shows as the total average demand is 6596.6m^3/day. However, the amount of water production in 2021 shows as 1,060,108m^3/year, which have only 44% coverage of the demand. Therefore, the result shows there is high gap between demand and supply. The above table shows that the annual production for the year 2021 is almost decreased by above 9.4% the annual production for the year 2019). This is due to increase number of population, expansion of urbanization decrease water productions from year to year, unplanned connection which are found in gravity main lines between balancing reservoir and service reservoir and there is abundant boreholes.

As clarified earlier the water supply coverage of the town, both in quantity and level of connection is low accordingly in GTP-1 the water supply access coverage has reached to 75.5%, 84.1% and 76.7% in urban, rural, and national respectively but wolkite town still now less than and half of the GTP-1 coverage. In areas where water supply coverage is sufficient, volume of domestics water consumption is expected to be linear related to the level connection. Areas having better level of connection are expected to consume more water as they can easily get it within their building or compound. On the other hand in areas having insufficient supply, some areas may have better level of connection but may not necessarily mean they are consuming more volume of water as the possibility of getting the water does not depend only on the location. There are number of places that get low volume of water due to their topographic location. As the town mainly uses gravitational supply system, topography has a great impact on the per capital consumption.

4.3.5. Water distribution network analysis

In the modern water supply system, clear water shall be delivered to the service reservoirs directly through the transmission main and which is completely isolated from the distribution system. But, existing wolkite town water supply system which was constructed before 15 years ago and as it was the old system; water is pumped simultaneously into the distribution network and service reservoir. So, the impact of this network configuration and the capacity of distribution system components were described as below.

4.3.5.1. Reservoirs capacity

In order to provide for security of supplies above the need for balancing purposes it is recommended that the minimum total reservoir storage capacity be in the range of 30% to 50% of the average daily demand. When determining the level of storage, within the above range, the following criteria will be considered:

- Reliability of pumping arrangements at the source works,
- Reliability of electricity supplies if 100% standby generation capacity is not provided,
- socio-economic status of the town or an indicator of the level of qualified staff available for system operation,

The capacities of reservoirs in the water supply system were determined using different methods (MoWR, 2006)**.**The peak hour and Maximum day factor varies inversely with the size of the consumer base.

Table 4.12. Peak hour and Maximum day factor

Population Range	**Peak hour factor**	**Maximum day factor**
< 20000	2	1.3
20001 to 50000	1.9	1.25
50001 to 100000	1.8	1.2

Source:-Design Manual of MoWR (2006)

4.3.5.2. Maximum daily demand

The maximum day demand (MDD) represents the maximum consumption during any one day of the year. The ratio of the maximum daily consumption to the mean annual daily consumption is the maximum day factor. The maximum day demand (MDD) wolkite town is 7915.92 m^3/day or 91.62 l/s. This demand is used to design source capacity, riser mains, and service reservoir.

4.3.5.3. Peak Hour Factor

Water demand varies greatly during the day. The distribution system must be designed to cope with the peak demand, which is taken into account by the use of a peak hour factor. The peak hour demand is one of the highest demands within any one hour over the year and estimated taking in to account the possible water collection hours and amount collected by each demand category. Previous studies and experiences clearly demonstrate that peak hour factor is greater for a smaller population. According to water supply design criteria prepared by ministry of water resource and tropics studies the proposed maximum day and peak hour factor are 11873.88 m^3/day or 137.43 l/s.

In order to provide for security of supplies above the need for balancing purposes it is recommended that the minimum total reservoir storage capacity be in the range of 30% to 50% of the average daily demand (MoWR, 2006).The Wolkite Town Have three functional reservoirs, 1000m^3 reservoir, one 500m^3 reservoir and one 100m^3 elevated reservoirs which have a total of 1600m^3 reservoir. To check this capacity enough or not the total average day demand as per computed above is 6,596.6 m^3/day &the level of existing storage computed as:- From the analysis shows the storage capacity of existing reservoirs are less than the recommended range, so the wolkite town water scheme is not safe regarding to storage capacity and to recommend the town should be construct additional reservoir.

4.3.6. Discussion I

From the above analysis of average per capital consumption of the wolkite town found to be 18.6 L/person/day, while an overview of GTP-2 Provide urban water supply access with minimum service level of 60 l/c/day for category 3 towns according to the standard set by MoWR wolkite town was third level and average per capital consumption is lower while compared with the minimum requirement of domestic demand which is 25 l/c/day set by (Wallingford,2003). Based on the above results own water supply consumptions are very less.

The average domestic water production of the town is found to be 26.3 l/per/day, the result shows that an average daily per capital production of the town is low b/c from the production more than 30% are loss before reach to costumer.

In the analysis, the average connection per family for the entire wolkite town is found to be 0.61. This implies that at average two families or eleven persons are sharing one connection or water tap. In other words the average in-house or yard connection of the town is about 61%. Similar to the per capita consumption, the distribution of the level of connection per family shows variation.

The other issue that has been addressed was analysis of water coverage as per domestic and non-domestic demand. The result shows as the total average demand is 6,596.6 m^3/day. However, the amount of water production in 2021 shows as 1,060,108 m^3/year or 2,905 m^3/day, which have only 44% coverage of the demand. Therefore, the result shows there is

high gap between demand and supply the analysis shows that the annual production for the year 2021 is almost decreased by above 9.4% the annual production for the year 2019).
On the other hand the analysis shows as the maximum day demand is 7915.92 m^3/day (91.62 l/s) and peak hour demand is 11873.88 m^3/day (137.43 l/s). and also the analysis of the storage capacity of existing reservoirs which have1600m^3 the recommended range was 1978.98 m^3/day to 3298.3 m^3/day, the results shows less than the recommended range, so the wolkite town water scheme is not safe regarding to storage capacity, to recommend the town should be construct additional reservoir. Therefore, to satisfy the demand the pressure main pipe line and the capacity of the pump existing pump should have ability to meet the maximum day demand 91.62 l/s However, the existing pump has a capacity to lift 80 l/s which is 87% of the maximum day demand. This show as possible to need of more pump.

4.4. Water Loss Analysis

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water loss for the sub city. 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 quantity to demands, and correspondingly made challenges to keep the water tariffs in the system at a reasonable level. Water loss for Wolkite town was assessed and discussed as below;

4.4.1. Evaluation of water loss analysis at town level

Water losses in the water supply distribution system, illegal connections, overflow from reservoirs and improper metering etc. referred to as uncounted for water. Unaccounted for water (losses) was expressed as percentage of domestic plus public water demands and is calculated the difference between water produced and water consumed or sold. The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water loss for the entire town.

The 12 months water production, consumption and Loss based on using the following expressions (Mebet, 2007)

Table.4.13. Monthly Production, Consumption and Loss 2021

Month	Production (m^3)	Total Billed data (m^3)	Monthly Loss	Loss%
January	95325	48808	46517	48.8
February	102267	55688	46579	47.12
March	92342	64216	28126	41.8
April	89462	55575	33887	40.8
May	91086	86089	4997	34
June	94897	69583	25314	32.8
July	98453	75883	22570	28
August	99453	64968	34485	29
September	65881	45605	20276	28.9
October	48124	10470	37,654	31.6
November	96768	56050	40718	32.7
December	86050	54894	31156	33
Total	1,060,108	710,483	349,625	**33**

The cumulative average water loss of the wolkite town is in the above table. Ware loss is usually expressed in terms of percentage. Loss per kilometer length of main pipes and loss per property or number of connections. The total water loss has been evaluated based on cumulative production and consumption of the month's years.

Generally based on the analysis results in the above Table 4.13 the total annual or monthly water produced and distributed to the system within the specified year has been 1,060,108 cubic meters and the annual total water loss from the system is 349,625 m^3/year and approximately 33% of the total production. The analysis shows town have high loss of water.

4.4.2. Total Water Loss Expressed As Percentage

The total annual water produced and distributed to the system with in the specified year (2021) has been 1,060,108 M^3 and the annual total water loss as derived using the expression was 349,625 M^3 which accounts of 33% of the total water production.

Table.4.14.Existing Wolkite Town Water Tariff

Consumption ranges in m^3	Price in Br per m^3 by type of users				
	Domestic	Institutional	Commercial	Industrial	Public water points
0- $5m^3$	8.25	8.25	8.25	8.25	10
6-10 m^3	10.9	10.9	10.9	10.9	10
11-20 m^3	14.2	14.2	14.2	14.2	10
Above 20 m^3	17.60	17.60	17.60	17.60	10

Taking the average tariff of water in the city as 12.19 Ethiopian Birr (1 USD=50.98Eth. Birr) the water loss estimated to be 83,910 USD every year (4.3 million Ethiopian Birr) every year. However, the real loss is beyond this as the water tariffs like other developing countries are usually subsidized.

Table.4.15.Water Production, Consumption and Loss (2019-2021)

Year	Production (m^3)	Total Billed data (M^3)	Yearly Loss	Loss%
2019	1170259	716376	453883	39%
2020	1095627	656001	439626	40.1%
2021	1,060,108	710,483	349625	33%

4.4.3. Water Loss as Per Number of Connection

Water loss expressed as a percentage could be an appropriate means to show the extent of the loss within a given environment, but it is not a good indicator for comparing the losses from one area to another. According to some literatures, comparison of water loss between different areas is recommended to be done using the water loss per service connection per day. Taking the total number of connection in the wolkite town in 2021 is 13101 m and the water loss per connection for the similar duration was calculated as 73.1 liter/connection /day. This shows as litters per service connection per day increase water losses also increases.

Table.4.16.Number of connection (customers)

Type of customers	Year			
	2018	2019	2020	2021
Domestic	8225	9112	10334	11651
Commercial	1112	1278	1284	1291
Institutions	121	156	152	156
Industries	3	3	3	3
Total connection (costumer)	**9461**	**10549**	**11773**	**13101**

❖ **Guideline for Water Loss Level**

For systems with per capita consumption of less than 150 l/day the general rule for water loss level is:

- Good condition of system < 250 Liter/connection /day
- Average condition 250 - 450 Liter/connection/day
- Bad condition of system > 450 Liter/connection/day

➢ Another guideline for the water loss level is the "Benchmark" Liter/km mains/day:

- Good condition of system < 10,000 Liter/km main/day
- Average condition 10,000 – 18,000 Liter/km main/day
- Bad condition of system > 18,000 Liter/km main/day

Guideline for Water Loss Level

Source: (UNESCO-IHE, April 2008) Gerhard Zimmer (Experiences from Kfw funded programs).

Taking the total number of connections in the town as 13101 Km, the water loss per connection for the similar duration was 73.1L/connection/day.

4.4.4. Water Loss Expressed as per Length of Pipes

Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non-densely populated areas using the total pipe length of the entire city, the water loss per kilometer length of main pipes was derived to be evaluated for the following expiration (Mebet, 2007).

Table.4.17.Pipe line Length and materials

No	Material type	Diameter(Inch)	Total Length(m)
1	DCI and UPV	12 (304mm)	31,500
2	PVC	8	472
3	DCI	6	3464
4	HDP	6	1539
5	GI	4	5264.8
6	HDP	4	3879
7	PVC	4	14,086
8	GI	3	12998.7
9	HDP	3	7646
10	HDP	2.5	1784.6
11	GI	2	3435.2
12	HDP	2	25,329.9
13	PVC	2 (50mm)	2191.5
14	GI	1.5	1943
15	HDP	1.5	1280
16	HDP	1	1497.7
Total			118,288.4

The other good indicator of water loss in the distribution network is determining loss as per pipe length (liters per kilometer of pipe line per day, l/km/d). Evaluating the water loss as per kilo meter of main pipe is one way to indicate the loss. The total length of pipes of size 50mm to 300mm is 113.57km and these total pipe length used to the water loss per kilometer length of main pipes was express. Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non-densely populated areas. Using the total pipe length of the entire sub city, the water loss per kilometer length of main pipes was calculated as 8.43 m^3/ km/day or 8430 L/Km/day depending on total water loss and total pipe length. This shows that as length of the pipe increases the amount of water losses per day increases.

4.4.5. Analysis of Real and Apparent Loss

Water Losses volume is obtained by deducting unbilled authorized consumption from non-revenue water. Water Losses consist of two components: Apparent Losses and real losses.

4.4.6. Apparent Losses

Sometimes called commercial or non-physical losses, refers to volumes of authorized consumption that reach consumers, but are not billed. They include unauthorized consumption, customer metering errors, errors in estimates of unmetered consumption, and errors throughout the data acquisition Process. The purpose of this operational indicator was to evaluate the volume of apparent losses per service connection in the utility system. This is a useful indicator to compare between utility systems (Sarah, 2006). It was calculated as: the difference between revenue water (NRW) (m^3/year) and unavoidable average real losses.

4.4.7. Unavoidable Average Real Losses (UARL):

UARL is defined as an allowable volume of real losses from the system, which estimates a volume of leaks that are undetectable or would be uneconomical to repair during the year (Liemberger & farely, 2004). During field visit, it was also observed that the utility do not have any recorded data related with average leak flow, number of reported bursts and average leak duration; due to these physical loss in the main was assessed base on the available data, and it was adopted by considering the minimum achievable annual physical losses (unavoidable annual real loss) in the system (Lambert, 2008). The average operating pressure of b/n 20 and 100 meters and the customer meters located 0 and 30 meters from the edge of the street (UNESCO-,IHE, 2008)water loss and distribution system based on statistical analysis of international data).and the wolkite town operating pressure is 21 and 95 meters based on hydraulic analysis of pressure main and gravity lines (show appendex.4 and 5). This category represents the allowable volume of real losses from the system, which estimates a volume of leaks 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 components). Considerable work was undertaken to assess the minimum level of leakage for any system (Lambert, 2008) and after careful analysis a relatively simple and using the developed equations the value of UARL is 278,058.4 M^3/Year and apparent loss is 71,566.6.2 M^3/Year. This value is represents the unavoidable annual real losses (UARA) is the 78% of technically achievable volume of real losses which is 349,625 M^3/Year of at current operating pressure.

4.4.8. Customer Metering Inaccuracies

Customer metering inaccuracies are defined as the discrepancy between the amount of water actually consumed and the amount of water reportedly consumed due to under or over registering meters (Sarah, 2006). This type of error can be beneficial or detrimental to the utility, although typically meters tend to under-register more often than over-register. Based on AWWA acceptable standards of average accuracy range is 0.98-1.015 of any water meters. Billed metered consumption the town 2021 year is 710,483 (m^3/year). Based on a general expression for estimating metric is 38.9 m^3/day.

4.4.9. Infrastructure Leak Index (ILI)

The ILI indicators are defined as a ratio of real losses (RL) and unavoidable annual real losses (URAL). It is a new indicator of water supply systems expressing the technical condition of the system from the point of view of water loss. This indicator is proposed and recommended by the international water association IWA (Lambert, 2008).The infrastructure leakage index for the wolkite town distribution system is calculated as 1.28 m^3/year and this shows us that the current annual real losses are assessed as being around two times as high as the unavoidable annual real losses for the system.

4.4.10. Financial Performance Indicators (FPI)

- Non-Revenue Water: as % of system input volume

This volume will be described as the water which does not provide any revenue to the utility. It should not be used for assessing any aspect of operational performance management of water losses (Farley., 2010). The total annual wolkite town water produced and distributed to the system with in the specified year (2021) has been 1,060,108 M^3 and the annual total water loss as derived using the expression was 349,625 M^3 which accounts of 33% of the total water production. According to GTP-2 plan Decrease urban Non-Revenue Water (NRW) from 39% to 20% by 2020 for urban water supply utilities of 3 category. But the analysis shows Wolkite town water loss becomes increase not decrease.

4.5. Evaluating Possible Causes of the Water Loss

There are several reasons for the high level of water loss generally in Wolkite Town. These factors are given below, and some advisory solutions were briefly proposed in next sections.

4.5.1. Age of Pipe Network

Pipe age is one of the factors that affects the magnitude of the loss specially that of physical loss. Aged pipes are more likely having more water loss through leakage than newly installed pipes. It is estimated that nearly above 60% of the main pipe network in the Wolkite Town was 10-20 years age and the total pipe length of the town was less than 30 years age. The main duties which made more than half a month is checking of each customer (door to door water connection) by sounding rod .In this time, it was found so many invisible & visible leakages both on the private connection & also on the main line. From field survey from 30 km pressure lines I found 28 leakages, burst, this leakages were easily detectable and unplanned connections are found in gravity main lines. So I discussed from the town water head about this unplanned connections and decided to solve the problems. And water loss expressed as per length of pipes age analysis result shows 16.5m^3/km/day or 16500L/ km/day Therefore, this analysis shown that if distribution line is expanded, the age of pipe increase the water loss also increases in the pipe network.

Table.4.18.Wolkite town pipe length and age categories

Age category	All pipes category		Main pipe category		Secondary pipes category	
	Total length (M	% from Total	Pipe leng	%from main total	Pipe length(m)	% from secondary, tota
10 years & less	45,527	38.5	5906	14	39,621	50.3
10-20 years	51,571	43.6	31,500	79.59	20,071	25.5
20-30 years	21,190.4	17.9	2174	5.49	19,016.4	24.16
Total length of Main pipes	**118,288.4**	**100**	**39,580**	**100**	**78,708.4**	**100**

4.5.2. Poor Maintenance of Networks

In some places like pressure main areas including Bojebar source to Balance reservoir,(near Tsedey water, and Yefeketerke Eden water branch) and Balance reservoir to town Service reservoir (Etereke,Worereber, Emateye, Deneb, Gubere)etc. water authorities has performed a maintenance program for distribution system, but in gravity main lines unplanned connections from the main lines and does not maintained by technicians most of the time maintained by non -professionals ,So the areas have high leakages due to poor maintenance.

Thus, the lack of finance to proper materials and poor construction materials resulted in increased leakage in the system.

Figure. 4.4. Picture of leakage due to poor Maintenance

4.5.3. Customer Side Leakage

Many water institutions do not give enough attention for water losses caused as a result of metering errors but it has a considerable impact unless due attention is given like to that of the pipe networks. As per the feedback from the local experts, until recently the water authority was not checking the customer meters by itself unless the customers apply for checkup. However, customers apply most probably when the problem were over-registration rather than under registration.

4.5.5. Damage due to Utility Construction

In the town there are many construction of utility like roads, sewer line, Telecommunication line, etc were worked from time to time. During those utility was constructed water line including main line and customer line were broken and water lose is highly occurred up to the authority technician came and maintain. As it was tried to observe, any contractor or the client of those utility don not care about water line during excavation. Even though when broken the water line and water is highly lose do not report for the authority. So wolkite town water supply and sewerage enterprise were significantly concern this issue and communicate with the owner of those utility before starting excavation or construction and also ready to stand by during excavation on the site especially during excavation of main and secondary of line at different sites.

4.6. Possible Solution to reduce water loss and leakage

Knowing the magnitude and the spatial distribution of the loss greatly helps to intervene giving priority to those areas with higher magnitude of loss with regard to 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 town is leakage and losses due to meter errors. Once 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. Shortage of water is a crucial problem in the wolkite town, great attention is given to the issue of water loss by the water authority. Furthermore, Wolkite town water supply sewerage enterprise one of its responsibilities is to reduce water loss. Generally the following may be considered to be possible solution to be taken to reduce water loss and leakage in a distribution system.

4.6.1. Improving billing system and meter readings

Improving a billing system is one step forward for improving the overall demand management of the town and helps to a great extent to better evaluate the water balance and water loss. The most important part of determining how much water is being lost in a system is to accurately quantify the volume of water which is entering that system. Metering of input volumes and inflows into zone distribution systems is essential for water balance calculations. But Customer meters also require careful management of water loss if representative and significant results are to be obtained. Billing system can be reviewed and updated for the integrity and quality of the data. The location and the historical records like ages of the meter, periods of calibration, etc. need also be integrated with the billing systems.

4.6.2. 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.

4.6.3. 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. In spite of the many pipe networks in the town seem to have less than 30 year ages, the loss found from the analysis reaches up to 34% 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 to attention should be given to maintain as well the service connections 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 (Farley., 2010).

4.6.4. 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 wolkite town water supply sewerage enterprise, but lack of qualified and experienced personnel is the major problem of the country in general and WTWSSE in particular. Capable management and technical staff are paramount take training regarding to water loss management 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 level is also very important. Effective leakage management requires an input from a number of 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 led to lower leakage levels (Farley., 2010).

4.6.5. Establishing of Information Disk

Observed during field study, water was loss at different place by different cases as mentioned in previous section in the causes of water loss. Those water loss were continues to loss for one day or two day some time above until the authority technician WTWSSE.So in order to arrive automatically when water is loss and make a possible solution WTWSSE has established a free telephone service not only wolkite town customers also especially pressure mains in rural areas from balancing reservoir to Wabe river that can support to get information from the community in case of leakage and breakage of pipes immediately.

4.6.6. Discussion II

From Analysis of water loss and leakage needs a detail data due to its complex nature. The data are usually scarce in developing countries that the case of Wolkite is also similar. Due to limited data the analysis was focusing on evaluating the total water loss and un avoidable real loss on different pressure. Based on the result of the analysis the following conclusions and findings:-

- From the wolkite town water loss analysis in different location of the water supply system ,higher water loss is found relatively on gravity flow main line from Bojebare balancing reservoir to wolkite town service reservoir than other distribution system lines. This line have low pipe length and small number of connection compared to the distribution system but have relatively higher unavoidable real loss as a result of high pressure. The total annual wolkite town water produced and distributed to the system within the specified year (2021) has been 1,060,108 M^3 and the annual total water loss as derived using the expression was 349,625 M^3 which accounts of 33% of the total water production, the analysis shows Wolkite town have high loss of water.
- Based on the town water utility tariff the water loss in the wolkite town estimated water loss to be 4.3 million Birr every year. However, the real loss is beyond this as the water tariffs like other developing countries are usually subsidized.
- Taking the total number of connection in the wolkite town in 2021 is 13101 m and the water loss per connection for the similar duration was calculated as 73.1 liter/connection /day. This shows as litters per service connection per day increase water losses also increases.
- Evaluating the water loss as per kilo meter of main pipe is one way to indicate the loss. The total length of the town pipes are 118,288.4m from total length of pipes of size 50mm to

300mm is 113.57km and these total pipe length used to the water loss per kilometer length of main pipes was express. Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non-densely populated areas. Using the total pipe length of the entire town, the water loss per kilometer length of main pipes was calculated as 8.43 m^3/ km/day or 8430 L/Km/day depending on total water loss and total pipe length. This shows that as length of the pipe increases the amount of water losses per day increases.

- The value of unavoidable average real losses (UARL) is 272,674.8 m^3/year. This value is represents the unavoidable annual real losses (UARA) is the 78% of technically achievable volume of real losses which is 349,625 m^3/year of the total loss computed by using production and consumption data and the apparent plus avoidable real loss covers 22%.However, this proportion is not logical because unavoidable real loss is should be much less than avoidable plus real loss.
- Apparent customer metering inaccuracies losses due to meter errors are 38.9 m^3/year. The infrastructure leakage index for the wolkite town distribution system is calculated as 1.28 m^3/year and this shows us that the current annual real losses are assessed as being around two times as high as the unavoidable annual real losses for the system.

The total pipe age categories are estimated that nearly above 60% of the main pipe network of the Wolkite Town was 10-20 years age and the total pipe length of the town was less than 30 years age. And water loss expressed as per length of pipes age analysis result shows 16.5m^3/km/day or 16500L/ km/day. Therefore, this analysis shown that if distribution line is expanded, the age of pipe increase the water loss also increases in the pipe network.

4.7. Projected Demand (2022 – 2042)

The current estimation of water use by entire population required to review a set of various data. Water production data along with present and future population data were repeatedly reviewed. Accordingly, the two mentioned data were primarily used for water demand analysis. Prior to assigning project water demand, it was required to establish average use of water per person. Per capita water demand was taken as average water use. Maximum water use and minimum water use usually related to average water use by multiplication of peaking factors Results of water demand projection analysis to satisfy maximum day demand until the end of design period needs a discharge of 222.1l/s and to satisfy the peak hour demand needs

333.112l/sec. This means, the pressure main pipe should have a capacity to deliver 222.1l/s and the pump should have a capacity to lift 222.1L/sec. In addition the main distribution pipe should have a capacity to deliver 333.112l/sec. Wolkite town Projected Demand (2022 – 2042) shown appendix-9.

4.8. Hydraulic Analysis

Calibration is an iterative procedure of parameter evaluation and adjustment by comparing simulated and observed values. The Water Cad was calibrated by adjusting sensitive parameter such as Hazen Williams Coefficient. There for, this standard value of Hazen-Williams (C-value) for pipe material are:-

C value for pipe materials

S/N	Type of Material	C value for New Pipe	C Value For Existing Pipe
1	uPVC	150	100-110
2	Steel	110	90-110
3	DCI/GI	120	100-110

Source. Design Criteria Manual of MoWR (2006)

4.8.1 Pressure Calibration and validation

Pressure measurement throughout the entire day was conducted at different zones in the distribution system. A Pressure gauge is used to determine the line pressure and the size of the leak hole is measured, though error may be introduced due to irregularity of the shape of the hole. Depend on easy to identify the problem, topography and technical point of view all the pipe network system divided in to three zones:-Zone-one from balancing reservoir (Bojebare) to 1000m^3 service reservoirs(Wolkite), Zone-two from 1000m^3 ground reservoir to the down part of the reservoir and Zone-Three from 15m elevated 100m^3 reservoir to upper part of the reservoir. At location where pressure gauges were installed, elevation readings were also taken. Critical times were selected while pressure gauges were taken. These critical times were fixed based on the peak hour demand rate of the users which covers the time between 8:00-12:00 (early mid noon), 2:00-6:00 (after noon), 8:00- 12:00 (early mid night) and 2:00-4:00 (early morning: (Lambert and McKenzie, 2001). There are many ways to judge on the performance evaluation and calibration. The evaluation was made by calculating the squared relative difference between observed and simulated pressure for each test.

- **Performance Evaluation criteria**

The evaluation criteria used was statically method using correlation coefficient (R^2).

$$R^2 = \frac{\sum(X-X\,mean)\ \sum(Y-Y\,mean)}{\sqrt{\sum(X-X\,mean)^2}\ \ X\ \ \sqrt{\sum(Y-Y\,mean)^2}}$$

Where R^2 is Correlation Coefficient, X and Y are measured and simulated values, X mean and Y mean are average value of measured and simulated data respectively.

Illustrated that an average pressure difference of ± 15.2 kPa (± 1.51 m) with a maximum difference of ± 50.3 kPa (± 5.03 m) represents a "Good" data set and an average pressure difference of ± 29.6 kPa (± 2.96 m) with a maximum difference of ± 97.9 kPa (± 9.79 m) represents a "Poor" data set.

Table4.19. Comparison of simulated pressure with field measured.

Label	X (m)	Y (m)	Elevation(m)	observed pressure(m)	Simulated pressure(m)	Error(m)	Zone
J-9	365592.8	909640	1746	162	159.09	2.91	Zone 1
J-11	363260.8	913671	1803	105	102.95	2.05	Zone 1
J-3	374944.8	903930	1952	52	47.68	4.32	Zone 1
J-10	364274.8	911867	1712	198	193.31	4.69	Zone 1
J-21	367064.8	916902	1880	30	25.46	4.54	Zone 2
J-20	367363.8	917034	1868	40	37.73	2.27	Zone 2
J-32	365421.8	916026	1882	22	25.30	(3.3)	Zone 2
J-34	364353.8	915873	1874	30	32.80	(2.80)	Zone 2
J-47	365658.8	916610	1998	96	93.61	2.39	Zone 3
J-50	365457.8	916202	1888	20	17.06	2.94	Zone 3
J-53	364383.8	915904	1865	42	40.11	1.89	Zone 3
J-59	364466.8	915904	1868	36	40.18	(4.18)	Zone 3
Average				69.42	67.94	1.48	

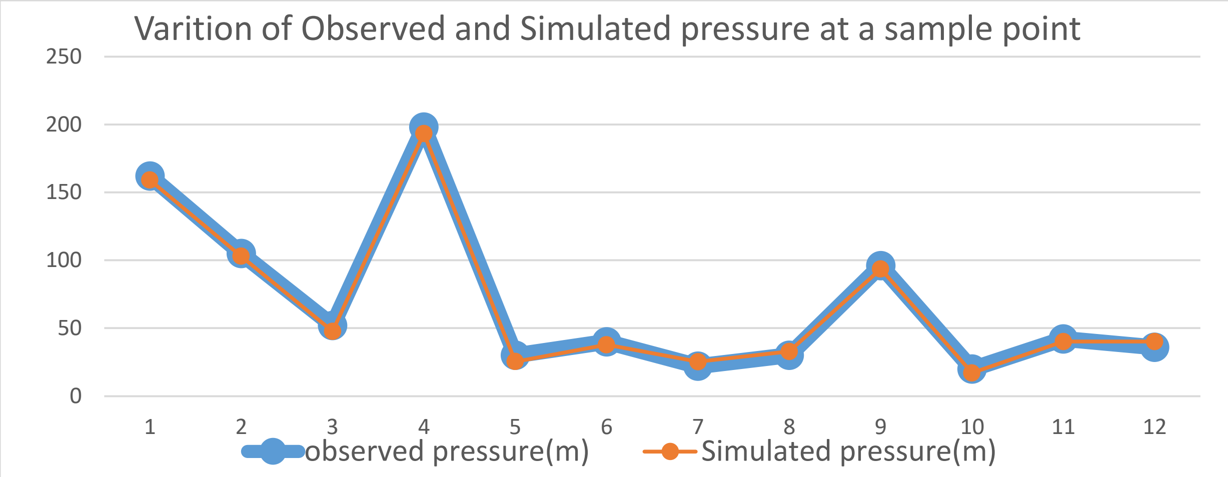

Figure 4.5. Actual and simulated pressure at samples junction

4.8.2. Simulation Results

Single period and extended period simulation were subsequently performed. In line with this running, single performing preliminary calibration. However, it should not be used for network assessment as water distribution system is likely to experience variations. Hence, only extended period simulation was exclusively used for entire model calibration and model assessment effort. The calibration of pressures were done in statically method and Figure 4.9 shows that the statistical correlation plot of observed versus computed pressure during calibration process .The result shows that R^2=99.7%.this implies that the computed pressure are within the acceptable limit.

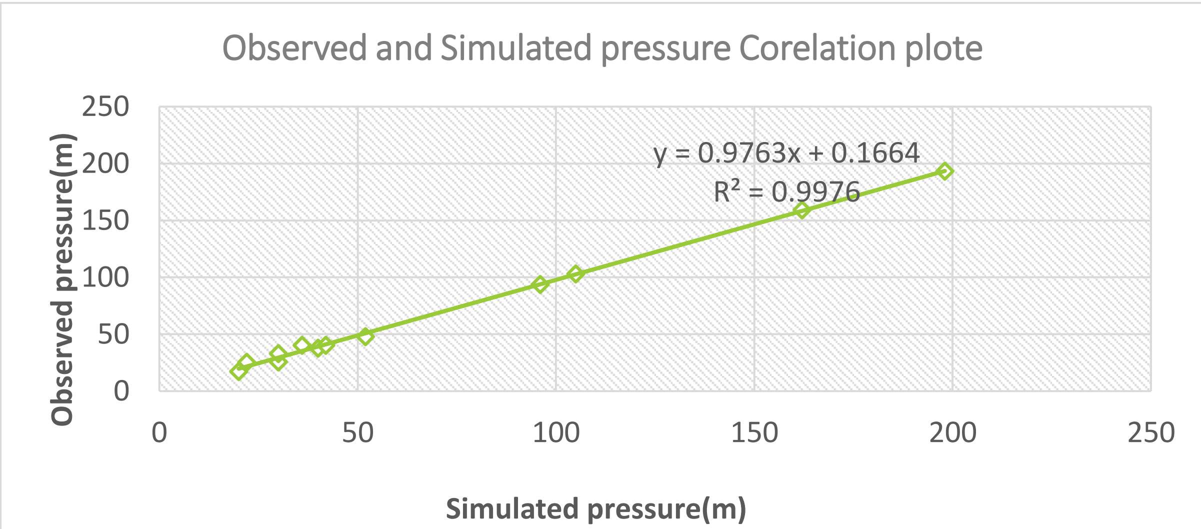

Figure 4. 6. Correlation between observed and simulated pressure

From the hydraulic analysis the maximum pressure occurred at gravity main 226 m is above to much the recommended value and it is the reason of pipe burst. In addition, the amount of pressure calculated in design document at the same location and demand period shows as 284 m. beside to this, for this critical location the design recommended pipe thickness of PN-35 but the pipe material on the ground is PN-25 and less so this is the reason behind the challenge around this location.

The gravity main pipe lines crossing the "Wabe river" (a tributary of gibe river) which is found between wolkite university and wolkite town, the topography goes up to balancing reservoir to service reservoir and the pipe crosses the asphalt road four time by following the gravel road side. Hence, due to the increasing topography and the bend of pipe in eight different locations, at service reservoir, the pressure reduces to 20 m. Therefore, unable to apply pressure reduction technics on high pressure zone due to the available head in service reservoir is low.

Bursting of the gravity pipe line was happened not only in the high pressure zone but also happened in normal pressure zone of PVC pipe due to operational problem. The reason is during the time of pump operation and the balancing reservoir out let open same time the pump stopped ether due to the light off or pump stuck. Since the outlet is open until the reservoir is empty. Consequently, the reservoir and the pipe line filled by air. Since, the next pump operation starts without air releasing this leads to atmospheric pressure in pipe greater than hydrostatic pressure and results pipe collapse.

The Negative Pressure shown at the hydraulic analysis indicate two things, the first, due to high demand along the smaller pipe size, there is high friction loss which is more than the ground elevation difference and the second is due to poor operation when the pipe fill by air and the hydraulic pressure less than the atmospheric pressure negative pressure will occurred as a result collapsing of pipe happened.

4.8.3. Up grading of water source, pump capacity and pressure main

The potential of Bozebar spring is more than 130 l/s and no difficulty to up grad the discharge. The existing three pumps have a capacity of lifting 80 l/s, to satisfy the average day demands and to fill gap different options are recommended. The first is adding pump which has a capacity of 20 l/s, must be Create solutions for illegal connection on gravity lines of rural area. The other is constricting or rehabilitation of the existing Reservoir and create source inside the town master plane During upgrading of the spring discharge capacity from 80 to 100 l/s need checking whether the capacity of pressure main pipe can able or not.

From hydraulics analysis the three existing pump has a capacity of 80 l/s with 95.27m pressure head and velocity of 1.1m/s (see table 4.20).Moreover, when the discharge became 100 l/s the head and the velocity as computed by Hazen William equation became 104 m and 1.37 m/sec (appendix.9). Hence, the PN-16 PVC pressurized existing pipe has capacity to resist pressure of more than this value and the velocity also on it is recommended limit. There for the system doesn't affect by additional pump.

Table.4.20.pressure main Hydraulic calculations.

Site	**X(m)**	**Y(m)**	**Z(m)**	**Static Head(m)**	**L(m)**	**Dia (inch)**	**Q(m^3/s)**	**V(m/s)**	**Loss(m)**	**Head(m)**
Spri	376857	900795	1934	-	-	-	-	-	-	-
P.H	376801	900605	1922	12	198	12.0	80.00	1.10	0.60	11.40
P1	376898	900547	1944	-10	115	12.0	80.00	1.10	0.35	(10.95)
P2	377138	900694	1947	-13	281	12.0	80.00	1.10	0.85	(14.80)
P3	377348	900750	1949	-15	217	12.0	80.00	1.10	0.66	(17.45)
P4	377744	900871	1960	-26	414	12.0	80.00	1.10	1.25	(29.70)
P5	378117	900962	1974	-40	384	12.0	80.00	1.10	1.16	(44.86)
P6	378471	900989	1988	-54	355	12.0	80.00	1.10	1.07	(59.93)
P7	378686	900994	1982	-48	215	12.0	80.00	1.10	0.65	(54.58)
P8	378879	901078	2014	-80	213	12.0	80.00	1.10	0.64	(87.22)
P9	379068	901072	1941	-7	203	12.0	80.00	1.10	0.61	(14.84)
P10	379330	901109	2012	-78	274	12.0	80.00	1.10	0.83	(86.66)
BR	379428	901200	2020	-86	134	12.0	80.00	1.10	0.61	**(95.27)**

Sixty observed pressure data were collected at main and distributing networks as shown in the table above 4.20 and appendix 6 for calibration and validation. Validation is in reality an extension of the calibration process. It is used to assure that the calibrated property assesses all the variables and conditions, which can affect results, and demonstrate the ability to predict field observation different data set. The hydraulic calibration parameters that are typically set and adjusted pipe roughness factors. The change in this parameter affects head losses and pressure. The result shows that when the Hazan-Williams roughness coefficient increases the value of the pressure increases and head losses decrease.

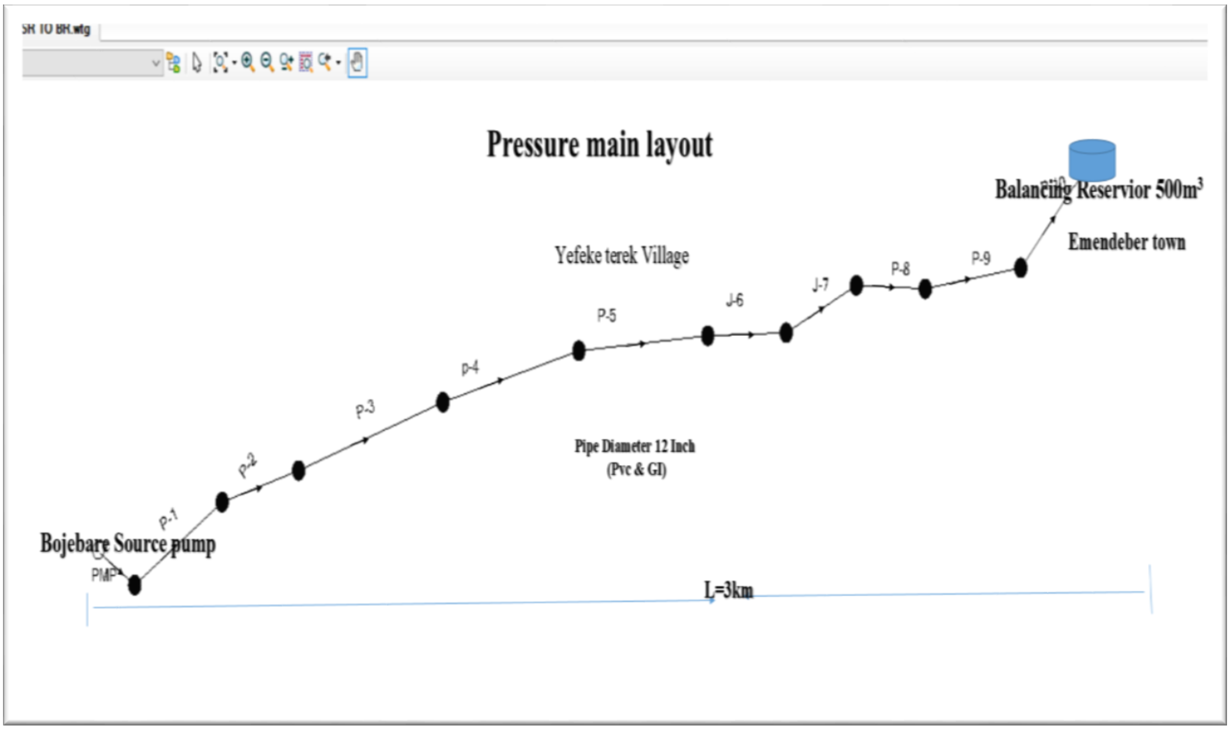

Figure. 4.7. Pressure main layout from WATER CAD

4.8.4. Existing Gravity main lines and alternatives

The gravity main was not isolated from the distribution network and it gives water to distribution line before entering to service reservoir between balancing reservoir and service reservoir. The service reservoir is found at the highest point in the town and the supply is done by gravity force from reservoir to the lower points. However, the system is also interconnected that water directly enters the distribution system when necessary. From field survey sample measure and hydraulically analysis report the existing Maximum water pressure in the gravity main was 226 m head (show appendix.6) and the alternative pressure head from hydraulic analysis 190 m head show table 4.21.The sizes of pipe in the main at a high pressure were lead for a frequent pipe bursting and leakage and the minimum pressure indicates that there is a less supply of water in the system so the alternative pressure head is important to reduce the problems.

Table.4.21.Gravity Main proposed Hydraulic calculation

Site	X(m)	Y(M)	Z(m)	StaticH(m)	L(m)	Dia(inch)	Q(m^3/s)	V(m/s)	Loss	Com.Loss(M)	Head(m)
P	379405	900023	2018	6	26.63	12	80	1.1	0.080	0.0803	5.9196
J-1	379344	900052	2012	12	67.81	12	80	1.1	0.205	0.2849	11.715
P1	379281	900101	2006	18	80.04	12	80	1.1	0.242	0.5264	17.473
P2	379167	900162	2000	24	129.4	12	80	1.1	0.391	0.917	23.083
P3	379039	900269	1994	30	166.9	12	80	1.1	0.504	1.4207	28.579
P4	379016	900369	1995	29	102.6	12	80	1.1	0.309	1.7303	27.27
P5	378890	900542	1989	35	214.1	12	80	1.1	0.646	2.3763	32.624
P6	378766	900694	2002	22	196.6	12	80	1.1	0.593	2.9695	19.031
J-2	378716	900771	1998	26	91.9	12	80	1.1	0.277	3.2468	22.7532
P7	378615	900903	1996	28	166.2	12	80	1.1	0.502	3.7483	24.2517
P8	378546	901046	1992	32	158.8	12	80	1.1	0.479	4.2275	27.7725
P9	378210	901276	1994	30	407.2	12	80	1.1	1.229	5.4561	24.5439
P10	377637	902045	1962	56	959.5	12	80	1.1	2.895	8.3513	47.6487
P11	377346	902282	1958	54	375.3	12	80	1.1	1.133	9.4838	44.5162
P12	376921	902630	1950	56	549.4	12	80	1.1	1.658	11.141	44.8586
P13	376432	902985	1952	48	604.3	12	80	1.1	1.823	12.965	35.0354
P14	375981	903146	1962	32	479	12	80	1.1	1.445	14.41	17.5902
P15	375017	903449	1970	25	1011	12	80	1.1	3.049	17.459	7.54109
J-3	374752	904366	1952	37	954.7	12	80	1.1	2.881	20.339	16.6605
P16	374621	905674	1947	55	1315	12	80	1.1	3.966	24.306	30.6941
P17	374515	906361	1945	53	695.1	12	80	1.1	2.0974	26.403	26.5967
P18	373809	906827	1949	47	845.9	12	80	1.1	2.5524	28.956	18.0443
P19	372938	906920	1950	42	876	12	80	1.1	2.643	31.599	10.4013
J-4	372334	906744	1946	48	629.1	12	80	1.1	1.8983	33.497	14.503
P20	369974	907442	1948	14	2461	12	80	1.1	7.4257	40.923	-26.923
P21	368084	908376	1965	-7	2108	12	80	1.1	6.3612	47.284	-54.284
P22	367008	908959	1832	118	1231	12	80	1.1	3.7143	50.998	67.0018
P23	367267	909491	1774	178	594.5	12	80	1.1	1.7939	52.792	125.208
P24	366598	909999	1781	181	840	12	80	1.1	2.5347	55.327	125.673
P25	366250	910809	1719	251	883.8	12	80	1.1	2.6666	57.993	190.007
P26	366055	911437	1830	122	666.9	12	80	1.1	2.0122	60.005	61.9945
P27	365904	911929	1890	57	518.1	12	80	1.1	1.5634	61.569	4.5688
P28	365824	912443	1902	43	520.3	12	80	1.1	1.57	63.139	20.139
S.R	365788	912897	1905	44	455.4	12	80	1.1	1.3742	64.513	**20.95**

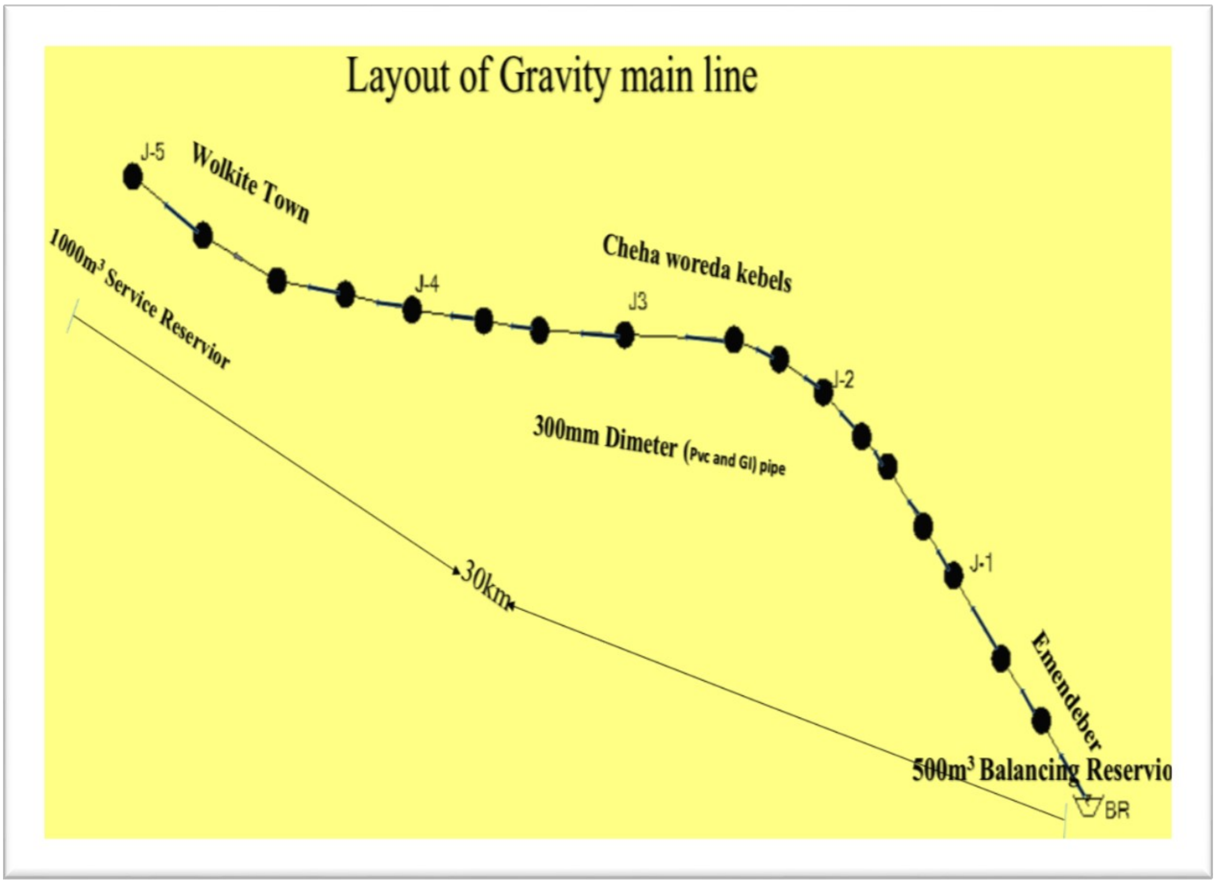

Figure. 4.8. Gravity main line layout from WATER CAD

4.8.5. Wolkite Water supply Distribution system and proposed main lines

Regards the topography of Wolkite town, to prevent the gravity main pipe line from bursting, unable to recommend pressure reduction components Example Pressure reduce valve and pressure breaker tank. The reason is the available free head in service reservoir is below 20m and if the pressure reduced on this critical location the water cannot inter in to service reservoir. Therefore, changing the pipe line route head is one option to minimize the problem. Changes the existing Wabe river pipe crossing locations and arrange upper pipe lines starting from junctions which is found Sisena Ematye villages existing pipe lines and critical location the pressure reduced from 226m head to 190.07m heads. Further detailed search another probability of finding safe value than the obtained. The proposed gravity pipe line hydraulic calculation result shows (Table 4.21) above and appendex-6.

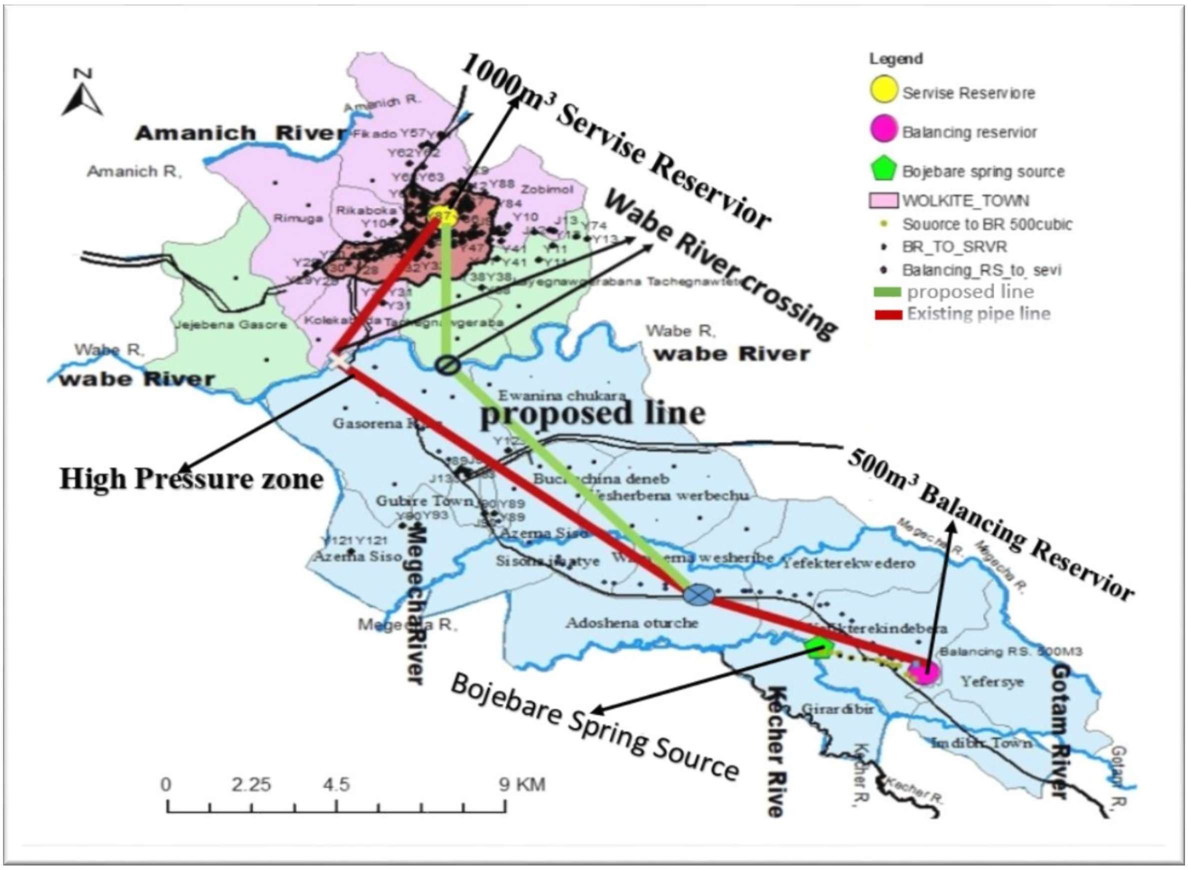

Figure. 4.9. Distribution Systems and proposed Gravity lines

4.9. Managements of Town Water Supply organization

4.9.1. Town Water Boards

Town Water Boards were responsible for planning and managing their town water supply systems. The Water Boards will enter into performance agreements or contracts with utility operators to handle routine operations and maintenance and improve efficiency and expand their system over time. Board members are in most cases representatives of government organizations from municipality, water bureau, health, education and representatives of the user community.

4.9.2. The Town Water Supply Enterprises:

The town water supply enterprises are concerned mainly with the scheme expansion and rehabilitation, operation and maintenance, financial and human resources management of the water supply scheme in the urban areas. The enterprises, depending on the size of the town, are autonomous in terms of town water supply development, operation and maintenance. The enterprises are managed by boards and executive body of the enterprise leads the activities of the utility and its management.

4.9.3. Customer Service and Fee Collection

The Wolkite town water supply system(2021) have a total 13,101 Water Connection, For Domestic 11651 Connection, Commercial 1291 Connection Government institution centers 156 Connection and industry 3 connection. Due to urban expansion and development a lot of privet as well as commercial customers looking for connection. However, due to water production shortage, technical and management problems water distribution is made on shift bases. The water supply system is poor in fee collection as well as scheme inspection, especially from institution.

4.9.3.1. Financial Management

WTWSSE have analysis of three years income and expenditure of the water supply system from 2019 to 2021. Income of enterprise is from water sales, technical service, from sales of plumbing materials and other different sources and expenditures are staff salary and cost of operation and maintenance. Hence the result shows that the difference between yearly income and expenditure in two years (2019 and 2020) are profitable but year (2021) not profitable see table below. However, following the water policy and its strategy the regional governments have also issued their respective proclamations in which they have made urban water supply services to operate as autonomous entities on full cost recovery base and its management by independent water board where urban populations are over 15,000. Therefore, the town water supply enterprise has responsibility to recover 3,387,783.72 birr/year from the last three years two years (2019 and 2020) are cover the cost but year 2021 is not cover the cost.

No.	Description	Unit	Year		
			2019	2020	2021
1	Income	birr	14,820,562.02	16,018,943.04	17,751,980.91
2	Expenditure	birr	11,293,417.2	12,229,213.64	14,448,840
3	Difference	birr	35271444.82	3,789,729.4	3,303,140.91
4	Annual expected cost recover	birr	3387783.72	3693891.81	3387783.72
5	Saving after cost recovery	birr	139361.1	95837.59	-84,642.81

Year	Production (m^3)	Consumption (M^3)
2019	1170259	716376
2020	1095627	656001
2021	1,060,108	710,483

From the above table result there is data recording and analysis problem is shown because water production and consumption in 2019 is larger than 2020 and 2021.Therefore, the income should be more in both years (2020 and 2021) but It is much less than 2020 and 2021, so need proper analysis. Therefore, the management of Wolkite town water supply totally need improvement to maximize the overall performance of the utility. Locally there are a number of water supply services that operate efficiently with the principle of cost recovery and full autonomy.

4.10. Customer Satisfaction Analysis, Result and Discussion

Wolkite town water utility customers are Total of 11651 private yard connection, institutional, commercial and industrial customers. The number of private yard connection customer estimated 88.9% of the total customer.

Interview samples

Customer type	Frequency	Percentage (%)
Private yard	190	79
Commercial	30	13
Institutions	20	8

4.10.1. Results of house hold Survey

1. Can you get water other than pipe water for all purpose? Based on the question the town Customer responses below the table:-

Table.4.22. Customer about the opportunity of water.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Yes	48	20	20.16	20.16
	No	192	80	80.67	100
	Total	238	99.16	100	
missing	Missing	2			
Total		240			

From 238 valid respondents for the question water source other than pipe water, 48 customers can get water other than pipe water, 192 cannot get water other than pipe water. Those who responded that they can access water from other sources have there is existing shallow wells and Wabe and Rebu rivers. The pipe water customers also uses from neighbor people who have their own water sources bore holes.

2. Does the water you get from the pipe have enough pressure**?** Customer responses below the table:-

Table.4.23. Customer responses about pipe line pressure.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Yes	153	63.75%	64.56%	64.56
	No	84	35%	35.44%	100
	Total	237	99.58%	100	
missing	Missing	3			
Total		240			

From 237 asked the town water users for the pressure of pipe water, 153 responded the pipe water reach to them with enough pressure,84 responded that the pipe water have no enough pressure at their tab. Water pressure during peak hour demand may become minimum because of the imbalanced water availability and topography of the town.

3. Do you use the pipe water for drinking purpose? Based on question Customer responses are below the table:-

Table. 4.24. Customer responses purpose of pipe water.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Yes	188	78.33	78.99	78.99
	No	50	20.83	21.01	100
	Total	238	99.166	100	
Missing	missing	2			
Total		240			

From 238 asked for the question "do use pipe water for drinking purpose? 188 use pipe water for drinking purpose, 50 do not use pipe water for drinking purpose. Get their drink water from bays and from neighbor peoples using own borehole.

4. Do you have any water cleaning mechanism at your home? Based on question Customer responses are below the table:-

Table.4.25. Customer responses water cleaning mechanism.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Yes	47	19.583	19.747	19.747
	No	191	79.583	80.253	100
	Total	238	99.166		
Missing	Missing	2			
Total		240			

From 238 communities asked the question "Do you have water cleaning mechanism at your home?" 47 customers have water cleaning mechanism at their home, 191 do not have water cleaning mechanism at their home. It is clear that the water Wolkite town water utility office must works on the quality of the water they are providing as more than eighty percent of the customers directly use the pipe water without cleaning it.

4. Does the water supply office respond earlier for your question on maintenance? Based on question Customer responses are below the table:-

Table.4.26. Customer responses of authorized office.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Yes	93	38.75	38.912	38.912
	No	146	60.833	61.088	100
	Total	239	99.583		
Missing	Missing	1			
Total		240			

From 239 valid respondents about water utility office respond quickly on maintenance 93 answered yes and 146 responded no.

5. How many Months you wait to get water meter after applying for it? Based on question Customer responses are below the table:-

Table.4.27. about Customer responses of authorized office.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Less than month	64	26.666	41.025	41.025
	One month	44	18.333	28.205	69.23
	Tow month	48	20	30.769	100
	Total	156	65	100	
missing	missing	84			
Total		240			

From 156 of customers asked the question “how many months you wait after applying for water meter?”64 responder less than a month, 44 responded one month, 48 responded two months. More than 20% of the customers in Wolkite town must wait at least a month to get water meter at their home. So I can conclude that the service is poor.

6. How many days you get water per week? And hours per day respectively? Based on question Customer responses are below the table:-

Table.4.28. How many days Customers get water per week.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	3 day per week	0	0	0	0
	2 day week	21	8.7	9.012	9.012
	1 day per week	72	30	30.901	39.913
	1 day per month	140	58.33	60.085	100
	Total	233	97.083	100	
missing	missing	7			
Total		240			

From 233 customers asked about “How many days you get water per week?” 21 responded twice a week and most of the wolkite town customers 140 responded one day per month. According to the respondents, no one can get water three days per week. Although Wolkite town is served from Bojebare spring found 30 km away from the town, there is high leakages and 1500 illegal connections. There is no continuous access of water in the town.

7. What is your level of satisfaction on water supply service? Based on question Customer responses are below the table:-

Table.4.29. Customers satisfaction on water supply.

	Valid Answer	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Very satisfied	12	5	5.084	5.084
	Satisfied	40	16.66	17.33	23.422
	fairly satisfied	64	26.66	27.118	52.540
	not satisfied	120	50	51	100
	Total	236		100	
missing	Missing	4			
Total		240			

From 236 town community asked about how much the customers are satisfied with the water utilities service, 40 responded satisfied, 64 responded fairly satisfied, 120 responded not satisfied. In general the customers" response and the research output are similar. The wolkite town's water utility is not providing adequate water with standardized quantity.

8. What do you think about wolkite town water supply problem? What is the cause? Based on question Customer responses are below the table:-

Table.4.30. about wolkite town water supply problem.

	Valid Answer	Frequency	Percent	Valid Percent
Valid	Shortage of water source problem	40	16.66	17.021
	manage mental problem	115	48	48.9
	technical problem	80	33.33	34.042
	Total	235	98	100
Missing	Missing	5		
Total		240		

From 235 town community asked. What do you think about wolkite town water supply problem? What is the cause? The water utilities service, 40 responded Shortage of water source problem, 115 responded manage mental problem, 80 responded technical problem. There is no water source problem however the problem is the manegemental and operation. Therefore, the water utility office must re organize how to operate in order to satisfy the customers need to access safe water.

4.10.2. Discussion III

From 238 valid respondents for the question water source other than pipe water, 48 customers can get water other than pipe water, 192 cannot get water other than pipe water. This mean about 80% of people are dependent on pipe water. From 238 asked for the question “do use pipe water for drinking purpose? 188 use pipe water for drinking purpose, 50 do not use pipe water for drinking purpose. In percentage, nearly 78% of the population use pipe water for drinking purpose. From 237 asked the town water users for the pressure of pipe water, 153 responded the pipe water reach to them with enough pressure, 84 responded that the pipe water have no enough pressure at their tab. Water pressure during peak hour demand may become minimum because of the imbalanced water availability and topography of the town.

From 239 asked about the quality of pipe water they use, 131 think that the pipe water is clean, 108 customers responded that the pipe water is not clean. 239 valid respondents about water utility office respond quickly on maintenance 93 answered yes and 146 responded no.

From 156 of customers asked the question “how many months you wait after applying for water meter?”64 responder less than a month, 44 responded one month, 48 responded two months. More than 20% of the customers in Wolkite town must wait at least a month to get water meter at their home. So I can conclude that the service is poor. From 233 customers asked about “How many days you get water per week?” 21 responded twice a week and most of the wolkite town customers 140 responded one day per month. According to the respondents, no one can get water three days per week and above 60% of customer gets water one day per month.

Therefore, the water utility office must re organize how to operate in order to satisfy the customers need to access safe water. From 236 town community asked about how much the customers are satisfied with the water utilities service, 48 responded satisfied, 64 responded fairly satisfied, 120 responded not satisfied. Above 51% of population in Wolkite town is not satisfied in the water utility service.

CHAPTER. 5. CONCLUSION AND RECOMMENDATIONS

The main objective of the research was to evaluate the water supply coverage and explore the water loss in the water supply distribution system of the Wolkite town. The analysis is focused on the evaluation of the existing water supply coverage of town based on the billed consumption and population of town, projection of demand for next 20 years, evaluating the total water loss and exploring the possible causes of the water loss with their remedial measurement.

- ✓ The analysis shows that the annual production for the year 2021 is almost decreased by above 9.4% the annual production for the year 2019).
- ✓ The average domestic water production of the town is found to be 26.3 l/per/day, the result shows that an average daily per capital production of the town is low b/c from the production more than 33% are loss before reach to costumer.
- ✓ The other issue that has been addressed was analysis of water coverage as per domestic and non-domestic demand. The result shows as the total average demand is 6,596.6 m^3/day. However, the amount of water production in 2021 shows as 1,060,108 m^3/year or 2,905 m^3/day, which have only 44% coverage of the demand. Therefore, the result shows there is high gap between demand and supply.
- ✓ The average water supply coverage and the intra town distribution were evaluated based on the daily per capital consumption and level of connection using the population data of the town. The analysis of average per capital consumption of the wolkite town found to be 18.6 L/person/day, while an overview of GTP-2 Provide urban water supply access with minimum service level of 60 l/c/day for category 3 towns/cities (with a population in the range of 50,000 -100,000), according to the standard set by MoWR wolkite town found third level and average per capital consumption is lower while compared with the minimum requirement of domestic demand which is 25 l/c/day set by Wallingford HR. Based on the above results wolkite town water supply consumptions are very less.
- ✓ The average connection per family for the entire wolkite town is found to be 0.61. This implies that at average two families or eleven persons are sharing one connection or water tap. In other words the average in-house or yard connection of the town is about 61%. Similar to

the per capita consumption, the distribution of the level of connection per family shows variation.

- ✓ This research analysis shows as the maximum day demand of wolkite town is 7915.92 m^3/day (91.62 l/s) and peak hour demand is 11873.88 m^3/day (137.43 l/s). The existing pump has a capacity to lift 80 l/s which is 87% of the maximum day demand.
- ✓ The storage capacity of existing reservoirs of wolkite town which have 1600m^3 the recommended range was 1978.98 m^3/day to 3298.3 m^3/day, the results shows less than the recommended range, so the wolkite town water scheme is not safe regarding to storage capacity.
- ✓ From Analysis of water loss and leakage needs a detail data due to its complex nature. From the wolkite town water loss analysis in different location of the water supply system ,higher water loss is found relatively on gravity flow main line from Bojebare balancing reservoir to wolkite town service reservoir than other distribution system lines. This line have low pipe length and small number of connection compared to the distribution system but have relatively higher unavoidable real loss as a result of high pressure.
- ✓ The total annual wolkite town water produced and distributed to the system with in the specified year (2021) has been 1,060,108 m^3 and the annual total water loss as derived using the expression was 349,625 m^3 which accounts of 33% of the total water production, the analysis shows Wolkite town have high loss of water.
- ✓ Taking the total number of connection in the wolkite town in 2021 is 13101 m and the water loss per connection for the similar duration was calculated as 73.1 liter/connection /day. This shows as litters per service connection per day increase water losses also increases.
- ✓ Evaluating the water loss as per kilo meter of main pipe is one way to indicate the loss. The total length of the town pipes are 118,288.4m from total length of pipes of size 50mm to 300mm is 113.57km and these total pipe length used to the water loss per kilometer length of main pipes was express. Using the total pipe length of the entire town, the water loss per kilometer length of main pipes was calculated as 8.43 m^3/ km/day or 8430 L/Km/day depending on total water loss and total pipe length. This shows that as length of the pipe increases the amount of water losses per day increases.
- ✓ The value of Unavoidable Average Real Losses **(**UARL) is 272,674.8 m^3/year. This value is represents the unavoidable annual real losses (UARA) is the 78% of technically achievable volume of real losses which is 349,625 m^3/year of the total loss computed by using production

and consumption data and the apparent plus avoidable real loss covers 22%.However, this proportion is not logical because unavoidable real loss is should be much less than avoidable plus real loss.

- ✓ Apparent Customer Metering Inaccuracies losses due to meter errors are 38.9 m^3/year. The infrastructure leakage index for the wolkite town distribution system is calculated as 1.28 m^3/year and this shows us that the current annual real losses are assessed as being around two times as high as the unavoidable annual real losses for the system.
- ✓ The total pipe age categories are estimated that nearly above 60% of the main pipe network of the Wolkite Town was 10-20 years age and the total pipe length of the town was less than 30 years age. And water loss expressed as per Length of Pipes age analysis result shows 16.5m^3/km/day or 16500 L/ km/day Therefore, this analysis shown that if distribution line is expanded, the age of pipe increase the water loss also increases in the pipe network.
- ✓ The water loss in the wolkite town estimated to be 4.3 million Birr every year.
- ✓ Customer Satisfaction Findings about 80% of wolkite town populations are dependent on pipe water but from the interview responses 60% of customer gets water one day per month. Above 51% of population in Wolkite town is not satisfied in water utility service.

5.1. Recommendations

- ❖ The Bojebare water supply scheme is joining the existing system from the cheha woreda (Bojebare) travelling almost more than 30 km, management of the Gravity line ,supply system unplanned connections , in general should be given due to consideration.
- ➢ Building reservoirs and pipe line for rural community to separate the connection from gravity main line, this helps to deliver more amount of water to town service reservoir. However, depend on the demand still there is a gap in town. There for the remaining gap should be covered by existing non-functional three boreholes which have sum of 9.5 l/s should rehabilitation work and already started drilling borehole.
- ❖ The storage capacity of existing reservoirs of wolkite town which have1600m^3 the recommended range was 1978.98 m^3/day to 3298.3 m^3/day, the results shows less than the recommended range, so the wolkite town water scheme is not safe regarding to storage capacity. To recommend the town should be construct additional reservoir. Therefore, to satisfy the demand the pressure main pipe line and the capacity of the pump should have ability to meet the maximum day demand 91.62 l/s. However, the existing pump has a capacity to lift 80 l/s which is 87% of the maximum day demand.
- ❖ Source should be create so as to serve in Gubere sub-city of the town's need as the population of the sub-city increasing and both government and private institutions are also expanding unexpectedly.
- ❖ The water utility should respond immediately to maintenance requests of customers to avoid water loss and complaints from customers and need to regular discussions with the customers. The water utility should also conduct a regular survey to know customers satisfaction level and the service deficiencies and should make improvements on its service to increase the customer's satisfaction.
- ❖ There is rapid growing of population and expansion of Wolkite town, therefore, Water supply and demand in town has a high gap presently, in order to meet the demand in future, water sector should Wabe River, Rebu River and Megecha rivers are surround the town so by taking one of these rivers and making a treatment plan and solve the town water supply problems.
- ❖ Protecting gravity main pipe line from bursting, unable to recommend pressure reduction components. Because the hydraulic analysis results of service reservoir head is below 20m head, so the pressure reduced on this systems water not available enter in to the service

reservoir. To recommend:- changing the pipe line route head to the upstream area is one option to minimize the problem , other structural activities building anchor blocks and avoid direct connections from gravity main lines.

- Above 51% of customers in Wolkite town is not satisfied in the water utility service. Due to this the management of Wolkite town water supply totally need improvement to maximize the overall performance of the utility.
- The water loss in the town estimated to be 4.3 million Birr lost every year. So the town should minimize loss.

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APPENDICES

Appendix -1. Interview Question

- Questionnaires on customer satisfaction of water supply as one indicator of Water supply coverage, losses and distribution system performance, a case of Wolkite town.

1. Can you get water other than pipe water for all purpose? Yes □ No □
   Other____
2. Does the water you get from the pipe have enough pressure? Yes □ No □
   Other____
3. Do you use the pipe water for drinking purpose? Yes □ No □
4. Does the water supply office respond earlier for your question on maintenance? Yes □ No □
   after week □ after month □ after three months □
   After five Month's □Other____
5. Is the water tariff you paid balance the water you used? Yes □ No □
   Other____________________
6. How many Months you wait to get water meter after applying for it?
   One week □ one month □ two months □ five months □ specify _________
7. Does your water meter works properly? Yes □ No □ Other___________
8. How many days you get water per week? And hours per day respectively?
   1days/week □ 2days/week □ 3days/week □ all days □
   Other___________
9. What is your level of satisfaction on water supply service?
   Very satisfied □ satisfied □ fairly satisfied □ not satisfied □ Other_______
10. What do you think about wolkite town water supply problem? What is the cause?
   Shortage of water source problem□ manage mental problem□ technical problem□
   Other____
12. Do you have any idea how to upgrade water supply system? Yes □ No □
   Other____

Appendix -2. Checklist for discussion

1. What are the main sources of water in the city? Are there any water sources that are not included to the distribution system? Where and how much?
2. Is there any difference in level of water distribution among different localities? If yes, how do you manage to balance the supply?
3. Is there any seasonal difference in amount (volume) of water supplied particularly in rainy season and dry season? If yes to what extent?
4. Are there any non-metered water consumptions? If so for what purpose and how do you estimate the volume of water consumed?
5. How do you estimate the residential water demand? Do you have any standard?
6. How do you identify leakage or breakage of water pipes? How do the residents/communities Support in reporting leakage or breakage of pipes?
7. How frequent do water meters become defective? Do the customers report on time in case of defective water meter? If yes, do they report equally for both in case of the defect causing over readings and under readings? In case they didn't report how do you monitor it?
8. Have you encountered with illegal water connections? If yes how frequent? Do you think that all customers pay for all water they have consumed? If not why?
9. From your experience, does leakage and breakage of pipes have significant relation with age of pipes
10. From your experience does the ground elevation difference of the city have a significant impact on pressure and distribution of water? How do you manage the pressure with the big elevation difference of the city?
11. Do you have a plan to replace aged pipes and water meters? What major criteria do you use for prioritization of replacement?
12. Do you have any plan regarding operation and management in general and leakage reduction in particular? If so what are the main components?

Appendix- 3. Wolkite town water supply Gravity main data

Remark	Easting(m)	Northing(m)	Elevation(m)
B Spring	376857	900795	1934
P.H	376801	900605	1921
Point	376898	900547	1944
Tesdey H20	377138	900694	1947
Point	377348	900750	1949
Point	377744	900871	1960
Eden Branch	378117	900962	1974
Point	378471	900989	1988
Point	378686	900994	1982
Point	378879	901078	2014
Point	379068	901072	1941
Point	379330	901109	2012
BSR(Tequtene)	379525	901200	2024

Appendix-4. Wolkite water pressure main Hydraulic calculation

Site	X(m)	Y(m)	Z(m)	Static Head(m)	L(m)	Dia (inch)	Q(m^3/s)	V(m/s)	Loss(m)	Head(m)
Spring	376857	900795	1934	-	-	-	-	-	-	-
P.H	376801	900605	1922	12	198	12.0	80.00	1.10	0.60	11.40
P1	376898	900547	1944	-10	115	12.0	80.00	1.10	0.35	(10.95)
P2	377138	900694	1947	-13	281	12.0	80.00	1.10	0.85	(14.80)
P3	377348	900750	1949	-15	217	12.0	80.00	1.10	0.66	(17.45)
P4	377744	900871	1960	-26	414	12.0	80.00	1.10	1.25	(29.70)
P5	378117	900962	1974	-40	384	12.0	80.00	1.10	1.16	(44.86)
P6	378471	900989	1988	-54	355	12.0	80.00	1.10	1.07	(59.93)

P7	378686	900994	1982	-48	215	12.0	80.00	1.10	0.65	(54.58)
P8	378879	901078	2014	-80	213	12.0	80.00	1.10	0.64	(87.22)
P9	379068	901072	1941	-7	203	12.0	80.00	1.10	0.61	(14.84)
P10	379330	901109	2012	-78	274	12.0	80.00	1.10	0.83	(86.66)
BR	379428	901200	2020	-86	134	12.0	80.00	1.10	0.61	**(95.27)**

Appendix- 5.Alternetive Gravity main Hydraulic analysis

Site	X	Y	Z	Static Head (m)	L(m)	Dia (inch)	Cum. L(m)	Q (m^3/s)	V (m/s	Loss	Com. Loss (m)	Head
BR	379428	900011	2024	0	0	0	0	0	0	0	0	0
	379405	900023	2018	6	26.63	12	26.63	80	1.1	0.080	0.0803	5.92
J-1	379344	900052	2012	12	67.81	12	94.44	80	1.1	0.205	0.2849	11.7
	379281	900101	2006	18	80.04	12	174.47	80	1.1	0.242	0.5264	17.5
	379167	900162	2000	24	129.4	12	303.91	80	1.1	0.391	0.917	23.1
	379039	900269	1994	30	166.9	12	470.85	80	1.1	0.504	1.4207	28.6
	379016	900369	1995	29	102.6	12	573.46	80	1.1	0.309	1.7303	27.3
	378890	900542	1989	35	214.1	12	787.57	80	1.1	0.646	2.3763	32.6
	378766	900694	2002	22	196.6	12	984.16	80	1.1	0.593	2.9695	19.1
J-2	378716	900771	1998	26	91.9	12	1076.1	80	1.1	0.277	3.2468	22.75
	378615	900903	1996	28	166.2	12	1242.3	80	1.1	0.502	3.7483	24.25
	378546	901046	1992	32	158.8	12	1401.1	80	1.1	0.479	4.2275	27.77
	378210	901276	1994	30	407.2	12	1808.3	80	1.1	1.229	5.4561	24.5
	377637	902045	1962	56	959.5	12	2767.8	80	1.1	2.895	8.3513	47.65
	377346	902282	1958	54	375.3	12	3143.2	80	1.1	1.133	9.4838	44.52
	376921	902630	1950	56	549.4	12	3692.5	80	1.1	1.658	11.141	44.86
	376432	902985	1952	48	604.3	12	4296.8	80	1.1	1.823	12.965	35.04
	375981	903146	1962	32	479	12	4775.8	80	1.1	1.445	14.41	17.59
	375017	903449	1970	25	1011	12	5786.3	80	1.1	3.049	17.459	7.541
J-3	374752	904366	1952	37	954.7	12	6740.9	80	1.1	2.881	20.339	16.66
	374621	905674	1947	55	1315	12	8055.5	80	1.1	3.966	24.306	30.69
	374515	906361	1945	53	695.1	12	8750.7	80	1.1	2.0974	26.403	26.59
	373809	906827	1949	47	845.9	12	9596.6	80	1.1	2.5524	28.956	18.04
	372938	906920	1950	42	876	12	10472.6	80	1.1	2.643	31.599	10.40
J-4	372334	906744	1946	48	629.1	12	11101.7	80	1.1	1.8983	33.497	14.50
	369974	907442	1948	14	2461	12	13562.8	80	1.1	7.4257	40.923	-26.9
	368084	908376	1965	-7	2108	12	15671.1	80	1.1	6.3612	47.284	-54.3
	367008	908959	1832	118	1231	12	16902.2	80	1.1	3.7143	50.998	67.01

	367267	909491	1774	178	594.5	12	17496.5	80	1.1	1.7939	52.792	125.2
	366598	909999	1781	181	840	12	18336.6	80	1.1	2.5347	55.327	125.7
	366250	910809	1719	251	883.8	12	19220.4	80	1.1	2.6666	57.993	190.1
	366055	911437	1830	122	666.9	12	19887.2	80	1.1	2.0122	60.005	61.9
	365904	911929	1890	57	518.1	12	20405.4	80	1.1	1.5634	61.569	-4.6
	365824	912443	1902	43	520.3	12	20925.7	80	1.1	1.57	63.139	-20.1
	365788	912897	1905	44	455.4	12	21381.2	80	1.1	1.3742	64.513	-20.5

Appendix- 6. Existing Gravity Main Hydraulic analysis

Site	X	Y	Z	Static Head	L(m)	Dia	Cum.L (m)	Q (m^3/s)	V (m/s)	Loss (m)	Com. Loss	Head (m)
RS	379432	900011	1934	0	0		0		0	0	0	0
p-1	379344	900101	2012	54	3462	12	3462	86	1.18	12	12	42.03
p-2	376744	902386	1958	60	2170	12	5632	86	1.174	7.44	19.4	40.6
p-3	374752	903246	1952	66	2468	12	8099	86	1.17	8.4	27.8	38.19
p-4	372335	903744	1946	74	3116	12	11215	85	1.161	10.4	38.3	35.74
p-5	369259	904240	1938	65	2646	12	13861	85	1.153	8.77	47	17.97
p-6	367143	905828	1947	67	1433	12	15293	84	1.137	4.63	51.7	15.35
p-7	366410	907059	1945	96	1162	12	16455	83	1.109	3.58	55.2	40.77
p-8	365856	908080	1916	162	989.8	12	17445	81	1.108	3.05	58.3	103.7
p-9	365400	908956	1850	194	2588	12	20033	81	1.099	7.84	66.1	127.9
p-10	364082	911183	1818	202	2069	12	22103	80	1.094	6.22	72.3	129.7
p-11	363068	912987	1810	107	4534	12	26636	80	1.087	13.5	85.8	21.19
p-12	365813	916594	1905	105	17.32	12	26654	79	1.083	0.05	85.9	19.14
p-13	365803	916580	1907	2	43.98	12	26698	79	0.139	0	85.9	-83.9
p-14	365846	916589	1905	1	216	12	26914	4.5	0.151	0.03	85.9	-84.9
p-15	366061	916568	1906	11	248	8	27162	4.9	0.067	0.01	85.9	-74.9
p-16	366307	916598	1896	9	263.8	8	27425	2.2	0.247	0.18	86.1	-77.1
p-17	366454	916817	1898	13	132.4	4	27558	2	0.247	0.09	86.2	-73.2
p-18	366586	916827	1894	33	638.1	4	28196	2	0.329	1.04	87.2	-54.2
p-19	366982	916327	1874	39	190.5	3	28386	1.5	0.592	1.48	88.7	-49.7
p-20	367171	916350	1868	27	327.1	2	28714	1.2	0.247	0.22	88.9	-61.9
p-21	366872	916218	1880	28	94.01	4	28808	2	0.247	0.06	89	-61

J-22	366966	916218	1879	13	918.3	4	29726	2	0.247	0.63	89.6	-76.6
p-23	366528	917025	1894	9	490.6	4	30216	2	0.185	0.2	89.8	-80.8
p-24	366788	917441	1898	23	117.7	4	30334	1.5	0.247	0.08	89.9	-66.9
p-25	366818	917554	1884	-23	811	4	31145	2	0.247	0.56	90.4	-113
p-26	366386	916868	1907	-21	613.9	4	31759	2	0.197	0.17	90.6	-112
p-27	365855	916560	1905	-16	215.1	6	31974	3.6	0.164	0.04	90.7	-107
p-28	365857	916345	1900	0	514.1	6	32488	3	0.263	0.25	90.9	-90.9
p-29	365887	915832	1884	-10	129.9	6	32618	4.8	0.219	0.04	91	-101
p-30	365806	915731	1894	-1	235	6	32853	4	0.247	0.16	91.1	-92.1
p-31	365597	915624	1885	2	463.6	4	33317	2	0.439	1.29	92.4	-90.4
p-32	365229	915342	1882	13	1824	3	35140	2	0.439	5.08	97.5	-84.5
p-33	363410	915213	1871	10	751.4	3	35892	2	0.493	4.17	102	-91.7
p-34	364161	915189	1874	-16	1886	2	37778	1	0.74	22.2	124	-140
p-35	365755	916197	1900	-21	435.4	2	38213	1.5	0.308	0.45	124	-145
p-36	365840	916624	1905	-24	137.9	4	38351	2.5	0.987	2.76	127	-151
p-37	365825	916761	1908	8	334.5	2	38686	2	0.987	6.71	134	-126
p-38	366154	916701	1900	4	407.8	2	39093	2	0.247	0.28	134	-130
p-39	365760	916596	1904	6	41.35	4	39135	2	0.185	0.02	134	-128
p-40	365719	916591	1902	14	567.5	4	39702	1.5	0.247	0.39	134	-120
p-41	365511	917119	1894	14	252.8	4	39955	2	0.247	0.17	135	-121
p-42	365390	917341	1894	6	628.8	4	40584	2	0.247	0.43	135	(129)
p-43	365674	916780	1902	3	195.5	4	40780	2	0.224	0.07	135	(132)
p-44	365617	916593	1905	8	211.7	6	40991	4.1	0.172	0.05	135	(127)
p-45	365601	916382	1900	9	72.84	6	41064	3.1	0.219	0.05	135	(126)
p-46	365549	916331	1899	-90	425.1	6	41489	4	0.37	0.93	136	(226)
p-47	365466	915926	1998	16	263.5	4	41753	3	0.849	4	140	-124
p-48	365416	915690	1892	18	104.1	2	41857	1.7	0.641	0.94	141	-123
p-49	365413	915586	1890	2	162.9	2	42020	1.3	0.483	0.87	142	-140
p-50	365265	915518	1888	4	85.93	2	42106	1	0.197	0.09	142	-138

Appendix- 7. Wolkite water supply Distribution data

X-start	Y-start	X-end	Y-end
365801	916693	365453	916006
365449	916006	365182	915575
365183	915575	364235	915408
364235	915408	363904	915333
365057	915792	365003	915955
365433	915756	365347	915728
365349	915729	365228	915742
365349	915729	364481	915513
367449	915998	367313	915719
367607	915950	367842	916206
368585	915978	368703	915010
369028	916054	369086	915517
369138	916024	370073	915747
367696	915924	367633	915660
365445	916662	365089	916636
365443	916674	365099	916583
365089	916453	365560	916458
365548	916407	365093	916374
365490	916204	365316	916607
365329	916203	365258	916254
365323	916202	365142	916037
364872	915520	364782	915826
365183	915575	364235	915408
364393	915435	364344	915636
365048	915608	365014	915657
364671	915544	364551	915584
365806	916676	365974	916489
365884	916493	363252	914854
363437	915151	362087	914532
362427	914915	362306	914807
364010	915033	364244	913461
364393	915282	365200	915031
364743	915340	364860	915122
365128	915423	365310	915187
365409	915673	365023	915365
365590	915645	365639	915502
365568	915609	365306	915372
365569	915609	367087	914006
365384	915280	365220	915140
365897	915894	367053	915960
367052	915958	367495	915017

365880	916084	366725	915910
366519	915909	366736	915867
366520	915869	366737	915814
366525	915816	366526	915626
366499	915663	366284	915498
366306	915909	366270	915629
365871	916398	366544	916515
365948	916394	366046	916314
365948	916313	366049	916254
365951	916251	366051	916194
366051	916194	366125	915981
365927	916085	365980	915941
365841	916685	366173	916954
366142	916808	366125	916964
365822	916673	365920	919485
365697	919028	365528	919177
365507	917199	366206	917112
365765	917184	365791	917371
365400	917402	365116	917294
365109	917365	365364	919088
365397	918309	364997	918452
365107	917384	365138	917575
365761	916669	365419	917301
365664	916849	365411	917177
365498	917005	365387	917169
365435	916985	365051	916976
365398	916972	365434	916875
365725	916668	365553	915911
365565	916469	365463	915632
365841	916674	366886	915921
365871	916381	365704	915839
365873	916322	365627	915860
365756	916325	369754	915838
365842	916685	366162	915824
365863	916650	366110	916629
366078	916652	366333	916454
365861	916671	366343	916680
366068	916672	366484	917815
366337	916724	366406	916738
366362	916715	366445	916796
366406	916701	366524	916766
366455	916690	366332	916654
366484	916738	367366	916638
366800	916896	366733	917050

366488	916945	366708	916763
366459	916901	366282	916710
365863	916637	367147	917365
366405	907411	367440	905888
367147	905893	364796	905459
365089	916453	364568	916385
364972	916452	367547	916105
366587	907462	365246	905497
365156	915646	365200	915490
365183	915467	365338	915423
365112	915467	365127	915551
365450	916007	365142	915985
365127	915981	365002	915812
365142	915812	364944	915779
365002	915781	365132	915922
365463	915835	365067	915872
365133	915872	365158	915967
365342	915843	365338	915868
365346	915787	363806	915921
363754	915226	365579	915151
365567	915610	365626	915515
365898	915892	366850	915812
366853	915962	366752	915767
366297	915999	366752	915981
366512	916983	366801	916896
366333	916680	366637	916954
366544	917033	366649	917264
365863	916648	365869	916381
366281	917363	366735	917597
366324	917385	366492	917597

Appendix- 8. Pipe line Length and materials

No	Material type	Diameter(Inch)	Total Length(m)
1	DCI and_UPV	12 (304mm)	31,500
2	PVC	8	472
3	DCI	6	3464
4	HDP	6	1539
5	GI	4	5264.8
6	HDP	4	3879
7	PVC	4	14,086
8	GI	3	12998.7
9	HDP	3	7646
10	HDP	2.5	1784.6
11	GI	2	3435.2
12	HDP	2	25,329.9
13	PVC	2 (50mm)	2191.5
14	GI	1.5	1943
15	HDP	1.5	1280
16	HDP	1	1497.7
Total			118,288.4

Appendix- 9. Wolkite town Projected Demand (2022 – 2042)

	Unit	Year						
		2021	2023	2025	2030	2035	2040	2042
Wolkite town population	No.	106488	115496	124990	150541	178615	208249	219715
Domestic Demand								
Privet house connection		3%	4%	5%	6%	7%	8%	9%
Yard connection		88%	86%	84%	82%	80%	78%	76%
Privet yard shared		9%	10%	11%	12%	13%	14%	15%
Number of Population								

per service level								
Privet house connection	No.	3195	4620	6250	9032.5	12503	16660	19774
Yard connection	No.	93709	99327	104992	123444	142892	162434	166983
Privet yard shared	No.	9584	11550	13749	18065	23220	29155	32957
Per capital water demand b Categories								
Privet house connection	L/c/d	60	65	70	75	80	85	90
Yard connection	L/c/d	30	32	34	36	40	42	44
Privet yard shared	L/c/d	40	41	42	43	44	45	46
Water demand Categories								
Privet house connection	M^3/d	192	300.3	437.5	677.44	1000.2	1416.1	1779.6
Yard connection	M^3/d	2811.3	3178.5	3569.7	4443.9	5715.7	6822.2	7347.3
Privet yard shared	M^3/d	383.4	473.55	577.5	776.8	1021.7	1311.9	1516
Total Domestic water Deman	M^3/d	3386.7	3952.4	4584.7	5898.14	7737.6	9550.2	10642.9
Non domestic Water Demanc	M^3/d	1,656.7	1,656.7	1,657	1,656.7	1,656.7	1,656.7	1,656.7
Average Day Demand	M^3/d	5043.4	5609.1	6241.4	7554.8	9394.3	111206.9	12299.6
Losses and Leakage (30%)	M^3/d	1513.02	1682.7	1872.4	2266.4	2818.3	3362.1	3689.8
Average Day Demand with Loss(ADD)	M^3/d	**6556.4**	**7291.8**	**8113.8**	**9821.2**	**12212.6**	**14569**	**15989.4**
Total Maximum day demand(ADD*1.2)	M^3/d	7867.7	8750.2	9736.6	**11785.4**	**14655.1**	**17482.8**	**19187.3**
Total Maximum Day Demand	L/sec	91.06	101.3	112.7	136.41	169.62	202.35	222.1
Peak Hour Demand (ADD*1.8)	M^3/d	11802	13125.24	14605	17678.2	21982.7	26224.2	28781
Peak Hour Demand	L/sec	136.59	151.9	169.03	204.6	254.43	303.5	333.112
Storage Capacity(33*MDD)		2596.3	2887.6	3213.1	3889.2	4836.2	5769.3	6332

Appendix- 10. Up grading pressure main hydraulic calculation

Site	X(m)	Y(m)	Z(m)	Static	L(m	Dia(	Cum.	Q(m^3/s)	Veloci	Loss(m	Com.Loss(m)	Head(m)
Spring	376857	900795	1934	-	#	#	-	-	-	-	-	-
P.H	376801	900605	1921	13	199	12.0	199	100.00	1.37	0.91	0.91	12.09
p_1	376898	900547	1944	-10	115	12.0	314	100.00	1.37	0.53	1.43	(11.43)
p_2	377138	900694	1947	-13	281	12.0	595	100.00	1.37	1.28	2.72	(15.72)
p_3	377348	900750	1949	-15	217	12.0	813	100.00	1.37	0.99	3.71	(18.71)
p_4	377744	900871	1960	-26	414	12.0	1227	100.00	1.37	1.89	5.60	(31.60)
p_5	378117	900962	1974	-40	384	12.0	1611	100.00	1.37	1.75	7.35	(47.35)
p_6	378471	900989	1988	-54	355	12.0	1966	100.00	1.37	1.62	8.97	(62.97)
p_7	378686	900994	1982	-48	215	12.0	2182	100.00	1.37	0.98	9.95	(57.95)
p_8	378879	901078	2014	-80	213	12.0	2394	100.00	1.37	0.97	10.92	(90.92)
p_9	379068	901072	1941	-7	203	12.0	2597	100.00	1.37	0.92	11.85	(18.85)
p_{10}	379330	901109	2012	-78	274	12.0	2871	100.00	1.37	1.25	13.10	(91.10)
BSR(Te	379525	901200	2024	-90	216	12.0	3087	100.00	1.37	0.98	14.08	(104.08)

Appendix -11.Pipe Data

Pressure Pipe Inventory Reports

ysis.wtg

Pressure Pipe Inventory

Pipes

	Diameter (in)	Length (Ductile Iron) (m)	Length (PVC) (m)	Length (All Materials) (m)	Volume (m³)
1.5 (in)	1.5	1,047	0	1,047	1.19
2.0 (in)	2.0	6,982	0	6,982	14.15
3.0 (in)	3.0	1,337	0	1,337	6.10
4.0 (in)	4.0	8,594	0	8,594	69.67
6.0 (in)	6.0	8,427	0	8,427	153.72
8.0 (in)	8.0	0	728	728	23.61
12.0 (in)	12.0	0	20,987	20,987	1,531.33
All Diameters	All Diameters	26,387	21,715	48,102	1,799.78

Close Help

Appendix- 12.Water Cade out Put of Pressure Junction at peak hour Demand

Label	ID	X (m)	Y (m)	Peak hour demand (l/s)	Elevation (m)	Pressure Head (m)	Zone
J-24	89	366980.8	918125	0.439	1898	7	Zone 2
J-13	97	365995.1	917264.7	0.13	1909	-4	Zone 2
J-28	116	366049.8	917029	1.6	1900	5	Zone 2
J-4	153	372527.8	904428	3.98	1946	-41	Zone 1
J-22	169	367158.8	916902	4.3	1879	26	Zone 2
J-6	189	367335.8	906512	7.19	1947	-42	Zone 1
J-23	198	366720.8	917709	0.5	1894	11	Zone 2
J-21	200	367064.8	916902	2.2	1880	25.46	Zone 2
J-7	201	366602.8	907743	11.98	1947	-42	Zone 1
J-18	212	366778.8	917511	1.5	1894	11	Zone 2
J-20	213	367363.8	917034	0.98	1868	37.73	Zone 2
J-25	219	367010.8	918238	1.39	1884	21	Zone 2
J-10	228	364274.8	911867	0.79	1712	193.31	Zone 1
J-19	230	367174.8	917011	1.5	1870	35	Zone 2
J-27	244	366047.8	917244	1.1	1907	-2	Zone 2
J-15	248	366253.8	917252	0.4	1902	3	Zone 2
J-16	249	366499.8	917282	0.14	1896	9	Zone 2
J-17	254	366646.8	917501	0.2	1896	9	Zone 2
J-26	269	366578.8	917552	0.119	1907	-2	Zone 2
J-5	284	369451.8	904924	0.42	1938	-33	Zone 1
J-29	287	366079.8	916516	1.3	1884	21	Zone 2
J-8	321	366048.8	908764	4.5	1932	-27	Zone 1
J-9	323	365592.8	909640	0	1746	159.09	Zone 1
J-11	324	363260.8	913671	0.98	1803	102.95	Zone 1
J-3	325	374944.8	903930	1.9	1952	-47	Zone 1
J-30	327	365998.8	916415	1.1	1894	11	Zone 2
J-31	328	365789.8	916308	1.47	1885	20	Zone 2
J-32	345	365421.8	916026	2.01	1882	25.3	Zone 2
J-33	346	363602.8	915897	1.96	1871	34	Zone 2
J-34	347	364353.8	915873	4.01	1874	32.8	Zone 2
J-35	348	365947.8	916881	2.39	1900	5	Zone 2
J-36	349	366031.5	917301.3	0.1	1905	0	Zone 2
J-37	350	366017.8	917445	1.5	1908	-3	Zone 3
J-38	351	366346.8	917385	0.7	1900	5	Zone 3
J-39	352	365952.8	917280	0.4	1904	1	Zone 3
J-40	353	365911.8	917275	0.8	1902	3	Zone 3
J-41	354	365703.8	917803	1.2	1894	11	Zone 3
J-42	355	365582.8	918025	1.5	1894	11	Zone 3
J-43	356	365866.8	917464	2.6	1902	3	Zone 3
J-44	357	365809.8	917277	1.1	1908	-3	Zone 3

J-45	358	365749.8	917066	0.62	1900	5	Zone 3
J-46	359	365749.8	917015	3.1	1899	6	Zone 3
J-47	360	365658.8	916610	1.98	1998	-93.61	Zone 3
J-48	361	365608.8	916374	0.01	1892	13	Zone 3
J-49	362	365605.8	916270	2	1890	15	Zone 3
J-50	363	365457.8	916202	1	1888	17.06	Zone 3
J-51	364	365373.8	916184	0.6	1886	19	Zone 3
J-52	365	364358.8	915928	1.7	1870	35	Zone 3
J-53	366	364383.8	915904	0.82	1865	40.11	Zone 3
J-54	367	365618.8	917234	0.89	1886	19	Zone 3
J-55	368	365891.8	917081	0.42	1905	0	Zone 3
J-56	369	365682.8	916242	2.98	1892	13	Zone 3
J-57	370	365581.8	916569	3.2	1896	9	Zone 3
J-58	371	364859.8	916165	3	1875	30	Zone 3
J-59	372	364466.8	915904	2.69	1865	40.18	Zone 3
J-14	478	366005.8	917279.4	0	1907	5.2	Zone 1
J-12	483	365995.1	917264.7	0	1905	7.3	Zone 1
J-2	489	376936.8	903070	2.23	1962	4.82	Zone 1
J-1	534	378897.8	900879.4	2.35	2012	13.9	Zone 1

Appendix-13.Pictures showing current situation of Wolkite town wate