HYDRAULIC ANALYSIS OF POTABLE WATER SUPPLY SYSTEM OF LEKU TOWN:
IN SIDAMA NATIONAL REGIONAL STATE

MSc WATER RESOURCE ENGINEERING AND MANAGEMENT THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A THESISSUBMITTED TO THE
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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF THE MASTERS OF SCIENCE

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Declaration

I hereby declare that this Msc thesis entitled **Hydraulic Analysis of Potable Water Supply System of Leku Town: In Sidama National Regional State** is my original work that was composed by myself and under the supervision of Dr. Mihret Dananto which 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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As members of the Examining Board of the Final MSc Open Defense, we certify that we have read and evaluated the thesis prepared by **Bereket Assefa Gebisso** entitled "**Hydraulic Analysis of Potable Water Supply System of Leku Town: In Sidama National Regional State"** and recommended that it be accepted as fulfilling the thesis requirement for the degree of **Master of Science** with specialization in water resource engineering and management.

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This is to Certify that the thesis entitled **Hydraulic Analysis of Potable Water Supply System of Leku Town: In Sidama National Regional State** Submitted in partial fulfillment of the requirements for the degree of Master's with specialization **in water resource engineering and management**, the Graduate program of the Department/school of **Water Resource and Irrigation Engineering** and has been carried out by **Bereket Assefa Gebisso ID. No PGWREMW/0009/11,** under my/our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby he can submit the thesis to the department.

Dr. Mhiret Dananto ______________________________

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Abbreviations and Acronyms

ADD	Adjusted Domestic Water Demand
BoWI	Bearu of Water Resource and Irrigation
CSA	Central Statistical Agency
DI	Ductile Iron
DCI	Ductile Cast Iron
DN	Nominal Diameter
EFY	Ethiopian Fiscal Year
EAR	European Academic Research
FGD	Focus Group Discussion
GTP	Growth and Transformation Plan
GI	Galvanized Iron
GIS	Geographical Information System
GPS	Geographical Positioning System
HC	House Connection
HDPE	High Density Ploy Ethylene
IWRM	Integrated water Resource Management
MoWR	Ministry of Water Resource and Irrigation
MDF	Maximum Day Demand
MDGs	Millennium Development Goals
MOH	Ministry of Health
NRW	Non-Revenue Water
PHD	Peak Hour Demand
PT	Public Tap
SNRS	Sidama Nation people Region
SRBoFED	Sidama Region Bearu of Faineance and Economic Development
SDG	Sustainable Development Goal
TWSO	Town Water supply office
UTM	Universal Transverse Mercator
UFW	Unaccounted for water
UN	United Nation

WHO	World Health Organization
YCU	Yard Connection Own
YSC	Yard Connection Shared

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ABSTRACT

In this study, Focus on Analyzing Hydraulic performance of water distribution system and Water supply coverage, for case study of Leku Town supply system has been assessed. The main objective of this study is to assess water supply coverage and determine the hydraulic performance of Leku Town water supply distribution system. Water CADv8i software used as tools to model water distribution system to evaluate hydraulic performance of water distribution system. The modeling effort included both hydraulic performance of existing and newly proposed distribution system. Simulation results for maximum and minimum pressures and velocity of distribution system were used as base tool to evaluate the hydraulic performance. Performance analysis of water supply distribution system includes efficiency of distribution systems, especially maximum and minimum pressure and velocity requirements, reservoir capacity, water loss etc, have been evaluated with WHO guideline and Ethiopia water supply standards. The adjusted domestic water demand at the end of the design periods, 2033 & 2043, is found to be in the order of 1,207 m3/day and 1,609 m3/day, respectively with considering the socio-economic and climatic adjustment factors. Water supply coverage was 65.6% in year 2020 G.C. The average per-capita water consumption was 13.11 l/c/day for year 2020 G.C. The result indicates that per-capita water consumption of Leku town was below the standard. Water loss of the town was range between 15% and 25% from the beginning up to the final design year. The hydraulic performance of water supply system was evaluated the operation of distribution network with reference to minimum and maximum pressure and velocity of junction and pipe respectively. The existing water supply distribution system 78.5% of the nodes were within recommended range between (15m to 70m). Whereas; the matter of concern of velocity shows that, 79% of the pipes in existing water supply distribution system were within recommended range velocity between minimum 0.6 m/s to maximum 2 m/s velocities. The analysis result indicates that the hydraulic performance of existing water supply distribution system of Leku town was poor performance, not permissible range and also there was low water supply coverage as well. Therefore; the existing water supply distribution system has low pressure throughout distribution system due to the topography of the area. The velocities in the water distribution system were extremely poor and cannot satisfy the demand of the community. So that; water distribution system need to improve hydraulic performance through redesigning the system.

Key Words: *Water supply coverage, Hydraulic performance, modeling water distribution system, pressure and Velocity of distribution system.*

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the study

Water is falling from the sky. It might be droplets or snowflake, sleet or hail. Water is always moving under your feet in unseen aquifers and in the pipes laid down by engineers to deliver drinking water for domestic consumption and also move wastes around our towns or cities. It moves nutrients inside soil for plants to feed themselves, animal and human being. Moreover; it moves inside our body (it is our blood), keeps your protein and DNA working and in their correct shapes and transport nutrients and signals in and out of cells (ALOK JHA, 2015). Therefore; Water is everything and essential to sustain life and a satisfactory (adequate, safe and accessible) supply must be available to all creature. Improving access to safe drinking-water can result in significant benefits to human health (WHO,2008).

The viability and distribution of water varies in nature with respect to space and time. It is scarce at some locations and at particular times and excess at other locations (and at another time at same location). Rainfall, which is the main water input to our ecosystem, is variable in space and time. The community needs water for domestic use and that for food production being the basic requirements, water needs of a society, both in quantity and quality depend upon its level of development. Water is also used for hydropower for energy production, industrial use, recreation, and navigation, to mention the most common ones. According to Thewodros and Seyoum, (2016), Water is a basic need in sustaining life. A safe, reliable, affordable, and easily accessible water supply is essential for good health.

The World Health Organization (WHO) and UNICEF (2011) Joint Monitoring Program currently estimates that 1.1 billion people (17 per cent of the global population) lack access to water resources (defined as the availability of at least 20 liters of water per person per day from an improved water source within a distance of 1 kilo meter). Moreover; universal water and sanitation coverage would still be far off in 2015, 605 million people would remain without access to an improved drinking-water source, and 2.4 billion people would be without access to improved sanitation facilities. Insufficient potable Water Supply services may result many water related and water born diseases, which ultimately affects the health of society. In addition, it affects productivity of the community and the performance of social services. It is known that safe water, adequate sanitation, and proper hygiene education (WASH) can prevent illness and death, leading to improved health, poverty reduction, and socio-economic development. Properly managed safe, water can substantially prevent water washed and insect borne diseases Thewodros and Seyoum, (2016).

Ethiopia has a large water resources potential which includes eleven major lakes with a total area of 7,400 Km2, twelve river basins with a total annual surface runoff of about 110 billion m and ground water with an estimated capacity of 2.56 billion m3. In Ethiopia majority of the citizens has unable to get an access to quantity and quality of potable water. Based on the National WaSH Inventory (NWI) conducted in 2011, the water supply access coverage estimated for the year 2011 was 48.85%, 74.64%, and 52.12% for rural, urban and total, respectively and the non-functionality rate was 25.5%. Accordingly, based on the National WaSH Inventory data for 2011, the base line water supply access coverage for 2010 would have been 43.46%, 72.56%, and 47.26%, for rural, urban and total respectively. This indicates that the baseline water supply access coverage used for the planning was exceeding the access figures interpolated to the baseline year based on the inventory findings by 22.4%, 18.9%, and 21.2% for rural, urban and total water supply access coverage, respectively and the non-functionality rate was higher by 5.5% than the base line data used for the planning, i.e. for year 2010. However, the sub-sector has taken boldly the outcome and revised the GTP-1 plan based on the new data MoWIE (2015) GTP-2 Plan.

The Regional government also has placed importance on improvement in access to safe water, where vision 2020, Regional BoWR long-term development plan, has aims to achieve 100% access and water supply services that satisfies the need of lower middle income of the people by 2020. However, the lead roll of water sector puts efforts into implementing various government water development projects. Nevertheless, the safe water access rate remains at 88% in urban Population and 38% of rural Population in the Region at 2020 G.C. This is due to high rate of non functionality of schemes, financial constraint and lack of local authorities to safe management and keeps water supply system operating as designed.

According to Thewodros and Seyoum (2016), the major problem facing the development of water supply sector is sustainability of the completed water schemes. The reasons for the failure of the schemes are many, which could be categorized in broad terms, as social, institutional, technical, financial and environmental. The current statistics indicate that 20-40 % of the completed water supply schemes are not functional due to the reasons mentioned above. According to the information generated from Regional BoWR, water supply schemes non functionality rate was 21% that need to be reduced. During the last years planning period it was planned to construct overall 31 water supply schemes of which 24 are rural and 7 urban. Of these, the construction of 25 water supply schemes of which 19 rural and 6 urban is completed. This indicates that the physical plan is achieved by 79% in rural and 86% in urban water supply. Therefore; the physical achievements in both rural and urban area were not meet.

Accordingly, Leku town was facing critical shortage of water supply for the last five years that requires urgent interventions. To alleviate the existing problem, large efforts have been made by the Regional government through providing technical and finance support and also inviting non-governmental organization to involve brining solution. The following activities have been done for the last five years by Government and non-governmental organization (Plan Ethiopia):-

- The Regional government involve in changing the main pipes along higher demand area by new distribution line based on the hydraulic analysis and design of the system.
- The Government also involve in drilling Remada deep well, since there were water shortage.
- Non-governmental organization (Plan Ethiopia) also involves in construction of Gudumale reservoir (100 m^3) and 17 water points.

Even though the above mentioned activities done so far the shortage of water supply for communities in Leku Town still continue.

Generally, Water Supply system in Leku Town has not been able to provide adequate drinking water services to all people. Therefore; it needs to improve the water supply performance and the water supply coverage. So as, to bring the community better health status; contribute for improve productivity and livelihood and the effectiveness of other social services. Therefore; this research was investigate the coverage of water supply, the effectiveness of system design performances and identifying the main reason of potable water shortage and recommend possible solution that will contribute for resolving the problem in Leku Town.

1.2 Statement of the Problem

According to the information gathered from Leku town Water supply service office and field survey, Leku town potable water Source were collected from five deep wells. The first water source were established in 1987 E.C by Chains development company and then expansion were made in 1997 E.C to meet grown demand of the community in Leku town. Currently among five wells two boreholes are out of function but water supplied for leku town is from three boreholes. The two boreholes are located at Taramisa well filed and the remaining one is Remeda well field. The first well "Taramisa No-1" were established in 1997 E.C and the depth of borehole172m. It has a yield of 16 liter/sec before, but now a days, it is giving 10 liter/sec. The water is pumped to Gudumalie 100 m^3 concrete service reservoirs. The second well "Taramisa No-2" was established in 1999 E.C and previously the depth of Well was 145 m but after rehabilitation the depth was decrease up to 100 m and also it has a yield of 10 litre/sec before, now it is giving 6 liter/sec is also pumped to the same Gudumalie 100 m^3 concrete service reservoir while the third well "Remeda well" has 5 litre/sec yield and finally discharged to 100m3 concrete service reservoir near to High school beside old main road. These situations indicate that the functionality and the discharge capacity of borehole (water produced) become decreasing through the time, while population of the town continuously increasing.

Existing storage reservoirs in Leku town was three ground level type reservoirs (GLR). Which were circular in shape and storage capacity 100m3 concrete reservoirs. This implies, existing town service reservoirs capacities are not enough to satisfy the current and future demand. The pipe in the existing water distribution system of Leku town has 31,811 meter in length and the pipe material was GI pipe that cover all over the system. The pipe installation work completed in 1987 E.C, the age of existing pipe was 27 years old. This implies the pipe in existing distribution system was getting old enough and on the way of retire service, Due the pipe bursting frequently. So that; the existing pipe was not in apposition of hold optimum pressure. In addition to this distribution lines were not laid according to the master plan of the town and laid at the center of the road and also same of the pipes are exposed and laid above ground soil. Thus, it is exposing to various damage that create frequent interruption in water supply and at the taps of residents with inadequate pressure.

Leku town existing water supply system has three pumps that used to lift water from three boreholes and drain to ground service reservoir (GSR) situated at high ground. The power sources for all pumps were electricity. Those pumps used for "Taramesa well One and Taramesa well Two" were driven by electric power called Marelli Generator, type – MgB 225 MA4, weight 412 kg and the transformer capacity of 110 KVA. Those pumps were installed in 1997 E.C and still functioning well. Whereas Pumps used for “Remeda Well” was type – ECSO 32-1 1/4, weight 60 kg and the transformer capacity of 100 KVA. It was installed in 1987 E.c and recently become out function and replaced by electrical pump. Based on the information of Town Water supply service office Leku town has experience of recurrent electric power fluctuation that contributes for interruption of water supply. The most common challenges in water distribution networks include capacity shortages, infrastructure ageing and deterioration, demand increases, and their ever-increasing energy consumption coupled with the global energy crisis (CSA, 2007).

In general, the access and coverage of potable Water Supply services are produced as sounding problem in study area. Therefore; inadequate access to water supply contribute to poor sanitation and personal hygienic practices is likely the cause of water borne diseases can cause significant damage to the Community.

Water Supply system in Leku Town has not been able to provide adequate drinking water services to all people. This lead that, a large proportion of population does not have access to improved services and those with access are also concerned with the quality of services such as water quantity, adequacy, reliability, response to consumer complaints. This research was investigating the major problem water supply system of the area. Finally, propose possible measures to ease the problem of Leku Town water supply situation.

1.3 Research Objectives

1.3.1 General objective

The general objective of this research is to assess water supply coverage and determine the hydraulic performance of potable water supply system of Leku Town.

1.3.2 Specific objectives

The specific objective of the research includes:

- To evaluate the existing water supply coverage and identify the existing problem.
- To analyze hydraulic performance of water supply system (Pressure, Velocity etc…)
- To find out the major problem of water supply system design that needs improvement.

1.4 Research Questions

This research will attempt to address the following research questions:

- What is existing water supply situation in the study area?
- What are the main hydraulic parameters affecting the performance efficiency of water supply system?
- What action should be taken to improve the situation?

1.5 Significance of the Study

This study is to investigate the state of the existing water distribution systems and to evaluate the hydraulic performance of the supply network under varying conditions of supply. It increases the knowledge and up to date information for individuals who are interested to study further. The information obtained from this research can help the community, different stakeholders, policy makers and other concerned bodies that concerning to improve water supply coverage, the efficiencies of the water distribution system operating and management. Moreover; existing water supply system will be assessed and the analysis of hydraulic performance that will contribute for the improvement the supply of safe drinking water for community in Leku town. It also serves as source for academicians and different stake holders those who want to study with same title. Furthermore, it helps to draw possible suggestions and recommendations in order to improve status of water supply and quality of drinking water in the study area.

1.6 Scope of the Study

This study specifically emphases on evaluation of potable water supply coverage and hydraulic performance of water supply system of Leku Town. The study area is limited to sub town of Leku water supply system. For this study required data was generated from primary and secondary data sources. The study faced same limitations such as shortage of time and budget to cover the whole areas of the Leku town. The studies of the research geographical limited sub-towns (kebeles) are Leku 01, Leku 02 and Leku 03 (Centrala part of Leku) and Morocho and Midiregent kebels are newly added kebels. The time coverage of the study was stretched from December 2021 to February 2022 GC based on the objectives of the study.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Water Supply in Ethiopia

Ethiopia is characterized by lower Water Supply coverage it is estimated that 62.7% of the Ethiopian population relies on unimproved water; diseases in Ethiopia are attributed to poor access to clean water and sanitation. The problem is more serious in rural area where the majorities of the people do not have access to potable water and therefore, depend on well, stream and river water for domestic use P.C et al (2013). In Ethiopia majority of the citizens has unable to get an access to quantity and quality of potable water. According to the report of UN-WATER/WWAP in 2004, relatively urban areas receive better water and sanitation service than rural. 65 percent of urban areas (excluding Addis Ababa) and 15 percent of rural areas has got potable water supply. Sewerage service is provided to a very a limited extent in Ethiopia. Moreover; relatively high urban water and sanitation coverage are reported for Ethiopia by the WHO-UNICEF Joint Monitoring Program (JMP 2015) based on national data collected by the CSA through household surveys. The JMP estimates 93% coverage with improved drinking water supplies (including 56% piped onto premises and 37% other improved sources). Urban water supply access of 84% is reported for 2014 using sector provider estimates (FDRE 2015). But millions of cases of illness associated with the lack of access to clean water and sanitation facilities have been diagnoized Thewodros and Seyoum, (2016).

Water supply plays the most important role in both social and economic development. Improved public health, better living standards and economic development are intimately related to the availability and access to adequate potable Water Supply. It has been widely argued that safe and adequate supplies of water together with proper sanitation are basic needs and essential components of primary health care (Lechissa, et al 2008). Scarcity of water forced the people to use unsafe water for the drinking and other domestic purposes (WHO, 2009). About 1.7 billion people in developing countries have no access to safe drinking water (Health UNICEF, 2013). As a result, about 50% of population in the developing countries suffered from water-borne diseases such as diarrhea, cholera, cascaras, hookworm (Murcoot, S., 2001).

Protection of water supplies from contamination is the first line of defense. Source protection is almost invariably the best method of ensuring safe drinking-water and is to be preferred to treating a contaminated water supply to render it suitable for consumption (Thewodros and Seyoum. 2016).

Access to safe water for drinking and sanitation should be available to every human being, now and in the future (WCOW, 2007). The survival and well being of a nation depends upon sustainable development and for this Purpose, Water Supply which are ingredients of a healthy and productive life are essential requirements. Water has always been a very important issue on the United Nations (UN) agenda. Likewise the Millennium Development Goals (MDGs), water will be also taken into account as one of the aspects for ensuring environmental sustainability. The UN states that the absolute daily minimum amount of water a person needs is 50 liters which include: 5 liters for drinking, 20 for sanitation and hygiene, 15 for bathing and 10 for preparing food. However because of scarcity, millions of people try to exist on 10 liters a day. Achieving these goals requires sustainable economic and social development in developing countries. (UNESCO,2003).

Provision of water and sanitation should be indispensable parts of the Poverty Reduction Strategies applied by developing countries. In the developing world today, poor access to safe water and adequate sanitation continues to be a threat to human health. Improving sustainable access to basic Water Supply a top priority for urban and rural community as a whole. So that, the recognizable development effort need for sustainable water supply infrastructure for know and the way forward.

2.2 Water Supply Condition in SNRS

Improving accessibility of water supply, sanitation and hygiene for every Community of SNRS has been a top agenda over the last decade and there have been committed efforts towards achieving the GTP-II or universal access plan targets. The water supply in SNRS has been steadily improving over the past two decades. In Sidama Region particularly, we can say that clean water is not adequately available especially for the rural as well as urban dweller, which accounts of more than 94.3%from the total population. In terms of access to safe drinking water as a main source of drinking water there will be significant difference between housing units in urban and rural areas.

According to 1999 E.C (2008/9) population and housing census results shows in urban areas close to 88% percent or more of the housing units had access to safe water supply as a main source of drinking water where as in rural areas the proportions were about 38% in the Region. In other, word the bulk proportions of rural households were getting drinking water mainly from unprotected well or spring, river, lake and pond. Due to lack of sustainability of project aggravated the existing poor coverage of water and sanitation implying negative impacts on coverage and on the attainment of the plan. However, due to the efforts made by governmental and non-governmental organization, the number of people with access to potable water supply increased. According to inventory data in 2008 E.C, The Region‘s clean water coverage is 81.56%, out of this 40.59% rural water coverage and 40.9% is the urban water supply coverage (SRBoFED and BoWR, 2012).

Drinking water is the minimum need of all human beings and provisions of convenient, safe, clean and adequate drinking water and also improves sanitation states should be the acknowledged commitment of Government. Population growth, rapid urbanization, water competition with different sectors that increases demand of water supply imbalance. Therefore; it needs a lot of effort by Government, community and concerned stakeholder to improve the situation.

2.3 Drinking Water Supply Coverage

The percentages of population with or without pipe water connection are a relevant indicator to compare the coverage of water supply in urban areas. To measuring the level of water consumption based on the amount of water consumed per capita per day (l/c/d). Water consumption is a function of availability, religion, climate conditions, and affordability. Another indicator used in measuring the level of water consumption is the quality of delivered water. In general, drinking water supply coverage was evaluated from per capita consumption with reference to (WHO, 2011) and (MoWR, 2006) standards for domestic water.

2.3.1 Per capita fresh water Availability

According to Yonas et al (2018), the available water resources should be adequate for different domestic and non domestic water uses. Many studies use falkenmark et al (1989). Water stress index to measure water scarcity. According to this index, Water availability < 500 m3/cap/year indicates water scarcity, while Values 500 m3/cap/year represent absolute water scarcity. This per capita water availability can be obtained from:

$$\mathbf{PWA} = \frac{\textbf{Water resources}}{\textbf{Total Population}} \text{ --------------------------------- } \mathbf{(1)}$$

Where:-

PWA= Per capita water availability (m^3/cap/year)

Water resources (m^3/year) and

A population (no of population)

2.3.2 Per capita water Consumption

This variable is used to determine the current state of consumption in routine household activities. According to Howard and Bartram, 2003) with a consumption of 100 L/cap/day at least all basic human needs are meet, including hygiene. Whereas GTP-2 minimum service level about 50 l/c/day for category 4, population of town(20,000 to 50,000) with in distance of 0.5 km for urban population as indicated in table 4.17 attached in Annex. The consumption can be assessed as:

$$\mathbf{PWC} = \frac{\textbf{Water Consumed}}{\textbf{Total Population}} \text{---------------------------------------} \mathbf{(2)}$$

Where:- PWC= Per capita water consumption (L/cap/year)

2.3.3 The population of piped water supply users with respect to the total population

According to Hsu et al, (2014), improved water supply means that a facility or delivery point protects water from external contamination particularly feacial contamination. This includes piped water to consumers. Therefore; the proportion of population having piped water supply must calculate in order to assess the states of improved water supply coverage of the city/town (Yonas et al, 2018).

$$\mathbf{PPWS} = \frac{\textbf{No of PPWSSUs}}{\textbf{Total Population}} * \mathbf{100} \text{------------------------------} \mathbf{(3)}$$

Where:-

- **PPWS = Proportion of piped water supply**
- **PPWSSU = Piped water supply service users**

2.4 Water Demand

Water Demand: the quantity of water required for a purpose. The demand of water depends on various types of uses. The consumption per head should be decided carefully considering all the possible uses of water. For the whole village, town or city refer to the total quantity of water required for the scheme. Requirements water for community purposes depend upon population size, living standard, degree of the culture and town development etc. They may be categorized into the following:

- **Domestic demand and**
- **Non Domestic demand**
  - Institutional and Commercial demand
  - Industrial demand
  - Public demand
  - Fire demand
  - Livestock demand
  - Demand for Losses and waste (Unaccounted water)

2.4.1 Classification of Demand

First of all when designing or expansion of water supply scheme, it is important to know the amount of water demanded by the different users. But, accurate estimation of water demand is difficult. So that, the problem of estimating water demand may be tackled by a detail study of the population, per-capita demand and design period of the scheme.

For the Purpose of water demand in the future, it needs consider various classification of demand are: Domestic, Institutional and Commercial, Industrial, Public, Demand for Losses (Unaccounted for water) and Fire demand.

2.4.1.1 Domestic Demand

Domestic water demand includes the water required in private houses for drinking, cooking, bathing, lawn sprinkling, gardening, sanitary purposes, etc. Domestic water consumption per person varies according to the living conditions of the consumers. Based on the UWSUAP of the country standard, the minimum quantity of water required for domestic consumption is taken as 20 l/c/day and non domestic consumption is 30% of the domestic (MoWR,2011).

In most countries the domestic demand accounts about 50 to 60% of the total demand. The total domestic water demand shall be equal to the total design population multiplied by per capita domestic consumption.

2.4.1.2 Non Domestic demand

Non domestic demand can be categorized into institutional demand, commercial demand, public demand, industrial demand, livestock demand, NRW and fire demand e.t.c. Therefore; it needs the detail study of present, past and future non-domestic demand should be calculated in design horizon.

2.4.1.2.1 Institutional and Commercial Demand

This includes the quantity of water required to be supplied to offices, factories, different industries, hotels, hospitals, etc. The quantity of utilization would vary considerably with number and type of industries, and number and type of commercial establishments.

- City with small industries = Average 50lit/person/day
- Industrial cities = Average 450 lit/person/day
- Less commercialized cities = Ave. 20 lit/person/day
- Highly commercialized cities = up to 50lit /person/day

The major industries use their own supply not to degrade the tow/city's water supply and cost. Hence, on average a margin of 18-25% of the total water demand may be taken for design (MoWR,2006).

- **Public Demand**

This is the quantity of water required for public utility purposes such as watering of municipal or public parks, gardening, washing and sprinkling on roads, use on public fountains and wastewater conveyance, etc. Usually the demand may range from 2-5% of the total demand (on the average 10lit/person/day).

- **Industrial Demand**

Industries water demand varies considerably with the type of industry and even for the same industry depending upon the age of the technology used. This makes demand estimation difficult. Based on the stage of Leku town majority of the industries are small scale industrial. Small scale industries taken to be 5.3% adjusted domestic water demand (MoWR, 2006).

- **Livestock Demand**

The quantity of water that required by individual resident to supply their livestock. For this purpose the amount of animals available in the area and the alternative source of water for livestock demand were surveyed and take in to consideration. It is assumed that most of the animals will be watered from such natural sources as rivers, streams, lakes, ponds, and springs in the vicinity (MoWR, 2001).

2.4.1.2.5 Fire Demand

The quantity of water required for extinguishing fire. This demand should be easily available and always kept stored in storage reservoirs. The volume of water required for firefighting is determined based on different factors among which fire incidence, duration, water flow in distribution system, density and size of buildings etc. According to Design Criteria Guide line of MoWR (2006), enlarging the total reservoir volume, by 10%, to reserve water for firefighting, is considered for design and planning purpose.

2.4.1.2.6 Unaccounted for water (UFW) or Demand for Losses

In water supply system, the individual meter readings are taken for every customer, they should exactly equal the amount of water that is measured leaving the treatment facility. In practice, however, this is not the case. Although inflow does indeed equal outflow, not all of the outflows are metered. These "lost" flows are referred to as unaccounted-for water (UFW). This is due to the water lost in leakage due to bad plumbing or damaged meters, or stolen water due to unauthorized water connection and errors in measurement, and unmetered usage. Therefore; these losses should be taken into account while estimating the total requirements.

In water distribution systems leakage could be reduction with optimal valve control. The inclusion of pressure- dependent leakage terms in network analysis allows the application of formal optimization techniques to identify the most effective means of reducing water losses in distribution systems. They describe the development of an optimization method to minimize leakage in water distribution systems through the most effective settings of flow reduction valves. (Vairavamoorthy and Lumbrs 1998)

Non Revenue Water = System Input Volume - Billed Authorized Consumption

$$\mathbf{NRW}\ (\%) = \frac{(\mathbf{WP-BAC})}{\mathbf{WP}} * \mathbf{100} \text{ ------------------------------------(4)}$$

Where: NRW = Non Revenue Water

WP – Water Production

BAC – Billed Authorize Consumption

2.4.2 Demand Multipliers

Water demand in a distribution system fluctuates over time. For example, residential water use on a typical weekday is higher than average in the morning before people choose work, and is usually highest in the evening when residents are preparing dinner, washing clothes, etc. This variation in demand over time can be modeled using demand patterns. Demand patterns are multipliers that vary with time and are applied to a given base demand, most typically the average daily demand Bletany (2008). The modeler needs to be recognized and take in to consideration of the impacts of temporal changes.

2.4.3 Time Varying Demand

The temporal variations in water usage for municipal water systems typically follow a 24-hour cycle called a diurnal demand pattern. However, system flow experience changes not only on a daily basis, but also weekly and annually. As one might expect, weekend usage patterns often differ from weekday patterns. Those are:-

- **Seasonal variation:** such variation occurs due to larger use of water in dry season, lesser use in rainy season.
- **Daily variation:** Day to day variations reflect household and industrial activity.
- **Hourly variation:** Hourly consumption usually attains peak value between about 7 A.M. to 11 A.M. and then again from 7 P.M. to 9 P.M.

➢ **Variation in Water Demand**

- **Average-day demand**: The average rate of demand for an average day (past, present, or future) (TAHAL, 2015).The sum of the design demand of domestic, commercial, institutional, industrial, public and unaccounted for water (losses).

- **Maximum-day demand:** The average rate of use on the maximum usage day (past, present, or future). It is the highest demand of any one 24-hour period over any specified year.
- **Peak-hour demand:** The average rate of usage during the maximum hour of usage (past, present, or future). The highest demand of any one hour over a day.

2.5 Population Forecasting

Demand Forecasting: Water resources planning and management is highly dependent on projections of future water needs or demand. The design of water supply scheme need to consider functionality of the various components now and in the future. The design period should neither be too long nor should it be too short. It implies that, the future water demand is a function of:

- Population at the end of design period
- Development plan of the city

Population data is important for predicting of water demand forecast is required to continuously satisfy consumers with quality water in adequate volumes and at reasonable pressure for Leku Town for coming 20 years at the end of design period. According to data obtained from CSA reports the population size of Leku town in 1994 and 2007 was 8,671 and 11,831, respectively. The population size of the town during the base year 2012 E.c which is obtained from CSA report and Water Supply Service Office of Leku town and the estimation about 36,842 of which the urban and rural population has been estimated to be 18,642 (51%)and 18,200 (49%) respectively.

Population Growth Rate: The growth rates which the town experienced in the past has been estimated based on observations on the past population size of town in 1994 and 2007. As it is explained above, the source of the population size of the town was growing at 2.4 percent per annum housing censuses conducted in1994 and 2007, respectively. Annual average growth rate the town experienced during 1994 -2007 was about 2.4 percent. For small towns like Leku a growth rate of 2.4 percent is too small since usually small towns experience large growth rate. Thus, the current growth rate about 4.66 percent found through Geometrical Increment Method. This growth rate is assumed to continue for the coming planning horizon. Accordingly, the urban population size of the town is expected to grow to about 46,264 at the end of design year (2043

G.C). To estimate water demand of the area the **Geometrical increment method**, used for population forecasting. According to Amanule et. al.(2020) the Geometrical increment method was adopted for the purpose of future population forecasting. Since, it is mostly applicable method for growing town having vast scope of expansion pattern like Leku town. Accordingly, Leku town population is projected up to year 2043 as shown in Table 2.1 below.

Table 2.1: Population Projection of Leku Town (2020-2043 G.C)

Year	**2020**	**2023**	**2028**	**2033**	**2038**	**2043**
Population	36,842	38,559	40,356	42,236	44,268	46,264

Per capita demand:- the average daily water requirement of a person. This is the most widely used for long time by utilities. The method assumes that only one variable, the population, provides adequate information on the water use and the development of use. The factors that affecting per-capita water demand for various purpose depending on the size of the town, living standard of the people and development status, pressure in distribution system, system supply, development of sewage facility of the towns, Cost of water and the climatic condition of the area.

$$\mathbf{PD} = \frac{\mathbf{Yearly\ WRT}}{\mathbf{365\ days * Design\ Population}} \quad \text{------------------------ (5)}$$

Where:-

- **PD = Per capita Demand**
- **WRT = Water requirement of Town(m^3/year)**

2.6 Water Distribution Hydraulic Analysis Software

Appropriate design of water supply distribution system is to deliver water of acceptable quality to individual users in adequate amount and with satisfactory pressure. The system should be capable of delivering the maximum expected design flow at sufficient pressure. There are quite a number of software which models and analyze water distribution systems. We have the open source which are free to download and use by individuals and organization while there are some which are practically closed from public use and others are commercially available to individuals and organization that may need them either for research, analyzing development of new water distribution systems or managing existing water distribution systems O.M. Awe *et al (*2019). The software each have their different aspect of forte and specialty which can denoted below.

2.6.1 Hydraulic Analysis by Using EPANET

The EPANET model simulates hydraulic and water quality behavior over extended periods of time. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of chemical species (EPANET User Manual) using the continuity equation and Bernoulli's equation.. EPANET can been applied to model chlorine residual analysis, understand the fate and movement of constituents in the drinking water system, model consumer exposure, and improve water quality in the system, including pipe cleaning and changing source utilization across multiple sources in the system. The software has several key features such as the ability to use cloud computing, access a freely available dataset when data is not available, and visualization tools. EPANET was developed by the United States Environmental Protection Agency and is available only on the Windows operating system (EPANET User Manual).

Advantage and Limitation of EPANET

Advantages and Limitations · **Program** has not been updated since 2008 · GUI interface is outdated · **Program** has no automatic calibration ability cannot process.

Advantages

- Perform extended period analysis
- Multiple methods to compute loss
- Program is open source
- Output data can be exported as a DXF file

Limitations

- Program has not been updated since 2008
- GUI interface is outdated
- Program has no automatic calibration ability
- Cannot process or import GIS spatial data
- Program cannot couple with SCADA

2.6.2 Hydraulic Analysis by Using Water CADv8i

Properly designed water supply distribution system with suitable layout of pipe network, storage tank, pump, Controlling valves provide acceptable pressure and flow rate for water supply and good water quality throughout in the system. This would contribute to meet demand for potable water one way anther. On the other hand, even though adequate water supply from source the system incorrectly designed it may lead low pressure or no water in some area and high pressure in other area that contributes to the leakage of the pipe.

According to O.M. Awe et al *(*2019), WaterCADv8i is a sub-set of Water GEMS. It is a user-friendly water distribution system modeling management and analysis software that has a range of functions which helps to improve design productivity. These functions include prefixed model building, data archiving and bespoke graphical data presentation, assessment of water demand, water distribution system configuration, design and operational scenarios and lastly CAD interoperability i.e. ability to model in any familiar platform of choice. WaterCADv8i was built with certain features and capabilities which differentiates it from other modeling software. These features include but not limited to ability to access fire flow capacity, analyze pipe and valve criticality, build and manage hydraulic models, design water distribution systems, development of maintenance, flushing and management plans, identify water leakages and manage energy use. WaterCADv8i is quiet easy to use and is generally considered a flexible and resourceful water distribution system modeling software. Moreover; Water CADv8i User Manual indicate that Utilities and engineering firms around the world trust Open Flows Water CAD as a reliable decision-support capability for their infrastructure. Design new water systems and manage existing water networks effectively to reduce disruption risks and energy use. Water CADv8i was developed by the United States Environmental Protection Agency and is available on the Windows operating system for the purpose of water distribution molding. Open Flows Water CADv8i ease-of-use helps you successfully plan, design, and operate water distribution systems:

- Increase capacity to adequate service levels.
- Supply clean potable water without interruption.
- Deliver high quality designs cost effectively.

Therefore; for this research purpose especially for hydraulic performance analysis water CADv8i software was used. Since software is ease-of-use helps you successfully plan, design, useful for improving the existing water supply system and designing a new water supply distribution system to meet future demand.

2.7 Type of Water Distribution System

Water supply distribution system performance indicators of urban water supply system are grouped under water resources performance, physical performance, and operational performance. Water resources availability and the availability of own water is mainly categorized under the water resource performance indicator. The capacity of storages, quality of the transmission and distribution lines and the density of the metered customers are taken as physical performance. On the other hand loss management, the operation and maintenance as well as quality of water supplied fall under operational performance Harry (2008)**.** Water distribution systems are designed to adequately satisfy the water requirements for a combination of domestic, commercial, industrial, and fire fighting purposes. The system should be capable of meeting the demands placed on it at all times and at satisfactory hydraulic performance Onin (2005).

2.8.1 Intermittent water supply system

In important component of water system is the distribution network which conveys water to consumer from the source. An urban area of developing counties of particular concern the quantity of portable water for supply is not sufficient enough to meet the demand of the community. In such case exhibited the water conservation measures would be employed.

The design of water distribution system in general has been base on assumption of continuous supply. In most developing countries water supply is not continuous but intermittent this could have seen for seen at the design stage. This has resulted in severe supply pressure problem in the network and great inequalities in the distribution of water.

The survey result implies that water Leku town water supply system was intermittent water supply system due to shortage of water supply from the source and insufficient storage capacity of service reservoir.

The problem of intermittent water supply system;

- Overall shortage of water
- In sufficient pressure in distribution system (several areas in the network had zero pressure)
- Inequitable distribution of the available water
- Very short duration of supply
- High level of contamination etc--

In the intermittent supply system the consumers depend on the individual of land or ground storage tanks there to provide their daily need of water for domestic industrial and other uses.

2.8.2 Continuous water supply system

A continuous water supply system is conveying the water through the distribution net work continuously without interruption. Due to availability of surplus water source effective supply system and well designed distribution network

In the continuous supply system water distribution net work should be designed to with stand rang of pressures corresponding to minimum and maximum supply conditions. Moreover: the hydraulic relation between the demand and water supply is clear.

2.9 Water Distribution System Simulation

Simulation refers to the process of imitating the behavior of one system through the functions another. Farther, the term simulation refers to the process of using a mathematical representation or real system, called a model (Bentley, 2008). Using simulations, problems can be anticipated in proposed or existing systems, and can be evaluated before time, money, and materials are invested in a real-world project Tomas, et al. (2003).There are two types of simulations in water distribution networks type of model simulations are either steady-state or extended-period simulation.

2.9.1 Steady State Simulation

Steady state simulations were used to determine the operating behavior of a system under static conditions. It compute the hydraulic parameters such as flows, pressures, pump operating characteristics, and others by assuming that demands and boundary conditions were not change with respect to time. In general, this type of analysis is used to determining the short-term effect of demand conditions on the system (Tomas, et al., 2003).

2.9.2 Extended Period Simulation

This analysis used to evaluate the dynamic behavior of a system over a period of time, and it analyzes the system on assumption that the hydraulic demands and boundary conditions were changed with respect to time. The need to use extended period simulation is due to the system operations change over time.

- Demands vary over the course of the day.
- Pumps and wells go on and off.
- Valves open and close.
- Tanks fill and draw.
- Water quality

Therefore; regardless of project size, model-based simulation can provide valuable information to assist an engineer in making well-informed decisions (Tomas, et al., 2003).

2.10 Hydraulic Model Calibration

The existing water supply network simulated model would be calibrated by direct field measurement with the sample hydraulic parameters (pressure, velocity, and flow rate etc.) Hydraulic behavior refers to flow conditions in pipes, valves and pumps and pressure or head levels at junctions and tanks. According to (EPA,2005) for hydraulic model calibration parameters that are typically set and adjusted include pipe roughness factors, minor losses, demands at nodes, the position of isolation valves (closed or open), control valve settings, pump curves and demand patterns. When initially establishing and adjusting these parameters, care should be taken to keep the values for the parameters within reasonable bounds. Use of unreasonable values may lead to a better match for one set of data would typically not provide a robust set of parameters that would apply in other situations.

2.11 Hydraulic Design Parameter

The main hydraulic parameters in water distribution networks are the pressure and the flow rate, other relevant design factors are the pipe diameters, velocities and the hydraulic gradients (Masri M. 1997).

2.11.1 Pressure

The pressure at nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances, and the size of the network (Masri M. 1997). The minimum pressure should be maintained to avoid water column separation and to ensure that consumer’s demands are provided at all times. The maximum pressure constraints results from service performance requirements such fire needs or the pressure bearing capacity of the pipes, also limit the leakage in the distribution system, especially that there is a direct relationship between the high pressure and the increasing of leakage value in the system.

2.11.1.1 Pressure Management

The pressure management approach seems to help maintain average pressures throughout the system, eliminating extreme transients in pressure during peak hours and preventing pipe damage. Pressure transients and extremely high peak pressures are major causes of failures and leaks in the distribution network. Adequate installed and maintained pressure reduction valves could provide the distribution network with an easy, cost-effective leak prevention method significantly reducing the risk of leakage Faraj (2013).

- **Low Pressure condition**

Poor pressures can be caused by inadequate capacity in a pipe or pump, high elevations, or some combination of the two (Chambers, et al., 2004). Pressure loss can be created due to friction inside the pipe wall and its magnitude dependent on properties of the fluid that is passing through the pipe, water demand, the velocity of fluid moving inside the pipe, and the internal roughness of the pipe, pipe length, gradient and diameter of the pipe.

- **High Pressure condition**

High pressure during low demand conditions can cause pipe bursting, leakage and large amount of water losses through the distribution networks. Therefore, when dealing with high pressures, PRVs should be used to reduce and regulate pressure in the system (Tomas, et al., 2003).

- **Negative Pressures**

In water distribution system the negative pressures should always be avoided. Since, it has the potential to allow contaminants enter the system. Faecal organisms and cultivable human viruses may be present in ground adjacent to a pipeline and drawn into a pipe during transient low or negative pressures Lechevallier et al.(2003 cited in Mosissa 2008). Hydraulic models can be used to identify where, when and how negative pressures may occur.

2.11.2 Flow rate

Flow rate is the quantity of water passes within a certain time through a certain section. Velocity is directly proportional to the flow rate. Since, a known pipe diameter and a known velocity, the flow rate through a section can be calculated. Low velocities affect the proper supply and will be undesirable for hygienic reasons i.e sediment formation may cause due to the long time of retention. The effect of the velocity on the diameters of pipe system can be observed from the following equation:

$$V = \frac{4Q}{\pi D^2} \text{---} (6)$$

$$D = \sqrt{\frac{4Q}{\pi * V}} \text{---} (7)$$

Where : D : diameter of the pipe (m)

Q : discharge (m3 /sec)

V : velocity (m/sec)

From the above equation it is clear that the velocity increasing while decrease the diameter value. Generally, hydraulic performance of water supply system was evaluated the operation of distribution network with reference to minimum and maximum pressure and velocity of junction and pipe with reference to peak hour consumption and low hour consumption stated in Ministry of water resource urban Water Supply Design Criteria Guideline (MoWR, 2006).

2.12 Review of Related Works

Seleamlak M. (2015) Hydraulic Modeling and Improvement of Addis Ababa Water Supply, the Case of Bole Bulbula System shows that, Water supply coverage analysis was evaluated with the number of domestic connections per family and the average daily per capita consumption are used to analyze the domestic water supply coverage for the entire system. 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 capita consumption using the population.

According to Siraj A. (2020), An average per capital consumption has been derived from the annual and monthly consumption of each kebeles which aggregated from customers' water meters. Also distribution of domestic connection per family has been evaluated using number of connections with population and average per capita consumption. Tthe finding of this research, the percentage domestic water supply coverage of Adama town is 64% which was less than the Oromia

Urban Water Supply Coverage achievement planed in 2015 to be 96% as well as when compared to the MDG targets of urban Water Supply Coverage.

Naeeni S (1996) developed a computer program, which enables to obtain the optimum design of various kinds of water distribution networks so that all constraints such as pipe diameters, flow, velocities, and nodal pressures are satisfied. A computerized technique will be developed to obtain the optimum design, which achieves the demands of the consumers at lowest cost using the commercial pipes (Al-Abbase R.2000). Likewise, for optimum design of water distribution networks, Masri M (1997) will be develop a computerized technique for the analysis and optimal design of water distribution networks. The results show that the selection of the hydraulic restrictions should be reasonable and reflects the real capacity of the water distribution system. The performance of the network was evaluated from a hydraulic point view using a systematic, engineering approach, and the results indicated that the performance would be adequate and the system provided an acceptable level of service based on pressure considerations (Abdel-Latif,M.Y 2001).

Vairavamoorthy et al., (2000) suggested a new method of design sustainable water distribution systems in developing countries. They developed a modified mathematical modeling tool specifically developed for intermittent water distribution systems. This modified tool combined with optimal design algorithms with the objective of providing an equitable distribution of water at the least cost forms the basis of this new approach.

Siraj A. (2020), Assessments of Urban Water Supply Situation of Adama Town, indicate that a water distribution system is designed at peak hour demand. By examine what is going on the system as result of peak hour, solutions have been given to the problems faced (pressures and velocities out of the design limit) within the network. The model modified by these the procedures::

- At minimum hour demand, pressures at junction of low elevation were high, reduction to desired pressure has been made by using pressure reducing valves
- At peak hour demand, the velocities out of the design range are modified by resizing pipe diameters.

Dessalegn and Fekadu (2021), Hydraulic performance Analysis of water supply distribution network using water GEM v8i. in the case of Alibo Twon shows that, in the distribution network system same velocity can be less than permitted level of MoWR and the negative pressure junction can also occur in the systems of networking distribution. Some of the nodes have low values of pressure, steady state analysis (5<=P<=10m) and nodes having high values of pressure, steady state analysis (80>=P<=128.45m). The software finds the lowest allowable diameter for each pipe segment that was allow the system to function, or more specifically, to meet the minimum pressure requirements at all junctions.

CHAPTER THREE

3 MATERIALS AND METHODS

This study was start with the evaluation of existing water coverage and the efficiency of the water supply system of the Leku town. The assessment water supply coverage focus on the volume of consumption and level of water connection. To investigate system efficiency difficulty, the main pipe and distribution pipe line including water loss due to leakage will be elevation and other relevant date was collected. The water loss will evaluate by using data of water production and consumption. Moreover, pressure, velocity, discharge and water quality in distribution system (residual chlorine & water age) data Collected and analysis by Water CAD model. In addition that to evaluate the existing water supply problem in the ground households interview, field survey and key informant interviews will be carry out and data analysis through SPSS. Finally, based on the analysis result key factors was identified and possible recommendation was proposed to solve the problem

3.1 Description of the study area

Leku Town is one of a towns found in Shebedino woreda in Sidama National Regional State of Ethiopia which is located at the North-central part of SNRS at a distance of 27 km from the capital city of Hawassa. Astronomically it is located at 6°55'10"- 7°04'10" North Latitude and 38°31'27"-38°36'29" East Longitude. The total area that covers by Leku Town is about 1,682.95 ha.

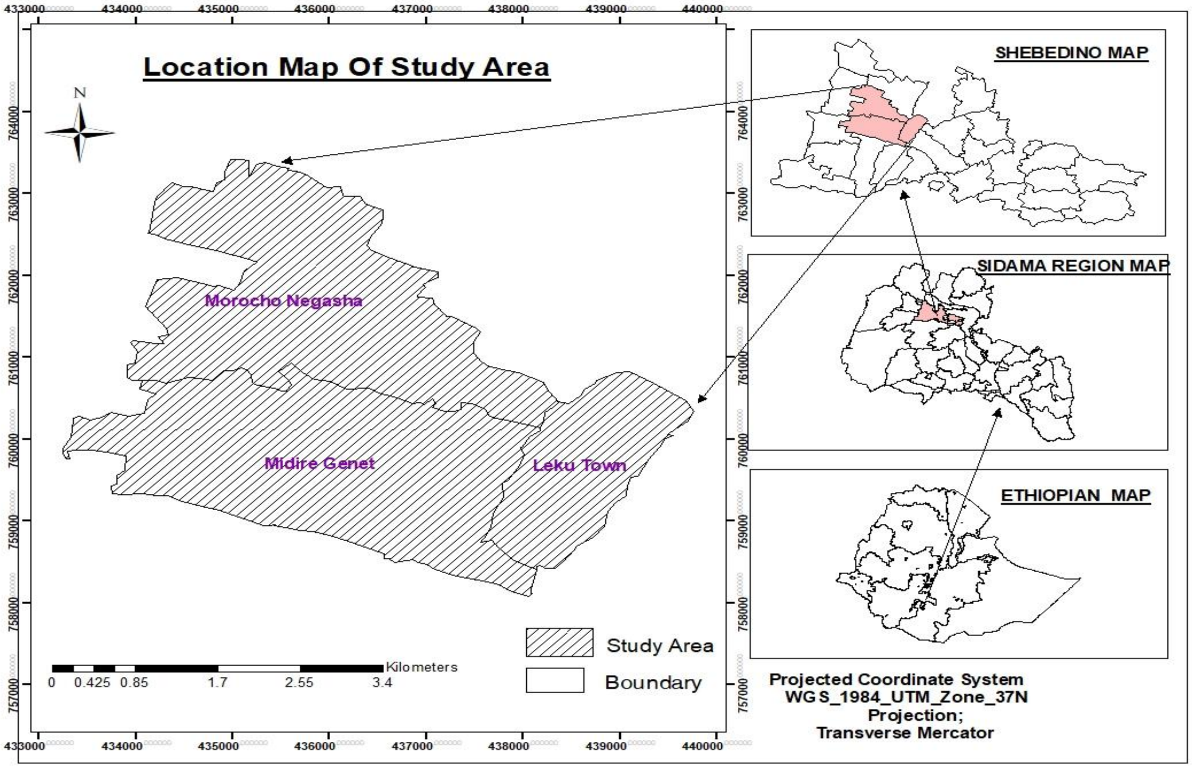


Figure 3.1 Map of Study area

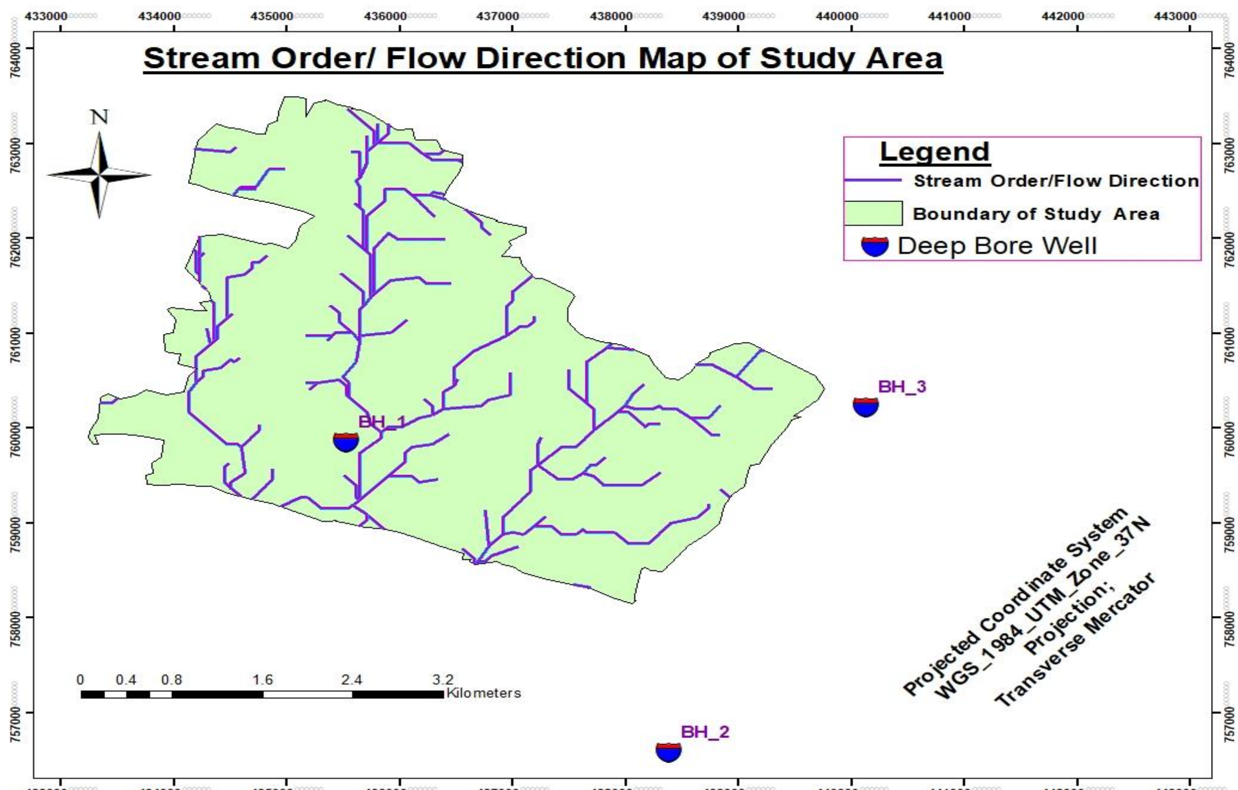


Figure 3.2 The Stream Network of Study area

3.1.1 Population

According to the Reports of CSA and the Water Supply Office of Leku town are the sources of secondary data on the population size of the town. According to CSA reports, the population size of the town during the 1994 census was about 8,671. During the second national censuses conducted in 2007, the population size of the town has grown to about 11,831. Based on the population size of the town in 1994 and 2007, the rate at which the population was growing between the two periods has been estimated to be 2.4 percent.

According to data obtained from Water Supply Office of Leku town and statistics of the Sidama Region Bureau of Finance and Economic Development (BoFED,2015), the population growing rate the year between 2007 and 2013 E.C has been estimated to be 3.4 percent. Accordingly, the population size at 2012 E.C was become 36,842people in the Leku Town who live in 5kebeles, out of which 51% (18,642) were males and the rest 49% (18,200) were females, as per the 2012 E.C. The family size is 5 and total household size was 7,368 HHs live in the Town. The population density of the area is 6,590 per/ km^2.

According to data obtained from CSA reports and Water Supply Service Office of Leku town, the population size at 2012 E.C was about 36,842.

Table 3.1: Population Size of Leku Town

Year	Male	Female	Total
1994	4464 (51.5%)	4207 (48.5%)	**8,671**
2007	6298 (53.2%)	5533(46.8%)	**11,831**
2012	18,642 (51%)	18,200 (49%)	**36,842**

Source: CSA reports, and Water Supply Office of Leku Town

3.1.2 Climate and Topography

Climatic condition of Leku Town generally categorized as Woina Dega and the slop class of the area were 0-3% cover 273..92 ha of land (16.3%), slope class 3-8% cover 513.27 ha (30.5%), slope class 8-15% cover 535.09 ha (31.8%), slope 15-30% cover 322.04 ha (19.1%), slope class 30-50% cover 36.56 ha (2.2%) and slope greater 50% cover 2.07 ha of land (0.1%). The elevation is ranges between 1,600-2,609 m.a.s.l, and the average Temperature 12-26℃ and the average rainfall is 1,123 mm/year.

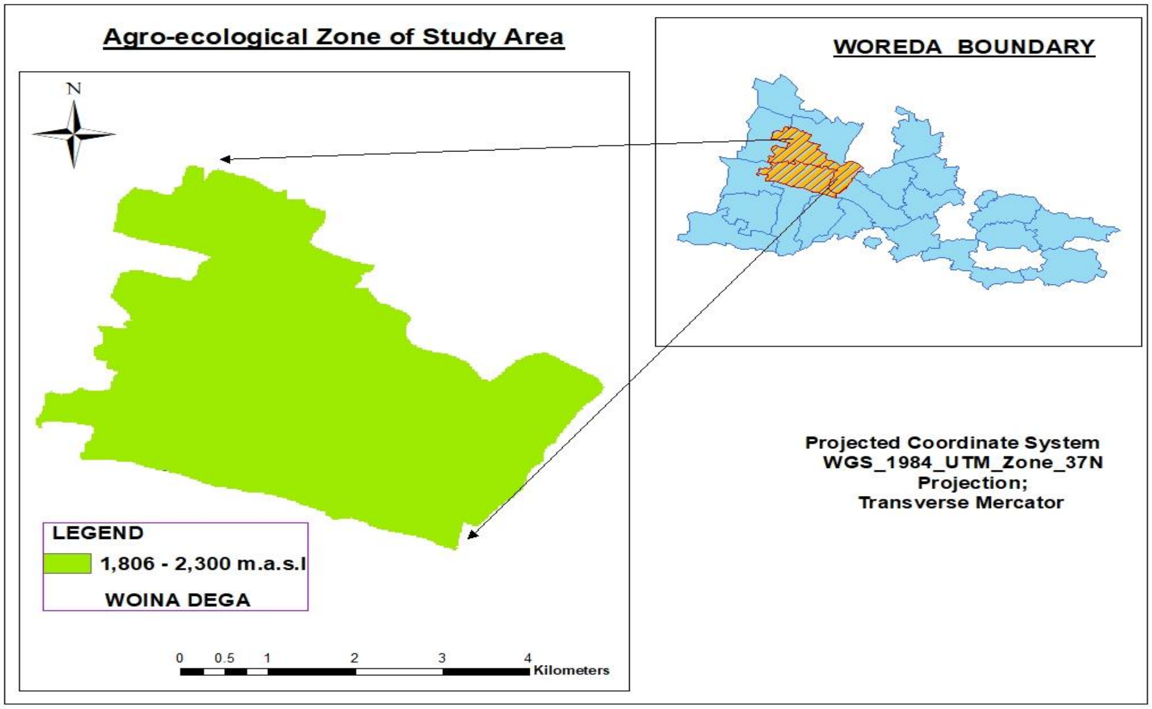


Figure 3.3 Agro-ecology of Study Area (ARC GIS 10.3 software)

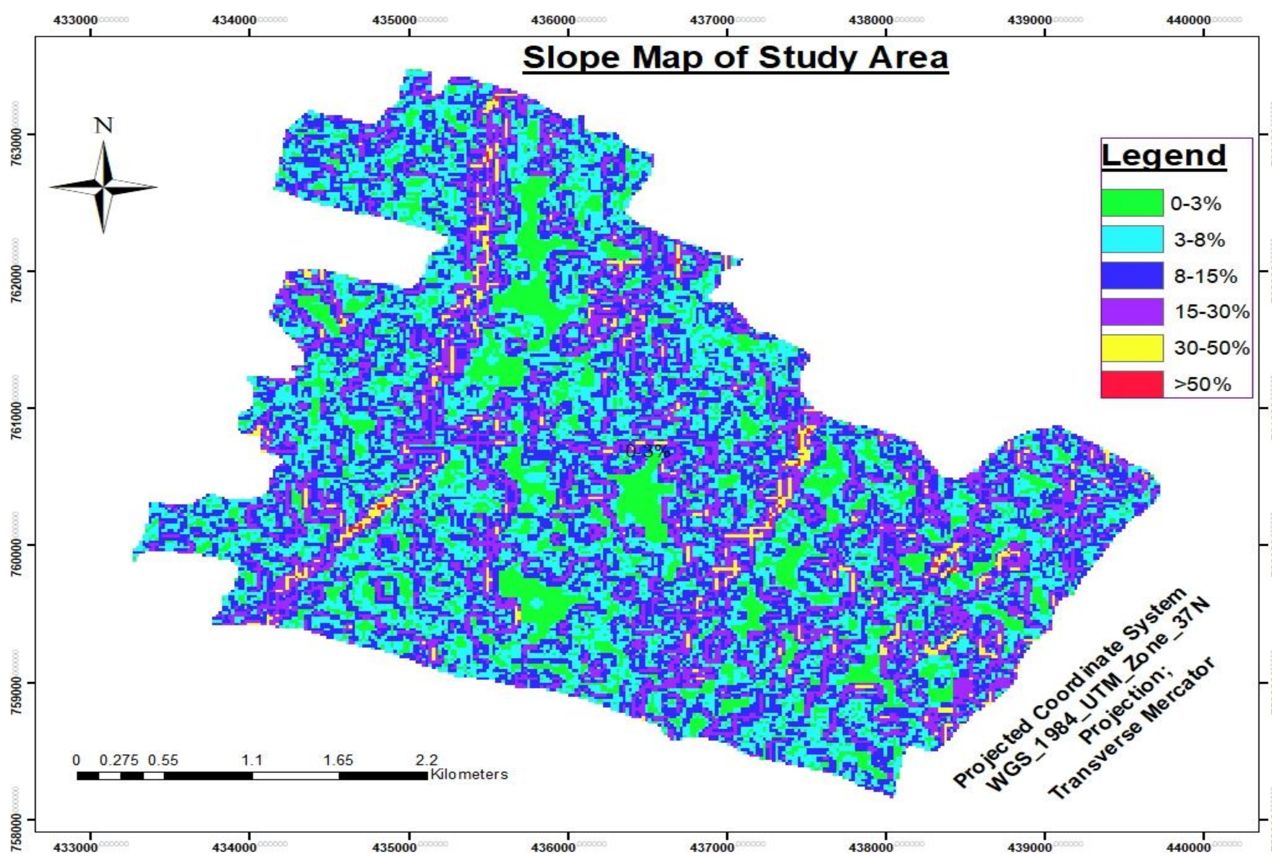


Figure 3.4 Topography of the area (ARC GIS 10.3 software)

3.1.3 Socio-economy

The socio-economy situations of Leku Town are both small scale trading and agriculture. The major crop cultivated in this Town are Coffee, Enset, Vegetables, Sugarcane, Bean, Avocado, Mango and Chate can be mentioned Homestead consist of round huts surrounded by abundant garden of agro-forestry type, with tree of Coffee plant, Enset, and a variety of fruit trees, including mangoes, avocados, peaches, and many others grow in abundance. Among those Coffee, Chate, livestock production and Vegetables are the main cash crops of the area, This Town situated in one of Lake Hawassa catchment which is sensitive ecosystem for degradation that to be found Great Rift Valley. Lake Hawassa is one of the biggest Lake in the region which has wider catchment and fragile ecosystem.

3.2 Materials

For this research purpose the following materials and software's were used to collect data, processing, analyze data and evaluation of output.

- GPS used for field survey
- Structured and unstructured questioners for households interview
- Water CADv8i software used to evaluate hydraulic performance (Pressure and Velocity)
- Arc GIS software used for delineation, stream flow direction, slope class and land use of study area.
- Excel and SPSS software also used.

3.3 Data Collection Method

Leku Town the existing water supply system distribution network, pressure, velocity, discharge, pipe diameter, length, reservoir & tank information, distribution means (Gravity or pump) and X,Y,Z co-ordinate e.t.c…all relevant data of old distribution system was collected if data available Leku town WSO otherwise surveyed. The secondary data main line used to compare with the surveyed data, forecasted population, Consumption and production data and level of connection dates were collected from concerned governmental institutions.

So that; collected data hydraulic performance of existing water supply system was analysis by Water CADV8i software. Likewise to evaluate and triangulate the existing problem of water supply situation of Leku Town households interview, field survey and key informant interviews were used and data analysis through SPSS.

In this study; Structured and unstructured interview, personal observation and document analysis are the principal means of gathering the data appropriate method in the study. The researcher supervised and managed the interview of the key informant. Furthermore, a focus group discussion (FGD) was also selected as a data-collecting tool for this research. In addition to this the spatial distribution of water sample of the study area location are carried out using GPS and Arc GIS software.

3.3.1 Primary Data Collection

Primary data of hydraulic analysis of water system was collect from Town water supply office and field survey to evaluate existing water supply coverage and the efficiency of the system, by using (GPS, water meter and field observation)

- The type of pipe materials, pipe diameter, pipe length, fittings and valves has been collected from the site and TWSO in order to identify whether the system have material quality problem or not.
- Reservoir & tank information, distribution means (Gravity or pump) and x.y.z co- ordinate.
- Pump information and source of power.
- Pressure, velocity and discharge measurement taken at different time and in different location to perform calibration and validation.
- Population present and Population forecast
- Key informant discussion with the officials and experts in the concerned government offices at woreda and Regional level to obtain organizational information.

In addition to this the structured and unstructured interview were used for household survey, key informant interviews and personal observations of Water Supply conditions of the study area.

3.3.1.1 Household Survey

For the assessment of Leku Town water supply systems, four indicators have been taken in to consideration according to the guidelines of WHO (2004). These indicators mainly focused on water quantity and quality supplied to users, the accessibility for continuity supply of the water supply system, convenience of the water sources. In addition to this, access to water supply, operation and maintenance are addressed through the questionnaires.

The household survey was conducted to collect primary information on current socio-economic situation. And also the information on present water supply situation, future water demand, and existing problem on water supply services, existing capacities, water supply facilities and possible water sources in the town.

Before starting the data collection work, orientation was given for five enumerators, selected by researcher. Then after pre-testing the questionnaires, leading the enumerators to gather information on water supply situation from the household and making corrections. The actual survey was conducted in five town kebeles.

- **Interview procedure**

Formal and informal interviews were conducted to collect information on present water supply situation of the town. The collected evidences through interviews used to draw idea regarding people's feeling about the current water supply service and their attitudes towards the need for planned intervention to boost up the services.

3.3.1.2 Key Informant Interview

Key informants interviews were carried out to collect background information on water supply system network, hydraulic efficiency, coverage of water demand, and supply situation of the Leku Town. The interviews were held with select individuals of Town and Regional water office experts who were believed to have good knowledge, skill &experience about the subject matter.

3.3.2 Secondary data collection

Secondary data were gathered from various data sources such as publications, related research, and design of scheme & report documents. A literature review of the related documents was exhaustively made. The purpose of the literature review is to distinguish what have been done before and what the gaps were observed.

Hydraulic analysis of main pipe line from design document or surveyed data and used to compare with the model analysis result made by using primary surveyed data. Moreover:

- Water production and water Consumption and loss data were collected and analyzed to evaluate the coverage of water supply system.

- Existing water supply system data was collected which used to analysis of hydraulic performance of the system and future water demand projection.
- The amount of consumer data as per level of connection were collected which used to analysis the coverage.
- Total number of population and population forecast.
- Per capital demand of the town and compared with standards.

3.4 Sampling techniques

Samples were taken from locations that are representative of the water source, storage facilities, distribution network, points at which water is delivered to the consumer, and points of use. For colleting necessary data random sampling were used to obtain distinct sets of field measurements. Leku Town has 5 kebeles were selected, due to seriousness of the problem, budget and time constraint three Kebeles are select by using purposive sampling techniques.

For hydraulic performance analysis field survey, primary and secondary data were collected based on the following conditions.

- Peak loading area
- Average loading area
- Under low loading area

Based on the criteria distribution route, elevation, demand pipe size, length, and type of materials, reservoir capacity, flow rate, velocity at pipe and pressure at 24 selected points junction and other relevant parameters on selected point of distribution system of water supplies network analyzed by using Water CADv8i software.

Table 3.2: Sample size for hydraulic performance indicators (Pressure and Velocity)

No	**Sampling Conditions**	**Sampling area/Location**				**Total**	**Remark**
		MP	**Pd**	**SD**	**PJ**		
1.	High load area	2	2	2	2	8	
2.	Average load area	2	2	2	2	8	
3.	Low load area	2	2	2	2	8	
	Sum	**6**	**6**	**6**	**6**	**24**	

N.B: Main Pipe /MP/, Primary Distribution /PD/, Secondary Distribution /SD/, and Pipe Junction /PJ/

Sample size; Ideally, during water distribution model calibration process was adjusted for each link and node; however 2%-10% of representative sample measurement can be made available for the use of model calibration due to limited financial and labor requirement for data collection. In general, international guidelines instruct or proposed that for a medium to highly detailed network model (medium to low skeletonization), this limits was take in to consideration (AWWA, 2005).

Based on the information obtained from TWSO and field survey, the existing water supply system of Leku town has 61 junctions and 67 pipes. For a purpose of hydraulic performance evaluation as indicated above in table 3.2, a total of 24 samples were used for evaluation of velocity at pipe and pressure at selected junction. This indicates that 20% of the sample represents pressure evaluation. Whereas 18% of the sample was took for evaluation of velocity at pipes.

3.5 Hydraulic Performance of Water Supply System

The main purpose of modeling is to assessing the existing system and to evaluate the hydraulic performance of Leku town water supply system and propose efficient water supply system in the area. The existing data, procedure of evaluating of the system as follows:-

- First of all skeletonizing the existing water supply distribution network of Leku town by conversion of the existing network of the town through Water CADv8i software.
- Then, important elements such as junctions or nodes, pipe, tanks and reservoirs, pumps, etc. were located.

Data entering procedure- all the existing data collected and generated data have been entered into the built Water CADv8i software. Then the system has been simulated for steady state and extended period simulation.

Calibration Approach- The trial and error process that usually follows Water CADv8i calibration or manual approach was used for calibration. This generally carried out through simple estimated of pipe diameter, length, roughness as well as nodal demands and elevation, analysis of simulation, and comparing predicted performance to practical performance. The result of analysis is unacceptable, then the cause of the problem must be hypothesized and modifications of same parameter must be made and continue the same procedure until it riche acceptable output.

3.6 Principles of Hydraulic Analysis

Flow in a pipe network satisfies two basic principles, conservation of mass, and conservation of energy.

3.6.1 Conservation of Mass

Conservation of mass states that, for a steady state system, the flow into and out of the system must be the same (Lansey,1991). Based on the principle, at any node in the system under incompressible flow conditions; the total volumetric or mass flow in must equal the mass flow out.

This relationship holds for the entire network and for individual nodes. One mass balance equation is written for each node in the network as:

$$\sum \mathbf{Q\ in} - \sum \mathbf{Q\ out} = \mathbf{Q\ demand} \quad \text{---} \ \mathbf{(8)}$$

Where: $\sum$ Q in: flows in pipes entering the node.

$\sum$ Q out: flows in pipes exiting the node.

Q demand: the user demand at that location.

Separating the total volumetric flow into flows from connecting pipes, demands, and storage, we obtain the following equation Heasted methed, (1999):

$$\sum \mathbf{Q\ in}\ \Delta \mathbf{t} = \sum \mathbf{Q\ out}\ \Delta \mathbf{t} + \Delta \mathbf{VS} \quad \text{--} \mathbf{(9)}$$

Where: $\sum$ Q in: the total flow into the node.

$\sum$ Q out: the total demand at the node.

ΔVS: is the change in the storage.

Δt: is the change in time.

3.6.2 Conservation of Energy

It is the second governing equation that describes the relationship between the energy loss and pipe flow. The head losses through the system must balance at each point. For pressure networks, this means that the total head loss between any two nodes in the system must be the same regardless of what path is taken between two points. The head loss must be sign consistent with the assumed flow direction gain head when proceeding opposite the direction of flow, and lose head when proceeding with the flow Heasted methed, (1999).

The Energy equation is known as Bernoulli's equation Daugherty et al,(1989). It consists the pressure head, elevation head, and velocity head. There may be also energy added to the system (such as by a pump), and energy removed from the system (due to friction). The changes in energy are referred to as head gains and head losses.

In the hydraulic applications, energy values are often converted into units of energy per unit weight resulting in units of length. Balancing the energy across any two points in the system. The energy equation will be as follow:

$$\frac{p_1}{\gamma} + Z_1 + \frac{V_1{}^2}{2g} + HG = \frac{p_2}{\gamma} + Z_2 \frac{V_2{}^2}{2g} + HL \text{--} \quad \textbf{(10)}$$

Where :

P : is the pressure (Ib/ft2 or N/m2)
γ : is the specific weight of the fluid (Ib/ft3 or N/m3)
z : is the elevation at the centroid (ft or m)
V : is the fluid velocity (ft/s or m/ s)
g : is gravitational acceleration (ft/s2 or m/ s2)
HG : is the head gain, such as from a pump (ft or m)
HL : is the combined head loss (ft or m)

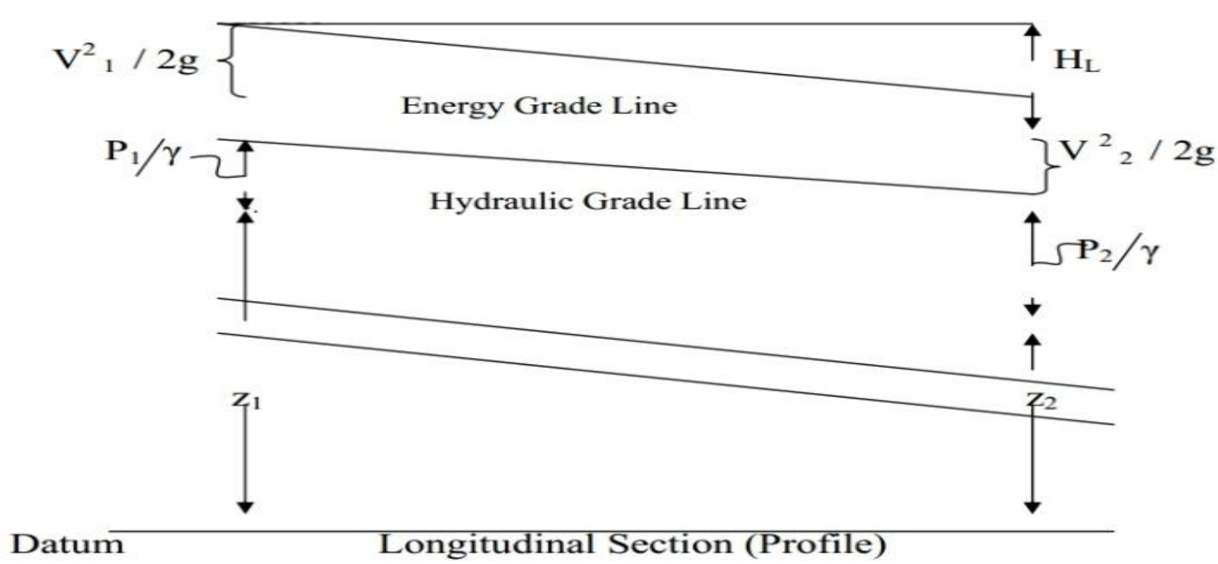


Figure 3.5: The Energy Principle Source; (Shaher H. 2003)

3.7 Sampling size

According to Cochran (1977), the main primary data sources of this study were beneficiaries of Leku Town. In order to ensure the generalization of the finding to larger population, the study considered adequate sample respondent for selection through appropriate techniques. The numbers of sample HHs for interview are determined by using this formula:

$$n' = \frac{z^2pq}{d^2} \text{-- (11) and}$$

$$n = \frac{n'}{1+\frac{n'-1}{N}} \text{--(12)}$$

Where, n' = desired sample size when the population > 10,000

n= Nº of samples size when the population < 10,000

Z= 95 % confidence level corresponding z-value is 1.96

P= 0.05 (proportion of the population to be included in the sample i.e. 5 %)

q = 1 - 0.05 i.e. (0.95)

N= total number of HHs (7,368)

d= margin of error or degree of accuracy (0.05).

Table 3.3: Total Number of Sampling HH from Leku Town

No	Sub Town	Population in Number			Total HHs	Sampling HHS	Remark
		Male	Female	Total			
1.	Leku 01	4,848	4,476	**9,324**	**1,865**	**17**	
2.	Leku 02	4,279	3,949	**8,228**	**1,645**	**15**	
3.	Leku 03	4,031	3,721	**7,752**	**1,550**	**15**	
4.	Midire Genet	3,740	3,594	**7,334**	**1,466**	**14**	
5.	Morocho	2,144	2,060	**4,204**	**842**	**7**	
	Total	**19,042**	**17,800**	**36,842**	**7,368**	**68**	

Source: (SRBoFED, 2012)

The populations (HHs) of the 5 sub Town involved in the study area are less than 10,000. Both equations (9 and 10) are used to determine the sample size as follows:

$$n' = \frac{z^2pq}{d^2} = n' = \frac{(1.9)^2*(0.05)*(0.95)}{(0.05)^2} = \underline{\underline{69}}\text{, then}$$

$$n = \frac{n'}{1+\frac{n'-1}{N}} = n = \frac{69}{1+\frac{69-1}{7368}} = \underline{\underline{68}}$$

The sample size required (n) was based on the above formula, 68 HHs were taken for interviews to generate primary data from 7,368 HHs of the study area.

3.8 Data Analysis

Data were generated from field survey, primary and secondary data source, key informant and selected household. Hydraulic data like the elevation, pipe length, pipe size, pipe material type and the demand of each junction, minimum, initial and maximum elevation of the reservoirs and the maximum, average and minimum head and discharge of the pump were investigated and carried out analysis typical:

- The pressure and Velocity analysis based on optimal pipe diameters for a given layout & demand scenario and pump condition.
- The selection of optimal models for pumps and the optimization of the pump scheduling with minimize energy consumption.
- The selection of optimal position, elevation and volume of the reservoir/Tank.
- The optimization of the reservoir operation.
- The optimization of the valve operation and fire demand.

Those analyses were carried out by using Water CADv8i computer software and also statistical tools like Excel and SPSS was employed.

- **Data Analysis and Presentation**

The quantitative data which shows the population, water use, water production and water loss in percentage as well as the numerical data were analyzed interpreted in tabular and graphical forms. Qualitative data that shows the existing situation, major problem of the town water supply and demand scenario was aggregated, interpreted and explained with the support of the quantitative data analysis. Excel was used to analyze the data generated from different offices and field survey data. Moreover; for hydraulic performance evaluation of water supply distribution system Water CADv8i software was used. The analysis of future water demand scenario is based on the Urban Water Supply Design Criteria Guideline (MoWR, 2006). The result was presented in tabular form, percentage, Maps and graphical form.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Evaluating Existing Water Supply Coverage

4.1.1 Water Production and Demand

4.1.1.1 Past Trend of Water Production

Trend of Production: It is known that demand for water increase with increase in population size as well as improvement in the economic condition of town. The population size of Leku town is growing rapidly. The population size which was 11,831 during the 2007 E.c. The population growing rate the year between 2007 and 2012 E.c has been expected to be 3.4 percent. According to CSA and Water Supply Office of Leku town projection, the population has been grown 36,842 in 2020 G.C. With growth in the population of the town, the total water production as well as water consumption has also increasing parallel. Based on the information gathered from TWSO presented in table below shows that five years trend on water production and consumption. It can be seen in table 4.1 below, the water production and consumption which was 287,265 m^3 and 149,812 m^3 at base year 2016 G.C has grown to 219,241 m^3 and 176,293 m^3 in 2020 G.C, respectively, assuming a water loss of 20 percent. During the last five years the average water production was increasing by **7,994 m^3**annually, this indicates 3.9% increment. Similarly, average water consumption was also growing by **6,620m^3** annually, means 4.1% increment during the same period.

According to TWSO the gross water production capacity of existing boreholes is 1,814.4 m^3/day but, currently water production is 1,360.8 m^3/day with average working/pumping/ for 16 hours per day. The difference is **453.6 m^3/day.**

This implies the capacity of water production can satisfy the demand up to year 2026 G.C. But the reality in ground was opposite, means the community could not get the quantity of water they need. Thus is due to the shortage of existing reservoir, poor hydraulic performance of existing distribution system and frequent fluctuation electric power.

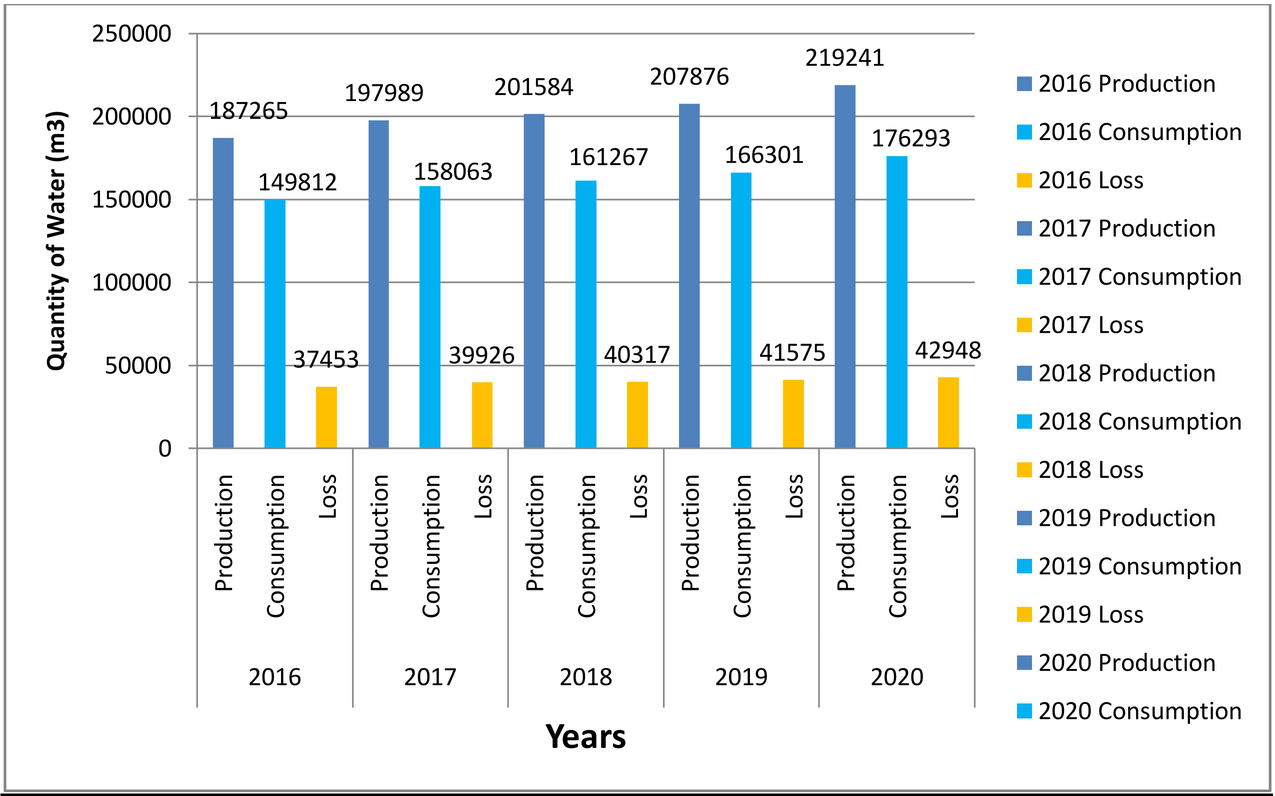


Figure 4.1: Water production, Consumption and Loss (m^3)

Source: Water Supply Office of Leku Town

4.1.2 Analysis of Water Supply Coverage Scenarios

4.1.2.1 Average Per-Capita Consumption

Leku town water supply coverage was evaluated from the average per-capita consumption. The average water consumption per-capita was obtained from town's annual consumption, which was aggregated from the individual water meter and the public tap. Therefore; annual consumption data was converted to average daily per-capita consumption using the population data of the town as follows:-

Thus, Leku town aggregated per-capita water consumption of year 2019 G.C and 2020 G.C was Calculated. The Population of Leku town 35,298 in 2019 G.C and 36,842in 2020 G.C take in to consideration.

The aggregated average per-capita water consumption of Leku town in year 2019 G.C were obtained as 12.91 l/c/day and 13.11 l/c/day for year 2020 G.C. Based on the UWSUAP of the country standard, the minimum quantity of water required for domestic (house hold) consumption is taken as 20 l/c/day and non domestic consumption is 30% of the domestic (MoWR,2011).

Thus, the above result indicates that the aggregated per-capita water consumption of Leku town is below the standard.

4.1.2.2 Water Supply Coverage

The percentages of population with or without pipe water connection are a relevant indicator to compare the coverage of water supply in urban areas. Therefore; the water supply coverage of Leku town calculates both the UWSUAP of the country standard (MoWR,2011) and GTP-2 goal for urban minimum service level of water supply access. Accordingly based on the analysis carried out, UWSUAP of the country standard, (MoWR,2011); water supply coverage in year 2019 G.C were 64.6% and 65.6% coverage in year 2020 G.C. Based on the result water supply coverage of Leku town has a gap and not meet the country standard. Whereas; comparison made GTP-2 goal that providing urban safe water supply access with minimum service level about 50 l/c/day for category 4, like Leku town for population of town(20,000 to 50,000) with in distance of 0.5 km for urban population. The analysis of water supply coverage of the town for year 2019 G.C and 2020 G.C were 25.8% and 26.2% respectively. So that, the analysis result indicated that there is a large gape of water supply coverage of Leku town with respect to GTP-2 goal minimum urban safe water supply access.

4.1.2.2.1 Water Supply Areal Coverage

Water supply systems represent an important part in the urban infrastructure and critical factor of public health issue and economic development. The effectiveness of any resource management depends upon the nature of a sequence of measures preceding the decision. Information regarding Coverage, and location, at any given point of interest is necessary in the analysis and design of several resources management activities or projects such as water supply coverage, dam construction, pipe-lining, water reservoir operation, water distribution and waste water disposal (Johnson, 2009).

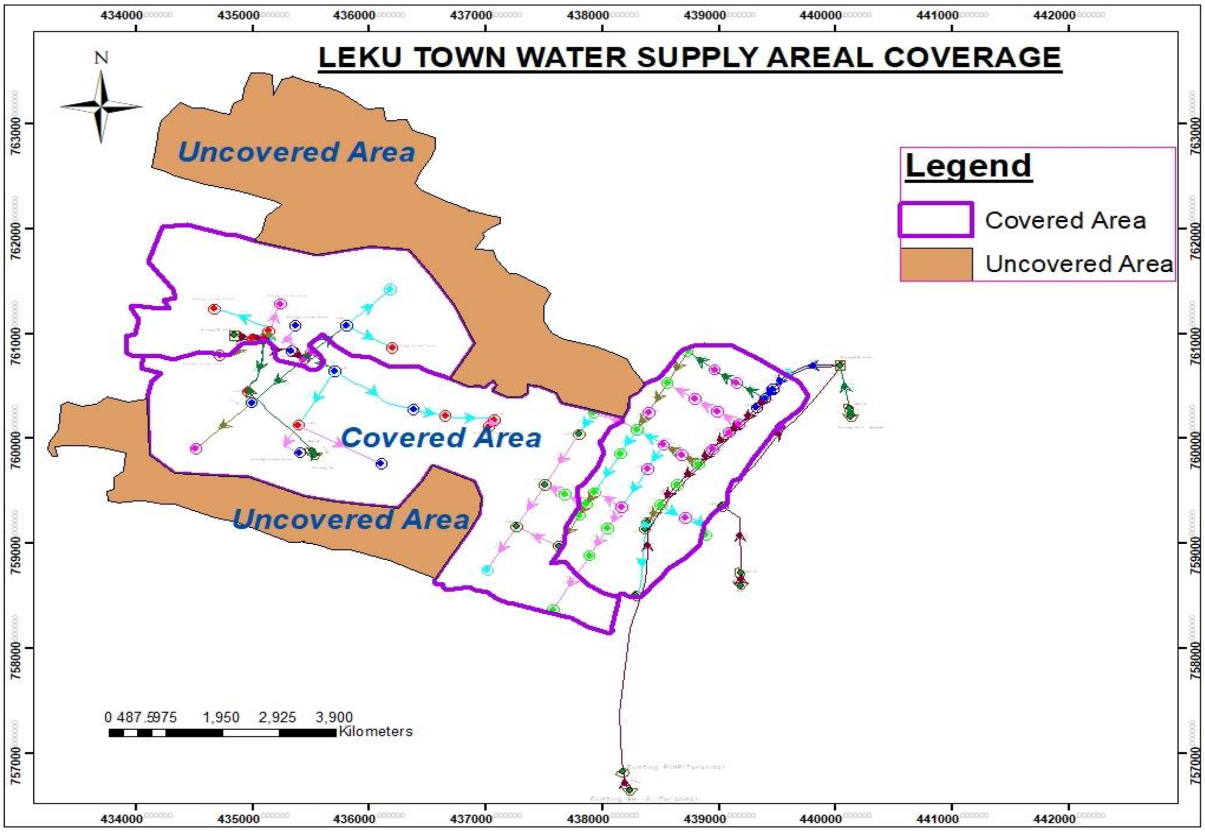


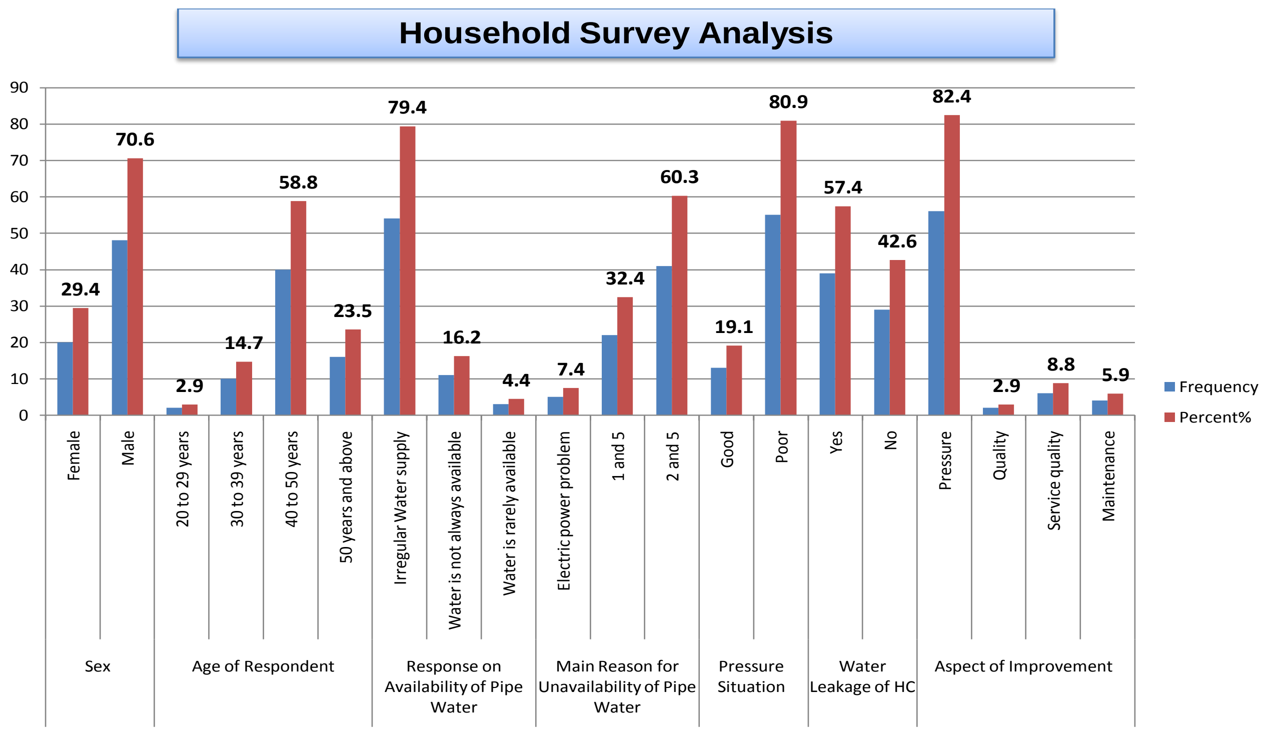
Figure 4.2 ; Leku Twon Water Supply Areal Coverage

For evaluation of Leku Twon water supply Areal coverage mapping "Arc GIS 10.8" has been used. This tools widely used in urban water supply Areal coverage, landscape planning and design. GIS concept and tools plays an important role in all aspect of data collection and archiving, support for condition assessment through display the output.

According to the Master Plan of Leku Town the total area the Town are 1,682.95 ha or 16,829,500 km^2. As clearly seen form the analysis result in figure 4.2, the areal coverage existing distribution system of Leku Town was 1,092.78 ha or 10,927,800 km^2 (65%). Whereas the area that not covered by existing distribution system was 590.17 ha or 5,901,700 km^2 (35%). The residence live in Leku town that was not addressed by existing distribution system, required journey of average distance between (0.5 - 1 km) to fetch water for their domestic consumption from public tap.

4.2 Response of Households

To observe the existing water supply situation of Leku town, the structured and unstructured interviews were used for household survey. For this study a total of 68 households were interviews to collect their attitude on the existing water supply situation in the area. The result of survey analysis is presented in graph below and the table attached in Annex.



NB: Total Respondent was 68
1) Water is not available from the source, 2) Distribution system problem, 5) Electric power problem

Figure 4.3; Household Survey Analysis

As the information analysis obtained from the response on availability of pipe water shown in figure 4.3 above and in table 7 attached in Annex indicate that, 79.4% of respondent were answered that water is sometimes available, 16.2% of respondent were answered water is not always available, 4.4% of respondent were respond that water is rarely available. This clearly shows that availability of pipe water for customers is available for short time and do not meet their demand.

To observe costumer’s view on the reason behind for unavailability or shortage of pipe in leku town, as figure 4.3 above and in table 8 attached in Annex, indicated that those who responded distribution system and electric problem were 60.3%, the respondent that reason out their perception as water is not available from the source and electric problem were 32.4% and the remaining 7.4% of respondent reflect their were electric power problem, since the costumers does not have water whenever electricity off, because Leku town experience with high electric fluctuations. The result of survey clearly shows that the major reasons for water supply system problem of Leku town were shortage of water from the source, water distribution network (bursting and hydraulic) problem and electricity power fluctuation. This is due to inappropriate layout of distribution network and old pipe contribute to water supply interruption.

The finding result from respondent on the pressure of Leku town water supply distribution system stated in table 9 attached in Annex indicated, 80.9% responded the pipe water reach to them with poor pressure, only 19.1% responded that the pipe water have good pressure at their pipe. Water pressure during peak hour demand may become minimum due to water shortage and topography of the town. Among the respondents, the customers who live in high elevation (Leku 03, Moroch and Midire Genet kebeles) of town responded that water reaching to their tap has low or no pressure.

To assess the information about house connection water leakage situation household survey were conducted. As the result in table 10 attached in Annex indicted that 57.4 % of respondent observe water leakage in their private pipe (HC), whereas 42.6% of respondent were free of water leakage.

4.3 Population Projection

Population Projection: Population projection provides information on the future size and composition of population of given area. In case of this study, the objective of the population projection is to forecast the demand of domestic water supply during the planning period. The base year urban population size of the town has been estimated to be close to 36,842. As it is indicated in the above table, the annual average growth rate the town experienced during 1994 - 2007 was about 2.4 percent. For small towns like Leku a growth rate of 2.4 percent is too small since usually small towns experience large growth rate. Thus, the current growth rate about 4.66 percent computed through Geometrical Increment Method. This growth rate is assumed to continue for the coming planning horizon. Accordingly, the urban population size of the town is expected to grow to about 46,264 at the end of design year (2043G.C).

Table 4.1: Population Projection of Leku Town (2020-2043 G.C)

Year	**2020**	**2023**	**2028**	**2033**	**2038**	**2043**
Population	36,842	38,559	40,356	42,236	44,268	46,264

Source: CSA reports, Water Supply Office of Leku Town and Own Calculation (Geometrical Increment Method Used)

4.4 Water Demand Estimation

4.4.1 Classification of Demand

The potable water demand classified based on the type of users and purpose of water consumption can be as domestic water demand, non-domestic water demand and non-revenue water. The water demand projection for these demand categories can be computed by considering the following methods.

4.4.1.1 Domestic Water Demand

Domestic water demand is a water demand at a household level needed for drinking, food preparation, washing, cleaning, bathing and other miscellaneous domestic purposes. The amount of water used for domestic purposes greatly depends on the lifestyle, living standard, climatic condition, mode of service and affordability of the users.

4.4.1.1.1 Mode of Services

Depending on living standard and hardship of water collecting there are four types mode of connection in a water supply system. These include House connection, yard owned connection, and yard shared connection and public tap (fountain).As clearly depicted in design criteria house and yard connection users increase yearly, whereas public fountains users decrease. The community uses Yard Tap, public water point, shallow wells and traditional unprotect water source.

The mode of services projection is made based on the target design year phase I (2033) and phase II (2043) of the project at which the town the communities will get sufficient amount of water they require considering the current mode of services. In the future as a result of development of the town associated with willingness of residents to have their own connection and pay more for the water they use; **As has been observed from table 4.2** the current modes of services**,** the percentage of users in house connection **(HC)** mode of services 8%, yard connections owned **(YCU)** 36%, yard connections shared **(YSC)** 22% and public tap users **(PT)** 34% from the current mode of service.

Table 4.2: Percentage mode of services based on current modes of services and Population served in year 2020 G.C

Connection Type	Description	No of Population Served	Percentage (%)
HC	**House Connection**	2,947	8
YCU	**Yard Connection Own**	13,263	36
YSC	**Yard Connection Shared**	8,105	22
PT	**Public Tap**	12,526	34
	Total	**36,842**	**100**

4.4.1.1.2 Mode of Services Projection

The mode of service projection is made based on the target design year 2043 of the project at which the town water coverage will stay at 100% and the communities will get sufficient amount of water they need considering the current mode of services as a reference. In the future as a result of further development of the town associated with willingness of residents to have their own connection and pay more for the water they use; it is forecasted that at the target year of 2043, the percentage of users in HC mode of services is 18% while yard connections own 50.6%, yard connections shared 15.6% and public tap/fountain/ users 15% from the current mode of service. According to the information obtained house and yard connection users increase yearly, whereas yard connections shared and public fountains users decrease.

These mode of services projection are obtained based on average increment was 17.2% in first phase to 17.5% in the second phase of annual connection increment for house connection and 6.9% to 7% annual connection increment for yard connections in the first & second phases, respectively, was adopted by taking in to consideration the opportunity of get support from Government and NGOs, socio-economic situation and living standard of the community.

Table 4.3: Projected Percentage of Mode of Services

Connection Type	Unit	Years					
		2020	2023	2028	2033	2038	2043
HC	%	8	8.6	10.2	12.8	15.8	18.8
YCU	%	36	38.8	42.2	44	47.6	50.6
YSU	%	22	19.6	18.6	17.6	16.6	15.6
PT	%	34	33	29	25.6	20	15
Total	%	**100**	**100**	**100**	**100**	**100**	**100**

Table 4.4: Population Distribution by Mode of service in (No)

Connection Type	Unit	Years					
		2020	2023	2028	2033	2038	2043
HC	No	2947	3316	4116	5406	6994	8698
YCU	No	13263	14961	17030	18584	21072	23410
YSU	No	8105	7558	7506	7434	7348	7217
PT	No	12526	12724	11703	10812	8854	6940
Total	**No**	**36842**	**38559**	**40356**	**42236**	**44268**	**46264**

According to the above projected mode of connection, the population of the town has also been projected up to the design horizons as presented in table 4.5. Moreover; based on the assessment made during site visit and data collected, the town command area based on the topographical situation of the town and the configuration of the water supply facilities, the town water supply system were sub divided in to two pressure zone. Accordingly pressure zone – 1 is central part of the town comprise (Leku 01, Leku 02 and Leku 03 kebeles). Whereas pressure zone – 2 is the newly added kebeles the comprise (Morocho and Midregent Kebeles).

Table 4.5: Projected population figure based on mode of service (for years 2020-2043 G.C)

Description	unit	Year 2033		Year 2043	
		Pressure Zone-I	Pressure Zone-2	Pressure Zone-I	Pressure Zone-2
Total Population	No	**21540**	**20696**	**23595**	**22669**
HC	%	12.8	12.8	18.8	18.8
YCU	%	44.0	44.0	50.6	50.6
YSU	%	17.6	17.6	15.6	15.6
PT	%	25.6	25.6	15	15
Description	unit	Year **2033**		Year **2043**	
		P. Zone-I	P. Zone-2	P. Zone-I	P. Zone-2
Total Population	No	**21540**	**20696**	**23595**	**22669**
HC	%	2757	2649	4436	4262
YCU	%	9478	9106	11939	11471
YSU	%	3791	3642	3681	3536
PT	%	5514	5298	3539	3400

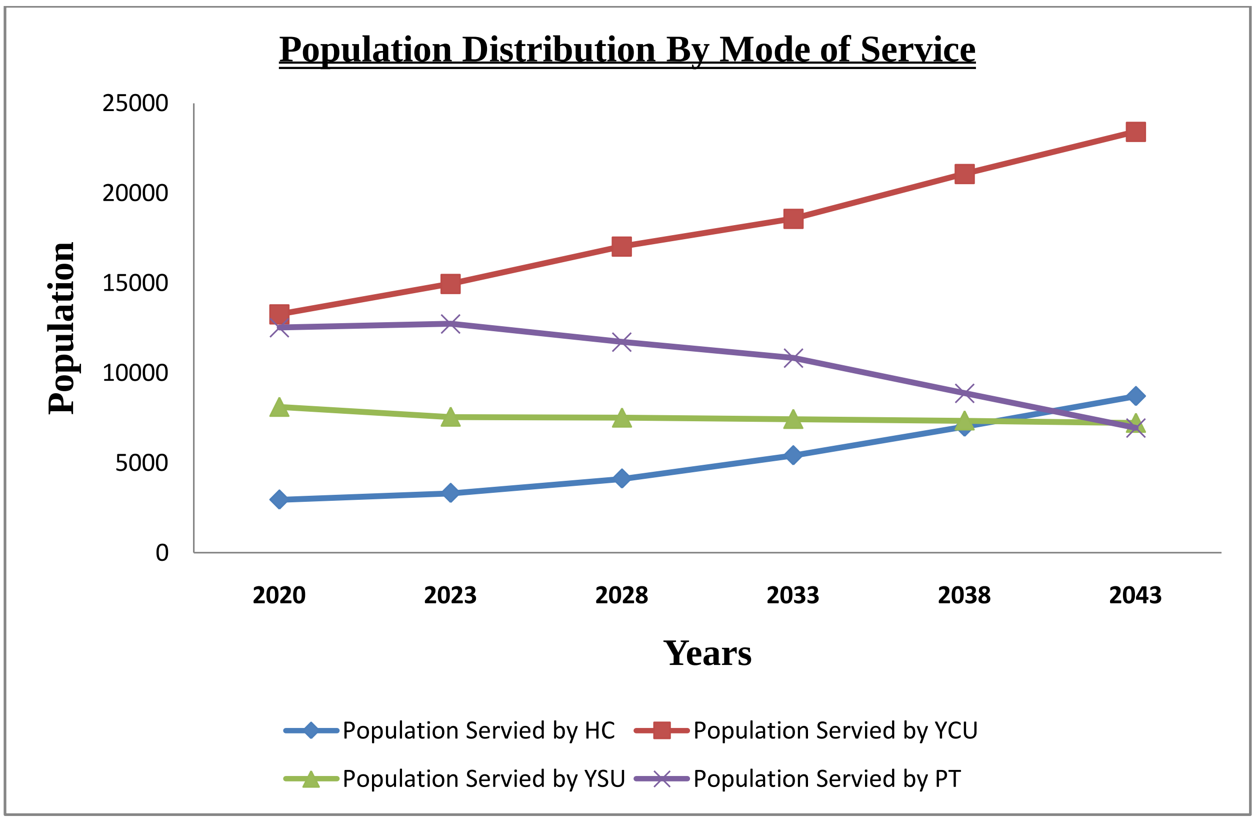


Figure 4.4: Population Distribution by Mode of Service (for years 2020-2043 G.C)

4.4.1.1.3 Per-Capita Demand

The per-capita water demand for various demand categories varies depending on the size of the town and the level of development, the type of the water supply scheme, the socio-economic conditions of the town and the climatic condition of the town. The per-capita water demand is the sum of the water requirement for different uses, which are related to specific, conditions the town, living standard of customer or end users and availability of water supply facilities, etc. The water requirement for different domestic uses could also vary based on the mode of service to be used and the convenience and proximity to water supply facilities.

It is obvious Per Capita Water Demand increases from time to time based on the growing, awareness and improvement of the living standard of the consumers. In urban water supply design criteria of MoWR, 2006 it is clearly stated that the design horizon is divided into two stages, the first 10 years as first stage (Stage I) and the second 10 years as second stage (Stage II). The Per Capita demand is stated by stages table 2 for various modes of services to be used the Ministry of water resource guideline.

But, As per GTP-II indicated in table 3 attached in Annex, water supply service level standard, required for providing safe water for urban community; this means the towns/cities were classified with category based on the population.

For this study for both phases the projected population ranges up to category- 4 towns/cities (with a population range of 20,000-50,000) and so Leku town population falls under category- 4. Therefore; the minimum/average service level was 50 l/c/day.

Therefore; Ministry of Water Resources (2006) guide line base below table 4.6, adjustment was not required for per capita demand of each mode of services to fulfill the gap to achieve the Growth and Transformation plan II. Accordingly, the projected per capita water demand for each mode of service in Leku Town is summarized below in table 4.6.The projected per-capita consumption set for different mode of services based on their percentage mode of connection assumed above and the presumed average day per-capita consumption. The average day per-capita water demand is assumed to increase by the percentage of users in HC mode of services by 2% while yard connections 1%, Shared increase by 1.015% and public tap increase by 1.01% from the current mode of service to design horizon per-capita at the end of second phase.

Table 4.6: Projected per-capita water demand (lpcd) by Mode of Service

Per Capita Demand by Mode of Services	Unit	Years					
		2020	2023	2028	2033	2038	2043
HC	l/c/d	50	53	58	64	71	78
YCU	l/c/d	25	26	27	28	30	31
YSU	l/c/d	30	30	31	31	32	32
PT	l/c/d	20	20	20	21	21	21

Based on the above mode of service and presumed per-capita water consumption; the average per-capita per day water consumption of Leku town at the end of the phase-I and phase-II design period is found to be 36 and 42.3 liters, respectively.

Table 4.7: Domestic Water Demand by Mode of Services (m3/day)

Domestic Water Demand by Mode of Services (m3/day)	Unit	Years					
		2020	2023	2028	2033	2038	2043
HC	m3/day	147	176	240	347	493	675
YCU	m3/day	332	385	460	528	628	733
YSU	m3/day	243	230	232	233	234	233
PT	m3/day	251	257	239	223	184	146
Total Domestic Demand	**m3/day**	**973**	**1048**	**1171**	**1341**	**1540**	**1787**
	l/s	**11.3**	**12.1**	**13.6**	**15.5**	**17.8**	**20.7**

According to the above table 4.7 above, the total domestic water demand for year 2033 were 1,341 m^3/day and for year 2043 were 1,787 m^3/day.

Depend on the socio-economic development and climatic nature of the research area; the above anticipated per-capita consumption will be adjusted as follows.

- **Climatic and Socio-economic Adjustment Factors**

The water used by a person may vary depending on the climatic and socio-economic conditions of the town. This means more water is used at hot area than cold area. In same way rich people consume more water than the poor.

- **Adjustment of Climatic Factor**

In order to account for changes in climate which affect the water consumption trends, climactic factor should take in to consideration. The average annual temperature and average altitude of Leku town falls temperate zone. Hence based on this criterion Leku Town climatic factor 1 has been adopted based on Urban Design Criteria Guide line of MoWR (2006).

- **Adjustment of Socioeconomic Factor**

The domestic water demand greatly depends on socio-economic factors. Based on Urban Design Criteria Guide line of MoWR (2006) the socioeconomic category of the Leku town was categorized as group C - towns under normal Ethiopian conditions. Therefore, a socio-economic adjustment factor of 1.0 has been adopted MoWR (2006).

4.4.1.1.4 Estimation of Domestic Demand

After the percentage share of different mode of services and the corresponding per-capita demands are determined, the total domestic water demand have been calculated for the town residents as indicated in table 4.8 below. The adjusted domestic water demand at the end of the design periods, 2033 & 2043, is found to be in the order of 1,207 m3/day and 1,609 m3/day, respectively and Considering this socio-economic and climatic adjustment factors; the adjusted day per-capita consumption for Leku town in the coming design horizons become 14 and 19 liters, respectively, which will be distributed to the two proposed pressure zone as shown below.

Table 4.8: Growth of Domestic Water demand for all subsystems of Leku Town (2033 and 2034 G.C)

Description	Unit	Year/Pressure Zone		Year/Pressure Zone	
		2033		2043	
		Pressure Zone-I	Pressure Zone-2	Pressure Zone-I	Pressure Zone-2
Total Population	No	**21540**	**20696**	**23595**	**22669**
HC	%	12.8	12.8	18.8	18.8
YCU	%	44.0	44.0	50.6	50.6
YSU	%	17.6	17.6	15.6	15.6
PT	%	25.6	25.6	15	15
Population by Level of Service					
HC	No	2757	2649	4436	4262
YCU	No	9478	9106	11939	11471
YSU	No	3791	3642	3681	3536
PT	No	5514	5298	3539	3400
Demand by Level of Service standard					
HC	m3/day	246	101	506	169
YCU	m3/day	285	243	433	300
YSU	m3/day	135	98	142	91
PT	m3/day	107	126	72	74
Total Domestic Demand	**m3/day**	**773**	**568**	**1153**	**634**
Socio- Economic Factor		1	1	1	1
Climatic Factor		1	1	1	1
Adjusted Domestic Water Demand (ADD)	**m3/day**	696	511	1038	571
Adjusted Domestic Water Demand for the Stages	**m3/d**	**1207**		**1609**	
Average day per-capita consumption	**l/c/d**	**14**		**19**	

4.4.1.1.5 Future Demand of Water

Water Demand Projection: Residential water consumption depends on the type of delivery of water to the end consumer and the standard of the community. In this report, the per capita water consumption set by the Ministry of Water Resource has been considered. The projection and assumptions made on per capita consumption for different consumers (Domestic and non-domestic consumers) was presented below.

Table 4.9: Annual Water Demand Projection in m^3

Year	Domestic Demand			Institutional and Commercial Demand	Industrial	Fire Fighting	Total Demand	NRW/Loss/	Demand including Loss
	P. Zone - 1	P. Zone - 2	Total						
2023	184,482	179,371	363,853	65,494	17,296	32,747	479,389	75,744	555,133
2024	195,529	185,575	381,104	68,599	18,127	34,299	502,129	81,747	583,876
2025	207,286	191,993	399,279	71,870	19,004	35,935	526,088	88,804	614,892
2026	219,801	198,633	418,434	75,318	19,928	37,659	551,339	96,374	647,713
2027	233,123	205,502	438,625	78,953	20,904	39,476	577,958	103,917	681,875
2028	247,308	212,609	459,917	82,785	21,933	41,393	606,028	109,691	715,719
2029	262,410	219,962	482,372	86,827	23,019	43,413	635,631	118,736	754,367
2030	278,492	227,570	506,062	91,091	24,165	45,546	666,864	123,903	790,767
2031	295,617	235,440	531,057	95,590	25,376	47,795	699,818	134,225	834,044
2032	313,856	243,583	557,439	100,339	26,654	55,744	740,176	146,407	886,583
2033	333,281	252,007	585,288	105,352	28,004	58,529	777,173	158,543	935,716
2034	350,449	258,128	608,577	109,544	29,138	60,858	808,117	168,735	976,851
2035	368,564	264,398	632,962	113,933	30,326	63,296	840,517	180,543	1,021,060
2036	387,679	270,821	658,500	118,530	31,571	65,850	874,451	184,334	1,058,785
2037	407,850	277,399	685,249	123,345	32,875	68,525	909,994	196,377	1,106,370
2038	429,136	284,137	713,273	128,389	34,243	71,327	947,232	215,022	1,162,254
2039	451,598	291,039	742,637	133,675	35,677	74,264	986,252	228,613	1,214,866
2040	475,302	298,108	773,410	139,214	37,180	77,341	1,027,145	244,255	1,271,400
2041	500,317	305,349	805,666	145,020	38,757	80,567	1,070,009	260,868	1,330,878
2042	526,716	312,766	839,482	151,107	40,410	83,948	1,114,947	274,054	1,389,001
2043	554,575	320,364	874,939	157,489	42,145	87,494	1,162,067	290,517	1,452,584

Due to availability of rivers and streams in the town, water consumption by livestock hasn't been included

4.4.1.1.6 Water Production Capacity and Demand during the Planning Period

Water Production: According to data obtained from Water Supply Service Office, the existing water source for Leku town was three bore wells. The first well "Taramisa No-1" was able to give 10 liter/sec, the second well "Taramisa No-2" was able to give 6 liter/sec and the third well "Remeda well" was 5 liter/sec yields. Those three bore wells can yields **21 lit/sec (1,814.4 m^3/day)** as well as four new bore wells that a potential of yielding **46 liter/sec (3,974.4m^3/day**) have **a total capacity of producing 5,788.8 m^3** of water per day. Based on the daily production, the annual amount of production has been estimated to be 2,112,912 m^3 up to 2043 G.C.

Water Demand: As it is explained above, the water demand is expected to grow to 1,162,067 m^3 in 2043 G.C. Similarly, the water demand (water demand including water loss (15-25%)) has been projected to grow to 1,452,584 m^3 in 2043 G.C. As it is explained above, the existing and the new bore holes have the capacity of producing 2,112,912 m^3 of water annually. Thus, during the planning period (2023 – 2043) there would not be shortage of water supply provided that the new bore holes would be developed during the same period.

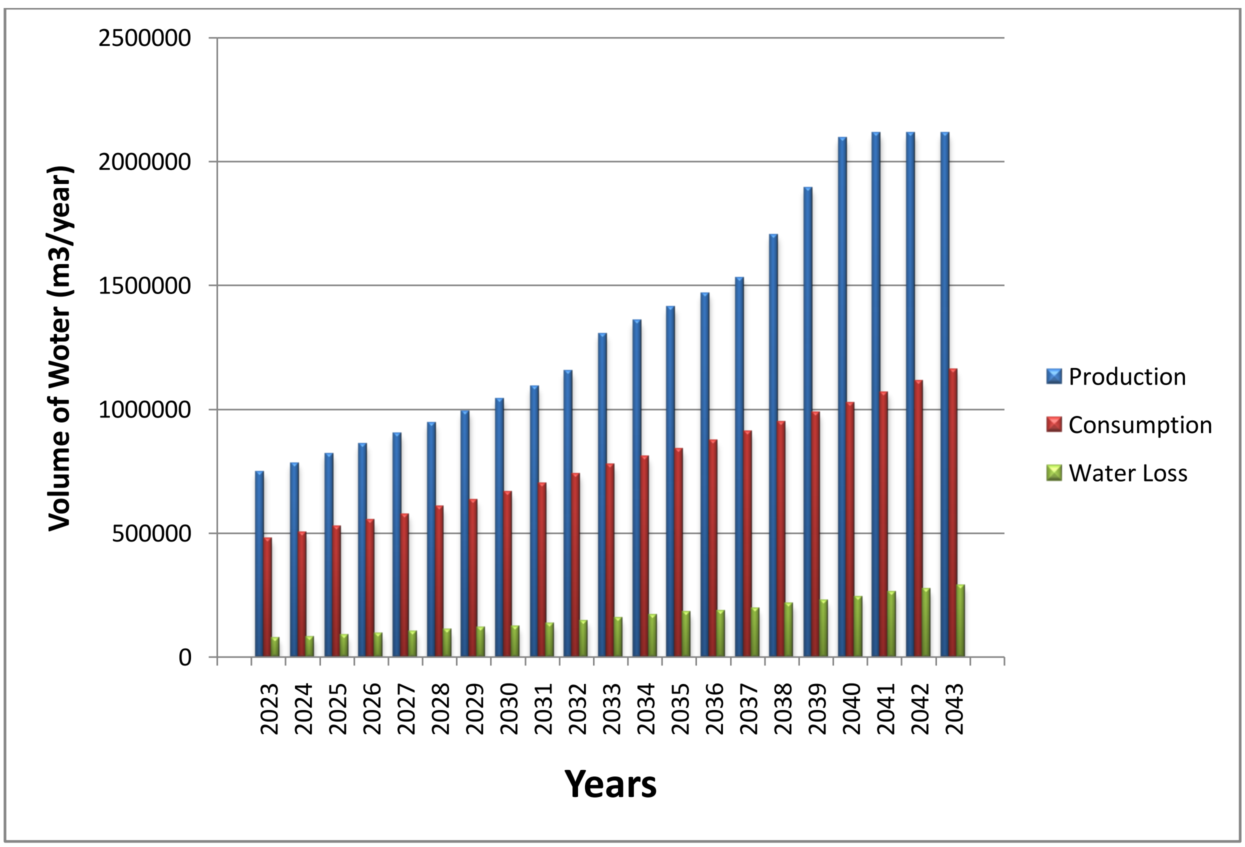


Figure 4.5: Annual Water Demand Projection m^3/year (2023 - 2043 G.C)

4.4.1.2 Non Domestic Water Demand

Non-domestic water demand can be broadly classified into the following major categories:

- Institutional and Commercial water demand,
- Industrial water demand,
- Livestock water demand
- Firefighting water demand,
- Non-Revenue Water

4.4.1.3 Intuitional and Commercial Demand

Water demands of institutions and commercial centers will be determined based on the type and nature of services available. Institutional and commercial demands are grouped together and termed public water demand and are usually expressed as a percentage of the average domestic demand. The water demand for both activities was found to be 18% of adjusted domestic demand.

- **Educational Water Demand**

The numbers of students attending schools are normally expected to grow parallel to the total population growth. It is assumed that the demand for education will be 5 l/d per seat MoWR (2006). The current number of students of Leku town is as follows according to the information from Leku town water supply office.

Table 4.10: Per Capita Consumption of Education sector in Leku Town

Consumer category	Daily Demand	No of Students and Teachers	Demand (l/day)	Demand (m3/day)
Schools				
Morocho Primary 1-8 grade	5	4,200	21000	21
Midregenet Primary 1-8 grade Leku Primary 1-8 grade Remeda Primary 1-8 grade	5	8,980	44900	44.9
Leku secondry& preparatory 9-12	5	6,000	30000	30
Average demand (l/d)			**95900**	
Average demand (m^3/day)				**95.9**

Source:-Leku Town Water Supply Office for year 2020 G.C

- **Health Centers Water Demand**

Based on socio-economic report of Leku town, currently there are one health center and one Hospital in the town. The demand for hospital was 75 l/d per bed and for health center will be 60 l/d per bed adopted based on MoWR (2006). Moreover, the number of beds available in the health center is 30 and 8 according to the information from Leku town TWSO.

Table 4.11: Per Capita Water Consumption of Health center

Consumer category	Qty	Demand l/ Beds	No of Beds/visitors	Demand (l/day)	Demand (m3/day)
Hospital	1	75	30	2250	2.25
Health center	1	60	8	480	0.48
Total Average demand (l/day)				**2730**	
Average demand (m^3/day)					**2.73**

Source:-Leku Town Water Supply Office for year 2020 G.C

- **Water Demands for Governmental and Non-Government Offices**

According to socio-economic survey report of Leku town currently there are 38 sectors of governmental & two NG offices in the town and there are also employees in those offices. According to MoWR (2006), the daily consumption demand of 5l/d per capita was adopted and on available employees in each organization water demand has been calculated as follow:

Table 4.12: Per capita water Consumption of Governmental and Non-Government Offices

Consumer category	Qty	Demand l/employee	No of Employee	Demand (l/day)	Demand (m3/day)
Governmental Institutions	38	5	3873	19365	19.37
Non-Governmental	2	5	34	170	0.17
Total Average demand (l/day)				**19535**	
Average demand (m^3/day)					**19.54**

Source:-Leku Town Water Supply Office for year 2020 G.C

- **Religious Water Demand**

Religious water demand also was 5 l/d per Worshippers adopted based on MoWR (2006).

Table 4.13: Demand for Religious water demand

Religion	%	Demand l/Worshippers	No of Worshippers	Demand (l/day)	Demand of worshipper 4 days per month in liter	Demand (m3/day)
Protestant	81%	5	30294	151470	20196	20.20
Orthodox	10.64%	5	3979	19895	2652.67	2.65
Muslim	3.4%	5	1272	6360	848.00	0.85
Others	4.96%	5	1855	9275	1236.67	1.24
Total Average demand (l/day)					**24933.33**	
Average demand (m^3/day)						**24.93**

Source:-Leku Town Water Supply Office for year 2020 G.C

- **Commercial Water Demand**

Commercial water demand includes water requirement for Restaurant, Cinema house, Bus stations, shopping centers, abattoir, public baths, hotels, restaurants, bars, fuel stations, and local drink houses (Tej, Areke, Tella bet)etc. are considered to be commercial water demand. Leku town commercial water demand considered according to Design Criteria Guide line of MoWR (2006).

Table 4.14: Commercial water demand

Consumer category	Quantity	Daily Demand (l/d)	No of Beds/visitors	Demand (l/day)	Demand (m3/day)
Hotels	10	50	8	4000	4
Bars & Restaurants	20	10	35	7000	7
Trading businesses	120	5	3	1800	1.8
Barberry	18	5	20	1800	1.8
Tej bet	10	5	30	1500	1.5
Local drink center	15	5	10	750	0.75
Abattoir	2	150	4	1200	1.2
Beauty salon	12	5	50	3000	3
Public latrines/ no water flash	4	5	50	1000	1
Average demand (l/d)				**22050**	
Average demand (m^3/day)					**22.05**

Source:- Leku Town Water Supply Office for year 2020 G.C

Table 4.15: Summary of Commercial and Institutional water demand for year 2020 G.C

Description	Demand (m3/day)	Demand (l/day)
Commercial	22.05	0.26
Religious Institution	24.93	0.29
Organization	115.44	1.34
Health Institution	2.73	0.03
Total	165.15	1.91

Table4.16: Percentage of Commercial and Institutional water demand for year 2020 G.C

Description	Unit	Amount
Commercial water Demand	m^3/day	22
Institutional water Demand	m^3/day	143
Institutional and Commercial water Demand	m^3/day	165
Adjusted Domestic Demand	m^3/day	875
Percentage increment for Commercial and Institutional water demand in relative to ADD	%	18

4.4.1.4 Industrial Water Demand

Small scale industries water demand varies considerably with the type of industry and even for the same industry depending upon the age of the technology used. This makes demand estimation difficult. Most of the time big industries, universities, and institutions generally have their own water supply arrangements from the private tube-wells. Small-scale industrial enterprises will not be categorized separately but should be included in the allowance for institutional and commercial demand (MoWR, 2006). Small scale industries taken to be 5% adjusted domestic water demand.

Table 4.17: Per capita water demand for small scale industry

Consumer category	Qty. in Number	No of Employee	Demand l/employee	Demand (l/day)	Demand (m3/day)
Grain mills	8	5	5	200	0.2
Small Garages	2	10	5	100	0.1
Wood Work	3	5	5	75	0.075
Metal Work	4	5	5	100	0.1
Coffee pulping industry	2	15	1500	45000	45
Total Average demand (l/day)				**45475**	
Average demand (m^3/day)					**45.48**

Source:-Leku Town Water Supply Office for year 2020 G.C

Table4.18: Percentage of Industrial Water Demand

Description	Unit	Amount
Small Scale Industrial Water Demand (small industries 5% of ADD)	m^3/day	**45.48**
Adjusted Domestic Demand	m^3/day	**875**
Percentage increment for Small Sale Industrial water demand in relative to ADD	%	**5**

4.4.1.5 Livestock Water Demand

In designing water supply projects, water demand calculation has greater role. However, the use of improved domestic water sources for livestock is not encouraged. It is assumed that most of the animals will be watered from such natural sources as rivers, streams, lakes, ponds, and springs in the vicinity (MoWR, 2001). Therefore, in the Leku town there are small perennial streams and river located at south east, south west and north boarder of the town side. The information gathered from the town community the streams are high in summer and winter season. So that livestock water demand is calculated but not take consideration in Leku town total water demand, since there is other water sources (River & Spring)

Table 4.19 Livestock water Demand

Consumer category	Qty. in Number	Daily Demand (l/day)	Demand (l/day)	Demand (m3/day)
Cattle	7515	50	375750	375.75
Donkey &Horse	48	50	2400	2.4
Sheep and Goat	358	10	3580	3.58
Poultry	2363	0.3	590.75	0.591
Average demand (l/d)			**382321**	
Average demand (m^3/day)				**382.32**

Table 4.20: Percentage of Livestock Water Demand

Description	Unit	Amount
Livestock Water Demand	m^3/day	382
Adjusted Domestic Demand	**m^3/day**	**875**
Percentage increment for Livestock water demand in relative to ADD	**%**	**44**

4.4.1.6 Fire Fighting Water Demand

The annual volume required for firefighting purpose is small, but the demand may be exceedingly high during the period of need. Thus, fire flows must be considered while designing of distribution storage and pumping requirements.

The volume of water required for firefighting is determined based on different factors among which fire incidence, duration, water flow in distribution system, density and size of buildings etc. According to Design Criteria Guide line of MoWR (2006), enlarging the total reservoir volume, by 10%, to reserve water for firefighting, is considered for design and planning purpose.

- The required water flow through hydrants, fire duration and pressure in the system. The estimated flows as 16.66 l/s were sufficient for fire fighting for durations of 4hrs. So that to total volumetric consumption for firefighting 240 m3.
- Therefore, fire fighting demand is taken care by increasing the volume of dedicated service reservoirs by 16.66 l/s for duration of 4 hrs equivalent to 10% (240 m3) of volume reservoir, and then the sizes of the hydrants and other accessories will be determined accordingly.

4.4.1.7 Non-Revenue Water

Water losses in the water supply distribution system, leakage of the system, illegal connections, overflow from reservoirs, improper metering, etc. are referred to as non-revenue water. The probable water Non-revenue water in the water supply system of Leku town, based on the information gathered from TWSO, on water production and consumption records. The result indicated that Non-revenue water of Leku town with recommended rage of MoWR (2006). For projection the percentage of accounted for Non revenue water varies between 15% and 25% from starting from the first design year up to the final design year were adopted from Ministry of water resource Urban design Criteria Guide line of MoWR (2006).

4.5 Average Water Demand

Average daily demand for water supply is the combined total of domestic demand, Non-revenue (system losses), Commercial and Institutional demand, livestock demand and industrial water demands. The average water demand represents the daily demand of the town averaged over the implementation period indicated in table 4.21 below.

Table 4.21: Summary of average day water demands (m3/day)

Demand Type	Unit	Design Horizon	Summary of Water Demands (m3/day)		Total
			Pressure Zone-I	Pressure Zone-2	
Adjusted Domestic Water Demand (ADD)	m3/day	2033	696	511	**1207**
		2043	1038	571	**1609**
Non-Domestic Demand					**0**
Small Scale Industrial Water Demand (small industries 5% of ADD)	m3/day	2033	34.79	25.56	**60.35**
		2043	51.89	28.53	**80.42**
Commercial & Institutional Water Demand with allowance of small scale industry (18% of ADD)	m3/day	2033	125.23	92.02	**217.24**
		2043	186.79	102.71	**289.49**
Livestock Demand	m3/day	2033			**0**
		2043			**0**
Total Demands	**m3/day**	2033	**855.71**	**628.78**	**1484.49**
		2043	**1276**	**702**	**1978**
Unaccounted-for water	m3/day	2033	174.57	128.27	**302.84**
		2043	319.09	175.46	**494.6**
Average Day Demand	**m3/day**	**2033**	1030.3	757.0	**1787**
		2043	1595.5	877.3	**2472.76**

4.6 Maximum Day Demand

The maximum day water demand is the highest demand of any one-day in a specified year. The rate of water demand keeps changing from season to season, from day to day and from hour to hour. In hot season, more water is consumed for drinking, bathing and washing clothes than in wet season. The consumption of water is high at weekends and holidays than on normal days, and also more water is required in morning and evening than early in the afternoon and late at night. Therefore, to account these fluctuating water demands, it is necessary to adjust the average day demand by certain factor to get the maximum day demand and the peak hour demand.

Table 4.22: Maximum Daily Coefficient

Population	Maximum Day Factor	Peak Hour Factor	Remarks
0 to 20,000	1.3	2	Small Towns
20,001 to 50,000	1.25	1.9	Moderate Towns
50,001 to 100,000	1.2	1.8	Large Towns
100,001 and above	1.2	1.6	

Source:- Design Criteria Guide line of MoWR (2006)

- **Maximum day factor**

The maximum day water demand is the highest demand of any one 24-hour period over any specified year. The ratio of the maximum daily consumption to the mean annual daily consumption is the peak day factor. Thus maximum daily demand is determined by multiplying the average daily demand by maximum day factor. Based on recommendation of (MoWR, 2006) criterion for Leku 1.25 and 1.9 maximum day factor and PHF were adopted.

4.7 Peak Hour Water Demand

It is the highest demand of any one-hour over the maximum day. It represents the diurnal variations in water demand resulting from the behavioral patterns of the local population. The peak hour demand is obtained by multiplying the maximum day demand with the peak hour factor.

- **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 factor varies inversely with the size of the consumer base (MoWR, 2006).

Table 4.23: Recommended peak hour factors

Population	PHF
0 – 20,000	2
20,001 - 50,000	1.9
50,001 -100,000	1.8
>100,000	1.6

Source:-Urban Design Criteria Guide line of MoWR (2006)

The total population of 42,236 for phase I and 46,264 for phase II. Hence Population is between 20,000-50,000 for phases I and II. Thus the peak hour factors were 1.9 adopted for calculations based on (MoWR, 2006).

4.8 Summary of Water Demand Assessment

Based on above different types of water demands and demand variations, the following table 4.24 illustrates the summary of the projected water demand for Leku town up to end of the design horizon.

Table 4.24: Summary of maximum day & peak hour water demands

Demand	Unit	Planning Horizon	Subsystem		Total
			Pressure Zone-I	Pressure Zone-2	
Avg. Day Demand	m3/day	2033	1030.3	757.0	**1787.3**
		2043	1595.5	877.3	**2472.8**
	l/s	2033	11.92	8.76	**20.69**
		2043	18.47	10.15	**28.6**
Maximum Day demand Factor	-	2033	1.25	1.25	
		2043	1.25	1.25	
Maximum Day demand	m3/day	2033	1287.85	946.31	**2234.2**
		2043	1994.33	1096.62	**3091.0**
	l/s	2033	14.91	10.95	**25.9**
		2043	23.08	12.69	**35.8**
Existing sources	l/s	2033	11	10	**21**
		2043	11	10	**21**
	m3/day	2033	518.4	864	**1382.4**
		2043	518.4	864	**1382.4**
New proposed water sources requirement	m3/day	2033	769	82.31	**851.8**
		2043	1476	233	**1708.6**
	l/s	2033	8.91	0.95	**9.86**
		2043	17.08	2.69	**19.77**
Peak Hour Demand Factor	-	2033	1.9	1.9	
		2043	1.9	1.9	
Peak Hour Demand	m3/day	2033	2446.91	1797.98	**4244.9**
		2043	3789.2	2083.6	**5872.8**
	l/s	2033	28.32	20.81	**49.13**
		2043	43.86	24.12	**67.972**

Summary of Water Demand Assessment

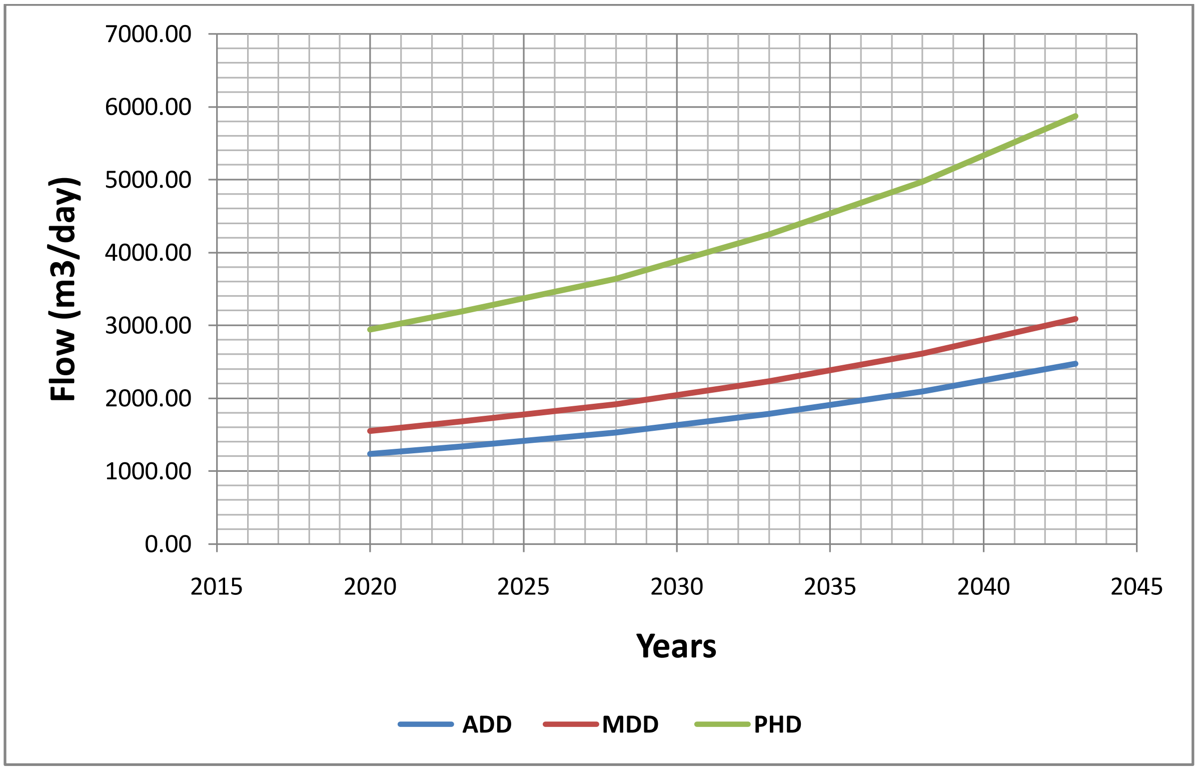


Figure 4.6: Summary of Water Demand Assessment

4.9 Hydraulic Design of Newly Proposed Water Supply System

The proposed water supply components for the water supply system like Water source, pipe line installation (pressure and distribution lines) service reservoir, public fountains, electro-mechanical situation, and other accessories are evaluated as follows.

4.9.1 Water Sources

Safe and adequate potable water supply is an important input for the health and well-being of society. Safe drinking water has considerable contribution to the better health and Productivity of target community as well as socioeconomic development of the users in particular area and at nation level.

The sources will be selected based on the required water demand to meet the town to next considered design period and shall be designed for maximum day demand. The selected water sources are based on hydro geological investigation. According to the investigation of regional BoWR and information gathered from TWSO, the water sources for Leku town are Ground (Borehole/well water and spring) and Surface water (stream and rives).

The current water supply for the town fully comes from groundwater sources. From the geological, hydro geological and hydrological nature of the study area it can be concluded that the area has good groundwater potential. The location, depth and yield of the existing boreholes, both successful and abandoned wells, confirms that the ground water potential of the Leku town is sufficient to supply the current and future demand of the town.

- **Borehole Water Source**

Based on previous investigation, water supply coverage of Leku town is one of the low water supply coverage in the region. Groundwater is the only water supply source for the town currently. The water supply for Leku town drowns from five wells that were drilled in 1987 and 1997 E.C for the town's water supply sources. Currently only three deep wells are serving the community live in town. The other two wells are abandoned mainly due to low well yield.

The existing in Leku town are three wells, the first well "Taramisa No-1" was able to give 10 liter/sec, the second well "Taramisa No-2" was able to give 6 liter/sec and the third well "Remeda well" was 5 litre/sec yield, those three boreholes know a day's a total yields of 21 lit/sec are available for a moment for Leku town for water supply. This indicates the existing water source is not enough to supply sustainable water to the future population of Leku town.

According to Urban water supply design criteria, (MoWR, 2006) multiple boreholes are needed for any particular scheme, consideration will be given to providing 50% stand by borehole capacity, full equipped, depending on vulnerability of the scheme. By taken in consideration water supply design criteria, to meet future potable water demand for Leku town, two wells each yielding 10 litre/sec is recommended for the first phase and additional two wells which are expected to yield 13 litre/sec are recommended for the second phase to satisfy the water supply demand of Leku town in respectively.

Those three bore wells can yields **21 lit/sec (1,814.4 m^3/day)** as well as four new bore wells that a potential of yielding **46 liter/sec (3,974.4m^3/day**) have **a total capacity of producing 5,788.8 m^3** of water per day. Based on the daily production, the annual amount of production has been estimated to be **2,112,912 m^3 up to 2043 G.C.**

Based on projected water demand, the demand will be expected to grow to 1,162,067 m^{3}up to 2043 G.c. Accordingly, the water demand including water loss (15-25%)) has been projected to grow to 1,452,584 m^3 in 2043 G.C. Therefore; the existing and the new bore holes have the capacity of producing 2,112,912 m^3 of water annually. Thus, during the planning period (2023 – 2043 G.C) there would not be shortage of water supply.

4.9.2 Reservoirs

Reservoirs are designed for the purpose of distribution, transfer and fire fighting storages based on the set design criteria. The capacities of the reservoirs have been determined based on the surplus-deficiency storage fluctuation named as “Mass Curve Analysis” based on estimated minimum hour demand and hourly variation of the town. The storage requirement for the new water supply the reservoirs have been sized for the four water collection systems independently to meet the extra head and storage requirements.

Table 4.25: Proposed Reservoirs based on Mass Curve Analysis (2033 and 2043 G.C)

Description	Pressure Zone-I	Pressure Zone-2
	Stage- I	**Stage- I**
Maximum positive Storage (m3)	510	300
Minimum negative Storage (m3)	-492	-290
Balancing vol.(m3)	1002	590
Reserve for fire demand 10% (m3)	100	59
Total reservoir capacity(m3)	1102	650
Existing reservoir(m3)	100	100
Proposed Reservoir stage-I(m3)	300	250
New proposed reservoir (m3)	702	300
Adopted Standard Standard(m3)	**700**	**300**

Based on this empirical method and water required for emergency, the required storage capacity needed for Leku town is determined to be about **700m^3** storage reservoir for Pressure zones One and additional **300m^3** storage reservoir for Pressure zones Two need to be constructed with in first phase for both Pressure Zones. According to Urban water supply design criteria, (MoWR, 2006). A reservoir location should maintain the design pressure range in the supply network. Possible future extension of storage capacity should be taken in to consideration when selecting a site. Therefore; based on the information gathered from Sidama region BoWR, about ground water potential of Leku town, propose service reservoirs for Leku town that can meet the growing demand in the future are located at two different location with UTM location of the first at E- 440400.08, N- 761363.46and Elevation of 1926.86m a.m.s.l (**700 m^3** for Phase I) the service reservoir at UTM location of E- 437043.75, N- 760800.39 and Elevation of 1885.44m asl (**300 m^3** at Morocho for Phase I).

4.10 Hydraulic Performance Analysis

4.10.1 Existing Water Distribution Network

To evaluate existing water supply distribution network system, the information was collected from TWSO of Leku town and Survey data. Based on generated information as shown in table 4.41 below; the longest of water supply distribution network in Leku town were coved by 100 mm diameter pipe (30%) and 50 mm diameter pipe (21%), in between 38 mm diameter pipe (17%), 75 mm diameter pipe (15%), and 63 mm diameter pipe (10%). Whereas the lowest proportion of pipe size found in the area are 25 mm diameter pipe (4%) and 150 mm diameter pipe (2%).

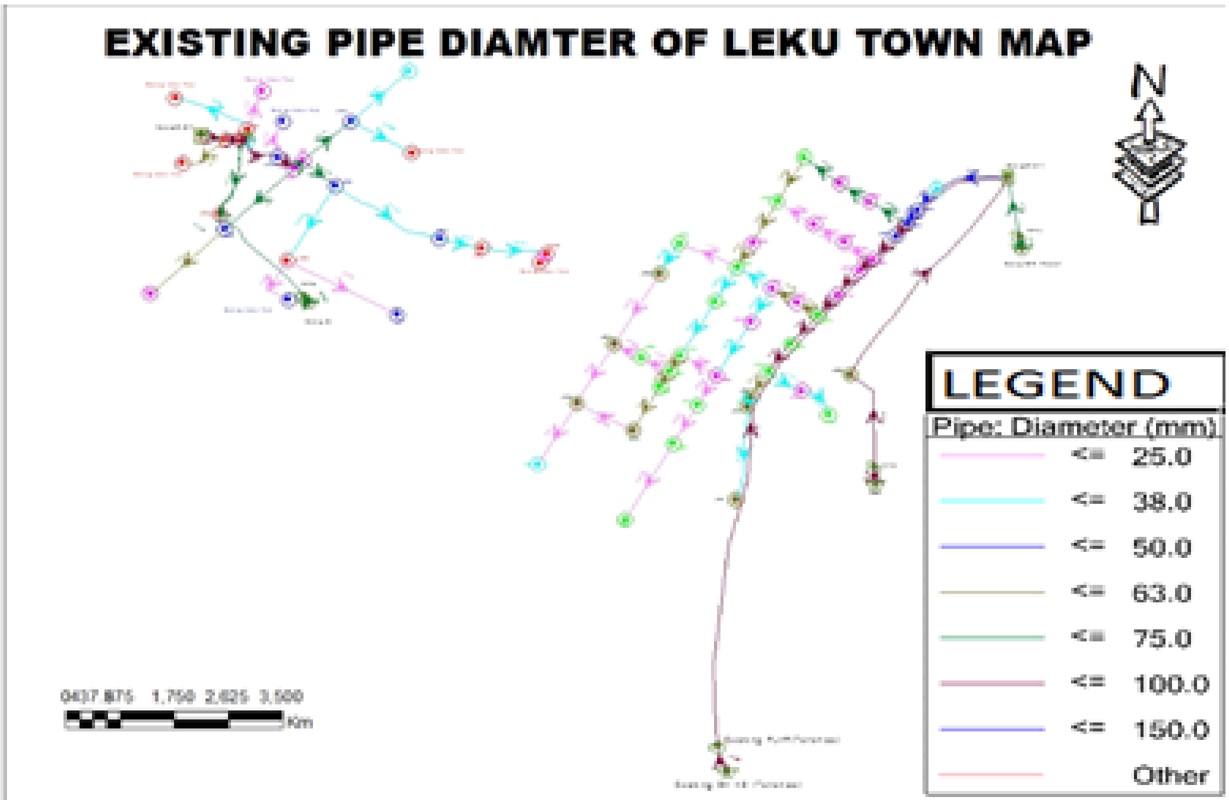


Figure 4.7: Existing Pipe Diameter and type pipe of the System

4.10.1.1 Pressure Analysis

The operating pressure in the distribution network based on minimum and maximum pressure which are 15m and 70m respectively (MoWR,2006). The pressure at nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances, and the size of the network (Masri M. 1997). The minimum pressure should be maintained to avoid water column separation and to ensure that consumer's demands are provided at all times.

The maximum pressure constraints results from service performance requirements such fire needs or the pressure bearing capacity of the pipes, also limit the leakage in the distribution system, especially that there is a direct relationship between the high pressure and the increasing of leakage value in the system.

Table 4.26: Existing water supply system pipe Pressure Leku Town

Pressure (m)	No of Nodes	Percentage (%)
<= **10**	9	14.75%
<= **15**	3	5%
<= **25**	12	20%
<= **35**	13	21%
<= **45**	16	26%
<= **49**	7	11.5%
>=**70**	1	1.64%
Total	**61**	**100**

This study was mainly focused on the Ministry of water resource guideline on urban water supply design criteria (MoWR, 2006).The result of hydraulic analysis existing water supply distribution system of Leku town as indicated in table 4.26, The 14.75% and 5% of the nodes are below desirable minimum pressure 10m and15m respectively, during peak hour consumption. Moreover; 1.64% of the nodes were exceeding maximum allowable pressure during peak hour consumption. However, 78.5% of the nodes are within recommended range between (15m to 70m). Exceptionally 6.6% junctions (J-102, J-84, J-77, J-22 and J-31) were negative pressure at peak hour consumption that can cause low supply, intrusion of contamination and deterioration (MoWR, 2006).

Based on researcher observation during filed visit the above mention constraints; the distribution lines were not laid according to the master plan of the town and laid at the center of the road and also same of the pipes are exposed and laid above ground. Thus, it is exposing to various damage that create frequent interruption in water supply and at the taps of residents with adequate pressure. Moreover; some parts of the town 590.17 ha (35%) are not yet covered by the existing distribution network and 80% of distribution line were getting older and create burst. So that, the existing water supply distribution system needs improvement of the system to provide permissible pressure.

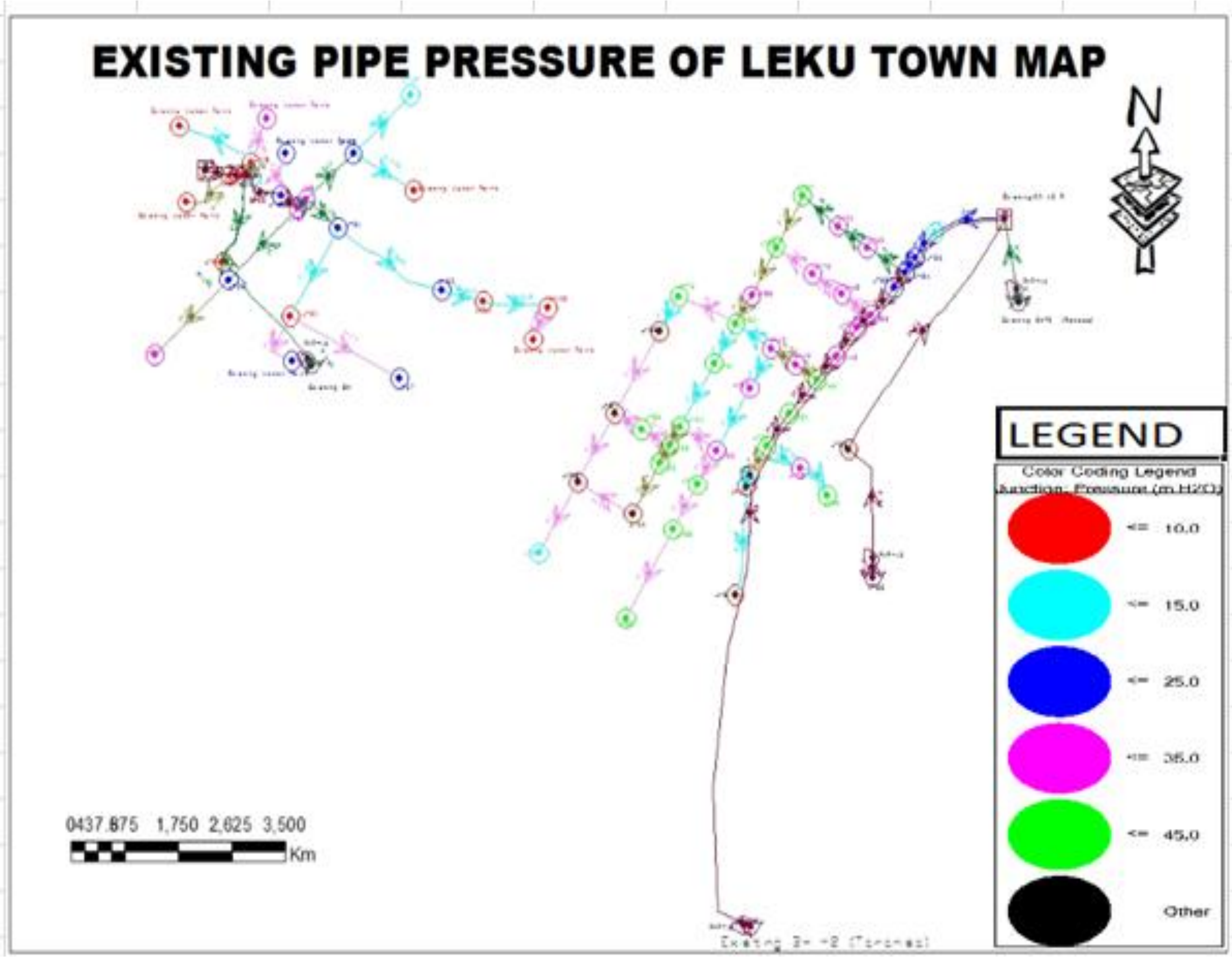


Figure 4.8: Existing pipe pressure in Leku Town

4.10.1.2 Velocity Analysis

To evaluate hydraulic performance of existing water supply system in particular area, velocity is one of important parameter that need to be addressed. Flow rate is the quantity of water passes within a certain time through a certain section. Velocity is directly proportional to the flow rate. Since, a known pipe diameter and a known velocity, the flow rate through a section can be calculated. Low velocities affect the proper supply and will be undesirable for hygienic reasons i.e. sediment formation may cause due to the long time of retention.

Table4.27: Existing water supply system pipe Velocity of Leku Town

Velocity (m/s)	No of Pipes	Percentage (%)
<= 0.30	14	21%
<= 0.60	29	43%
<= 2.0	24	36%
Total	**67**	**100**

Urban water supply criteria stated that the minimum velocity 0.6 m/sec and the maximum velocity maintained at less than 2 m/sec (MoWR, 2006). The study result of velocity analysis of the existing water supply distribution system at Leku town in table 4.27 above indicates that 36% of the pipes are within the recommended ranges of velocities between minimum 0.6 m/s to maximum 2 m/s. However; 64% of the pipes are below desirable minimum velocity during peak hour water consumption which needs further improvement to attain the minimum recommended velocity.

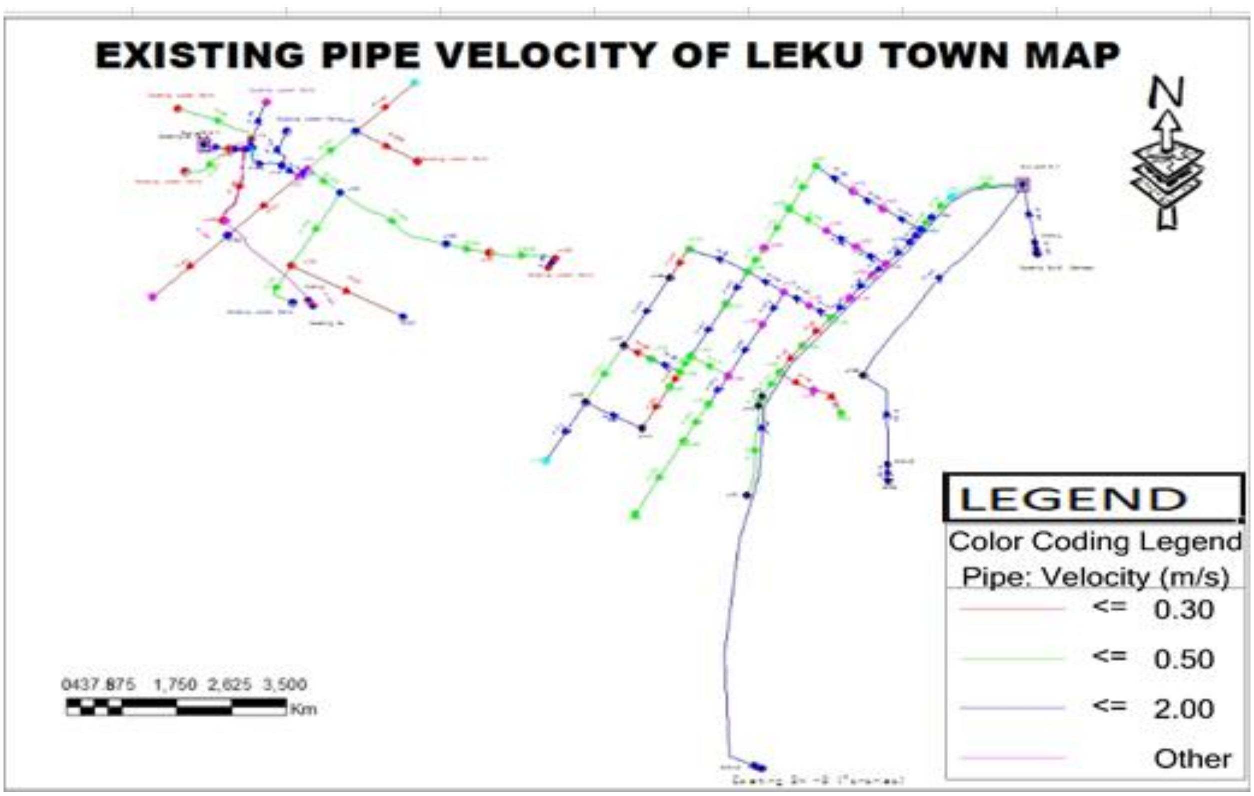


Figure 4.9: Existing Water Velocity in Leku Town

4.10.2 Proposed Hydraulic Network Improvement

4.10.2.1 New Water Distribution Network

According to Naeeni (1996) developed a computer program, which enables to obtain the optimum design of various kinds of water distribution networks so that all constraints such as pipe diameters, flow, velocities, and nodal pressures are satisfied. Water supply distribution network input parameter such as type of pipe, diameter, length and roughness coefficient are obtained from Bentley water CADv8i design, inventory report as shown in table 4.28 below; the majority of water supply distribution network in Leku town were coved by 90 mm diameter pipe (20%), 50 mm diameter pipe (15%), 75 mm diameter pipe (15%), 100 mm diameter pipe (14%) and 63 mm diameter pipe (14%). Whereas the lowest proportion of pipe size found in the area are 160 mm diameter pipe (3%) and 300 mm diameter pipe (2%). Moreover; the proportion of type of pipe in distribution system were HDPE pipe cover 62.8%, GI pipe 22.3%, Ductile Iron 8.4%, and 6.5% was covered by DCI pipe. The experience shows that a pipe designed to flow at a velocity between 0.6 and 1.5 m/sec, depending on diameter, is usually at optimum condition (head loss versus cost) (MoWR, 2006).

Generally; Based on data generate from TWSO, field observation and Analysis result the existing and newly proposed Water supply distribution system as follows:-

The total length of pipe in the existing water distribution system of Leku town was 31,811 meter in length and the pipe material was covered by GI pipe all over the system. Based on information generated from TWSO and field observation, service delivery for some of residence were not addressed or nearby their residence. Moreover; the existing water distribution system the pipe installation work completed in 1987 E.C with Chain Development Company. This implies the age of existing pipe was 27 years old.

According to Ministry of water resource guideline (MoWR, 2006), the pipe age of existing water distribution of Leku town was getting old enough to retire service and have the experience of bursting. So that; the existing pipe was not in a position of hold optimum pressure. The pressure at nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances, and the size of the network (Masri M. 1997). So that; to resolve the above mentions constraints in existing water distribution system, various pipe material such as HDPE, GI, Ductile Iron, and DCI pipes with range of diameter with length of 81,206 meter were used in new water distribution system based on nature of material, compatibility of the soil and existing pressure of distribution system. So as to improve the hydraulic performance of Leku town water supply distribution system. Since, the physical characteristics (crushing strength, resistance to corrosion, etc) of the pipes should suit the actual service conditions arising in the system with respect to internal and external loads and soil conditions (MoWR, 2006).

Table 4.28: Pipe type and Length in newly proposed System

No	Outside Diameter (OD) (mm)	Length (HDPE) (m)	Length (Ductile Iron) (m)	Length (GI) (m)	Length (DCI) (m)	Length (All Material) (m)	Percent age (%)	Remark
1	**50**	11,969	0	0	0	**11,969**	**15**	
2	**63**	7,282	0	0	0	**7,282**	**9**	
3	**75**	12,567	0	0	0	**12,567**	**15**	
4	**75**	0	0	1,248	0	**1,248**	**2**	
5	**90**	16,839	0	0	0	**16,839**	**20**	
6	**95**	0	0	5,854	0	**5,854**	**7**	
7	**100**	0	0	10,986	0	**10,986**	**14**	
8	**160**	2,335	0	0	0	**2,335**	**3**	
9	**175**	0	6,825	0	0	**6,825**	**8**	
10	**200**	0	0	0	3,772	**3,772**	**5**	
11	**300**	0	0	0	1,529	**1,529**	**2**	
	All Diameters	**50,992**	**6,825**	**18,088**	**5,301**	**81,206**	**100**	

Source: Bentley water CADv8i inventory report

NB: the Pipe Outside diameter (OD) and Inside diameter (ID) attached in Annex.

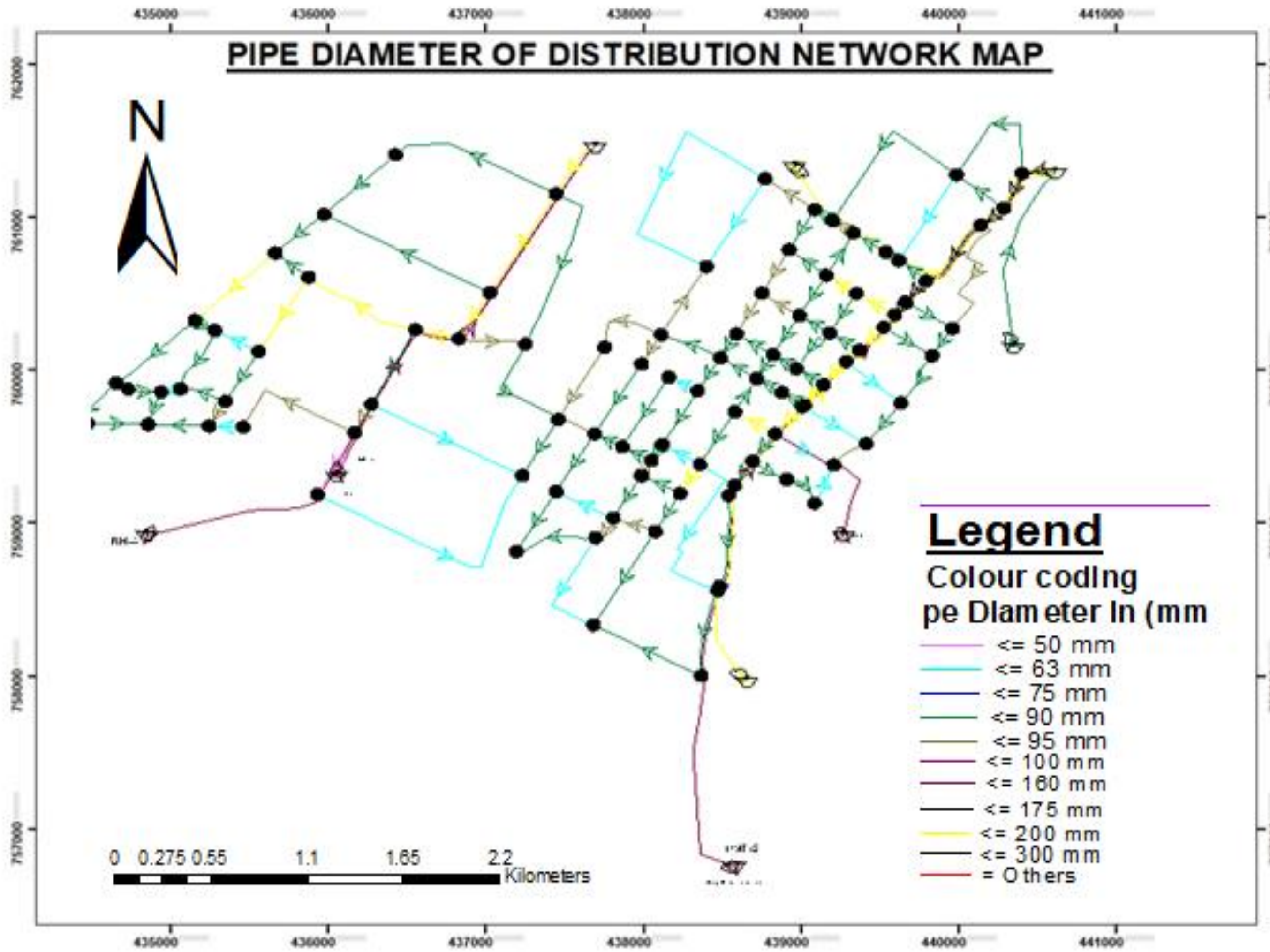


Figure 4.10: Pipe type and Length in Newly proposed System

Source: Bentley water CADv8i

4.10.2.2 Pressure Analysis

According to Ministry of water resource design criteria guideline (MoWR,2006), the operating pressure in the distribution network based on minimum and maximum pressure which are 15m and 70m respectively. The pressure at nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances, and the size of the network (Masri M. 1997). Number of nodes and nodal demands are important parameters in the design and simulation of distribution system. The provision of nodes for a certain area depends on the land use plan of that area.

The minimum pressure should be maintained to avoid water column separation and to ensure that consumer's demands are provided at all times. The maximum pressure constraints results from service performance requirements such fire needs or the pressure bearing capacity of the pipes, also limit the leakage in the distribution system, especially that there is a direct relationship between the high pressure and the increasing of leakage value in the system.

Table 4.29: Distribution of Pressure at Peak hour Consumption

Pressure (m)	No of Nodes	Percentage (%)
<= 10	4	4.4%
<= 15	2	2.2%
<= 25	9	9.9%
<= 35	25	27.5%
<= 45	33	36.2%
<= 62	18	19.8%
Total	**91**	**100**

The result obtained from hydraulic analysis Bentley water CADv8i indicated in table 4.29, The 85 nodes (93.4%) of the nodes have pressure within recommended range between (15m - 62m) with reference to MoWR, (2006) standard. Moreover; 2 nodes (2.2%) also acceptable (14.2m to 14.3m) in exceptional Conditions. So those, the analysis result of newly proposed distribution system indicate that 87 nodes (95.6%) have pressure within recommended range. This shows that pressure in newly proposed water distribution system was adequate and the system provided an acceptable level of service flow to satisfy community. But the 4 nodes (4.4%) of the nodes are below desirable minimum pressure range between (4.4m - 9m), during peak hour consumption. Even though 4.4% junctions (J-212, J-1, J-50 and J-14) below 10m water pressure at peak hour consumption also have no significant influence in pressure since those nodes were near to reservoir. In general, the analysis results indicated that the performance was adequate and the system provided an acceptable level of service based on pressure considerations (Abdel-Latif,M.Y 2001).

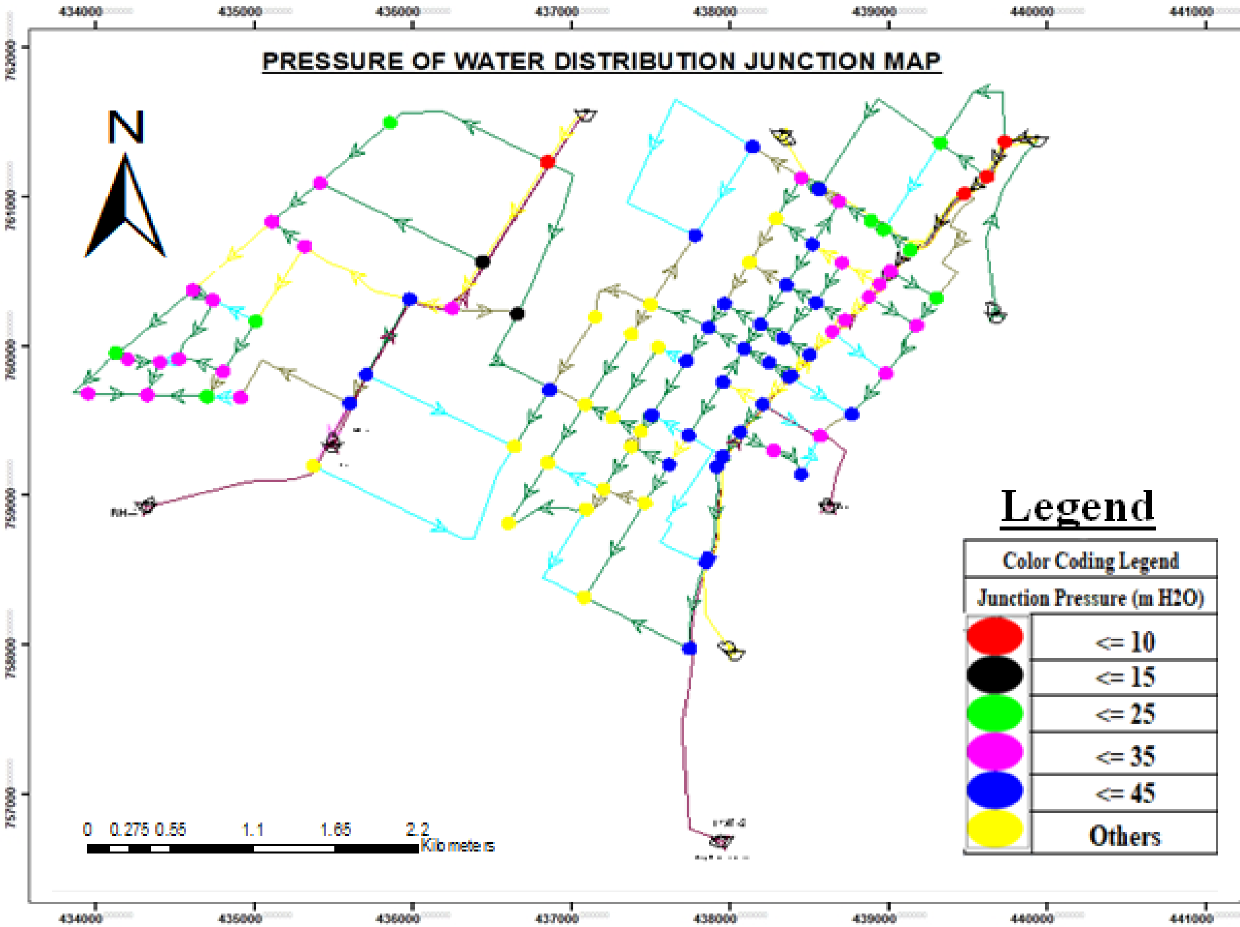


Figure 4.11: Distribution of pressure at peak hour consumption
Source: Bentley water CADv8i

Table4.30: Distribution of Pressure at Low Consumption

Pressure (m)	No of Nodes	Percentage (%)
<= 10	4	4.3%
<= 15	0	0%
<= 25	7	7.6%
<= 35	18	19.7%
<= 45	25	27.4%
<= 70.2	37	41%
Total	**91**	**100**

As indicated in table 4.30 above, only 4 nodes (4.3%) specially (J-1, J-212, J-50 and J-14) are under allowable minimum pressure range between (5.3m – 9.8m) during low hour consumption.

Unfortunately there are no any nodes that are exceeded maximum allowable pressure during minimum hour consumption. However; 87 nodes (95.7%) within the allowable pressure range minimum 16.8m and maximum 70.2m during low consumption at midnight where majority of the community were not using water. The analysis result shows that the performance of pressure was adequate and the system provided an acceptable level of service based on Ministry of water resource design criteria guideline (MoWR, 2006).

4.10.2.3 Velocity Analysis

The hydraulic performance of water supply system in particular area, velocity is one of important parameter that needs to be addressed. For newly propose water supply distribution system, It is preferable that flow velocities remain in the range 0.6 to 1.5 m/s although in exceptional circumstances this may increase to 2.0 m/s.

Table 4.31: Velocity of water distribution at Peak hour Consumption

Velocity (m/s)	No of Pipes	Percentage (%)
<= 0.30	0	0%
<= 0.60	32	21%
<= 2.0	118	79%
Total	**150**	**100**

After designing newly proposed water supply distribution system, the result of velocity analysis of Leku town shows in table 4.31, According to Ministry of water resource design criteria guideline (MoWR,2006), indicate that velocity of the pipes should within recommended range between minimum 0.6 m/s to maximum 2 m/s velocities during peak hour consumption. The hydraulic analysis result shows that 32 pipes (21%) are velocity between (0.32 m/s to 0.58 m/s), it is below minimum recommended velocity 0.6 m/s. Whereas; 118 pipes (79%) are below 2 m/s velocity between (0.6 m/s to 1.87 m/s) during peak hour consumption. Based on Ministry of water resource design criteria guideline (MoWR,2006), The result indicated that Velocity in newly proposed water distribution system was adequate and the system provided an acceptable level of flow in distribution system to satisfy community and hydraulically effective system.

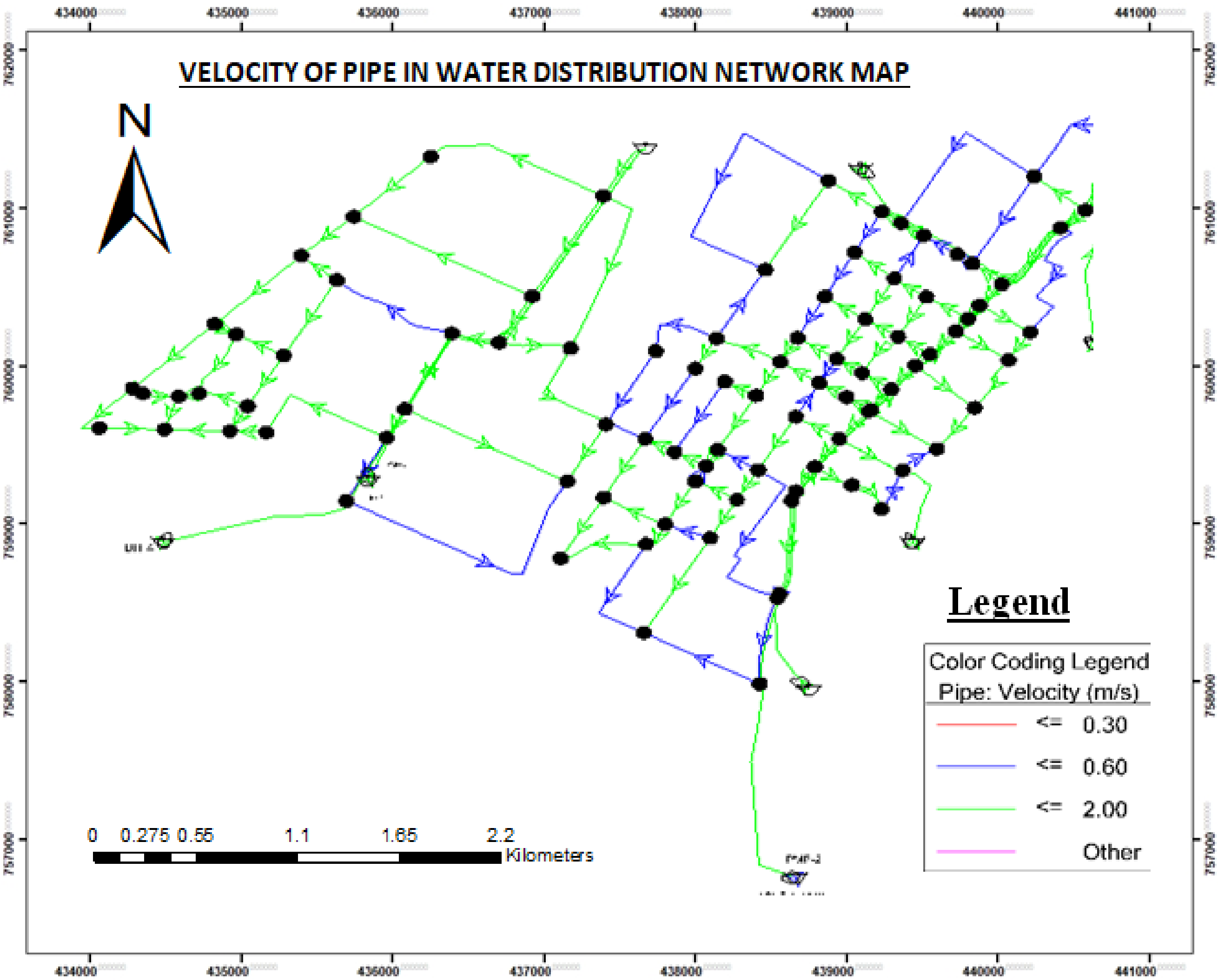


Figure 4.12: Velocity of water distribution at Peak hour Consumption
Source: Bentley water CADv8i

Table4.32: Velocity of water distribution at Low Consumption

Velocity (m/s)	No of Pipes	Percentage (%)
<= 0.30	4	2%
<= 0.60	37	25%
<= 2.0	109	73%
Total	**150**	**100**

The newly proposed water supply distribution system, the result of velocity analysis of Leku town shows in table 4.32; 109 pipes (73%) are within recommended range velocity between minimum 0.6 m/s to maximum 2 m/s velocities during low hour consumption. Moreover; 37 pipes (25%) are velocity range between (0.30 m/s to 0.59 m/s). However; only 4 pipes (2%) are below 0.3 m/s velocity during low hour consumption. The analysis result shows that the velocity was adequate and the system provided an acceptable level of flow based on Ministry of water resource design criteria guideline (MoWR,2006).

- **Nodal Demands**

Number of nodes and nodal demands are important parameters in the design and simulation of distribution system. The provision of nodes for a certain area depends on the land use plan of that area. Domestic nodes are provided for residential areas and non-domestic nodes for public, institutional, commercial and industrial areas. However, in areas where the land use plan is mixed, the numbers and locations of the nodes are determined based on the spatial distribution of water for the entire area.

Accordingly, the nodal demand of the urban area has been fixed based on the proposed Land Use Plan where as that of the urban area has been determined based on the proportion of people residing in each local area. So that, Leku town water distribution system nodal demands have been fixed to enable future expansion sustainable. So that, to determine existing water distribution system nodal demand up to first phase, the population that use existing water distribution system were 42,236 and the average per capita demand was 36 l/c/day, so as the total nodal demand was 17.5983 l/s found in existing water distribution system. Whereas; the element of existing water distribution system nodal demand is presented in table 4.33 below.

Table 4.33: Nodal Demands of Existing Water Supply System

Label	Population at Junction	Nodal demand (l/s)	Hydraulic Gradient (m)	X (m)	Y (m)	Elevation (m)
J-22	1200	0.5	1,879	760,445	434,955	1,880
Existing Water Point	384	0.16	1,873	760,865	436,193	1,873
Existing Water Point	1920	0.8	1,862	760,114	437,023	1,861
Existing Water Point	3000	1.25	1,879	760,794	434,715	1,878
Existing Water Point	1920	0.8	1,875	761,237	434,668	1,871
J-90	720	0.3	1,868	760,128	435,391	1,862
J-107	864	0.36	1,872	761,421	436,176	1,863
Existing Water Point	864	0.36	1,866	759,865	435,400	1,853
J-3	1080	0.45	1,855	758,744	437,010	1,840
Existing Water Point	1920	0.8	1,870	761,078	435,363	1,853
J-99	3240	1.35	1,873	761,077	435,800	1,855
J-81	720	0.3	1,873	760,643	435,702	1,853
J-38	1440	0.6	1,875	760,342	434,987	1,854
J-67	720	0.3	1,865	759,763	436,100	1,843
J-11	1440	0.6	1,874	759,904	434,508	1,851
Existing Water Point	1920	0.8	1,872	761,283	435,233	1,847
J-70	720	0.3	1,914	760,655	438,959	1,888
J-73	360	0.15	1,912	760,377	438,789	1,884
J-23	720	0.3	1,899	759,346	438,163	1,866
J-53	1441	0.6003	1,906	760,084	438,291	1,871
J-74	360	0.15	1,895	759,145	438,040	1,858
J-85	1344	0.56	1,909	760,532	438,554	1,873
J-87	3619	1.508	1,911	760,832	438,725	1,874
J-34	1440	0.6	1,897	759,484	437,927	1,858
J-66	1296	0.54	1,914	759,079	438,884	1,874
J-88	1296	0.54	1,885	758,366	437,575	1,842
J-33	720	0.3	1,897	759,268	437,795	1,854
J-56	576	0.24	1,889	759,468	437,676	1,844
J-76	720	0.3	1,895	760,245	437,921	1,850
J-98	624	0.26	1,885	759,159	437,261	1,839
J-57	720	0.3	1,887	759,559	437,502	1,841
J-9	720	0.3	1,915	759,201	438,383	1,868
J-10	720	0.3	1,914	759,136	438,360	1,867
J-69	1488	0.62	1,912	758,501	438,285	1,863
Total	**42,236**	**17.598**				

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The aspire of this research to analyze water supply coverage and hydraulic performance water supply system of Leku town. As water supply coverage of the area, first existing situation of water supply and Population analysis were carried out. Accordingly, the population of Leku town was projected 38,559 at base year and projected population in first design phase 42,236 in year 2025 E.c and population become 46,264 at the end of design period in year 2043 G.C.

The average domestic water demand at first design phase (2033) was found to be 1,207 m3/day and at the end of the project design periods 1,609 m3/day (2043). Considering this socio-economic and climatic adjustment factors; the average day per-capita consumption for Leku town in the coming project design horizons become 14 and 19 liters, at (2033 & 2043 G.C) respectively. The maximum day demand with reference to pressure zone for the first design period were 14.91 l/s and 10.95 l/s at pressure zone one. Whereas; the maximum day demands for pressure zone two were 23.08 l/s and 12.69 l/s at 2nd design period. Accordingly, the maximum day water demand 2,234.2 m3/day for phase I and maximum day water demand 3,091m3/day for phase II of design periods. The aggregated average per-capita water consumption of Leku town in year 2019 G.C were obtained as 12.91 l/c/day and 13.11 l/c/day for year 2020 G.C. Based on the UWSUAP of the country standard, the minimum quantity of water required for domestic (house hold) consumption is taken as 20 l/c/day and non domestic consumption is 30% of the domestic (MoWR,2011).

Thus, the finding indicates that the aggregated per-capita water consumption of Leku town is below the standard. Moreover; the water supply coverage of Leku town was Calculated based on set goal in GTP -2 for urban minimum service level of water supply access. So that Leku town fall under category -4 about 50 l/c/day, the water supply coverage of Leku town was found 26%.

The hydraulic performance analysis of existing water supply distribution for Leku town especially pressure and velocity analysis were carried out to identify hydraulic shortcoming. Then propose improved water supply distribution system designed with aid of water CADv8i using the master plan that optimize hydraulic performance to meet water demand of community.

Therefore; for this analysis purpose, 61 nodes and 67 pipes were identified and evaluated with water CADv8i software.

The result of hydraulic analysis existing water supply distribution system of Leku town, the 14.75% and 5% of the nodes are below desirable minimum pressure 10m snd15m respectively, during peak hour consumption. Moreover; 1.64% of the nodes were exceeding maximum allowable pressure during peak hour consumption. However, 78.5% of the nodes are within recommended range between (15m to 70m). Exceptionally 6.6% junctions (J-102, J-84, J-77, J-22 and J-31) were negative pressure at peak hour consumption that needs to improve.

The result of velocity analysis existing water supply distribution system indicated that 79% of the pipes are within recommended range velocity between minimum 0.6 m/s to maximum 2 m/s velocities. However; 21% of the pipes are below desirable minimum velocity during peak hour consumption.

However, the newly proposed water distribution system The 85 nodes (93.4%) of the nodes have pressure within recommended range between (15m - 62m) with reference to MoWR, (2006) standard. Moreover; 2 nodes (2.2%) also acceptable (14.2m to 14.3m) in exceptional conditions. So those, the analysis result of newly proposed distribution system indicate that 87 nodes (95.6%) have pressure within recommended range. But the 4 nodes (4.4%) of the nodes are below desirable minimum pressure range between (4.4m - 9m), during peak hour consumption. Even though 4.4% junctions (J-212, J-1, J-50 and J-14) below 10m water pressure at peak hour consumption also have no significant influence in pressure since those nodes were near to reservoir. Accordingly, velocity analysis result shows that 32 pipes (21%) are velocity below minimum recommended velocity 0.6 m/s. Whereas; 118 pipes (79%) are below 2 m/s velocity between (0.6 m/s to 1.87 m/s) during peak hour consumption. The result of newly proposed water supply distribution system indicated that Velocity in newly proposed water distribution system was adequate and the system provided an acceptable level of flow in distribution system to satisfy community and hydraulically effective system.

In general, the analysis result of this research shows that the overall performance of existing water distribution of Leku town was very poor, which exhibited:-

- Weak hydraulic performances of distribution system (velocity and pressure unacceptable range) because of unsuitable layout of water supply distribution network.
- Water shortage from the source and frequent service interruption is not only as consequence of shortfall between demand and supply but also as the result of leakage.
- Low level of water supply coverage and service delivery.
- Old aged pipe frequently burst,
- Frequent fluctuation of power supply (Electric power) and
- Shortages in capacity of service reservoirs etc are the shortcoming of existing water supply system of Leku town need to be resolved.

5.2 RECOMMENDATIONS

According to this research finding, to meet continuously increasing demand of water supply of Leku town, the following recommendation will be proposed.

- The water supply system of Leku town will be redesigned to improve hydraulic performance especially Pressure and velocity with acceptable level.
- Additional borehole should be drilled to meet future potable water demand for Leku town, two wells each yielding 10 litre/sec is recommended for the first phase and additional two wells which are expected to yield 13 litre/sec are recommended for the second phase to satisfy the water supply demand of Leku town in respectively, to fulfill the current gab between water demand and water supply.
- To alleviative water scarcity of the town additional four reservoirs should be constructed, the required storage capacity needed for Leku town is determined to be about **700m^3** for pressure zone one and additional **300m^3** for pressure zone two within the first phase for both Pressure zones.
- To meet timely varying demand and maintaining standard pressure range, it is necessary installed pressure controlling valve, establishing break pressure tank and replacing the unsuitable size pipe within the system with the new one that has a diameter of appropriate size. The pipe in the existing water distribution system of Leku town has 31,811 meter in length and the pipe material was GI pipe that cover all over the system. The pipe installation work completed in 1987 E.C, the age of existing pipe was 27 years old. This implies the pipe in existing distribution system was getting old enough and on the way of retire service, Due the pipe bursting her and there. So that; the existing pipe was not in

apposition of hold optimum pressure. To improve the hydraulic performance of the existing water distribution system, need to replace by new proposed pipes such as;-

- HDPE pipe with diameter (50 mm, 63 mm, 75 mm, 90mm and 160 mm) that has a length of 50,992 meter.
- Ductile Iron (DI) pipe with diameter (175 mm) that has a length of 6,825 meter.
- Galvanized Iron (GI) pipe with diameter (75mm, 95mm and 100mm) that has a length of 18,088 meter.
- Ductile Cast Iron (DCI) pipe with diameter (200mm and 300mm) that has a length of 5,301 meter. Accordingly the pipes with above mentioned range of diameter with length of 81,206 meter were used based on nature of material, compatibility of the soil and existing pressure of distribution system.

- To reduce variation of water supply caused by topographic situation, pressure zones are established to ensure minimum pressures can be provided to high ground areas, particularly at higher elevations.
- The old pipes should be replaced to avoid water loss of water and supply interruption due to burst.
- To reduce water supply interruption due to fluctuation of electric power, reserved diesels power generator should be supplied.

Finally, it needs a new design of water supply distribution system in accordance to master plan of the town that can meet the present and future water demand for the coming 20 years period as proposed by the paper.

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Appendix A

Existing Pressure (Junction) result; for peak demand time (7:00)

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-102	760,177.97	437,066.70	1,871.45	0	1,864.14	-7.3
J-84	760,217.31	436,648.85	1,870.00	0	1,866.69	-3.3
J-22	760,444.79	434,954.99	1,880.00	0.5	1,879.30	-0.7
J-31	760,952.33	434,993.65	1,881.35	0	1,880.91	-0.4
Existing Water Point	760,865.00	436,193.10	1,872.85	0.16	1,872.59	-0.3
Existing Water Point	760,114.29	437,022.85	1,861.00	0.8	1,862.37	1.4
Existing Water Point	760,793.65	434,715.38	1,877.50	1.25	1,879.39	1.9
J-11	760,951.18	435,090.13	1,877.00	0	1,879.49	2.5
J-15	761,021.99	435,133.87	1,875.00	0	1,878.32	3.3
Existing Water Point	761,236.71	434,667.59	1,871.00	0.8	1,875.11	4.1
J-90	760,128.36	435,391.11	1,861.50	0.3	1,868.01	6.5
J-107	761,420.70	436,175.84	1,863.30	0.36	1,872.04	8.7
J-14	760,950.61	435,140.94	1,870.00	0	1,878.82	8.8
J-51	760,614.33	439,585.56	1,910.30	0	1,920.98	10.7
Existing Water Point	759,864.98	435,399.60	1,852.50	0.36	1,866.03	13.5
J-3	758,743.94	437,009.69	1,840.22	0.45	1,855.12	14.9
Existing Water Point	761,077.86	435,362.50	1,853.00	0.8	1,869.59	16.6
J-99	761,077.09	435,799.96	1,854.90	1.35	1,872.74	17.8
J-83	760,279.49	436,374.84	1,849.90	0	1,868.38	18.4
J-26	760,470.93	439,457.85	1,900.85	0	1,920.56	19.7
J-81	760,643.04	435,702.35	1,853.25	0.3	1,873.08	19.8
J-38	760,342.39	434,986.94	1,853.75	0.6	1,874.51	20.7
J-18	760,835.50	435,328.67	1,855.00	0	1,876.46	21.4
J-24	760,381.51	439,390.40	1,898.45	0	1,920.32	21.8
J-67	759,762.75	436,099.51	1,842.65	0.3	1,865.04	22.3
J-25	760,295.63	439,319.02	1,896.55	0	1,919.65	23
J-11	759,903.81	434,508.16	1,850.50	0.6	1,873.76	23.2
J-5	760,812.99	435,493.42	1,850.50	0	1,874.37	23.8
J-21	760,758.53	435,439.50	1,850.85	0	1,875.59	24.7
Existing Water Point	761,282.59	435,233.18	1,847.00	0.8	1,871.87	24.8
J-69	760,529.83	439,147.30	1,891.18	0	1,917.00	25.8
J-70	760,654.86	438,959.05	1,887.55	0.3	1,914.35	26.7
J-28	760,137.37	439,167.72	1,891.35	0	1,918.33	26.9
J-73	760,377.05	438,789.13	1,883.50	0.15	1,911.75	28.2
J-65	760,255.56	438,981.84	1,886.50	0	1,915.09	28.5
J-29	760,059.68	439,083.22	1,888.80	0	1,917.79	28.9
J-49	759,940.89	438,519.89	1,879.48	0	1,909.83	30.3

J-27	759,710.28	438,383.13	1,874.85	0	1,905.54	30.6
J-48	759,898.32	438,940.40	1,883.75	0	1,916.77	33
J-23	759,345.94	438,163.40	1,865.50	0.3	1,898.73	33.2
J-52	760,248.66	438,393.74	1,873.30	0	1,907.36	34
J-43	759,844.00	438,679.76	1,878.55	0	1,913.04	34.4
J-75	759,243.51	438,709.46	1,879.80	0	1,914.74	34.9
J-63	759,755.75	438,820.81	1,880.50	0	1,915.90	35.3
J-53	760,084.37	438,291.49	1,870.70	0.6	1,906.23	35.5
J-74	759,144.53	438,039.60	1,858.40	0.15	1,894.61	36.1

Existing Pressure (Junction) result; for peak demand time

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-85	760,531.61	438,554.29	1,872.50	0.56	1,909.26	36.7
J-87	760,832.24	438,724.87	1,874.30	1.5	1,911.48	37.1
J-61	759,855.19	438,150.55	1,865.50	0	1,902.78	37.2
J-82	758,882.44	437,883.57	1,853.45	0	1,891.24	37.7
J-34	759,484.35	437,927.46	1,857.62	0.6	1,897.24	39.5
J-20	759,560.20	438,638.05	1,875.24	0	1,915.67	40.3
J-66	759,079.23	438,883.61	1,873.50	0.54	1,913.97	40.4
J-32	759,373.97	437,859.70	1,854.62	0	1,896.88	42.2
J-88	758,365.62	437,575.13	1,841.65	0.54	1,884.58	42.8
J-33	759,268.38	437,795.40	1,853.75	0.3	1,896.74	42.9
J-60	759,368.98	438,495.19	1,871.65	0	1,915.46	43.7
J-56	759,468.15	437,675.89	1,843.85	0.24	1,888.51	44.6
J-76	760,244.93	437,920.98	1,850.23	0.3	1,895.26	44.9
J-44	758,976.01	437,619.91	1,851.38	0	1,896.62	45.2
J-98	759,158.84	437,260.97	1,838.50	0.26	1,884.53	45.9
J-57	759,559.34	437,502.01	1,840.89	0.3	1,887.46	46.5
J-9	759,201.24	438,383.47	1,868.00	0.3	1,914.63	46.5
J-10	759,135.82	438,359.58	1,866.70	0.3	1,914.10	47.3
J-3	758,501.17	438,285.03	1,863.35	0.6	1,911.82	48.4
J-55	760,040.59	437,796.12	1,845.35	0	1,894.47	49
J-28	759,351.10	439,024.89	1,883.00	0	1,999.94	116.7

Appendix B

Existing Pipe Result; for peak demand time (7:00)

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-330	447	Existing Water Point	J-99	50	GI	120	-0.16	0.08	0
P-116	341	J-33	J-44	63	GI	120	0.31	0.1	0
P-69	542	J-11	J-22	75	GI	120	0.5	0.11	0
P-404	509	J-107	J-99	50	GI	120	-0.36	0.18	0.001
P-22	649	J-38	J-11	63	GI	120	0.6	0.19	0.001
P-115	124	J-32	J-33	63	GI	120	0.61	0.19	0.001
P-63	239	J-20	J-60	100	GI	120	1.74	0.22	0.001
P-87	268	J-63	J-20	100	GI	120	1.74	0.22	0.001
P-120	196	J-56	J-57	25	GI	120	0.12	0.25	0.005
P-70	797	J-90	J-67	38	GI	120	0.3	0.26	0.004
P-66	615	J-21	J-38	75	GI	120	1.2	0.27	0.002
P-74	250	J-60	J-75	50	GI	120	0.54	0.28	0.003
P-75	263	J-75	J-66	50	GI	120	0.54	0.28	0.003
P-122	240	J-76	J-55	50	GI	120	0.58	0.29	0.003
P-27	645	J-3	J-10	50	GI	120	-0.6	0.31	0.004
P-114	130	J-34	J-32	63	GI	120	0.97	0.31	0.003
P-152	379	Existing Water Point	J-90	38	GI	120	-0.36	0.32	0.005
P-17	274	J-34	J-23	38	GI	120	-0.37	0.32	0.005
P-124	467	J-57	J-98	38	GI	120	0.4	0.35	0.006
P-64	202	J-60	J-9	63	GI	120	1.2	0.38	0.004
P-103	341	J-31	Existing Water Point	63	GI	120	1.25	0.4	0.004
P-347	282	J-83	J-84	50	GI	120	0.8	0.41	0.006
P-346	780	J-81	J-83	50	GI	120	0.8	0.41	0.006
P-342	423	J-84	J-102	50	GI	120	0.8	0.41	0.006
P-60	532	J-15	Existing Water Point	50	GI	120	0.8	0.41	0.006
P-88	281	J-73	J-85	38	GI	120	0.48	0.42	0.009
P-344	405	J-99	J-5	75	GI	120	-1.88	0.42	0.004
P-65	71	J-9	J-10	50	GI	120	0.9	0.46	0.007
P-97	194	J-52	J-53	63	GI	120	1.45	0.46	0.006
P-96	325	J-85	J-52	63	GI	120	1.45	0.46	0.006
P-139	269	J-5	J-81	75	GI	120	2.06	0.47	0.005
P-55	112	J-26	J-24	150	GI	120	8.28	0.47	0.002
P-54	194	J-51	J-26	150	GI	120	8.28	0.47	0.002
P-97	472	Existing100 m3 R	J-51	150	GI	120	8.28	0.47	0.002

P-107	305	J-74	J-82	38	GI	120	0.54	0.48	0.011
P-108	602	J-82	J-88	38	GI	120	0.54	0.48	0.011
P-95	346	J-87	J-85	63	GI	120	1.52	0.49	0.006
P-356	602	J-90	J-81	50	GI	120	-0.96	0.49	0.008
P-123	564	J-55	J-57	38	GI	120	0.58	0.51	0.012
P-59	72	J-14	J-15	63	GI	120	1.6	0.51	0.007
P-59	216	J-29	J-48	100	GI	120	4.33	0.55	0.005

Existing Pipe Result; for peak demand time (7:00)

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-60	186	J-48	J-63	100	GI	120	4.33	0.55	0.005
P-58	115	J-28	J-29	100	GI	120	4.33	0.55	0.005
P-86	220	J-28	J-65	38	GI	120	0.63	0.55	0.015
P-87	228	J-65	J-73	38	GI	120	0.63	0.55	0.015
P-106	236	J-23	J-74	38	GI	120	0.69	0.61	0.017
P-112	269	J-53	J-61	50	GI	120	1.2	0.61	0.013
P-113	433	J-61	J-34	50	GI	120	1.2	0.61	0.013
P-89	58	Existing BH - 2 (Taramisa)	PMP-12	100	GI	120	4.9	0.62	0.006
P-90	5,036	PMP-12	Existing100 m3 R	100	GI	120	4.9	0.62	0.006
P-22	403	J-44	J-98	25	GI	120	0.31	0.63	0.03
P-36	270	J-49	J-53	50	GI	120	1.23	0.63	0.013
P-56	112	J-24	J-25	100	GI	120	4.96	0.63	0.006
P-57	219	J-25	J-28	100	GI	120	4.96	0.63	0.006
P-67	135	J-18	J-21	100	GI	120	5.14	0.65	0.006
P-85	294	J-70	J-87	75	GI	120	3.02	0.68	0.01
P-105	425	J-27	J-23	50	GI	120	1.36	0.69	0.016
P-104	268	J-49	J-27	50	GI	120	1.36	0.69	0.016
P-61	282	J-15	Existing Water Point	38	GI	120	0.8	0.71	0.023
P-63	300	J-18	Existing Water Point	38	GI	120	0.8	0.71	0.023
P-88	77	J-102	Existing Water Point	38	GI	120	0.8	0.71	0.023
P-119	207	J-32	J-56	25	GI	120	0.36	0.74	0.04
P-84	227	J-69	J-70	75	GI	120	3.32	0.75	0.012
P-83	285	J-24	J-69	75	GI	120	3.32	0.75	0.012
P-62	281	J-14	J-18	100	GI	120	5.94	0.76	0.008
P-37	405	J-53	J-76	38	GI	120	0.88	0.77	0.027

P-35	187	J-43	J-49	63	GI	120	2.59	0.83	0.017
P-34	166	J-63	J-43	63	GI	120	2.59	0.83	0.017
P-65	77	J-5	J-21	75	GI	120	-3.94	0.89	0.016
P-24	485	J-98	J-3	25	GI	120	0.45	0.92	0.061
P-58	51	J-11	J-14	100	GI	120	7.54	0.96	0.013
P-102	96	J-31	J-11	100	GI	120	8.04	1.02	0.015
P-101	160	Existing100 m3 R	J-31	100	GI	120	9.29	1.18	0.019
P-93	83	Existing BH-3 (Remeda)	PMP-14	75	GI	120	7.98	1.81	0.059
P-94	418	PMP-14	Existing100 m3 R	75	GI	120	7.98	1.81	0.059
P-83	1,693	J-28	Existing100 m3 R	100	GI	120	14.86	1.89	0.046
P-91	115	R-22	PMP-13	100	GI	120	14.86	1.89	0.046
P-92	712	PMP-13	J-28	100	GI	120	14.86	1.89	0.046
P-105	48	Existing BH	PMP-16	75	GI	120	8.81	1.99	0.071
P-106	1,584	PMP-16	Existing100 m3 R	75	GI	120	8.81	1.99	0.071

Appendix C

Newly Proposed System Pressure (Junction) result; for peak demand time (7:00)

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-212	437,258	761,219	1,892	0	1,896.86	4.4
J-1	440,191	761,361	1,927	0	1,931.55	5
J-50	440,075	761,121	1,925	0	1,930.41	5.9
J-14	439,930	761,002	1,921	0	1,929.70	9
J-93	436,843	760,535	1,878	0	1,892.08	14.2
J-102	437,067	760,178	1,873	1.8	1,887.81	14.3
J-94	439,777	761,351	1,912	1.8	1,928.06	16.2
J-71	439,751	760,287	1,908	1.8	1,924.13	16.6
J-51	439,586	760,614	1,910	0	1,927.75	17.4
J-11	434,494	759,911	1,851	0	1,872.55	22
J-22	439,333	760,816	1,903	0	1,925.05	22.5
J-21	439,416	760,758	1,902	1.8	1,925.52	23.1
J-58	435,077	759,613	1,847	0.9	1,871.14	23.6
J-107	436,250	761,488	1,863	0	1,887.64	24.3
J-90	435,391	760,128	1,862	0	1,886.34	24.8
J-59	435,180	759,781	1,853	0	1,877.99	25.4
J-26	439,458	760,471	1,901	0	1,927.11	26.2
J-64	435,291	759,604	1,846	0.9	1,873.07	26.7
J-84	436,649	760,217	1,863	0	1,890.45	27
J-12	434,569	759,869	1,845	0.9	1,872.04	27.2
J-38	434,987	760,342	1,854	0	1,881.11	27.3
J-72	439,625	760,098	1,895	1.8	1,922.52	27.6
J-99	435,800	761,077	1,855	8.1	1,882.61	27.7
J-31	434,897	759,870	1,846	5.4	1,874.10	28.1
J-24	439,390	760,382	1,898	0	1,926.77	28.3
J-39	435,114	760,273	1,851	0.9	1,879.93	28.4
J-25	439,319	760,296	1,897	0	1,925.53	28.9
J-79	439,006	759,344	1,883	0.9	1,912.01	29
J-92	439,428	759,771	1,887	1.44	1,916.72	29.8
J-30	434,777	759,848	1,839	2.7	1,870.14	30.8
J-77	434,694	759,623	1,837	9	1,868.62	31.2
J-5	435,494	760,810	1,851	0	1,882.24	31.7
J-40	439,129	760,948	1,892	1.8	1,923.93	31.7
J-75	438,709	759,244	1,880	0	1,911.87	32
J-28	439,168	760,137	1,891	0	1,923.70	32.3

Newly Proposed System Pressure (Junction) result; for peak demand time (7:00)

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-69	439,147	760,530	1,891	0	1,924.97	33.7
J-29	439,083	760,060	1,889	0	1,922.86	34
J-81	435,702	760,643	1,853	1.8	1,887.42	34.1
J-91	434,315	759,633	1,836	0	1,870.32	34.5
J-37	438,886	761,112	1,886	0	1,921.42	34.9
J-65	438,982	760,256	1,887	0	1,922.29	35.7
J-3	438,288	758,501	1,863	5.4	1,899.60	36.2
J-78	439,209	759,490	1,876	5.4	1,912.01	36.4
J-70	438,959	760,655	1,888	1.8	1,924.14	36.5
J-4	438,277	758,473	1,862	0	1,899.37	37
J-47	438,622	760,106	1,880	5.4	1,917.72	37.2
J-73	438,789	760,377	1,884	0.9	1,920.82	37.2
J-66	438,884	759,079	1,874	3.6	1,910.99	37.4
J-48	438,940	759,898	1,884	0	1,921.38	37.5
J-23	438,163	759,346	1,866	0	1,903.38	37.8
J-49	438,520	759,941	1,879	0	1,917.46	37.9
J-46	438,770	760,009	1,880	5.4	1,919.25	38.9
J-83	436,375	760,279	1,850	0	1,889.36	39.4
J-36	439,000	761,033	1,884	0	1,923.04	39.5
J-63	438,821	759,756	1,881	0	1,920.44	39.9
J-2	438,809	759,747	1,880	0	1,920.37	39.9
J-43	438,680	759,844	1,879	0	1,919.04	40.4
J-53	438,291	760,084	1,871	0	1,911.60	40.8
J-60	438,495	759,369	1,872	0	1,912.71	41
J-61	438,151	759,855	1,866	0	1,906.59	41
J-67	436,100	759,763	1,843	2.16	1,883.93	41.2
J-9	438,381	759,203	1,868	0	1,909.85	41.8
J-10	438,344	759,132	1,867	0	1,908.70	41.9
J-97	438,205	760,716	1,864	2.7	1,906.25	41.9
J-68	435,992	759,566	1,839	0	1,881.38	42
J-95	438,574	761,323	1,874	0	1,917.02	42.9
J-52	438,394	760,249	1,873	0	1,916.37	43
J-27	438,383	759,710	1,875	0	1,918.65	43.7
J-34	437,927	759,484	1,858	5.4	1,901.53	43.8
J-105	438,172	757,885	1,854	0	1,897.69	43.9

Newly Proposed System Pressure (Junction) result; for peak demand time (7:00)

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-104	437,274	759,657	1,838	0	1,882.34	43.9
J-20	438,638	759,560	1,875	0	1,919.55	44.2
J-74	438,040	759,145	1,858	0	1,902.99	44.5
J-3	435,758	759,137	1,835	0	1,880.48	45.4
J-85	438,554	760,532	1,873	1.8	1,918.59	46
J-106	437,047	759,270	1,833	5.4	1,879.21	46.1
J-87	438,725	760,832	1,874	5.4	1,920.82	46.4
J-32	437,860	759,374	1,855	0	1,901.29	46.6
J-82	437,884	758,882	1,853	0	1,900.27	46.7
J-45	437,508	758,840	1,851	0	1,897.34	46.7
J-33	437,795	759,268	1,854	1.8	1,901.30	47.5
J-44	437,620	758,976	1,851	0	1,899.71	48.2
J-54	437,968	759,951	1,854	0	1,902.41	48.6
J-88	437,495	758,236	1,842	6.3	1,895.57	53.8
J-3	437,010	758,744	1,840	5.4	1,895.57	55.2
J-76	437,921	760,245	1,850	1.8	1,906.54	56.2
J-56	437,676	759,468	1,844	1.44	1,900.82	56.9
J-55	437,796	760,041	1,845	0	1,903.40	57.9
J-57	437,502	759,559	1,841	1.8	1,900.25	59.2
J-98	437,261	759,159	1,839	0.9	1,897.86	59.2
J-80	437,564	760,158	1,842	0	1,904.05	62.1

Appendix D

Newly Proposed System Pressure (Junction) result; for Low Consumption time night flow

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	440,191	761,361	1,927	0	1,931.82	5.3
J-212	437,258	761,219	1,892	0	1,898.05	5.6
J-50	440,075	761,121	1,925	0	1,931.01	6.5
J-14	439,930	761,002	1,921	0	1,930.50	9.8
J-93	436,843	760,535	1,878	0	1,894.64	16.8
J-94	439,777	761,351	1,912	1.5	1,929.33	17.4
J-102	437,067	760,178	1,873	1.5	1,891.59	18.1
J-51	439,586	760,614	1,910	0	1,929.11	18.8
J-71	439,751	760,287	1,908	1.5	1,926.53	19
J-22	439,333	760,816	1,903	0	1,927.19	24.6
J-21	439,416	760,758	1,902	1.5	1,927.52	25.1
J-26	439,458	760,471	1,901	0	1,928.66	27.7
J-107	436,250	761,488	1,863	0	1,891.47	28.1
J-90	435,391	760,128	1,862	0	1,890.54	29
J-24	439,390	760,382	1,898	0	1,928.41	29.9
J-84	436,649	760,217	1,863	0	1,893.48	30
J-11	434,494	759,911	1,851	0	1,880.70	30.1
J-72	439,625	760,098	1,895	1.5	1,925.38	30.5
J-25	439,319	760,296	1,897	0	1,927.53	30.9
J-59	435,180	759,781	1,853	0	1,884.58	32
J-58	435,077	759,613	1,847	0.75	1,879.70	32.2
J-99	435,800	761,077	1,855	6.75	1,887.88	32.9
J-38	434,987	760,342	1,854	0	1,886.81	33
J-40	439,129	760,948	1,892	1.5	1,926.39	34.2
J-92	439,428	759,771	1,887	1.2	1,921.24	34.3
J-39	435,114	760,273	1,851	0.75	1,885.97	34.4
J-64	435,291	759,604	1,846	0.75	1,881.07	34.7
J-28	439,168	760,137	1,891	0	1,926.22	34.8
J-79	439,006	759,344	1,883	0.75	1,917.89	34.9
J-12	434,569	759,869	1,845	0.75	1,880.34	35.4
J-31	434,897	759,870	1,846	4.5	1,881.81	35.8
J-69	439,147	760,530	1,891	0	1,927.13	35.9
J-29	439,083	760,060	1,889	0	1,925.62	36.7
J-5	435,494	760,810	1,851	0	1,887.61	37
J-75	438,709	759,244	1,880	0	1,917.78	37.9

Newly Proposed System Pressure (Junction) result; for Low Consumption time night flow

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-81	435,702	760,643	1,853	1.5	1,891.31	38
J-37	438,886	761,112	1,886	0	1,924.59	38.1
J-65	438,982	760,256	1,887	0	1,925.22	38.6
J-70	438,959	760,655	1,888	1.5	1,926.54	38.9
J-30	434,777	759,848	1,839	2.25	1,878.98	39.6
J-77	434,694	759,623	1,837	7.5	1,877.90	40.5
J-73	438,789	760,377	1,884	0.75	1,924.17	40.6
J-48	438,940	759,898	1,884	0	1,924.56	40.7
J-47	438,622	760,106	1,880	4.5	1,921.96	41.4
J-36	439,000	761,033	1,884	0	1,925.75	42.2
J-49	438,520	759,941	1,879	0	1,921.77	42.2
J-78	439,209	759,490	1,876	4.5	1,917.89	42.3
J-46	438,770	760,009	1,880	4.5	1,923.05	42.7
J-83	436,375	760,279	1,850	0	1,892.70	42.7
J-63	438,821	759,756	1,881	0	1,923.89	43.3
J-91	434,315	759,633	1,836	0	1,879.12	43.3
J-2	438,809	759,747	1,880	0	1,923.85	43.4
J-66	438,884	759,079	1,874	3	1,917.15	43.6
J-43	438,680	759,844	1,879	0	1,922.89	44.3
J-3	438,288	758,501	1,863	4.5	1,909.03	45.6
J-67	436,100	759,763	1,843	1.8	1,888.82	46.1
J-23	438,163	759,346	1,866	0	1,911.72	46.1
J-4	438,277	758,473	1,862	0	1,908.87	46.5
J-60	438,495	759,369	1,872	0	1,918.38	46.6
J-53	438,291	760,084	1,871	0	1,917.59	46.8
J-95	438,574	761,323	1,874	0	1,921.45	47.4
J-52	438,394	760,249	1,873	0	1,920.99	47.6
J-68	435,992	759,566	1,839	0	1,887.00	47.6
J-27	438,383	759,710	1,875	0	1,922.62	47.7
J-20	438,638	759,560	1,875	0	1,923.26	47.9
J-9	438,381	759,203	1,868	0	1,916.34	48.2
J-61	438,151	759,855	1,866	0	1,914.01	48.4
J-10	438,344	759,132	1,867	0	1,915.52	48.7
J-104	437,274	759,657	1,838	0	1,887.68	49.3
J-97	438,205	760,716	1,864	2.25	1,913.78	49.4

Newly Proposed System Pressure (Junction) result; for Low Consumption time night flow

Label	X (m)	Y (m)	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-87	438,725	760,832	1,874	4.5	1,924.17	49.8
J-85	438,554	760,532	1,873	1.5	1,922.57	50
J-3	435,758	759,137	1,835	0	1,886.36	51.3
J-106	437,047	759,270	1,833	4.5	1,885.46	52.4
J-34	437,927	759,484	1,858	4.5	1,910.41	52.7
J-74	438,040	759,145	1,858	0	1,911.45	52.9
J-105	438,172	757,885	1,854	0	1,907.67	53.8
J-32	437,860	759,374	1,855	0	1,910.23	55.5
J-82	437,884	758,882	1,853	0	1,909.51	55.9
J-33	437,795	759,268	1,854	1.5	1,910.24	56.4
J-45	437,508	758,840	1,851	0	1,907.41	56.8
J-54	437,968	759,951	1,854	0	1,911.03	57.2
J-44	437,620	758,976	1,851	0	1,909.11	57.6
J-76	437,921	760,245	1,850	1.5	1,913.98	63.6
J-88	437,495	758,236	1,842	5.25	1,906.15	64.4
J-3	437,010	758,744	1,840	4.5	1,906.15	65.8
J-56	437,676	759,468	1,844	1.2	1,909.90	65.9
J-55	437,796	760,041	1,845	0	1,911.74	66.3
J-57	437,502	759,559	1,841	1.5	1,909.49	68.5
J-98	437,261	759,159	1,839	0.75	1,907.79	69.1
J-80	437,564	760,158	1,842	0	1,912.20	70.2

Appendix E

Newly Proposed System Pipe Result; for peak demand time (7:00)

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-10	695	J-21	J-94	50	HDPE	130	-0.41	0.32	0.004
P-91	194	J-47	J-49	75	HDPE	130	0.98	0.34	0.003
P-96	325	J-85	J-52	63	HDPE	130	0.7	0.34	0.004
P-23	489	J-68	J-3	50	HDPE	130	0.46	0.35	0.005
P-19	281	J-82	J-44	63	HDPE	130	0.73	0.36	0.004
P-8	305	J-79	J-66	50	HDPE	130	-0.46	0.36	0.005
P-24	1,840	J-3	J-106	50	HDPE	130	0.46	0.36	0.005
P-115	124	J-32	J-33	63	HDPE	130	-0.8	0.39	0.005
P-11	339	J-70	J-40	92	HDPE	130	1.67	0.4	0.003
P-94	323	J-37	J-87	75	HDPE	130	1.16	0.4	0.004
P-23	842	J-45	J-88	50	HDPE	130	0.54	0.42	0.007
P-95	346	J-87	J-85	63	HDPE	130	0.88	0.43	0.006
P-26	30	J-3	J-4	75	HDPE	130	1.34	0.45	0.005
P-16	763	J-88	J-105	75	HDPE	130	-1.34	0.46	0.005
P-335	604	J-4	J-105	75	HDPE	130	1.34	0.46	0.005
P-69	254	J-78	J-79	63	HDPE	130	-0.96	0.47	0.007
P-33	532	J-76	J-80	63	HDPE	130	0.96	0.47	0.007
P-121	810	J-80	J-57	63	HDPE	130	0.96	0.47	0.007
P-21	564	J-54	J-56	75	HDPE	130	1.38	0.47	0.005
P-39	550	J-97	J-76	63	HDPE	130	-0.97	0.47	0.007
P-48	1,227	J-36	J-94	75	HDPE	130	-1.46	0.5	0.006
P-46	1,856	J-97	J-95	50	HDPE	130	-0.65	0.5	0.01
P-49	939	J-94	J-1	75	HDPE	130	-1.49	0.51	0.006
P-41	107	J-21	J-22	75	HDPE	130	1.56	0.53	0.007
P-42	237	J-22	J-40	75	HDPE	130	1.56	0.54	0.007
P-8	26	Existing BH - 2 (Taramisa)	PMP-2	100	GI	120	4.25	0.54	0.005
P-21	1,046	J-71	J-14	63	HDPE	130	-1.15	0.56	0.009
P-346	780	J-81	J-83	200	DCI	120	-17.68	0.56	0.002
P-17	274	J-34	J-23	50	HDPE	130	-0.73	0.57	0.012
P-123	564	J-55	J-57	75	HDPE	130	1.68	0.58	0.008
P-104	268	J-49	J-27	75	HDPE	130	-1.69	0.58	0.008
P-25	1,276	J-23	J-3	50	HDPE	130	0.75	0.58	0.013
P-9	5,854	PMP-2	500 m3 R For Phase- II	95	GI	120	4.25	0.6	0.006

Newly Proposed System Pipe Result; for peak demand time (7:00)

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-52	2,324	PMP- 4	500 m3 R For Phase- II	175	Ductile Iron	130	14.78	0.61	0.003
P-334	449	J-104	J-106	90	HDPE	130	4.03	0.63	0.006
P-114	130	J-34	J-32	75	HDPE	130	1.86	0.64	0.009
P-356	602	J-90	J-81	160	HDPE	130	-8.8	0.66	0.004
P-25	532	J-3	J-45	75	HDPE	130	-1.96	0.67	0.01
P-12	270	J-47	J-52	90	HDPE	130	2.92	0.7	0.009
P-22	403	J-44	J-98	50	HDPE	130	0.89	0.7	0.018
P-43	154	J-40	J-36	63	HDPE	130	1.43	0.7	0.014
P-344	406	J-99	J-5	90	HDPE	130	2.95	0.7	0.009
P-132	1,068	J-67	J-106	50	HDPE	130	0.91	0.71	0.019
P-66	228	J-71	J-72	75	HDPE	130	2.12	0.73	0.012
P-347	282	J-83	J-84	200	DCI	120	-23.08	0.73	0.004
P-87	228	J-65	J-73	75	HDPE	130	2.15	0.74	0.012
P-47	376	J-50	J-94	75	HDPE	130	2.18	0.75	0.013
P-32	214	J-58	J-64	50	HDPE	130	-0.97	0.75	0.021
P-21	690	J-5	J-38	160	HDPE	130	10.03	0.76	0.005
P-80	320	J-69	J-65	90	HDPE	130	3.24	0.77	0.011
P-86	220	J-28	J-65	75	HDPE	130	2.29	0.78	0.014
P-106	236	J-23	J-74	160	HDPE	130	10.42	0.79	0.006
P-88	281	J-73	J-85	63	HDPE	130	1.62	0.79	0.017
P-90	319	J-73	J-47	90	HDPE	130	3.33	0.79	0.011
P-62	253	J-2	J-20	200	DCI	130	25.03	0.8	0.004
P-341	372	J-93	J-84	200	DCI	120	25.11	0.8	0.004
P-81	364	J-65	J-46	90	HDPE	130	3.38	0.8	0.012
P-51	41	New BH-4	PMP- 4	175	Ductile Iron	130	14.78	0.81	0.005
P-24	485	J-98	J-3	90	HDPE	130	3.44	0.82	0.012
P-124	467	J-57	J-98	90	HDPE	130	3.45	0.82	0.012
P-122	240	J-76	J-55	63	HDPE	130	1.68	0.82	0.019
P-18	274	J-33	J-74	90	HDPE	130	-5.27	0.83	0.01
P-61	15	J-63	J-2	200	DCI	120	26.46	0.84	0.005
P-38	710	J-95	J-97	50	HDPE	130	1.09	0.85	0.026
P-130	586	J-83	J-67	90	HDPE	130	5.39	0.85	0.01
P-45	377	J-37	J-95	63	HDPE	130	1.73	0.85	0.02

Newly Proposed System Pipe Result; for peak demand time (7:00)

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-404	610	J-107	J-99	90	HDPE	130	5.43	0.85	0.01
P-403	1,119	J-212	J-107	90	HDPE	130	5.43	0.85	0.01
P-54	4,390	PMP-5 (PZ-I)	500 m3 R For Phase- II	175	Ductile Iron	130	20.6	0.86	0.005
P-355	380	J-91	J-77	75	HDPE	130	2.51	0.86	0.017
P-353	502	J-11	J-91	75	HDPE	130	2.51	0.86	0.017
P-150	383	J-77	J-58	90	HDPE	130	-3.68	0.88	0.014
P-89	326	J-70	J-73	90	HDPE	130	3.7	0.88	0.014
P-330	1,175	J-93	J-99	90	HDPE	130	5.63	0.88	0.011
P-120	196	J-56	J-57	75	HDPE	130	2.6	0.89	0.018
P-55	112	J-26	J-24	300	DCI	120	63.43	0.9	0.003
P-328	1,210	J-212	J-102	90	HDPE	130	3.79	0.9	0.015
P-350	145	J-38	J-39	75	HDPE	130	2.64	0.91	0.018
P-31	925	J-68	J-64	63	HDPE	130	1.87	0.91	0.023
P-116	341	J-33	J-44	75	HDPE	130	2.66	0.91	0.018
P-119	207	J-32	J-56	75	HDPE	130	2.66	0.91	0.018
P-84	227	J-69	J-70	160	HDPE	130	12.29	0.93	0.008
P-54	194	J-51	J-26	300	DCI	120	66.21	0.94	0.003
P-93	177	J-46	J-47	90	HDPE	130	5.98	0.94	0.012
P-3	347	J-26	J-71	75	HDPE	130	2.78	0.95	0.02
P-333	787	J-102	J-104	90	HDPE	130	4.03	0.96	0.016
P-331	240	J-30	J-77	75	HDPE	130	2.81	0.96	0.02
P-74	250	J-60	J-75	90	HDPE	130	4.06	0.97	0.017
P-75	263	J-75	J-66	90	HDPE	130	4.06	0.97	0.017
P-340	800	J-212	J-93	200	DCI	120	30.74	0.98	0.006
P-52	533	J-14	J-51	300	DCI	120	69.17	0.98	0.004
P-4	450	J-29	J-92	50	HDPE	130	1.26	0.98	0.034
P-6	364	J-25	J-72	75	HDPE	130	2.88	0.99	0.021
P-44	138	J-36	J-37	75	HDPE	130	2.89	0.99	0.021
P-51	189	J-50	J-14	300	DCI	120	70.31	0.99	0.004
P-342	423	J-84	J-102	63	HDPE	130	2.04	1	0.027
P-40	223	J-51	J-21	75	HDPE	130	2.95	1.01	0.022
P-26	296	J-20	J-27	160	HDPE	130	13.58	1.02	0.009
P-50	279	J-1	J-50	300	DCI	120	72.49	1.03	0.004

Newly Proposed System Pipe Result; for peak demand time (7:00)

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-113	433	J-61	J-34	90	HDPE	130	6.53	1.03	0.014
P-68	357	J-92	J-78	75	HDPE	130	3.02	1.04	0.023
P-53	223	500 m3 R For Phase- II	J-1	300	DCI	120	73.98	1.05	0.004
P-108	754	J-82	J-88	90	HDPE	130	4.42	1.05	0.019
P-60	186	J-48	J-63	200	DCI	130	33.49	1.07	0.006
P-110	206	J-61	J-54	50	HDPE	130	1.38	1.07	0.04
P-5	432	J-20	J-79	50	HDPE	130	1.4	1.09	0.041
P-67	421	J-72	J-92	75	HDPE	130	3.2	1.1	0.026
P-35	187	J-43	J-49	90	HDPE	130	7.04	1.11	0.017
P-34	166	J-63	J-43	90	HDPE	130	7.04	1.11	0.017
P-70	476	J-2	J-78	50	HDPE	130	1.43	1.11	0.043
P-53	70	New BH-5	PMP-5 (PZ-I)	175	Ductile Iron	130	20.6	1.13	0.009
P-131	224	J-67	J-68	63	HDPE	130	2.33	1.14	0.034
P-338	466	J-39	J-31	75	HDPE	130	3.33	1.14	0.028
P-354	70	J-11	J-12	90	HDPE	130	4.88	1.15	0.022
P-22	649	J-38	J-11	90	HDPE	130	7.39	1.16	0.018
P-83	285	J-24	J-69	160	HDPE	130	15.53	1.17	0.012
P-358	122	J-30	J-31	50	HDPE	130	-1.53	1.19	0.049
P-13	2,958	PMP-3	150 m3 R For Phase- II	100	GI	120	9.38	1.19	0.02
P-30	35	BH-3	PMP-3	100	GI	120	9.38	1.19	0.02
P-35	17	BH-4	PMP-4	100	GI	120	9.45	1.2	0.02
P-36	4,300	PMP-4	150 m3 R For Phase- II	100	GI	120	9.45	1.2	0.02
P-85	294	J-70	J-87	90	HDPE	130	5.12	1.22	0.025
P-117	197	J-44	J-45	63	HDPE	130	2.5	1.22	0.039
P-107	305	J-74	J-82	90	HDPE	130	5.15	1.23	0.026
P-359	312	J-39	J-90	50	HDPE	130	-1.58	1.23	0.052
P-156	300	J-31	J-59	75	HDPE	130	-3.6	1.24	0.032
P-97	194	J-52	J-53	75	HDPE	130	3.61	1.24	0.032
P-6	6	Existing BH - 1(Taramisa)	PMP-1	100	GI	120	9.75	1.24	0.021
P-7	3,645	PMP-1	500 m3 R For Phase- II	100	GI	120	9.75	1.24	0.021
P-112	269	J-53	J-61	90	HDPE	130	7.91	1.24	0.021
P-92	203	J-48	J-46	90	HDPE	130	8	1.26	0.021
P-339	421	150 m3 R For Phase- II	J-212	200	DCI	120	39.96	1.27	0.01

Newly Proposed System Pipe Result; for peak demand time (7:00)

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-37	405	J-53	J-76	90	HDPE	130	5.41	1.29	0.028
P-59	216	J-29	J-48	200	DCI	130	41.49	1.32	0.009
P-58	115	J-28	J-29	200	DCI	130	42.74	1.36	0.01
P-357	211	J-12	J-30	75	HDPE	130	3.98	1.37	0.039
P-65	71	J-9	J-10	90	HDPE	130	5.99	1.41	0.033
P-27	644	J-3	J-10	90	HDPE	130	-5.99	1.41	0.033
P-64	202	J-60	J-9	90	HDPE	130	5.99	1.43	0.034
P-57	219	J-25	J-28	200	DCI	130	45.03	1.43	0.011
P-56	112	J-24	J-25	200	DCI	120	47.91	1.53	0.014
P-36	270	J-49	J-53	90	HDPE	130	9.71	1.53	0.03
P-63	239	J-20	J-60	90	HDPE	130	10.05	1.58	0.032
P-39	9	Existing BH-3 (Remeda)	PMP-3	75	GI	120	7.07	1.6	0.047
P-40	1,239	PMP-3	500 m3 R For Phase- II	75	GI	120	7.07	1.6	0.047
P-139	267	J-5	J-81	90	HDPE	130	-7.08	1.69	0.046
P-152	406	J-59	J-90	90	HDPE	130	-7.22	1.72	0.048
P-151	198	J-58	J-59	63	HDPE	130	-3.61	1.77	0.077
P-105	425	J-27	J-23	90	HDPE	130	11.89	1.87	0.044

Appendix F

Newly Proposed System Pipe Result; for Low Consumption time night flow

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-10	695	J-21	J-94	50	HDPE	130	-0.34	0.27	0.003
P-91	194	J-47	J-49	75	HDPE	130	0.82	0.28	0.002
P-96	325	J-85	J-52	63	HDPE	130	0.58	0.28	0.003
P-23	489	J-68	J-3	50	HDPE	130	0.38	0.29	0.004
P-19	281	J-82	J-44	63	HDPE	130	0.61	0.3	0.003
P-8	305	J-79	J-66	50	HDPE	130	-0.38	0.3	0.004
P-24	1,840	J-3	J-106	50	HDPE	130	0.38	0.3	0.004
P-115	124	J-32	J-33	63	HDPE	130	-0.67	0.33	0.003
P-11	339	J-70	J-40	90	HDPE	130	1.39	0.33	0.002
P-94	323	J-37	J-87	75	HDPE	130	0.97	0.33	0.003
P-23	842	J-45	J-88	50	HDPE	130	0.45	0.35	0.005
P-95	346	J-87	J-85	63	HDPE	130	0.73	0.36	0.004
P-26	30	J-3	J-4	75	HDPE	130	1.12	0.38	0.004
P-16	763	J-88	J-105	75	HDPE	130	-1.12	0.38	0.004
P-335	604	J-4	J-105	75	HDPE	130	1.12	0.38	0.004
P-69	254	J-78	J-79	63	HDPE	130	-0.8	0.39	0.005
P-33	532	J-76	J-80	63	HDPE	130	0.8	0.39	0.005
P-121	810	J-80	J-57	63	HDPE	130	0.8	0.39	0.005
P-21	564	J-54	J-56	75	HDPE	130	1.15	0.39	0.004
P-39	550	J-97	J-76	63	HDPE	130	-0.81	0.39	0.005
P-48	1,227	J-36	J-94	75	HDPE	130	-1.22	0.42	0.004
P-46	1,856	J-97	J-95	50	HDPE	130	-0.54	0.42	0.007
P-49	939	J-94	J-1	75	HDPE	130	-1.24	0.43	0.004
P-41	107	J-21	J-22	75	HDPE	130	1.3	0.44	0.005
P-42	237	J-22	J-40	75	HDPE	130	1.3	0.45	0.005
P-21	1,046	J-71	J-14	63	HDPE	130	-0.95	0.47	0.007
P-346	780	J-81	J-83	200	DCI	120	-14.74	0.47	0.002
P-17	274	J-34	J-23	50	HDPE	130	-0.61	0.47	0.009
P-123	564	J-55	J-57	75	HDPE	130	1.4	0.48	0.006
P-104	268	J-49	J-27	75	HDPE	130	-1.41	0.48	0.006
P-25	1,276	J-23	J-3	50	HDPE	130	0.62	0.49	0.009
P-334	449	J-104	J-106	90	HDPE	130	3.36	0.53	0.004
P-114	130	J-34	J-32	75	HDPE	130	1.55	0.53	0.007

Newly Proposed System Pipe Result; for Low Consumption time night flow

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-8	26	Existing BH - 2 (Taramisa)	PMP-2	100	GI	120	4.25	0.54	0.005
P-356	602	J-90	J-81	160	HDPE	130	-7.33	0.55	0.003
P-25	532	J-3	J-45	75	HDPE	130	-1.63	0.56	0.007
P-12	270	J-47	J-52	90	HDPE	130	2.43	0.58	0.006
P-22	403	J-44	J-98	50	HDPE	130	0.75	0.58	0.013
P-43	154	J-40	J-36	63	HDPE	130	1.19	0.58	0.010
P-344	406	J-99	J-5	90	HDPE	130	2.46	0.59	0.007
P-132	1,068	J-67	J-106	50	HDPE	130	0.76	0.59	0.013
P-9	5,854	PMP-2	500 m3 R For Phase- II	95	GI	120	4.25	0.6	0.006
P-66	228	J-71	J-72	75	HDPE	130	1.77	0.61	0.009
P-347	282	J-83	J-84	200	DCI	120	-19.23	0.61	0.003
P-87	228	J-65	J-73	75	HDPE	130	1.79	0.61	0.009
P-52	2,324	PMP- 4	500 m3 R For Phase- II	175	Ductile Iron	130	14.78	0.61	0.003
P-47	376	J-50	J-94	75	HDPE	130	1.81	0.62	0.009
P-32	214	J-58	J-64	50	HDPE	130	-0.8	0.63	0.015
P-21	690	J-5	J-38	160	HDPE	130	8.36	0.63	0.004
P-80	320	J-69	J-65	90	HDPE	130	2.7	0.64	0.008
P-86	220	J-28	J-65	75	HDPE	130	1.9	0.65	0.010
P-106	236	J-23	J-74	160	HDPE	130	8.68	0.65	0.004
P-88	281	J-73	J-85	63	HDPE	130	1.35	0.66	0.012
P-90	319	J-73	J-47	90	HDPE	130	2.77	0.66	0.008
P-62	253	J-2	J-20	200	DCI	130	20.86	0.66	0.003
P-341	372	J-93	J-84	200	DCI	120	20.93	0.67	0.003
P-81	364	J-65	J-46	90	HDPE	130	2.82	0.67	0.008
P-24	485	J-98	J-3	90	HDPE	130	2.87	0.68	0.009
P-124	467	J-57	J-98	90	HDPE	130	2.87	0.68	0.009
P-122	240	J-76	J-55	63	HDPE	130	1.4	0.69	0.013
P-18	274	J-33	J-74	90	HDPE	130	-4.39	0.69	0.007
P-61	15	J-63	J-2	200	DCI	120	22.05	0.7	0.003
P-38	710	J-95	J-97	50	HDPE	130	0.91	0.71	0.018
P-130	586	J-83	J-67	90	HDPE	130	4.5	0.71	0.007
P-45	377	J-37	J-95	51	HDPE	130	1.44	0.71	0.014

Newly Proposed System Pipe Result; for Low Consumption time night flow

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-404	610	J-107	J-99	90	HDPE	130	4.52	0.71	0.007
P-403	1,119	J-212	J-107	90	HDPE	130	4.52	0.71	0.007
P-355	380	J-91	J-77	75	HDPE	130	2.1	0.72	0.012
P-353	502	J-11	J-91	75	HDPE	130	2.1	0.72	0.012
P-150	383	J-77	J-58	90	HDPE	130	-3.07	0.73	0.010
P-89	326	J-70	J-73	90	HDPE	130	3.08	0.73	0.010
P-330	1,175	J-93	J-99	90	HDPE	130	4.69	0.74	0.008
P-120	196	J-56	J-57	75	HDPE	130	2.17	0.74	0.013
P-55	112	J-26	J-24	300	DCI	120	52.86	0.75	0.002
P-328	1,210	J-212	J-102	90	HDPE	130	3.16	0.75	0.010
P-350	145	J-38	J-39	75	HDPE	130	2.2	0.76	0.013
P-31	925	J-68	J-64	51	HDPE	130	1.55	0.76	0.016
P-116	341	J-33	J-44	75	HDPE	130	2.22	0.76	0.013
P-119	207	J-32	J-56	75	HDPE	130	2.22	0.76	0.013
P-84	227	J-69	J-70	160	HDPE	130	10.24	0.77	0.006
P-54	194	J-51	J-26	300	DCI	120	55.18	0.78	0.002
P-93	177	J-46	J-47	90	HDPE	130	4.98	0.78	0.009
P-3	347	J-26	J-71	75	HDPE	130	2.31	0.79	0.014
P-333	787	J-102	J-104	90	HDPE	130	3.36	0.8	0.012
P-331	240	J-30	J-77	75	HDPE	130	2.34	0.8	0.014
P-74	250	J-60	J-75	90	HDPE	130	3.38	0.81	0.012
P-75	263	J-75	J-66	90	HDPE	130	3.38	0.81	0.012
P-51	41	New BH-4	PMP- 4	175	Ductile Iron	130	14.78	0.81	0.005
P-340	800	J-212	J-93	200	DCI	120	25.62	0.82	0.004
P-52	533	J-14	J-51	300	DCI	120	57.64	0.82	0.003
P-4	450	J-29	J-92	50	HDPE	130	1.05	0.82	0.024
P-6	364	J-25	J-72	75	HDPE	130	2.4	0.82	0.015
P-44	138	J-36	J-37	75	HDPE	130	2.41	0.83	0.015
P-51	189	J-50	J-14	300	DCI	120	58.59	0.83	0.003
P-342	423	J-84	J-102	63	HDPE	130	1.7	0.83	0.019
P-40	223	J-51	J-21	75	HDPE	130	2.46	0.85	0.016
P-26	296	J-20	J-27	160	HDPE	130	11.32	0.85	0.007
P-50	279	J-1	J-50	300	DCI	120	60.41	0.85	0.003
P-113	433	J-61	J-34	90	HDPE	130	5.44	0.86	0.010

Newly Proposed System Pipe Result; for Low Consumption time night flow

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-54	4,390	PMP-5 (PZ-I)	500 m3 R For Phase- II	175	Ductile Iron	130	20.6	0.86	0.005
P-68	357	J-92	J-78	75	HDPE	130	2.51	0.86	0.017
P-53	223	500 m3 R For Phase- II	J-1	300	DCI	120	61.65	0.87	0.003
P-108	754	J-82	J-88	90	HDPE	130	3.69	0.88	0.014
P-60	186	J-48	J-63	200	DCI	130	27.91	0.89	0.004
P-110	206	J-61	J-54	50	HDPE	130	1.15	0.89	0.029
P-5	432	J-20	J-79	50	HDPE	130	1.16	0.91	0.029
P-67	421	J-72	J-92	75	HDPE	130	2.67	0.92	0.018
P-35	187	J-43	J-49	90	HDPE	130	5.86	0.92	0.012
P-34	166	J-63	J-43	90	HDPE	130	5.86	0.92	0.012
P-70	476	J-2	J-78	50	HDPE	130	1.19	0.93	0.030
P-131	224	J-67	J-68	63	HDPE	130	1.94	0.95	0.024
P-338	466	J-39	J-31	75	HDPE	130	2.77	0.95	0.020
P-354	70	J-11	J-12	90	HDPE	130	4.06	0.96	0.016
P-22	649	J-38	J-11	90	HDPE	130	6.16	0.97	0.013
P-83	285	J-24	J-69	160	HDPE	130	12.94	0.98	0.009
P-358	122	J-30	J-31	50	HDPE	130	-1.27	0.99	0.035
P-85	294	J-70	J-87	90	HDPE	130	4.27	1.02	0.018
P-117	197	J-44	J-45	63	HDPE	130	2.08	1.02	0.028
P-107	305	J-74	J-82	90	HDPE	130	4.29	1.02	0.018
P-359	312	J-39	J-90	50	HDPE	130	-1.32	1.03	0.037
P-156	300	J-31	J-59	75	HDPE	130	-3	1.03	0.023
P-97	194	J-52	J-53	75	HDPE	130	3.01	1.03	0.023
P-112	269	J-53	J-61	90	HDPE	130	6.59	1.04	0.015
P-92	203	J-48	J-46	90	HDPE	130	6.66	1.05	0.015
P-339	421	150 m3 R For Phase- II	J-212	200	DCI	120	33.3	1.06	0.007
P-37	405	J-53	J-76	90	HDPE	130	4.51	1.07	0.020
P-59	216	J-29	J-48	200	DCI	130	34.57	1.1	0.006
P-53	70	New BH-5	PMP-5 (PZ-I)	175	Ductile Iron	130	20.6	1.13	0.009
P-58	115	J-28	J-29	200	DCI	130	35.62	1.13	0.007
P-357	211	J-12	J-30	75	HDPE	130	3.31	1.14	0.028
P-65	71	J-9	J-10	90	HDPE	130	4.99	1.17	0.023
P-27	644	J-3	J-10	90	HDPE	130	-4.99	1.17	0.023

Newly Proposed System Pipe Result; for Low Consumption time night flow

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (l/s)	Velocity (m/s)	Head Gradient (mm)
P-64	202	J-60	J-9	90	HDPE	130	4.99	1.19	0.024
P-13	2,958	PMP-3	150 m3 R For Phase- II	100	GI	120	9.38	1.19	0.020
P-30	35	BH-3	PMP-3	100	GI	120	9.38	1.19	0.020
P-57	219	J-25	J-28	200	DCI	130	37.52	1.19	0.008
P-35	17	BH-4	PMP-4	100	GI	120	9.45	1.2	0.020
P-36	4,300	PMP-4	150 m3 R For Phase- II	100	GI	120	9.45	1.2	0.020
P-6	6	Existing BH 1(Taramisa)	PMP-1	100	GI	120	9.75	1.24	0.021
P-7	3,645	PMP-1	500 m3 R For Phase- II	100	GI	120	9.75	1.24	0.021
P-56	112	J-24	J-25	200	DCI	120	39.92	1.27	0.010
P-36	270	J-49	J-53	90	HDPE	130	8.09	1.27	0.021
P-63	239	J-20	J-60	90	HDPE	130	8.38	1.32	0.023
P-139	267	J-5	J-81	90	HDPE	130	-5.9	1.41	0.033
P-152	406	J-59	J-90	90	HDPE	130	-6.01	1.43	0.034
P-151	198	J-58	J-59	63	HDPE	130	-3.01	1.47	0.055
P-105	425	J-27	J-23	90	HDPE	130	9.91	1.56	0.031
P-39	9	Existing BH-3 (Remeda)	PMP-3	75	GI	120	7.07	1.6	0.047
P-40	1,239	PMP-3	500 m3 R For Phase- II	75	GI	120	7.07	1.6	0.047

Annex

Table 1: Existing distribution lines in Leku Town

No	Pipe Size (mm)	Length (GI) (m)	Length (All Material) (m)	Percentage (%)
1	**25**	1,291	**1,291**	**4**
2	**38**	5,419	**5,419**	**17**
2	**50**	6,710	**6,710**	**21**
3	**63**	3,076	**3,076**	**10**
4	**75**	4,847	**4,847**	**15**
5	**100**	9,692	**9,692**	**30**
6	**150**	777	**777**	**2**
	Total	**31,811**	**31,811**	**100**

Source:-Leku Town Water Supply Office

Table 2: Per capita domestic water demand by category of service

No	Connection Type	Stage 1	Stage 2
1	House Connection	50 l/c/day	70 l/c/day
2	Yard Connection	25 l/c/day	30 l/c/day
3	Yard Connection shared	30 l/c/day	40 l/c/day
4	Public Tape User (Rural)	20 l/c/day	25 l/c/day

Source:- Design Criteria Guide line of MoWR (2006)

N.B:- The design horizon is divided into two stages, Stage I is the first 10 years of first design horizon and Stage II is the second 10 years of design horizon(MoWE, 2006).

GTP-2 Goals

Providing Urban safe water supply access with GTP-2 minimum service level about 50 l/c/day for category 4 with in distance of 0.5 km for urban population.

This means the towns/cities were classified with category based on the population.

Table 3: Minimum water supply service level standard

No	Category of towns/cities	Population in towns/cities	Minimum safe water supply l/c/day	Remark
1.	**Category -1**	More than 1 million	100	
2.	**Category -2**	100,000 to 1 million	80	
3.	**Category -3**	50,000 to 100,000	60	
4.	**Category -4**	20,000 to 50,000	50	
5.	**Category -5**	Less than 20,000	40	

Table 4: Sex of Sampled Respondent

Sex	Frequency	Percent%
Female	20	29.4
Male	48	70.6
Total	**68**	**100**

Source: Household Survey (own survey)

Table 5: Age Distribution of Respondent

Age Distribution of Respondent	Frequency	Percent%
20 to 29 years	2	2.9
30 to 39 years	10	14.7
40 to 50 years	40	58.8
50 years and above	16	23.5
Total	**68**	**100**

Source: Household Survey (own survey)

Table 6: Marital Status of Respondent

Marital Status of Respondent	Frequency	Percent %
Single	2	2.9
Marred	62	91.2
Divorced	1	1.5
Widow	3	4.4
Total	**68**	**100**

Source: Household Survey (own survey)

Table 7: Response on Availability of Pipe Water

Response on Availability of Pipe Water	Frequency	Percent%
Irregular Water supply	54	79.4
Water is not always available	11	16.2
Water is rarely available	3	4.4
Total	**68**	**100**

Source: Household Survey (own survey)

Table 8: Main Reason for Unavailability of Pipe Water

Main Reason for Unavailability of Pipe Water	Frequency	Percent %
Electric power problem	5	7.4
1 and 5	22	32.4
2 and 5	41	60.3
Total	**68**	**100**

Source: Household Survey (own survey)

NB: 1) Water is not available from the source, 2) Distribution system problem, 5) Electric power problem

Table 9: Response on Water Supply Pressure Situation in Leku Town

Response on Water Supply Pressure Situation	Frequency	Percent %
Good	13	19.1
Poor	55	80.9
Total	**68**	**100**

Source: Household Survey (own survey)

Table 10: Response on Water Leakage of HC

Response on Water Leakage of HC	Frequency	Percent %
Yes	39	57.4
No	29	42.6
Total	**68**	**100**

Source: Household Survey (own survey)

Table 11: Response on Aspect of Improvement on Water Supply System

Response on Aspect of Improvement on Water Supply System	Frequency	Percent %
Pressure	56	82.4
Quality	2	2.9
Service quality	6	8.8
Maintenance	4	5.9
Total	**68**	**100**

Source: Household Survey (own survey)

Table 12: Response on Water Meter Reading Frequency

Response on Water Meter Reading Frequency	Frequency	Percent %
Once a month	67	98.5
Twice a month	1	1.5
Total	**68**	**100**

Source: Household Survey (own survey)

Table 13: Response on Fairness of Water Tariff

Response on Fairness of Water Tariff	Frequency	Percent %
Yes	54	79.4
No	14	20.6
Total	**68**	**100**

Source: Household Survey (own survey)

Table 14: Response on Pipe Water Quality

Response on Pipe Water Quality	Frequency	Percent %
Very good	17	25
Good	51	75
Total	**68**	**100**

Source: Household Survey (own survey)

Table 15: Response on Pipe Water Color

Response on Pipe Water Color	Frequency	Percent %
Very good	16	23.5
Good	36	52.9
Poor	16	23.5
Total	**68**	**100**

Source: Household Survey

Table 16: Response on Pipe Water Taste

Response on Pipe Water Taste	Frequency	Percent %
Very good	21	30.9
Good	47	69.1
Total	**68**	**100**

Source: Household Survey (own survey)

Table 17: Adjustment of climatic factor

Mean annual Temp.(°C)	Description	Altitude	Factor
<10	Cool	>3300	0.8
10--15	Cool Temperate	2300--3300	0.9
15--20	Temperate	1500--2300	1
20--25	Warm Template	500--1500	1.3
25 and above	Hot	<500	1.5

Source:- Design Criteria Guide line of MoWR (2006)

Table 18: Adjustment of Socioeconomic factor

Group	Description	Factors
A	Towns enjoying high living standards & with high potential for development	1.10
B	Towns having a very high potential for development, but lower living standards at present	1.05
C	Towns under normal Ethiopian conditions	1.00
D	Advance rural towns	0.90

Source:- Design Criteria Guide line of MoWR (2006)

Table 19: Institution and Commercial Demand

No	Institution	Consumption	Remark
1.	Restaurants	10 l/seat	
2.	Boarding Schools	60 l/pub	
3.	Day Schools	5 l/pub	
4.	Public offices	5 l/employee	
5.	Workshop/ Shops	5 l/employee	
6.	Mosques & Church	5 l/employee	
7.	Abattoir	150 l/cow	
8.	Hospitals	50-75 l/bed	
9.	Hotels	25-50 l/bed	
10.	Public Bath	10 l/Visitor	
11.	Public Latrines	20 l/seat	

Souce:-Design Criteria Guide line of MoWR (2006)

MATRIX PIPING SYSTEMS

POLY PIPE SIZES

Code	Outside Diameter	Inside Diameter
	6m Black SDR11	
161106	16mm	12.6mm
201106	20mm	16.1mm
251106	25mm	20.1mm
321106	32mm	25.9mm
401106	40mm	32.3mm
501106	50mm	40.4mm
631106	63mm	51.0mm
751106	75mm	60.9mm
901106	90mm	73.1mm
1101106	110mm	89.4mm
1251106	125mm	101.5mm
1401106	140mm	113.8mm
	12m Black SDR11	
1601112	160mm	130.0mm
1801112	180mm	146.3mm
2001112	200mm	162.5mm
2251112	225mm	182.9mm
2501112	250mm	203.4mm
2801112	280mm	227.8mm
3151112	315mm	256.3mm
3551112	355mm	288.8mm
4001112	400mm	325.4mm
4501112	450mm	366.1mm
5001112	500mm	406.8mm
5601112	560mm	455.7mm
6301112	630mm	512.5mm
7101112	710mm	546.5mm
8001112	800mm	615.9mm

HDPE PIPE DIAMETERS AND RATINGS

Size Diameter OD mm	PE100 PN4 SDR41 ID mm	PE100 PN6.3 SDR26 ID mm	PE100 PN8 SDR21 ID mm	PE100 PN10 SDR17 ID mm	PE100 PN12.5 SDR13.6 ID mm	PE100 PN16 SDR11 ID mm
16	-	-	-	-	13.7	12.6
20	-	-	-	17.7	16.7	16.1
25	-	-	-	21.7	21.1	20.1
32	-	-	28.7	28.1	26.9	25.9
40	-	36.9	36.1	35.0	33.8	32.3
50	-	46.2	45.1	43.9	42.4	40.4
63	-	58.1	56.9	55.2	53.3	51.0
75	-	69.2	67.7	65.8	63.7	60.9
90	85.6	82.9	81.3	78.9	76.5	73.1
110	104.7	101.3	99.2	96.5	93.3	89.4
125	118.9	115.4	112.9	109.9	106.1	101.5
140	133.2	129.2	126.5	123.1	118.9	113.9
160	152.3	147.6	144.5	140.7	135.9	129.9
180	171.5	166.3	162.7	158.3	152.8	146.3
200	190.5	184.6	180.6	175.8	169.9	162.5
225	214.4	207.9	203.3	197.8	191.1	182.9
250	237.9	230.9	226.1	219.9	212.4	203.4
280	266.7	258.7	253.0	246.3	237.9	227.8
315	300.1	290.9	284.9	277.1	267.6	256.3
355	338.2	327.9	321.0	312.1	301.6	288.8
400	381.1	369.5	361.5	351.9	339.9	325.4
450	428.9	415.8	406.8	395.9	382.4	366.1
500	476.3	461.9	451.9	439.9	424.9	406.8
560	533.6	517.4	506.3	492.6	475.8	455.7
630	600.4	582.1	569.8	554.4	535.5	512.6
710	676.5	655.9	641.9	624.6	603.4	580.9
800	762.3	739.2	723.4	703.9	680.0	654.5