ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABEBA INSTITUTE OF TECHNOLOGY

ASSESMENT OF WELKITE WATER SUPPLY SYSTEM

IN GURAGE ZONE, SNNPR, ETHIOPIA

A Thesis of the Degree of Master of Science in Civil and Environmental Engineering.

(Major in Hydraulics)

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Approved By Board of Examiners

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ABSTRACT

The thesis paper focused on the water supply system of Welkite town, capital city of Gurage zone of Southern Nation Nationality People Regional State of Ethiopia.

The main objectives of this study is to identify the problems of Welkite water supply system by assessing, bursting and leakage problem of the pipe system, evaluate and compare the total demand and supply and to suggest some remedial measure.

The demand and supply coverage was evaluated depend on different supply level and the level of leakage evaluated as per the amount of production and consumption.

Moreover, to analyze the existing water distribution system, a model was developed by using Water CAD software. The model can be used to identify the zone of high pressure and low pressure in junctions and the level of velocity through pipe. In addition, sample pressure filed data used to compare with the simulated value.

The model run was performed for average, maximum, peak and low demand scenarios to analyze the system model.

The analysis result shows the domestic and non-domestic water supply coverage of the town is 52%. Hence, this result indicates that there is high gap between demand and supply. In addition, from three years obtain data of production and consumption the average loss become 19.27%.

Furthermore, the model analysis result shows that different problems of the system. These are aged pipes, oversized and undersized pipes, high pressures and low pressure. Hence, the maximum pressure occurred at gravity main pipe line in night demand is 284.78m which is above the recommended value and the reason of pipe burst at gravity main pipe line.

To handle the problems need providing additional pump to increase the production, rehabilitate the existing bore hole, maximizing the capacity of distribution pipe line and providing separate pipe line for rural community. Moreover, As for bursting of pipe, suitable anchoring, treating the system by using quality joints, changing pipe in same critical points and fixing air release valves should be done.

Key Words: Water Cad Model, Non-revenue Water and Calibration.

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LIST OF ABBREVIATIONS

WTWSSE	Welkite Town Water Supply and Sewerage Enterprise
C	Hazen-Williams coefficient
T	Tank
D	Diameter
DCI	Ductile iron
DCI	Ductile cast iron
Fig	Figure
GI	Galvanized iron
Km	kilometer
L	Length
l/s	liter per second
Lpcd	Liter per capital per day
m	meter
m/s	meer per second
mm	millimeter
Q	discharge
UFW	Unaccounted for water
V	velocity
MDD	Maximum day demand
PHD	Peak hour Demand
ADD	Average day demand
LHD	Low hour demand
J	Junction
P	Pipe
R	Reservoir
T	Tank
PRV	Pressure reduce valve
MDG	Millennium Development Goal
NRW	Non Revenue Water
O&M	Operation and Maintenance
MWR	Ministry of Water Resource

CHAPTER ONE

1. Introduction

1.1. Back Ground

Access to safe drinking water supplies and sanitation services in Ethiopia are among the lowest in Sub-Saharan Africa. Access to safe potable water for urban areas was 91.5 per cent, while the access to potable water in rural area is about 68.5%1 (within 1.5 km) in the year 2010. However, increasing the number of people with access to safe water supply, sanitation and hygiene has proven to be a tremendous challenge throughout the developing world. Despite huge investments over the years in the water and sanitation sector in the country millions of rural and urban poor communities still remain without adequate water supply and lack improved sanitation services. Although numerous schemes have been planned and implemented in Ethiopia, only a proportion of these schemes continue to provide water to the communities that they were intended to serve. The failure in service may have been caused by a multitude of reasons including poor design and technology selection, insufficient maintenance, inadequate community planning or participation and many others. **Sefiu.A .et.al(2010).**

Due to its unreliability and non-sustainable nature, the existing service level in different parts of Ethiopia is lesser than the required levels. The poor water supply and sanitation facilities, along with other infrastructure services, bear a high level of impact on national and regional development, inclusive of both urban and rural communities. The Ethiopian government's efforts on implementing a water sector development program are based on the national resource management policy. The national water resource sector strategy is a part of the water sector development program. The government receives a credit or grant for the urban water supply and sanitation (UWSS) component of the project. At the regional level, the Water Resource Bureau is engaged in planning, distributing, operating, maintenance, monitoring, and evaluating urban water supply and sanitation projects. Initially, there were scattered efforts in Water Supply and Sanitation to improve the provision of clean and adequate water supply and sanitation facilities, yet their coverage remains low and inadequate. **AMCoW(2015).**

The Southern Nations, Nationality and Peoples Regional Government (SNNPRG) is located in the south-western part of Ethiopia. It has an area of about 118,000 square kilo meter with a population of about 13million and Over 91% of the population lives in rural areas. **BoFED. (2015).**

Welkite is the capital city of Gurage zone of Southern Nation Nationality people regional state. The water supply system of Welkite town first established in 1989 when a borehole was drilled in the town and connected to a 30m3 elevated steel tank. The system then went under expansion at different times mainly for the source development. Almost over nine boreholes have been drilled since the first one and most of them were abandoned due to decrease in discharge.

During the Immediate Rehabilitation and Expansion Program (IRE) including of the two boreholes, collection chamber, 100m3 reservoirs and 13public fountain and the distribution network have been constructed. However, due to the development of the town and the increasing number of population in the town, coupled with the decreasing in the yield of the boreholes the water supply shortage become serious problem of the town.

To solve the problem of Welkite water supply system, the Federal Government at the year 2007 implemented a big project by developing “Bozebar” large spring which is located at 29km away from the town. The spring has a potential of 130lit/sec. The project contains power supply system of 200kva power transformer and three units 22kw pump to lift the water from spring to the 500m3 balancing reservoir have 3km long pressure main pipe and 29km pipe system installation have been carried out to deliver the water by gravity to 1000m3 service reservoir of the town.

These project aims to supply water for Welkite town and rural community living along the pipe line from the source to the town and that would satisfy the demand of the targeted beneficiaries and raise the water supply service level from 40% to 100% until the end of design period.

Even if the project planned to solve the problem definitely and permanently, after implementation, some technical and management problems came out. For example, bursting of main pipe line, leakage along the old distribution pipe system and poor operation and maintenance are some of the problems of the Welkite water supply system. This research now going to elaborate the problems of Welkite water supply system and propose remedial measure.

1.2. Statement of the Problem

The existing source of Welkite town water supply system is from “Bozebar” large spring which is located at 29km away from the town. The water supply was implemented to give service for the people of the town as well as the rural communities along the main pipe line and surrounding rural community of the town. However, throughout time, the Welkite town water supply system encountered major problems. Hence, the water supply system doesn’t provide the intended service effectively to its targeted community.

The rapid spatial extension of the town has not been fully supported by infrastructural developments. While the town grew spatially, expansion of water supply service did not. Moreover, during implementation of Welkite water supply system from “Bozebar” large spring the distribution pipe system of Welkite as well as the surrounding rural community not improved. Hence, water service has been giving by using the old small size distribution pipe network which is not design and constructed properly. Thus design and implementation of water supply projects have been unsuccessful and inefficient.

Regarding to sustainability recently constructed 29 km gravity flow main pipe line laid from 500m3 balancing reservoir around the source area to 1000m3 service reservoir as well as the old distribution system have bursting and leakage problem. Moreover, as the entire town water network system are interconnected to each other without separating which system is serving which area and how much water is distributed to which area, this makes difficult the identification and the distribution of water losses at different spatial location.

The problem of water supply in the town is not only the problem of distribution and reliability but also it has the problem of water production. The level of water production with the existing power system is not proportional with the town demand. In addition to this along the 29km gravity main pipe line a lot of unplanned connections are made directly from the line without separate storage due to new settlement and construction of different institutions and companies. Therefore, during the time of low production and peak water consumption ,much of the produced water consumed on gravity main pipe line before reaching to Welkite town service reservoir. As a consequence, the towns' people suffer due to shortage of potable water.

In addition, Welkite town water supply and sewerage enterprise, the legitimate body to supply water for the town, had many problems as an institution to ensure a sustainable water supply. Same of them are, have no well-equipped technically qualified technicians, has poor administration of the water supply system, budget shortage, lack of manpower to handle policy and regulatory issues and to plan, operate and maintain the service, poor institutional organization and lack of coordination with stakeholders were some of them. Moreover, the involvement of the private sector or civil society in the design, construction, operation and maintenance of water supply systems was very low.

To address the overall water supply system problem and to suggest appropriate measure, relevant data should be collected, analyzed accordingly and finally some measures should be taken.

1.3. Objective of the study

1.3.1. General objective

The main objective of the study is to assess the problem of Welkite water supply system with it is impact and to suggest remedial measure.

1.3.2. Specific objectives

The specific objectives of this study

- To identify the cause bursting and leakage problem of the pipe system.
- To assess the situation of exiting water supply system and to evaluate and compare total demand and supply.
- Evaluating the performance of scheme management
- To suggest the remedial measure which support the sustainability of the town water supply system.

1.4. Research Question

1). How much is the current status of water supply and demand of the town?

2). What is the level of water connection and Per capita demand of the town?

3). What is the Cause of bursting and Leakage on pipe system?

4). How much water is lost while comparing with the water produced ?

5). What mechanism will protect the pipe from bursting?

6). How was the level of scheme management ?

7). What is the solution to satisfy the demand?

1.5. The Thesis Content

The Thesis content consists of Five Chapters

- Chapter one: Contain general back ground, the problem statement, the research objective, research questions, description of the study area and outline of the research.
- Chapter two: Discusses literature related to, demand and supply, water loss and hydraulic modeling.
- Chapter Three:- Discusses about the method the data collection and preparation.
- Chapter Four: - Results and discussion, under this demand and supply coverage, analysis of water loss and hydraulic analysis and over all findings will be underscored.
- Chapter Five :-Conclusion and recommendation

CHAPTER TWO

2. Literature review

2.1. Introduction

The developing cities have great difficulty in both technical and financial capacity to develop and expand water supply projects. One of the difficulties among the other is imbalance between demand and supply, losses of water by various ways in all level of the distribution system and poor management of the scheme. As a result the distribution of water among the available resource becomes unsatisfactory. Because of the poor management, the existing infrastructure asset increases the level of losses in the water supply and results demand gap. As this research deals with imbalance between demand and supply, bursting and leakage problem of pipe system and hydraulic modeling issues related will be reviewed in this chapter.

2.2. Water demand and Coverage

2.2.1. General

"The MDG drinking water target, to halve the proportion of the population without sustainable access to safe drinking water (an increase in coverage from 76% to 88%) between 1990 and 2015, was met in 2010. Between 1990 and 2012, 2.3 billion people gained access to an improved drinking water source, raising global coverage to 89% in 2012. In a further 35 countries, 26 of which are in sub Saharan Africa, coverage of improved drinking water supply was between 50% and 75%. Between 1990 and 2012, 2.3 billion people gained access to an improved drinking water source: 1.6 billion gained access to a piped supply on premises, and 700 million gained access to an improved supply, which could range from a public tap to a hand pump, protected dug well or protected spring. Within Southern Asia, India increased access for 534 million people, and within Eastern Asia, China increased access for 488 million people, greatly contributing to both regional and global increases in coverage. Despite this progress, 748 million people still do not use improved sources of drinking water, 43% of whom live in Africa.” **(UNICEF, 2014)**

2.2.2. Urban Water Supply coverage

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

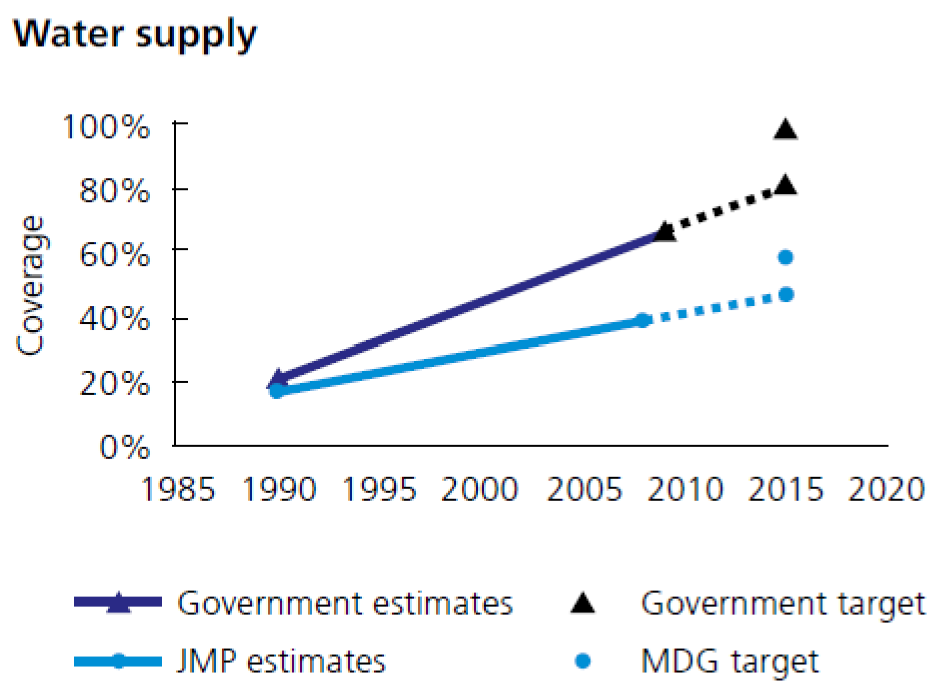

Figure.1. Ethiopia Water supply coverage by Gov & JMP Report

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

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

The problem of inadequate access to water and sanitation exists in both rural and urban areas, the problem is particularly pressing in cities. With internal migration and the “urbanization of poverty,” cities are where an increasing proportion of the poor live. In the last three decades, growth in urban populations in developing countries exceeded that of rural areas three times more. **USI (2012)**

The water, sanitation and hygiene infrastructure of many cities is therefore stressed beyond current capacity and infrastructure investments have not kept pace with rapid and unplanned urbanization. There may be smaller-scale, off-grid, innovative supply solutions. The solutions necessarily require clever innovations in design of contracts, pricing policies, and market development. USI identifies three key barriers:

1. **Insufficient supply**: Building water and sanitation infrastructure is costly and may involve numerous technical, bureaucratic, and legal constraints–particularly in the developing world. There may be smaller-scale, off-grid, innovative supply solutions, but realizing those solutions requires clever innovations in design of contracts, pricing policies, and market development.

2. **Insufficient demand**: Even in places where water and sanitation network exist, due to the limited demand to some services, it is technically feasible to connect to it. Some reasons and factors which could be seen as the cause of the limited demand can be also mentioned. These are lack of willingness-to-pay, different people’s demand may be

inter-linked, and the presence of transient or migrant populations may not be available as potentially dedicated customers.

3. **Institutional constraints**: if regional and local levels of government are not involved to facilitate implementation in the local context, centralized supply solutions may not be sustainable or even possible at all. In addition, coordination problems can arise when the sanitation or water infrastructure is shared and must be jointly maintained.

2.2.3. Municipal Water System Demands

Demand is an informed expression of desire for a particular service, measured by the contribution people are willing and able to make to receive this service.
The contribution does not have to be monetary, but should be:

- Perceived by the potential user as affordable
- Sufficient to empower the user as a consumer with associated rights and responsibilities and
- Related to the cost of the associated option, in order to facilitate the achievement of cost recovery objectives. **Paul et.al.(2001)**

The demand for water supplied by a municipal water system has two driving components.

1. **consumer consumption:** the amount of water per day that is used by all of the taps on the water mains to supply single-family homes, multiple-family residences of all types, health care facilities, schools at all levels of education, commercial enterprises, industrial complexes, and adjunct uses (street cleaning; water fountains; watering public parks and recreation including swimming pools; and the sale of water to contractors for building roads, structures, etc.) and
2. **An adequate and reliable water supply for fire protection.**

Consumer consumption: Consumer consumption is assessed by determining the amount of water that actually is used by consumers, based on three levels of usage as follows:

1) **Average daily consumption (ADC).**The total amount of water used in a day by the population and does not consider usage by different classes of occupancy including commerce and industry. AWWA reports this figure varies considerably by State and region.

2) **Maximum Daily Consumption (MDC)**: This value represents the single day within a year-long period on which the consumption rate was the highest.

3) **Instantaneous flow demand**: There are generally two peak periods in the day when consumption is greatest: between 7 a.m. to 9 a.m. and between 5 p.m. to 7 p.m.

Fire flow demand: At any time, the municipal water supply system should be able to deliver needed fire flows to representative fire risks throughout the municipality from properly located fire hydrants. An adequate amount of water is essential to confining, controlling, and extinguishing hostile fires in structures. The actual amount of water needed differs throughout a municipality, based on different building and occupant conditions. Therefore, water damage for structural fire protection must be determined at a number of different locations throughout a given municipality or fire protection district. These locations are selected by the Insurance Services Office, Inc. (ISO), to represent typical fire risks, including residential, commercial, institutional, and industrial properties for insurance rating purposes. **Harry E.(2008).**

2.3. Water Loss and Leakage

2.3.1. General

Before proceeding to discuss about causes, consequences and other aspects of leakage, it will be good to examine the types of leaks that are commonly encountered and their category of occurrence (where they can be located) in a distribution network of water supply system. Leaks can be categorized in different ways like physical and administrative losses. Physical losses can be caused by leaks which may occur in any part of the system like transmission pipes, service reservoirs, pumps, distribution networks, and house connections. Whereas administrative losses can be related to illegal connections, faulty (under-registering) or broken meters, inaccurate billing, etc. **Allan.L(2003).**

Table.1. The IWA 'best practice' standard water balance

System Input Volume (corrected for known errors)	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption (including water exported)	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metered Consumption	Non-Revenue Water (NRW)
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorised Consumption	
			Customer Metering Inaccuracies	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer metering	

Source. IWA WATER LOSS TASK FORCE (Water 21 - Article No 2)

2.3.2. Occurrence of Leaks

Generally, leaks can be divided into five main categories depending where they commonly occur or may be located. The five major categories are:

- **Water main leaks** typically range from 0.1 l/s to over 70 l/s. Leaks due to corrosion of water mains usually start through small holes but can grow to very large leaks. Mostly Causes on excessive pressure, poor workmanship, settlement of trenches overloading, and improper materials, and temperature stresses are the major ones.
- Service Line leaks typically range from as low as 0.03 l/s to over 1 l/s. The causes for service line leaks are the same as for the mains.
- Customer Meter Box leaks (near or within meter boxes of customers) range from 0.1 l/s to 0.7 l/s. Leaks may be caused by loose nuts on the meter, broken or damaged couplings and broken or damaged meters.

- Customer Connection Line leaks (customer side of the line) range from 0.1 l/s to 1.0 l/s; holes or breaks in customer connection lines and shutoff valves may cause these leaks.
- Valves and Appurtenance leaks in distribution system typically range from 0.07 l/s to as high as 30 l/s; loose connection and broken valves are common causes for this type of leak. Valve leaks in a water supply system may be observed in isolating valves, pressure reducing valves, drains and air-release valves. **(Water Aid Ethiopia,2010).**

2.3.3. Non-Revenue Water

2.3.3.1. General

The waste of resources resulting from high NRW levels in developing countries is considerable. The total cost to water utilities caused by NRW worldwide can be conservatively estimated at $141 billion per year, with a third of it occurring in the developing world. In developing countries, about 45 million cubic meters are lost daily through water leakage in the distribution network which is enough to serve nearly 200 million people. Similarly, close to 30 million cubic meters are delivered every day to customers, but are not invoiced because of pilferage, employees' corruption, and poor metering. All this directly affects the capacity of utilities in developing countries to become financially viable and fund necessary expansions of service, especially for the poor**. (World Bank 2006).**

Table. 2. The International Non-Revenue Water Assessment Matrix

NRW Management Performance Category		Non-Revenue Water in liters/connection/day when the system is pressurized at an average pressure of:				
		10 m	20 m	30 m	40 m	50 m
High Income Countries	A1		< 50	< 65	< 75	< 85
	A2		50–100	65–125	75–150	85–175
	B		100–200	125–250	150–300	175–350
	C		200–350	250–450	300–550	350–650
	D		> 350	> 450	> 550	> 650
Low and Middle Income Countries	A1	<55	<80	<105	<130	< 155
	A2	55–110	80–160	105–210	130–260	155–310
	B	110–220	160–320	210–420	260–520	310–620
	C	220–400	320–600	420–800	520–1000	620–1200
	D	> 400	> 600	> 800	> 1000	> 1200

Source: R. Liemberger. Recommendations for Initial Non-Revenue Water Assessment. IWA Water Loss 2010. Sao Paulo, Brazil. June 2010.

This matrix is based on an extreme simplification. Commercial loss allowances are based on an assumed average billed consumption per connection of 1,000 liters per day. This means that in systems with substantially higher average consumption, the values might be difficult to achieve, especially in the "A" categories.

• **Category A1**: World-class NRW management performance; the potential for further NRW reductions is small, unless there is still potential for pressure reductions or the accuracy improvement of large customer meters.

• **Category A2:** Further NRW reduction may be uneconomic, unless there are water shortages or very high water tariffs; a detailed water audit is required to identify cost-effective improvements.

• **Category B:** Potential for marked improvements; establish a water balance to quantify the components of NRW; consider pressure management, better active leakage control practices, and better network maintenance; improve customer meter management, review meter reading, data handling and billing processed, and identify improvement potentials.

• **Category C**: Poor NRW record; tolerable only if water is plentiful and cheap; even then, analyze level and causes of NRW and intensify NRW reduction efforts.

• **Category D:** Highly inefficient; a comprehensive NRW reduction program is imperative and high priority. **Rudolf F.et.al(2010)**

Not all the unaccounted-for water is physically lost. Either the utilities master meter or some of the customers' meters may be inaccurate. In cases of inaccurate customers' meters, the water is "lost" as far as accounting and billing is concerned, any meter inaccuracies make it difficult to assess the amount of water actually lost through leaks. Therefore it is important for a utility to reduce metering errors. Customer meters usually tend to under register. Sometimes customer meters do not work at all. Meters that under register or which do not function properly may account for significant water and revenue losses. An ongoing customer meter testing and replacement program is essential to alleviate this problem. The acceptable level of unaccounted-for water differs from community to community. A 15-percent loss has generally been considered acceptable for large water utilities. It is probably profitable to control any loss above 10 percent. Most authorities recommend implementing a water loss control program where losses exceed 20 percent or more.(**Bill kingdom et.al(2006).**

A case study was conducted by Metaferia Consulting Engineers for Water Aid Ethiopia in 2010 in seven towns which reveals the extent of leakage of each town. Summary of the study result is shown in table below.

Table.3. Level of Non-Revenue water in towns of Ethiopia

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

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

2.3.3.2. The Importance of Registered Services in UFW Assessment

Water utilities need some means of accurately measuring the water that is delivered to the consumer through the distribution network. If the meters are of the recording type, valuable information regarding hourly rates of consumption will be available. Metering of delivered water consists of placing a recording meter in the line leading from the water main to the area served. The area could be a district or zone. Consumers are then billed for the water they use based on reading of water meters installed at their yards. The alternative to these methods is charging the consumers on the basis of flat rates, which has no relation to the actual consumption or to the amount wasted. Billing by metering is advantageous. Pumping and treatment cost money and wasting of water means a greater cost to the utility, which in turn will be distributed among the customers. If deliveries are unmetered, the careful consumers are made to bear the burdens imposed on them by the careless and wasteful ones. It is almost impossible to construct a good system of water charges without the use of water meters and hence the necessity for the use of it to collect water charges based on actual consumption**. James et. al.(2005).**

2.3.4. Leakage Detection

Old or poorly constructed pipelines, inadequate corrosion protection, poorly maintained valves and mechanical damage are some of the factors contributing to leakage. Leak detection has historically assumed that all, if not most, leaks rise to the surface and are visible. In fact, many leaks continue below the surface for long periods of time and remain undetected. With an aggressive leak detection program, water systems can search for and reduce previously undetected leaks. Water lost after treatment and pressurization, but before delivered for the intended use, is water, money and energy wasted. Accurate location and repair of leaking water pipes in a supply system greatly reduces these losses. Once a leak is detected, the water utility must take corrective action to minimize water losses in the water distribution system.

Advances in technology and expertise should make it possible to reduce losses and unaccounted for water to less than 10 percent. Every industrial and commercial water system facility should implement cost effective water loss control measures that will minimize distribution system water losses. Water systems with pressurized distribution systems should promote water auditing, leak detection, and leak repair as a means to reduce operating costs and conserve water. The water audit can be used on systems with customer meters, while leak detection and repair can be used on any pressurized water system. **EPD, (2007).**

2.3.5. Pressure and Leakage

The efficiency of a distribution system can be judged on the basis of the pressure available in the system for a specific rate of flow. Pressures should be great enough to adequately meet consumer needs. At the same time they should not be excessive and as pressure increases, leakage increases and money is then spent to transport and process a product that is wasted.

Utilities are always expected to provide adequate and safe drinking water with sufficient pressure at all delivery points. Pressures at consumers yard connections have to be as close to the minimum level as possible, though this is supposed to be determined by local authorities. The minimum pressure at a customer's connection is in the order of 15 meters while the maximum is as high as 40 meters; pressure range in excess of 60 to 70 meters will damage house installations such as boilers, float valves, taps, gaskets inside the fittings, etc. Pressure variation in a distribution network is caused, amongst others, by changes of demand of the users. Frequent starts and stops of pumps, closure and opening of control valves that induce water hammer are also some of the causes to be mentioned for pipe breakage and water loss.

The pressure will be low during daytime with increase of demand and high during night hours when the demand is low. There is an excess pressure build-up in a network when demand drops especially during the night. Obviously, there is the need to cut down this unduly excessive pressure in order to avoid the bursting of pipes or reduce the amount of leakage. Variations of pressure may cause frequent pipe bursts or damages. Studies shows on the effect of high pressure on losses, particularly leakage from pipes, have indicated that leakage is almost proportional to the service pressure.

The following methods can be envisaged to achieve the cutting down of the excessive pressure:

- Adjust the speed of pumps to maintain reasonably constant pressures in the distribution network for areas supplied directly by pumps.
- Install a pressure-reducing valve (PRV) or
- Divide the system into pressure zones.**(Water Aid Ethiopia,2010)**

2.4. Design and operation of piped networks

2.4.1. Introduction

In design and operation of piped networks the purpose of a system of pipes is to supply water at adequate pressure and flow. However, pressure is lost by the action of friction at the pipe wall. The pressure loss is also dependent on the water demand, pipe length, gradient and diameter. Several established empirical equations describe the pressure-flow Relationship and these have been incorporated into network modeling software packages to facilitate their solution and use. When designing a piped system, the aim is to ensure that there is sufficient pressure at the point of supply to provide an adequate flow to the consumer .Pressure at any point in the system should be maintained within a range whereby the maximum pressure avoids pipe bursts and the minimum ensures that water is supplied at adequate flow rates for all expected demands. Hydraulic models are used to identify where, when and how negative and high pressures may occur and help to identify Preventative measures such as system controlling methods and for selection of pipe materials according to the pressure. **Kay Chambers et,el(2004).**

2.4.2. Model skeletanization

As **Elsheikh (2013)** reviewed that, in order to skeletonize the model to an acceptable degree, the study should follow the listed conditions such as: (1) At least 50% of total pipe length in the distribution system (2) At least 75% of the pipe volume in the distribution system (3) All 300 mm diameter and larger pipes; (4) All 200 mm and larger pipes that connect pressure zones, influence zones from different sources, storage facilities, major demand areas, pumps and control valves (5) All 150 mm and larger pipes that connect remote areas of a distribution system to the main portion of the system; (6) All storage facilities with controls or settings applied to govern the open/closed status of the facility that reflects standard operations; and (7) All active pump stations with realistic controls or settings applied to govern their on/off status that reflects standard operations.

Developing the hydraulic model for network follow the following steps.(1) Creating a pipe network from the water system GIS files using Water GEMS (Bentley Systems) and ArcGIS (Environmental Systems Research Institute); (2) Spatially allocating customer demands and pipe leakage to pipe network nodes; (3) Assigning elevations to pipe network nodes; (4) Incorporating boundary condition elements (e.g., pumps, ground storage reservoirs); and (5) Performing calibration and a quality control review of the resulting model.

2.4.3. Calibration

As Elsheikh (2013) reviewed the discussion and finding of Walski(1983) and ATSDR (2000). described 7 steps process for model calibration, including: identifying model use, determining parameter estimates, collection of calibration data, evaluation of model results, macro calibration, sensitivity analysis, and micro calibration. Pipe grouping for roughness calibration was based on pipe type, age, and size. The optimization approach for calibration was compared to the analytical and simulation approaches based on skeletonizing of the system by removing pipes.
Walski [1983] suggested that pressure-measuring devices should be located near points of high demand, near the perimeter of the skeletonized network, and generally distant from water sources.

ATSDR(200) illustrated that an average pressure difference of ± 15.2 kPa (± 1.51 m) with a maximum difference of ± 50.3 kPa (± 5.03 m) represents a "Good" data set and an average pressure difference of ± 29.6 kPa (± 2.96 m) with a maximum difference of ± 97.9 kPa (± 9.79 m) represents a "Poor" data set.

2.5. Institutional Assessment on Water Supply System

Institutional assessment of water supply system will help to identify poor operation and maintenance situation of relevant functions like defective design, ineffective supervision, insufficient training, lack of and absence of clarity of roles which consequently the water supply components fail to operate at optimum efficiency. **WHO (2006).**

The water schemes assessment made by **Amy.et.al.(2010)** from nine zone of Amhar Regional State from observed 32 water supply schemes in the study area they found that it is only 44% of the schemes are functional whereas the remaining 56% is either completely non-functional (13%) or functional with disrepair (43%) under the current management arrangement. However, if those schemes functioning with some disrepair are not properly maintained, they will stop functioning within a short period of time. Consequently, non-functional schemes in the study area will rise to 56%. Among those functioning with some technical breakdowns, damage of the faucets and valves are the major disrepair followed by leakage from pipes and poor construction of the scheme's components.

The sustainability of water supply facilities mainly depends on a timely and regular maintenance and operation of the system. However, in most developing countries, including Ethiopia, it has been found out that operation and maintenance (O&M) of water supply facilities is in a poor state of condition and the sustainability of the scheme is at stake. Regarding this, **MoWR (2002)** identified the following underlying problems.

- In appropriate tariff setting without emphasis on full cost recovery;
- Lack of clear guidelines for urban tariff setting including issues related to fairness, and financial sustainability;
- Inappropriate or lack of institutional incentives for urban WS to achieve financial viability and improved operational performance;
- Poor technical and financial capacity among the urban service providers that leads to high levels of unaccounted for Water (UFW); and
- Poor or nonexistent consumer services and grievance handling system that leads to a lack of willing to pay user charges.

CHAPTER THREE

3. Research Methodology

3.1. Description of the study area

3.1.1. General

Welkite is the Capital city of Gurage Zone of Southern Nation Nationality People Regional State of Ethiopia. The town is located on the main road of Addis Abeba to Jimma town at distance of 157 kilo meter (km) south-west of Addis Abeba. The town is situated in the south-west plateau about 80km to the west of the main Ethiopia Rift Valley on a water divide of “Rebu”, “Megecha” and “Wabe” rivers. The City stretches some 12 km towards south west direction of Gubra sub city which is recently being part of Welkite town and the place of Welikite University. The present population of the town is estimated to be 51,189 with an annual growth rate of 3.69%. at present the city divided in to three sub city namely, Bekur sub city,Addis sub city and Gubre sub city. The Welkite Water and Sewerage Enterprise (WWSE) is a public institution in the town that is responsible for the supply of potable water for the town.

Among the thirteen Woreda of Gurage Zone three of them (Abeshige Wereda ,Cheha Woreda and Kebena Woredas) are closed to Welkite town. Hence, some of their Kebles are beneficiaries of Welkite water supply system.

3.1.2. Water Supply and Distribution

The town has started getting water supply system in 1989.From the period of started up to 2007 the water source used by the town is drilling of boreholes Almost over nine boreholes have been drilled during these period. However, most of them were abandoned due to decrease in discharge.

As a result of the above problem and the increase in population of the town in 2007 there is serious water supply shortage in the town and the existing system hardly covers about 40% of the town’s population.

According to the appraisal report prepared by Metaferia Consulting Engineers in 2007 the yield from the four boreholes as shown in table 2

Table .4. Boreholes Operating as Water source for Welkite Town until 2007

Name of the Borehole	Estimated Yield
Tatessa Borehole	2 l/s
WTW3 (IRE borehole)	4.5 l/s
J & P Borehole (from Road contractor)	3.5 l/s
Rebu	7 l/s

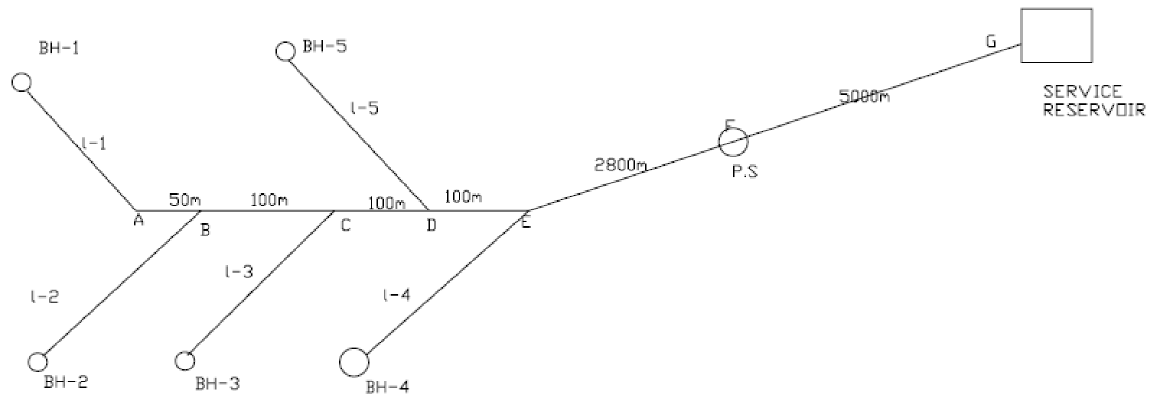

Figure. 2. Old pressure pipe layout from different bore hole

Now the Welkite town has three bore holes which is not functional due to pump stack, IRE Bore hole have 4.5L/s, J&P Bore hole have 3.5l/s and the Rebu bore hole 7l/sec, if the existing pump problem solved the town will have a total of 15l/sec alternative source.

Hence, new big project implemented in 2007 by developing “Bozebar” large spring which is located at 29km away from the town. The spring has a potential of 130lit/sec. currently, 2,219.6 m3/day water produced from this source and the design capacity of the power supply has performance to produce 2,656.8 m3/day for 18 hour pumping.

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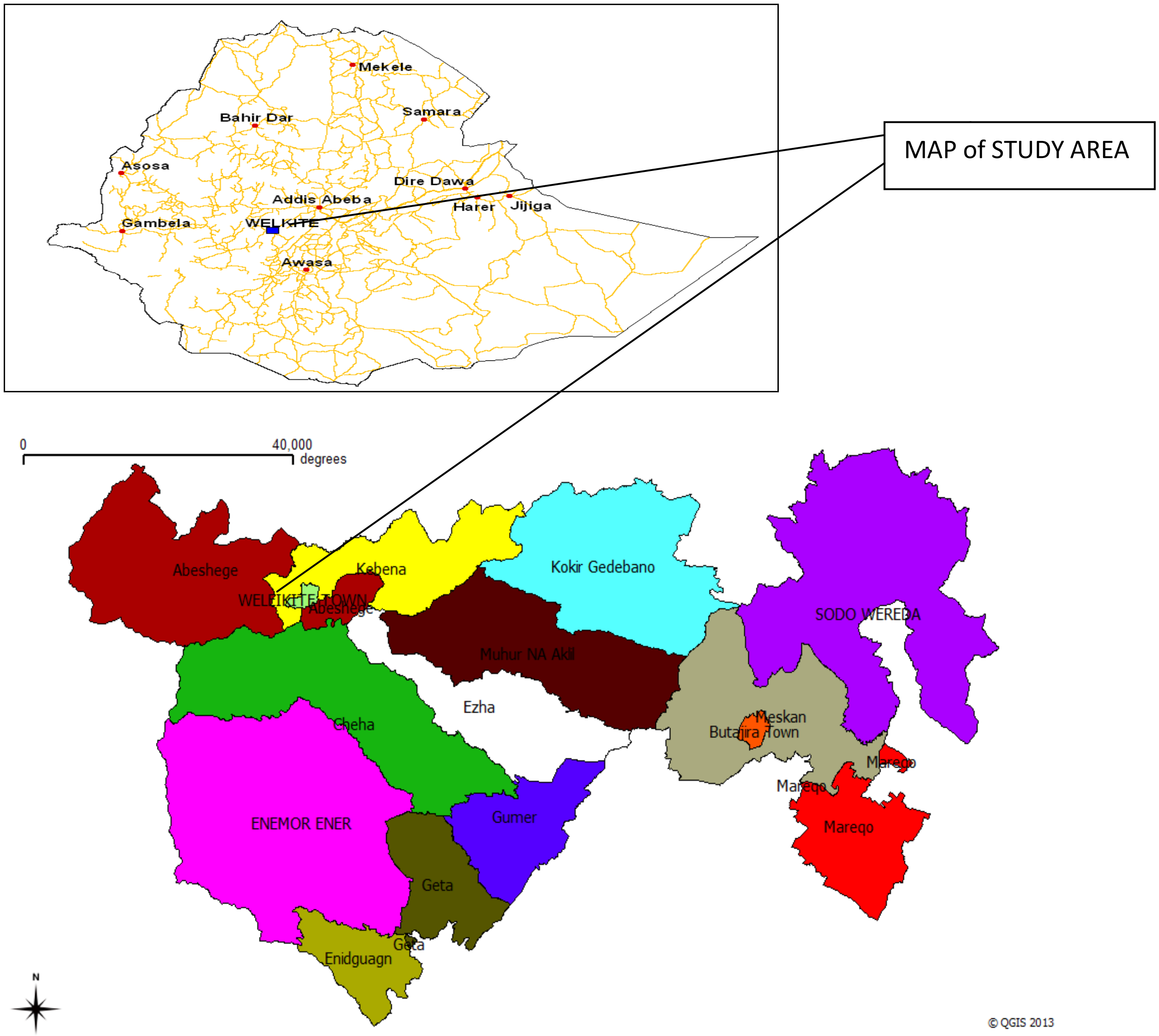


Figure. 3. Location Map of the Study Area

3.1.3.Existing Water Supply System

To solve the problem of Welkite water supply the Federal Government at the year 2007 implemented a big project by developing Bozebar large spring which is located 29km away from the town and the spring have potential of 130lit/sec. The project contains construction of spring capping, power house with power supply system of three horizontally installed 22kW pump one as standby, electric power transformer and 200KVA Generator which is used to lift the water from constructed wait wall to the 500m3 balancing reservoir through 3km long 300mm diameter pressure pipe line and 29km pipe system installation have been carried out to deliver the water by gravity to 1000m3 service reservoir of the town. These project aims to supply water for Welkite town and rural community living along the pipe line from the source to the town and that would planned to satisfy the demand of the targeted beneficiaries and raise the water supply service level from 40% to 100% until the end of design period.

Figure 4 .Well Protected Spring Capping and diversion structure

3.2. Research followed steps

The first step of this study was evaluation the water coverage of the town and surrounding rural villages. Evaluating the water supply coverage focus on the volume of consumption and level of water connection. As the water supply system gives service for Welkite town and surrounding rural communities the evaluation considers the difference of per capital demand in urban and rural area.

The next step will be identifying the loss of water due to leakage and bursting problem of the main pipe system. The loss will evaluate by using data of water production and consumption which is collected by Welkite water supply and sewerage enterprise (WWSSE) for the purpose of fee collection. To identify the bursting problem of main pipe line same part of the distribution pipe line elevation and other relevant date has been collected and used to analysis by Water CAD model .Moreover, pressure and discharge data measured and calibration performed. Finally, from analyzed data problems identified and remedial measures are suggested.

3.3. Selection of sample study area

The major factors considered during the selection of sample areas are:-

- The zone of high problem found
- Topography
- Data availability
- Suitability to identify the problem

By taking the above criteria in to consideration the main pipe line between the reservoirs around the source area to the town service reservoir was selected to identify the bursting problem and at different twenty points the level of pressure measured to perform calibration and validation.

As discussed in the problem statement part of this proposal the distribution pipe network of the town is old system and it is not part of the existing large spring development project. By using the surveyed primary and secondary data and some other relevant standards the main gravity pipe line and the main part of the distribution system hydraulic analysis has been done by using Water Cad Software.

3.4. Water Supply Coverage

The water supply coverage of study area has been evaluated on two ways, the first is in town level and the second is the whole scheme beneficiary area. The Welkite town water supply coverage evaluated based on the average per capital consumption by using yearly domestic consumption with the current population and level of connection per family by using the total domestic connection as per average family size. The whole system water coverage has been evaluated by considering urban and rural domestic as well as Non-domestic user by using Design guide line of **MOW(2006).**

3.4.1. Design Review

The Feasibility Study Report Welkite Town Water supply System from Bojebar spring source prepared by Tropics Consulting Engineers plc. (May 2001). And revised by Metaferia Consultant in 2007, the safe yield of the Bojebar spring is estimated to be 130 l/sec which is equivalent to 11,232 m^3/day. Based on the Study estimated maximum day demand of about 2,677 m^3/ day for Welkite Town and the villages along the gravity line for the year 2017 .

In addition the design locates the 1000m3 service reservoir next to the existing reservoirs located in the town. The spot is high ground for most part of the Town but there are now houses close to the reservoir and some house are also constructed on higher grounds which cannot be fed without pumping. It is therefore worse considering the location of the service reservoirs at the highest spot around the town so that water can be supplied by gravity.

The water from the spring has been directed to a wet well located downstream of the spring and lifted to a 500m3 balancing reservoir located at higher ground. The construction of intake structure and the drainage system should allow abstraction of sufficient flow of water into the intake chamber throughout the year without being affected by flood.

3.4.2.Demand Projection

The detail design of the Bozebar spring system has been made first in year 2001 by Tropic Consultant and the conditions regarding the development of the town and the yield of the existing boreholes has changed. Business plan for the town water supply is also prepared in year 2005 and design review for some of the proposed water supply components has been made. The review made during the business plan preparation in 2005, however, has not gone in to detail engineering issues therefore, the revise detail designs made for the water supply components based on the Bozebar spring by Metaferia Consultant in 2007 and the population projection and water demand projection described as follows.

- Design horizon –year 2008 up to year 2017
- Design population is taken as 31,660 for Welkite town and 10,180 for the rural areas a total of 41,841 by 2008 and 46,714 for Welkite town and 12,714 for rural areas a total of 59,428 at the end of design period 2017. **(See appendix -12)**
- Per capita water demand is taken as 15 l/c/day for public tap users, 20 l/c/day for neighborhood tap shared, 30 l/c/day for yard connections and 70 l/c/day for house connections in the town and 7 l/c/day for the rural areas.
- Population growth rate is taken as 4.5% for urban and 2.5% for rural area
- Public demand is taken as about 38% of the domestic demand
- Unaccounted for water is taken as 30% of the maximum day demand
- Total maximum day demand is 2,631 m^3/day or 30.45 l/s
- The maximum day demand assuming 18 hour pumping is 41 l/s.
- Average per capita water demand is calculated as 44 l/c/day.

3.5. Water Loss

In order to identify the total loss of water in the study area, the total volume of water supplied to the network distribution system was compared with the actual water consumption. In this case, yearly aggregated production and consumption data obtained from WWSE for three years from 2013 up to 2015 and used to compute NRW. Moreover, the apparent and real loss computed by using IWA water loss task force developed equation by providing input data of length of mains pipe line, number of service connection, total length of service connection from the edge of the street to customer meters.

3.6. Data collection

The Welkite water supply system have no organized data specially for old distribution network, hence all relevant primary data of main and distribution pipe line network has been collected .The secondary data of gravity main line used to compare with the surveyed data ,forecasted population ,Consumption and production data and level of connection dates are collected from concerned governmental institutions.

3.6.1.Collected Primary data

- By using GPS surveying instrument elevation data of the 57km surveyed (3km main Pressure Pipe line up to 500m3 balancing reservoir, 29km from balancing reservoir to 1000m3 town service reservoir and 25km of the main, secondary and some of tertiary pipe line of distributing network data surveyed and along the line the pipe size material and appurtenant structures like, 11 air release valve, 10 wash out structures etc. are part of the survey.
- The type of pipe materials, fittings and valves has been collected from the site in order to identify whether the system have material quality problem or not.
- Pressure and discharge test measurement taken at different time and in different location to perform calibration and validation.
- Discussion with the officials and experts in the concerned government bureau to acquire organizational information on WSS.

3.6.2. Secondary data

- Hydraulic analysis of main pipe line from design document and used to compare with the model analysis result made by using primary surveyed data.
- Total number of population and some other relevant documents.
- Per capital demand of the town as well as the rural community and some other relevant standards.
- The amount of customer data as per level of connection is collected which used to analysis the coverage.

- The boundary of the water supply system.
- Three years Water production and Consumption data used to analysis the Water loss.
- Personnel, Income and expenditure data of the WTWSSE

3.7. Hydraulic Model Analysis

3.7.1. Modeling of water supply system

By using surveyed data of pipe line elevation, Size of pipe, material type data of the pipe line and other relevant parameters the water supplies network developed by using Water CAD software.

The hydraulic analysis has been done under the following conditions.

- Average loading condition
- Peak loading condition
- Under low loading condition

Elevation, demand, length, pipe size and type of materials are the input of water CAD and velocity at pipe and pressure at every junction was the output.

3.7.2. Data Organization

Depend on the guide line of water Cad manual the collected primary and secondary data organized on excel sheet. Depend on easy to identify the problem, topography and technical point of view all the pipe network system divided in to three zones which have a total of have 59 nodes.

- Zone-1 from balancing reservoir to 1000m3 service reservoirs have 12 junction,
- Zone-2 from 1000m3 ground reservoir to the down part of the reservoir
- Zone-3 from 15m elevated 100m3 reservoir to upper part of the reservoir

The tabulated data includes the elevation, pipe length, pipe size, pipe material type and the demand of each junction, base, minimum, initial and maximum elevation of the three reservoirs and the maximum, average and minimum head and discharge of the pump. The detail attached in **Appendix 1.**

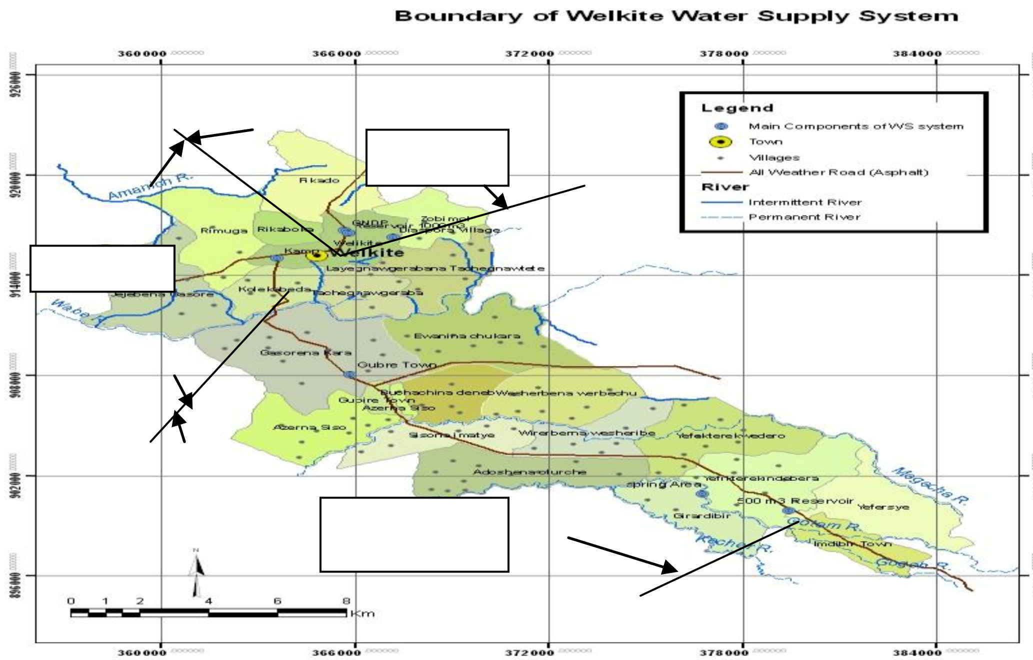


Figure.5. Boundary Map of Welkite Water supply System

3.7.3. Model Calibration and Validation

Once a water distribution model has been developed, it must be calibrated so that it accurately represents the actual working real life water distribution network under a variety of condition. This involves making minor adjustment to the input data then the model accurately simulated the pressure rate in the system. Pressures are measured throughout the water distribution system using pressure gage instrument to use the data for model calibration.

The computed pressure and measured field pressure will not exactly match, for every node contained within the network system is 85% of field test should be with +- 0.5m the computed or simulated pressure by water cad software at that nod.

3.7.3.1. Calibration and Validation Statistics

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

3.7.3.2. Calibration and Validation data

Devices used for taking field measurements were the static pressure gauges and flow measurement device by Ultra-Sonic waves or water meter to take three types of data as follows: (1) Steady state measurements; (2) Fire flow tests; and (3) Extended period measurements.

The hydraulic model was calibrated by adjusting Hazen-Williams coefficients (C) according to these three types of field measurements data:

3.7.3.3.Pressure and Discharge Test Measurement

By taking the above criteria in to consideration the main pipe line between balancing reservoirs to services reservoir and on selected point of distribution system the level of pressure and discharge measurement has been made at 20 selected points by using pressure gage and water mater instrument.

Figure.6. Pressure Measurement at different location

3.8. Limitation

During data collection and analysis of this study the following limitations are occurs.

- Welkite water supply system has no 24 hourly consumption data, due to this unable to compute total real loss and apparent loss.
- Welkite water supply system has no 24hour Demand pattern, which used to analysis the demand at different demand condition. Hence, other similar town demand pattern data used to compute the night flow demand.
- The available pressure gage instrument is can able to measure only up to 250m.Therefore, the peak pressure zone of gravity main which have more than 250m is not be part of calibration.
- The distribution pipe system of the town is old and has no suitable net- work. Hence, difficult to model the whole existing network by using primary survey data, therefore, only 25km main and secondary pipe line data surveyed and used for net-work model building.

CHAPTER FOUR

4. Result and Discussion

4.1. Water Demand and Supply Coverage

4.1.1. Water Demanded Coverage Analysis

The design document and things have been on ground was totally different, for example the projected population for 2016 in design document is 44,837 urban population and 12,404 rural population a total of 57,241 population plan to serve but the current number of population benefited from the system are 50,189 from urban and 28,000 from rural a total of 78,189, in addition to this due to un planed institution and factors are established around the town like Welkite University which have more than 10,000 students and other ,this implies the gap will be more.

To identify the gap between demand and supply three ways are followed, first by using annual domestic consumption identifying the level of per capital demand per person, second computing the per capital demand by level of connection and third by following the design criteria calculating the overall demand coverage.

Table.5. Population Data

S/N	Place/Location	No of Kebel	Population	Remarks
1	Cheha woreda	7	20,150	Water Used From Main Gravity Pipe Line
2	Abeshige woreda	4	3650	
3	Kebena woreda	4	4200	
	Total for rural community		28,000	
4	Welkite town	3 sub city	50,189	one of the sub city with 6,500 population located along the gravity main line
	Total Sum		**78,189.00**	Total of 26,650 Population Gate water from direct connection of the main line

Source. From Town and Weredas Water Offices

4.1.2. Urban Domestic Water supply Coverage

To evaluate the amount of water consumption, the annual water consumption is converted to average daily per capita consumption using the population data of the town and the number of domestic connection per family has been also used to analyze the level of connection.

4.1.2.1. Average Daily Per Capita Consumption

The volume of water consumed for domestic purpose has been distributed for all beneficiaries of the town to analyze the distribution of the water supply coverage.

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

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

The annual domestic consumption amount in 2015 is 357,165 m3 and the current total population of the town from three sub cities was estimated as 50,189 , there for by using the above expression the average daily per capita consumption became 19.5l/per capita/day.

According to Wallingford HR(2003) which is reviewed by Desalegn(2005) a minimum quantity of 25 l/c/day domestic water supply categorized as basic level of service which is higher than the average domestic consumption of the town. In addition, according to the standard set by MoWR for third level town like Welkite, the per capita per day is 60 liter, there for ,the current coverage is only satisfy one third of the demand.

4.1.2.2. Level of Connection per Family

Level of water connection per family is one mechanism to evaluate the level of water coverage. The total number of connection or water meter with in the town are about 6,833 that among these 5,467 are for domestic users, according to the census of the 1994,average family size of 5.5 is used for calculating the average number of connection per family using the following expression.

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

The level of water connection as per the above expression became 0.6; this implies that the current connection coverage is only 60%.

4.1.3. Analysis of overall Water demand Coverage

4.1.3.1. General

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

Some of the factors that affect water demand are:-

1. **Climatic condition: -** Water consumption during winter is more than summer. During winter no rain and more water used for all activities and also consumption of drinking and bath increased.

2. **Size of the town: -** Generally, the demand of water per head will be more on big city than that in small city. In big cities lot of water is required for maintaining clean and health environments while in small towns more or less small.

3. **Culture of people: -** High class community uses more water due to their better standard of living and high economic status. Middle class people uses water at average rate and for poor people a single water tap may be sufficient for several families.

4. **Industries: -** more water is used in highly industrial city

5. **Cost of water:** - If cost of water is high, the water demand will be less .Hence the rate at which water is supplied to consumer may affect the rate of demand.

6. **Quality of water:** - A water work system having good facility and portable water supply will be more popular with consumers.

7. **Pressure in the distribution system: -** There would be of great importance in the case of localities having number of two or three storied buildings. Adequate pressure would mean an uninterrupted and constant supply of water.

8. **System of supply: -** The system of water may be continuous or intermittent. In continuous system water is supplied all 24 hours .while in the case of intermittent system water is supplied for hours of the day only results in some reduction in the consumption. This may be due to decrease in loss and other waste of full use.

9. **Method of charging: -** In a town where meters are used less quantity of water will be used than in towns without meters in their system. A metered supply ensures minimum of waste as the consumer because of they know there is payment as per consumption.

Water consumption for various purposes is divided under the following categories.

1. Domestic demand
2. Public demand
3. Commercial & industrial demand
4. Fire demand
5. System loss
6. Animal water demand
7. Institutional water demand

4.1.3.2. Domestic water demand

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

A. Demand Computation by mode of service

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

1. House connected tap users (HTU)

2. Yard connected user (YU)
3. Yard shared connected user(YSU)
4. Public tap uses (PTU) for rural

The percentage distribution of population for each mode of service as shown in table below

Table.6. Primary water source of sample house hold

S/N	Connection Type	% of Population By mode of Service	Number of population per service(2016)
1	Privet house connection	7	3,513.23
2	Privet yard	47	23,588.83
3	Privet yard shared	46	23,086.94
	Sub Total	**100**	**50,189.00**
4	Public Tap User(Rural)	100	28,000.00
	Total		**78,189.00**

Source.From Welkite town water supply and sewerage enterprise

C. Average Demand by mode of service

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

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

Table.7. Domestic water demand for different categories of consumer

S/N	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 Tap User(Rural)	20 l/c/day	25 l/c/day

Source .Design criteria of MoWR(2006)

Table.8. Analysis of Average Day Demand

S/N	Connection Type	Number of population per service(2016)	Per Capital Demand(l/c/day)	Average Demand(l/c/day)	Average Demand(m3 /day)
1	Privet house connection	3513.23	60	210793.8	210.8
2	Privet yard	23588.83	30	707664.9	707.7
3	Privet yard shared	23086.94	40	923477.6	923.5
	Sub Total				**1841.9**
4	Public Tap User(Rural)	28000	20	560000.0	560.0
	Total				**2401.9**

4.1.3.3. Non-Domestic Demand

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

Non – domestic demands are:-

1. Institutional demand
2. Commercial demand
3 .Industrial demand
4 .Fire demand

Table.9. Institutional and Commercial Demand

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

Source: Design Criteria Guide Line of MoWR (2006)

A. Institutional demand

- **Educational demand**

The water demand for educational institutes is classified in to

i. Day schools

ii. Boarding school

i. Day Schools

There are five elementary schools with 3200 no of students, two junior schools with total students 4322 and one senior high school with 2500 students a total 10,022 students attending day school according to the Welkite town administration office education desk and the schools themselves. The demand calculated including 500 teachers

Demand =10,522*5 l/Stu/day=**52.6m3.**

ii. University and collage

In Welkite there is one University and one Collage the maximum number of students / trainee staff and supporting staff is around 12,000.

Demand=12,000*60lit/pub/day=**720m3**

Among this 50% of the total Demand Covered by university by drilling bore hole .There for, demand needed from Welkite water supply system will be **360m3/day**.

- **Health institutes**

In 2015, there is one hospital, three health center and six private clinics with a total of about 150 beds. The demand by taking average per capita demand per bed of 60lit/capita/bed became

Demand =150 bed *60lit/capita/day=**9m3/day**

❖ **Public and governmental offices**: -

According to CSA about 51% of the population of Welkite town is economically active and 7% of the population of Welkite is employed in public or government offices. And their consumption is recommended as 5 l/c/d.

=51,198*7%*5l/c/d=**17.9m3/day**

B. Commercial demand:-

Welkite town is fast growing commercial center and transit polite for an estimated 10,000 visitors per day .These visitors pass through the town on their way to western part of Ethiopia or come from this part of the country of Addis Ababa. The water demand of the hotels, bars and restaurants estimated as by taking the consumption in 2015 is **148m3/day.**

C. Industrial demand

There are two factories in Welkite town at present which have a total land area of about 47.822m2. According to recent survey, the existing industrial demand is **39.5m3/d.**

D. Churches and Mosques

There are 10 churches and 6 Mosques in Welkite town. The current (2015) water demand for mosques and churches is 35m3/day.I.e.10m3/d for churches and 25m3/d for mosques.

E. Fire Demand

Fire generally breaks out at commercial centers, stores etc. Big cities which have valuable properties require large quantity of water for firefighting. Fire demand is the quantity of water needed to extinguish fire which depends upon population, centers of buildings density of buildings and their resistance to fire. The quantity of water for fighting is small compared to the annual average consumption of water which will not be more than the amount of water distributed during the max day water demand. For this study firefighting purpose 10% added on the reservoir Size.

Table.10. Summary of Non-Domestic Demand

S/N	Institutions	Demand (M3/Day)
1	Day School	52.6
2	University and Collage	360
3	Health Institution	9
4	Public and Government office	17.9
5	Commercial demand	148
6	Industrial Demand	39.5
	Total Sum	**627**

Table.11. Summary of Domestic and Non-Domestic Demand

S/N	Item	Demand (M3/Day)
1	Domestic	
	Urban	1,841.9
	Rural	560.00
2	Non-Domestic	627.00
	Sub Total	3029
3	30% loss(for scheme having 10 year service)	908.7
	Total Sum	**3,937.7**

4.1.4. Demand Variations

4.1.4.1. Seasonal Peak

Towns in Ethiopia are characterized by widely varying climatic conditions and so the variations in consumption during the year, reflected by a peak seasonal factor, will similarly vary. Some consultants have adopted a seasonal peak factor of 1.1. The seasonal peak factor adopted for any particular scheme shall be selected according to the particular climatic conditions and existing consumption records (if reliable and unsuppressed). It is expected that seasonal peak factors will vary between 1.0 and 1.2, representing the relative increase in the average daily demand during the dry and/or hot season months compared with the average annual demand.

4.1.4.2. Peak Day Factor

Many communities exhibit a demand cycle that is higher in one day of the week than in others. This situation shall be taken into account by the use of a peak day factor. Some consultants have used peak day demand factors of between 1.0 and 1.3. The value adopted for the design of each individual scheme shall be selected according to judicious observance of the habits of consumers and the knowledge of the community and system operators. It is expected that any value selected for the peak day factor would not fall outside the above range.

4.1.4.3. Peak Hour Factor

Water demand varies greatly during the day. The distribution system must be designed to cope with the peak demand, which is taken into account by the use of a peak hour factor.

Table.12.Population Vs MDDF and PHF

Population	MDF	PHF
0 – 20,000	1.3	2
20,010 - 50,000	1.25	1.9
50,001 and above	1.2	1.8

Source: Design Manual of MoWR (2006)

- **Calculation MDD and PHD**

Average Day Demand (ADD) = 3,937.7 m3/Day

Maximum Day Demand= ADD *MDF = 3937.7*1.2 = 4,725.24m3/day = 54.7 l/sec

Peak Hour Demand (PHD) =ADD * PHF =3937.7 *1.8 =7,087.86m3/day= 82 l/sec

4.1.5. Reservoirs

4.1.5.1. General

Operational reservoirs should be provided to command a distribution system, located at elevations providing the required pressure for water flow within the system. They should have sufficient storage to cover the difference between hourly peak demand and actual supply from the source, firefighting demands if to be allowed for, and for a limited emergency volume in case of power breakdown, repairs or O&M activities.

4.1.5.2. Types of Reservoirs

The two main types of reservoir are the ground level type (GLR) and elevated water tank type (EWT). Whenever the local topographical conditions permit, ground level reservoirs are preferable. Ground level reservoirs will be usually be of solid block masonry or reinforced concrete, cylindrical or rectangular but under special circumstances may be of glass reinforced plastic (GRP). Elevated water tanks will be cylindrical or conical in reinforced concrete **(M0WR 2006)**.The study area has two ground and one elevated functional circular reinforced concrete reservoir

4.1.5.3. Reservoir Location

A reservoir location should maintain the desired pressure range in the supply network. Possible future extension of the storage capacity should be taken into consideration when selecting a site.

4.1.5.4. Reservoir Equipment's

Reservoirs should be provided with inlet, outlet, drainpipe, overflow pipe, water level indicator, manhole Ladder, ventilation pipe, lightening conductor.

4.1.5.5. Total Storage Requirement

In order to provide for security of supplies above the need for balancing purposes it is recommended that the minimum total reservoir storage capacity be in the range of 30% to 50% of the average daily demand **(M0WR 2006)**.

The study area has one 1000m3 reservoir, one 500m3 reservoir and one 100m3 elevated reservoirs which have a total of 1600m3 reservoir. To check this capacity enough or not the total average day demand as per computed above is 3,937.7 m3/day and the level of existing storage computed as:-

= 0.3*3937.7 to 0.5 *3937.7

= 1,181.31 m3/day to 1,968.85 m3/day

Their for, the storage capacity of existing reservoir has been on the recommended renege and so far the scheme is safe regarding to storage capacity .

4.1.6. Finding and conclusion

From the water supply analysis as per level of average per capital consumption of the town found to be 19.5 l/day. This average per capital consumption is lower while compared with the minimum requirement of domestic demand which is 25 l/c/day set by Wallinfford HR.

The other way followed to evaluate the town water coverage was the level of connection per family. The average level of connection in house or yard is about 60% which is relatively good coverage compared to per capita demand.

The other issue that has been addressed was analysis of water coverage as per domestic and non-domestic demand. The result shows as the total average demand is 3,937.7 m3/day. However, the amount of water production in 2015 shows as 810,153 m3/year or 2,220 m3/day, which have only 56% coverage of the demand. Therefore, the result shows there is high gap between demand and supply.

On the other hand the analysis shows as the maximum day demand is 4,725.24 m3/day (54.7 l/s) and peak hour demand is 7,087.86 m3/day (82 l/sec).Therefor, to satisfy the demand the pressure main pipe line and the capacity of the pump should have ability to meet the maximum day demand 54.7l /sec. However, the existing pump has a capacity to lift 40 l/s which is 69% of the maximum day demand .This show as the need of more pump.

4.2. Water Loss Analysis

4.2.1. Non-Revenue Water

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

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

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

A. Total Water loss expressed as

Three year production and consumption data of the study area used to compute the total loss as shown in table.10 below by using this expression.

$$NRW\ (\%) = \frac{(Production - metered\ use) \times 100\%)}{(Production)}$$

Table.13. Computed Total Water Loss

Year	Production(m3/Year)	Consumption(m3/Year)	Loss(M3/Year)	Loss (%)
2013	618334	495061	123273	19.94
2014	731955	581312	150643	20.58
2015	810153	649391	160762	19.84

B. Water loss expressed as per number of connection

The total number of connection in the study area is 6909 ,the water loss per connection computed by using this expression

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

From three years computed total annual water loss the last year value 160,762m3/Year used .

Water loss =160,762*1000/(6909*365)= **63.75 lit/connection/day**

C. Water loss expressed as per length of pipes

Expressing water loss as per kilo meter of main pipe is one way to indicate the loss. The total length of pipes of size 50mm to 300mm is 109km and these total pipe length used to express the water loss.

Table.14. Summary of pipe length by age category

S/N	Age Category	Pipe Length(m)	% from total	Remark
1	10 Years and less	71,400.00	65.50	Gravity main line and Distribution
2	10 to 20 years	25,600.00	23.49	Distribution
3	20 t0 30 years	12,000.00	11.01	Distribution
	Total length	109,000.00	100.00	

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

=160,762/(109km *365) = **4m3/km/day**

4.2.2. Real and Apparent Loss Analysis

Non-revenue or total loss is the sum of real loss and apparent loss. However, for this study unable to compute total real loss due to limitation of night hourly consumption data, instead of this unavoidable real loss is computed by using IWA expression. The expression is good indicator of loss and this study focus on two different areas which have relatively high and low average pressure.

The IWA Water Losses Task Force Developed equation and its parameters A,B,C based on statistical analysis of international data, including 27 different water supply systems in 20 countries.

Unavoidable Average Real Losses (UARL): It is recommended that the calculation of the UARL in litres/service connection/day is based on the following form of equation. This recognizes separate influences of real losses from length of mains (Lm in km), number of service connections (Nc), total length of service connections from the edge of the street to customer meters (Lp in km), and average pressure (P in meters) when the system is pressurized.

UARL = (A x Lm/Nc + B + C x Lp/Nc) x P (Litres/service connection/day)

The appropriate values for A (18), B (0.80) and C (25) The equation and its parameters A,B,C are based on statistical analysis of international data, including 27 different water supply systems in 20 countries.

Location 1.From 500m3 balancing reservoir to 1000m3 service reservoir.

There for,
Length of mains (Lm in km) =52 km
Number of service connections (N c) =798
Total length of service connections from the edge of the street to customer meters average 10m for individual (Lp in km), =20m*798=15,960m=15.96km

Average pressure (P in meters) =93m , From model pressure result of these pipe line

UARL = (A x Lm/Nc + B + C x Lp/Nc) x P
= (18 *52/798 +0.8 + 25 * 15.96/798)*93
= 230 Lit / Service connection / Day
Annual Volume UARL = 230 Lit *365= 83,950 Lit/Connection/year
Total Annual UARL in all Connection = 83,950 Lit/Connection/year*798 Connection = **66,992.1m3/Year.**

Location 2.From 500m3 balancing reservoir to 1000m3 service reservoir.

There for,

Length of mains (Lm in km) =57km

Number of service connections (N c) =6,111

Total length of service connections from the edge of the street to customer meters average 10m for individual (Lp in km), =20m*6,111=122,220m=122.2km

Average pressure (P in meters) =22m, **From Model result for distribution system.**

UARL = (A x Lm/Nc + B + C x Lp/Nc) x P

=(18 *57/6,111 +0.8 + 25 * 122.2/6111)*22

= 32.3Lit / Service Connection /Day =

Annual Volume UARL = 32.3 Lit *365= 11,787.2 Lit/Connection/year

Total Annual UARL in all Connection = 11,787.2 Lit/Connection /year*6,111 Connection =**72,031 m3/Year.**

Total sum from location 1 and 2 =139,023m3/year

Apparent loss =NRW-UARL

NRW of 2008 used from the table 10 which is **160,762m3/year**

Apparent loss plus avoidable real loss =160,762m3/year -139,023m3/year

= 21,739m3 /year

5.2.3. Findings and conclusion

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

- From the water loss analysis in different location of the water supply system ,higher water loss is found relatively on gravity flow main line from balancing reservoir to service reservoir than distribution system. This line have low pipe length and connection compared to the distribution system but have relatively higher unavoidable real loss as a result of high pressure found in this location.

- The total pipe age categories are aged less than 30 years. From this, it can be conclude that all the pipe have relatively younger ages. On the other hand the unavoidable real loss is higher. This can give an indication that the impact of non-physical water loss is bursting of pipe due to high pressure and availability of low size pipe as per the demand.

- From the analysis the unavoidable real loss covers 86.5% of the total loss computed by using production and consumption data and the apparent plus avoidable real loss covers only 13.5%.However, this proportion is not logical because unavoidable real loss is should be much less than avoidable plus real loss. For good scheme URL can be reduced to 10%. Therefore, need giving attention on the used production and consumption data reliable or not.

Furthermore, the case study done by Water Aid Ethiopia in 2010 for seven towns of the country shows as the water loss of Welkite Town is 43%, However, the production and consumption data obtained from the town water supply and sewerage enterprise shows as the loss in 2013 reduced to 19%, without followed any mechanism to detect the leakage how can reduced to such level?. In addition, Ethiopian GOV plan to reduce NRW from 39% to 20% until 2020.Moreover, as shown on the raw data of meters bill, there is a number of unregistered periods and to compute the annual consummation they fill the gap by assumption. This shows as the used data of production and consumption is not reliable as well the result doesn't show as the current level of NRW. Therefore, need further research to identify appropriate value of water loss by collecting primary data.

4.3. Hydraulic Model Analysis

4.3.1. Model skeletonization

In order to skeletonize the model to an acceptable degree, **Elsheikh et al,(2014)** reviewed the study adopted by **USEPA(2005)** and conditions used as follows:

- ❖ At least 50% of total pipe length in the distribution system (as shown in Table 12 below) for current study reaching 53.2%.
- ❖ At least 75% of the pipe volume in the distribution system (as shown in Table 12 below) for current study reaching 88.64%).
- ❖ All 200 mm and 300 mm diameter and larger pipes, storage facilities, major demand areas, pumps, and control valves are part of the study.

Table.15. Size ,length and Volume of Surveyed Pipe material

S/N	Length of pipe(L=KM)	Diameter(mm)	Diameter(m)	Volume (m3) (Pi*d2/4)*L
1	32	300	0.3	2262
2	2	200	0.2	251.3
3	2.4	150	0.15	169.65
4	7.35	100	0.1	231
5	5.8	80	0.08	116.6
6	8.4	60	0.06	95
Sum	**57.95**			**3,125.55**

The Remains pipe has length of 51,005m with 50mm diameter and has volume of 400.6m3.

Table.16. Length and volume of pipes before and after skeletonization

Item	Before model skeletonization	After model skeletonization	Percentage of skeletonization
Total Length of pipe	109km	57.95	53.2%
Total Volume of pipe	3,526.15	3,125.55	88.64%

4.3.2. Node Demand Analysis

The water demand Analyzed based on the number of customer of Domestic, Public and industrial user of each junction by using the current per capital demand. The demand analyzed by considering 24 hours demand patters and as information obtained from Welkite town water supply and sewerage enterprise indicates that the peak hour demand of the town is occur at 9:00 AM to 12 AM. and 6:00 PM to 9:00 PM.

To compute the demand at different loading condition needs respective demand factors. According to design manual of M.WR(2006) the maximum day factor and peak hours factor set as per the number of population. Hence, the MDF and PHF of Welkite town is 1.2 and 1.8 respectively. Moreover, Welkite town has very high potential for development. Therefore, by using 1.05 adjustment factors the peak hour factor became 1.9.

Population Vs MDDF and PHDF

Population	**MDF**	**PHF**
0 – 20,000	1.3	2
20,0010 - 50,000	1.25	1.9
50,001 and above	1.2	1.8

Source: Design Manual of MWR(2006

- **Adjustment due to socio-economic factors**

Socio-economic factors determine the degree of development towns.

Group A towns enjoying high living standards and with very high potential for development factor of 1.10

Group B towns having a very high potential for development but now lower living standards factor of 1.05

Group C towns under normal Ethiopian conditions a factor of 1.00. **MoWR(2006)**

However, low demand is occur at night time and to fix low demand factor needs night flow data of the system. But, Welkite town water supply system has no night flow data. Their for, for this research by considering the level of the town, population size and climate condition Arbaminch town 24 hours demand patter data has been used. Hence, the low demand factor is 0.25. **See Appendix (7).**

Their for, by using those factors and computed base demand for each junction peak hour ,low hour and maximum day demands calculated for all junctions and by using the model the level of Pressures analyzed in four scenario (ADD,MDD,PHD,LHD). **See Appendix (8).**

❖ **Here Sample Calculation made at J-1**

J-1 located near to balancing reservoir which supplies water for 3002 rural community from the main line from constructed four public water points.

Base Demand = Population * Per Capita Demand per Day (20 l/day)

= 3002 * 20 l/day=60,040 l/day=0.69 li/sec

MDD=0.69 l/s *1.2 =0.83 l/s

PHD =0.69 l/s* 2 = 1.38 l/s

LHD= 0.69 l/s *0.25= 0.17 l/s

4.3.3. Relationship between Pressure and Water Demand

Pressure variation in a distribution network is caused, amongst others, by changes of demand of the users. Frequent starts and stops of pumps, closure and opening of control valves that induce water hammer are also some of the causes to be mentioned for pipe breakage and water loss. The pressure diagram has an almost reversed pattern: low during daytime with increase of demand and high during night hours when the demand is low., there is an excess pressure build-up in a network when demand drops especially during the night. However cut down this unduly excessive pressure in order to avoid the bursting of pipes or reduce the amount of leakage

The following methods can be used to cut down of the excessive pressure:

- Install a **pressure-reducing valve** (PRV) or
- Divide the system into **pressure zones.**

❖ Pressure Control in the Network

The pressure in the Control (nodal) Point can be made constant by opening and closing the PRV as dictated by the changes in demand. The PRV allows the regulation of pressure for only one Control Point. Similar installation has to be made elsewhere at nodes where unnecessarily high pressures are identified.

Figure.7.Typical installation of PRV

4.3.4. Analysis and discussion of the model out put

According to the imported data to model the pipe system network established and hydraulic analysis made in all junction. As the network system built as per different demand pattern, the level of pressure and velocity compered between four Scenarios.

- **At average Day demand Condition**

Maximum Pressure =283.4m, at J-00010

Minimum Pressure = 3.6m, at J-13

Maximum Velocity =1.71m/se at p-16

Minimum Velocity = 0.03m/s, at P-24

- **At Maximum Day Demand**

Maximum Pressure =281m, at J-00010

Minimum Pressure = -1.21m, at J-51

Maximum Velocity =2.1m/se at p-51, with Pipe Diameter 63mm

Minimum Velocity = 0.16m/s, at P-64, with pipe diameter 110mm

- **At Peak Hour Demand**

Maximum Pressure =277m, at J-00010

Minimum Pressure = -79m, at J-49

Maximum Velocity =2.74m/se at p-53, with Pipe Diameter 63mm

Minimum Velocity=0.01m/s,atP-37,with pipe diameter 110mm:(**See Appendix- 9)**

❖ **At Low Hour Demand**

Maximum Pressure =284.11m, at J-00010

Minimum Pressure = 4.5m, at J-13

Maximum Velocity =1.26 m/se at p-53, with Pipe Diameter 63mm

Minimum Velocity = 0.01m/s,at P-36, with pipe diameter 110mm: (**See appendix 10).**

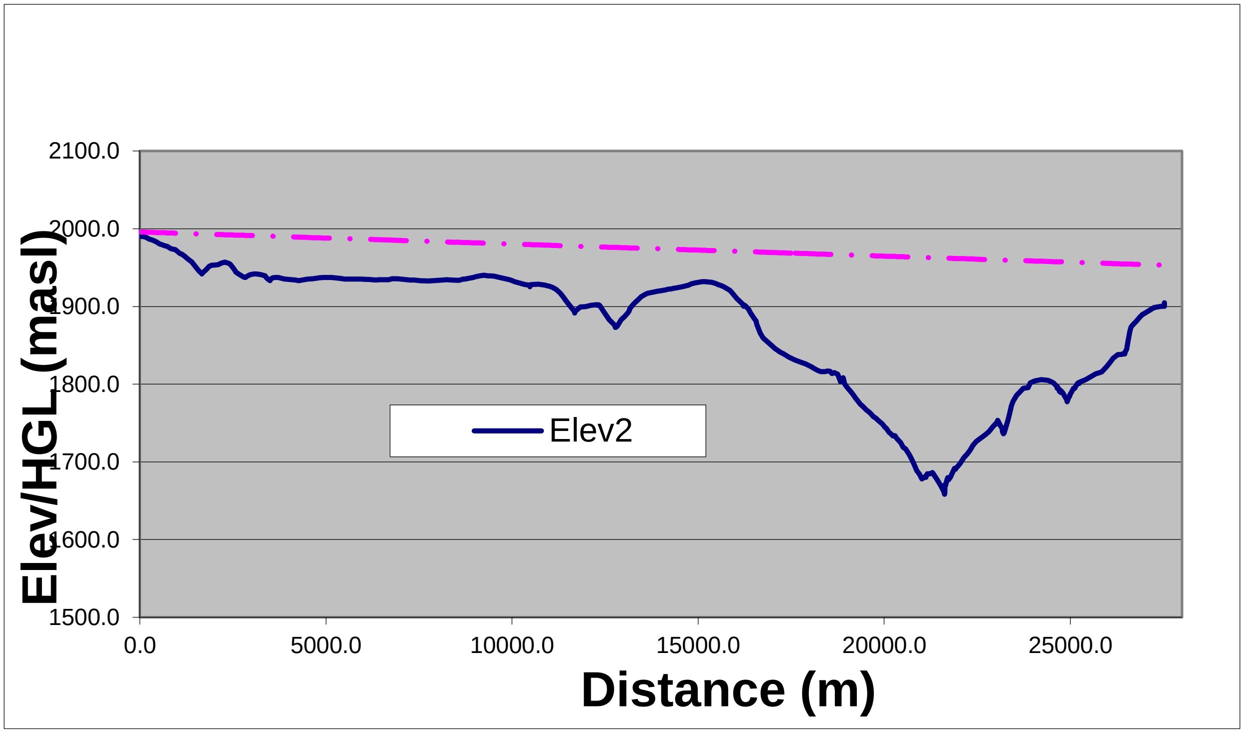


Figure .8.Profile of Gravity Main Pipe line

For safe Hydraulic system recommended value of pressure and velocity by MoWR(2006) is at distribution system the pressure must be not less than 15m and more than 60 m head ,the minimum velocity not less than 0.6l/s and the maximum velocity should be less than 2l/s.

❖ Pipe Net Work

The color coding of the pipe and junction related to velocity and pressure is

Pressure = 0 - 15m Red

= 15 --60m Megenta

= 60---285 Cyan

Velocity = 0 – 0.6m/s Blue

= 0.6---1.5m/s Yellow

= 1.5 –2m/s Green

As shown in the network below at low demand there is high pressure and low velocity and at peak demand the pressure became less and relatively the velocity increase

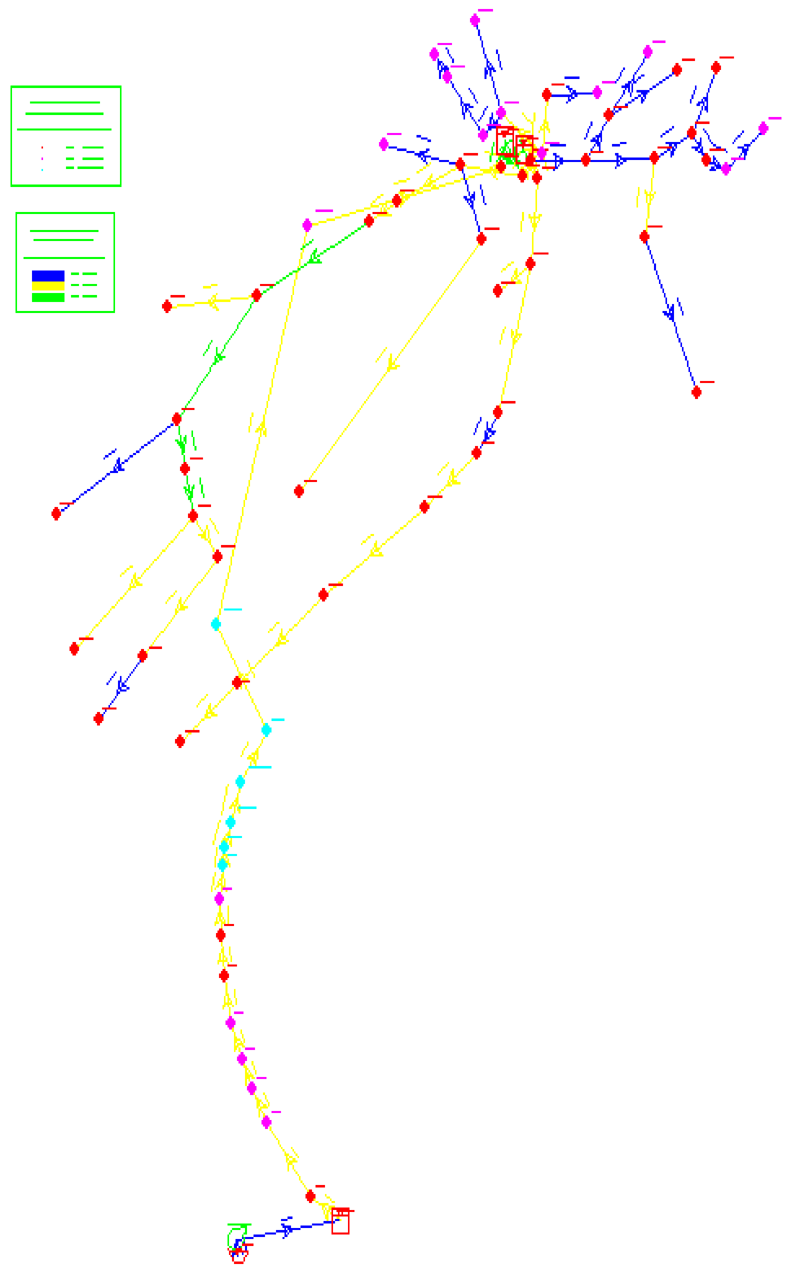


Figure.9. Pipe Network at Peak Demand

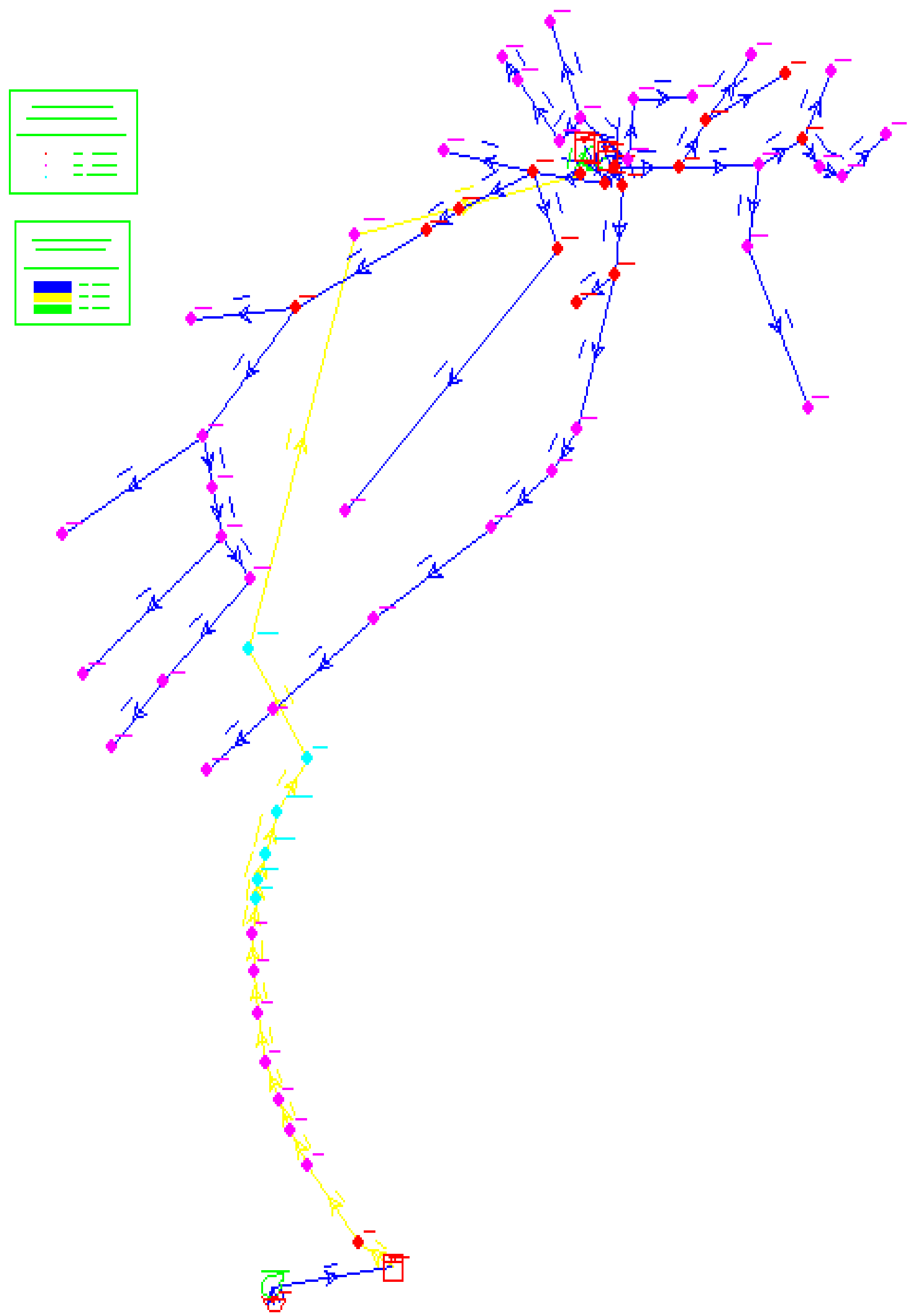


Figure.10. Pipe Network at Low Demand

4.3.5. Model Calibration and Validation

Calibration is an iterative procedure of parameter evaluation and adjustment by comparing simulated and observed values

The Water Cad Model was calibrated by adjusting sensitive parameter such as Hazan Williams Coefficient. As the model gives automatically C value of DCI Pipe 130 and for uPVC pipe 150 since, the system is old and should have roughness coefficient of pipe less than the model value. There for, this standard value of Hazen-Williams (C-value) used to adjust the model Value until closed to the measured value.

Table.17. C value for pipe materials

S/N	Type of Material	C value for New Pipe	C Value For Existing Pipe
1	uPVC	130	100-110
2	Steel	110	90-110
3	DCI/GI	120	100-110

Source. Design Criteria Manual of MoWR (2006)

Twenty observed pressure data were collected at main and distributing networks as shown in the table below for calibration and validation.

Model validation is in reality an extension of the calibration process. It is used to assure that the calibrated model property assesses all the variables and conditions, which can affect model results, and demonstrate the ability to predict field observation different data set. The hydraulic model calibration parameters that are typically set and adjusted pipe roughness factors. The change in this parameter affects head losses and pressure. The result shows that when the Hazan-Williams roughness coefficient increases the value of the pressure increases and head losses decreases.

4.3.5.1. Model Performance Evaluation criteria

There are many ways to judge on the performance of model calibration. The evaluation was made by calculating the squared relative difference between observed and simulated pressure for each test. The evaluation criteria used was statically method Using correlation coefficient (R^2).

$$R^2 = \frac{\text{Sum(X-X mean)(Y-Y mean)}}{\text{(SQUR(Sum(X-X mean)}^2\text{) x Sum(Y-Y mean)}^2}$$

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

4.3.5.2. Pressure Calibration and validation

ATSDR(200) illustrated that an average pressure difference of ± 15.2 kPa (± 1.51 m) with a maximum difference of ± 50.3 kPa (± 5.03 m) represents a "Good" data set and an average pressure difference of ± 29.6 kPa (± 2.96 m) with a maximum difference of ± 97.9 kPa (± 9.79 m) represents a "Poor" data set.

Table. 18. Data Arrangement for pressure Calibration and Time series with pressure networks

S/N	Sample Location pints	Measured Pressure(m)	Computed Pressure	Difference	Measured Time	Sample Location		
						X(m)	y(m)	Elevation
1	J-1	15	14.6	0.4	7:00	366,235.07	913,292.38	2,008.00
2	J-2	50	52.86	-2.86	7:15	366,075.61	913,375.56	1,954.00
3	J-4	40	41.16	-1.16	7:45	365,607.49	913,555.98	1,945.00
4	J-6	15	14.07	0.93	8:15	365,372.27	913,763.43	1,944.00
5	J-8	45	45.36	-0.36	8:30	365331.02	914072.12	1,912.00
6	J-9	200	201.37	-1.37	9:00	365,388.40	914,191.14	1,749.00
7	J-11	120	121.2	-1.2	10:00	365,548.78	914,506.37	1,808.00
8	J-17	10	12.89	-2.89	10:15	367,969.23	916,201.10	1,898.00
9	J-22	35	31.93	3.07	10:45	367,994.09	915,951.59	1,878.00
10	J-23	15	15.88	-0.88	11:00	368,067.56	916,344.78	1,895.00
11	J-31	25	24.42	0.58	11:30	367,174.38	915,109.74	1,885.00
12	J-32	30	29.62	0.38	12:00	366,802.38	914,822.74	1,880.00

The calibration of pressures were done in statically method and Figure 12 shows that the statistical correlation plot of observed versus computed pressure during calibration process .The result shows that R2=99.92%.this implies that the computed pressure are within the acceptable limit.

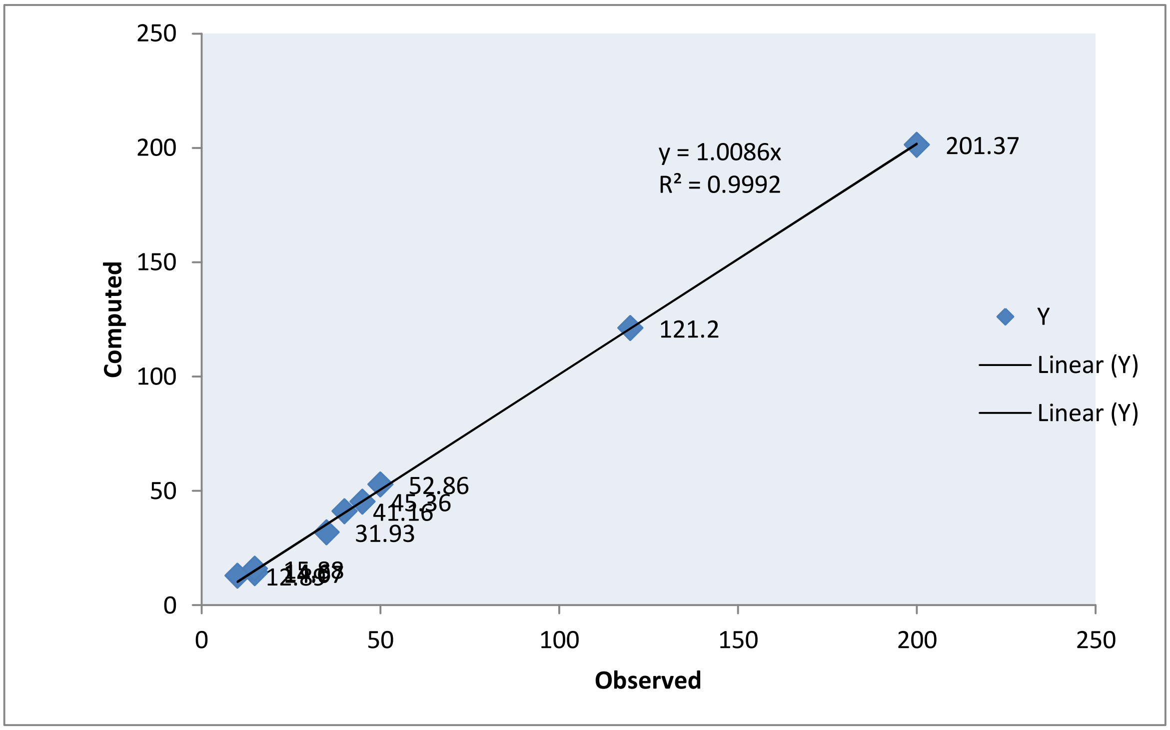
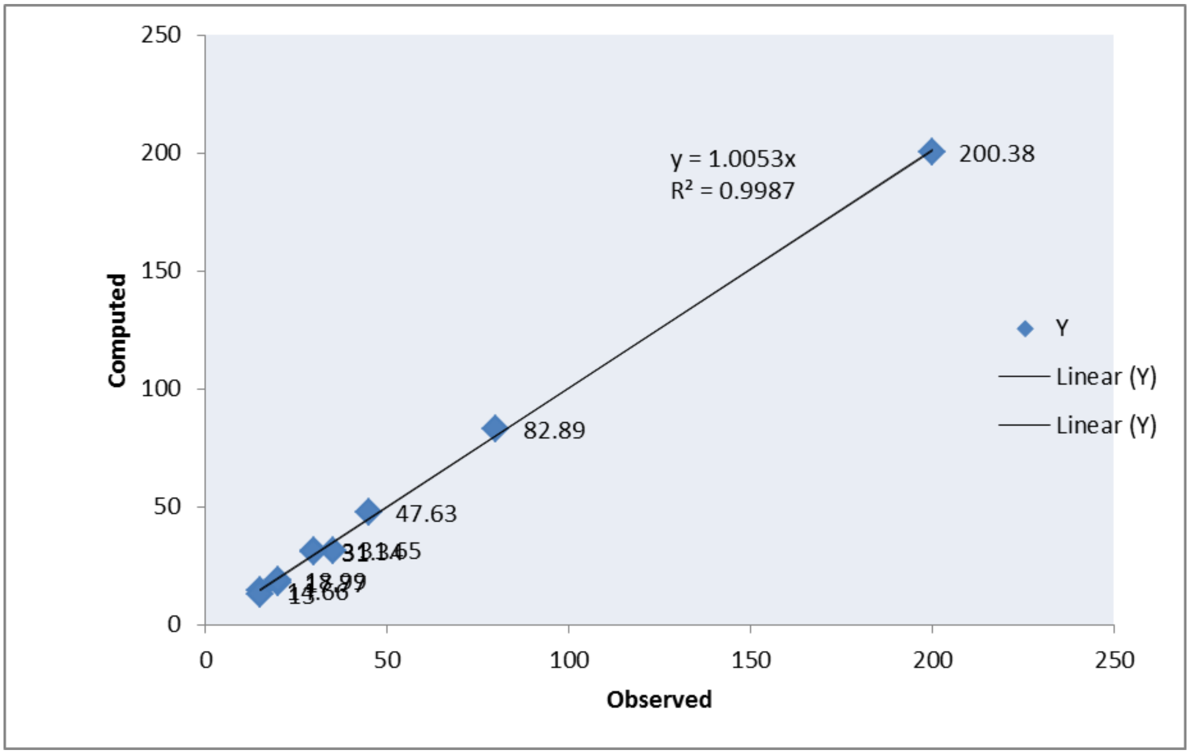


Figure.11. Correlated Plot of Observed Vs Computed Pressure during Calibration

The Validation of pressures were done in statically method and Figure 13 shows that the statistical correlation plot of observed versus computed pressure during Validation process .the result shows that R^2=99.87%.this implies that the computed pressure are within the acceptable limit.

Table. 19. Data Arrangement for pressure Validation and Time series with pressure networks

S/N	Sample Location pints	Measured Pressure(m)	Computed Pressure	Difference	Measured Time	Sample Location		
						X(m)	y(m)	Elevation
1	J-1	15	14.66	0.34	3:00	366,235.07	913,292.38	2,008.00
2	J-3	45	47.63	-2.63	3:30	365,823.92	913,471.82	1,951.00
3	J-6	20	17.77	2.23	3:45	365,372.27	913,763.43	1,944.00
4	J-9	200	200.38	-0.38	4:00	365,388.40	914,191.14	1,749.00
5	J-11	80	82.89	-2.89	5:00	365,548.78	914,506.37	1,808.00
6	J-17	15	13	2	5:30	367,969.23	916,201.10	1,898.00
7	J-18	20	18.99	1.01	5:45	368,097.40	916,243.93	1,892.00
8	J-21	35	31.65	3.35	6:00	367,849.67	915,882.29	1,879.00
9	J-22	30	31.34	-1.34	6:30	367,994.09	915,951.59	1,878.00
10	J-32	30	31	-1	6:45	366,802.38	914,822.74	1,880.00
11	J-33	35	36.66	-1.66	7:15	365,994.06	914,694.37	1,870.00
12	J-34	35	35.84	-0.84	8:00	365,744.10	914,652.84	1,871.00



Figur.12. Correlated plot of observed Vs Computed Pressure during Validation

4.3.6. Finding and conclusion

- Regarding the Model out Put, high pressure has been found at low demand and high velocity occurred at the period of peak demand. As shown on filed visit the pipe size of the existing distribution system is installed not corresponding with the demand, same place there is high demand with low pipe size like at P-53,63mm diameter and low demand with high pipe size at P-37,110mm diameter. As a result high velocity occurred for smaller Pipe size and low velocity occurred for largest pipe size with low demand.
- From model out put the maximum pressure occurred at gravity main 284.1m is above to much the recommended value and it's the reason of pipe burst. In addition, the amount of pressure calculated in design document at the same location and demand period shows as 336m. The difference shown due to night demand variation. Beside to this, for this critical location the design recommended pipe thickness of PN-35 but the pipe material on the ground is PN-25 and less so this is the reason behind the challenge around this location. The Chart and Pressure at night flow demand of the design document Attached in **Appendix 13.**
- Moreover, after gravity main pipe crossing the "Wabe river" (on the side of Welkite town), the topography goes up to service reservoir and the pipe crosses the asphalt road four time by following the gravel road side. Hence, due to the increasing topography and the bend of pipe in eight different locations, at service reservoir, the pressure reduces to 17.5m. Therefore, unable to apply pressure reduction technics on high pressure zone due to the available free head in service reservoir is low.
- Bursting of the gravity pipe line was happened not only in the high pressure zone but also happened in normal pressure zone of uPVC pipe due to operational problem. The reason is during the time of pump operation and the balancing reservoir out let open same time the pump stopped ether due to the light off or pump stuck. Since the outlet is open until the reservoir is empty. Consequently, the reservoir and the pipe line filled by air. Since, the next pump

operation starts without air releasing this leads to atmospheric pressure in pipe greater than hydrostatic pressure and results pipe collapse.

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

4.4.Water Supply Scheme Management

4.4.1. Sector Organization

4.4.1.1. Key Sector Institutions

Ethiopia's decentralized local government structure consists of federal level ministries, nine regional administrations, 2 administrative cities (Addis Ababa and Dire Dawa), and about 550 weredas (district) level administrations. Each wereda consists of a number of Kebeles (villages), which is the lowest level of government at the community level.

Over the past 50 years, the institutional structure of the water sector had undergone significant changes. The Water Resources Department was established in 1956 under the Ministry of Public Works, the Water Resources Commission in 1982 followed by Ministry of Natural Resources in 1992. Ministry of Water Resources (MOWR) was established in 1995, the Water Works Construction Enterprise, the Water Well Drilling Enterprise and Water Works Design and Supervision Enterprise were also created to undertake water resources development works.

In line with the Government's on-going decentralization strategy, the responsibility for both urban and rural water supply was transferred to the regional governments in 1995 while the Addis Ababa Water Supply and Sewerage Authority (AAWSSA) remained an autonomous public Authority. Presently, the main institutional players in the water sector are described below.

4.4.1.2. Role of the Sector Institutions

The Ministry of Water Resources (MOWR): The MOWR at federal government level is mainly entrusted with the policy formulation, guidance and review, implementation, operation and regulatory work. It also has the responsibility of building the capacity of Regional Governments regarding water resource development, and preparation of plans for the proper utilization of water resources. The ministry also coordinates donor funded projects among the financiers and the implementing regions.

The Regional Water, Mine and Energy Bureaus(RWMEB): Each of the nine regions and the Dire Dawa city administration has a Regional Water Bureau and Addis Ababa Water and Sewerage Authority. The Regional Water Bureaus are in charge of all water resources development activities within their regions. They are responsible for the strategic planning, organizing, coordinating, supervising the overall development and management of water resources projects. RWMEBs are now responsible for approving the zonal water, mine and energy department programmes as well as consolidating M&E reports of the Zones for transmittal to MOWR.

The Zonal Water, Mine and Energy Department (ZWMED): are in charge of all water resources development activities within their zone. They are responsible for the strategic planning, organizing, coordinating, supervising the overall development and management of water resources projects. ZWMEDs are now responsible for approving the woreda water, mine and energy office programmes as well as consolidating M&E reports of the weredas for transmittal to RWMEB.

The Wereda Water Office (WWO): are in charge of water supply development activities for rural areas within their weredas including financial and procurement management and monitoring and evaluation and for contracting with consultants and local service providers. Moreover the office will have a role in initiating, facilitating and providing motivation for community management of rural water services, the application of cost recovery principles, and in monitoring and evaluation. The office will be assisted by the regions, zone and wereda support groups (to build capacity in preparing wereda level Water Supply and Sanitation Programmes.

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

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

4.4.2. Management and Personnel of Welkite Town Water Supply Enterprise

The town water supply is managed by a manager accountable to the Board of Directors chaired by the Mayor of the town. The board meets once in a month since the initiation of the project. The purpose of the meeting is to evaluate the level of service and assurance of remedial solutions taken to alleviate the current shortage of water in the town.

The General Manager(GM) is the responsible person of the town water supply and sewerage enterprise and under GM there are three units such as administration unit, finance unit, and technical unit.

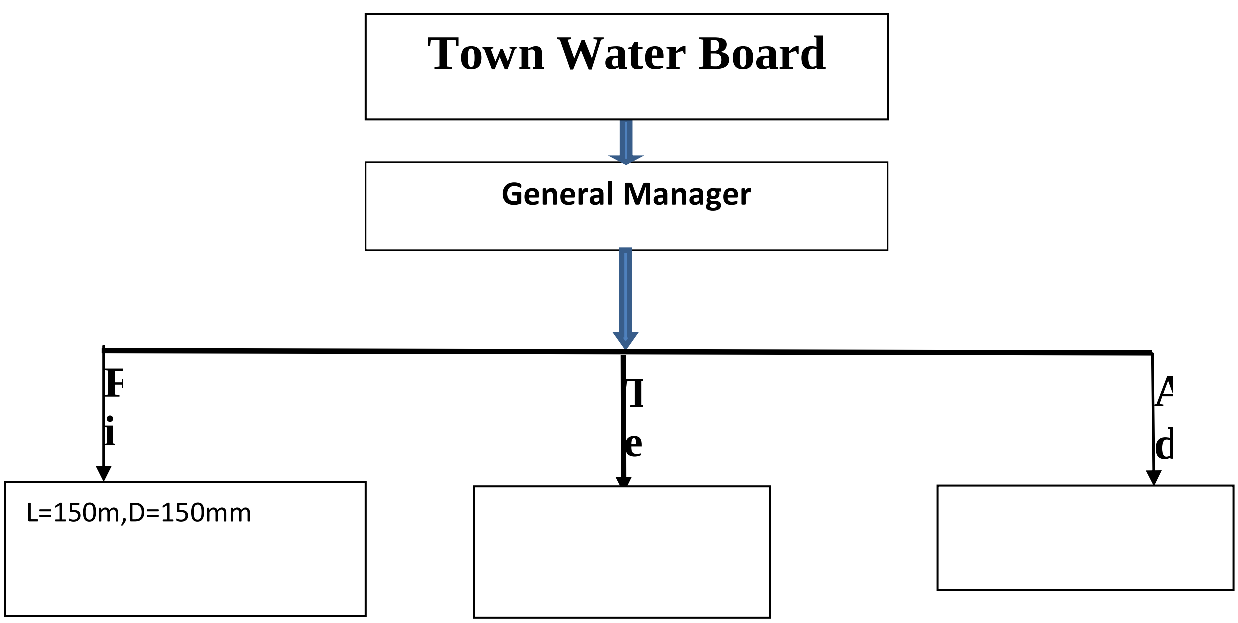


Figure. 13. Structure of Welkite Town Water Supply and Sewerage Enterprise

The service has currently 36 permanent and 18 contract employed staffs. The head of technical staff, finance staff and administration are accountable to the general manager. The scheme have only eleven personnel for operation and maintenance and unable to address all area to solve the current problems. Moreover, Welkite water supply enterprise has no enough committed technical as well as administration staff. In addition to skill gap of the export the enterprise is not well equipped. When pump stack or bursting happened on main line technical invited from zone or region, through this the community suffers for days and weeks by searching water from far away.

4.4.3. Customer Service and Fee Collection

The Welkite town water supply system have a total 6,914 Water Connection, For Privet 5,467 Connection, Government institution 1,242, Commercial centers 122 , 2 connection for industry and 76 Public connection. Due to urban expansion and development a lot of privet as well as commercial customers looking for connection. However, due to water production shortage, technical and management problems water distribution is made on shift bases. To mitigate the problem the utility has currently trying to rehabilitate the existing three bore holes with the budget support of Welkite University which are not function due to pump stack and some other technical problems.

Regarding water fee collection all public taps are operated by the community water point committee; the Utility has entered in to agreement with the water point committee to operate at a normal tariff. The water committee have responsibility to submit the collected fee as per the meter reading. However, as information obtained from office experts most of the water point committee members are not paid the collected money timely. Moreover, for all connections the scheme has only six temporary metering personnel. Therefore, the water supply system is poor in fee collection as well as scheme inspection, especially from institution and rural water points same time the water meter reading made per three month and more. For example the water fee of Welkite University water consumption doesn’t collect for more than a year.

3.1.4.4. Financial Management

Welkite town water supply and sewerage enterprise have analysis of three years income and expenditure of the water supply system from 2013 to 2015. Income of enterprise is from water sales, technical service, from sales of plumbing materials and other different sources and expenditures are staff salary and cost of operation and maintenance. Hence, the result shows that the difference between yearly income and expenditure in 2013 and 2015 became negative and 2014 relatively profitable see table below.

However, following the water policy and its strategy the regional governments have also issued their respective proclamations in which they have made urban water supply services to operate as autonomous entities on full cost recovery base and its management by independent water board where urban populations are over 15,000. Therefore, the town water supply enterprise has responsibility to recover 3,387,783.72 birr/year but for last three years the scheme unable to cover the cost and works only to cover the salary of the staff.

Table.20. Income and expenditure of Welkite town water supply enterprise

S/N	Description	Unit	Year		
			2013	2014	2015
1	Income	Birr	4,309,891.60	7,793,672.79	5,687,587.26
2	expenditure	Birr	4,309,891.72	6,608,774.89	6,026,332.50
3	Difference	Birr	-0.12	1,184,897.90	-338,745.24
4	Annual expected cost recovery amount	Birr	3,387,783.72	3,387,783.72	3,387,783.72
5	Saving after cost recovery	Birr	- 3,387,783.84	- 2,202,885.82	- 3,726,528.96

Source. Welkite town water supply and sewerage enterprise report document

From the table result there is data recording and analysis problem is shown because water production in 2015 is larger than 2014.Therefore, the income should be more in 2015 but it's much less than 2014 so need proper analysis.

Therefore, the management of Welkite town water supply totally need improvement to maximize the overall performance of the utility. Locally there are a number of Water

Supply Services that operate efficiently with the principle of cost recovery and full autonomy. Visiting such institutions would be helpful to improve the performance of the board, management and staffs. Timely upgrading and acquaintance of staffs with innovative ideas, new technologies with clear purpose and change is a tool for improvement.

4.5. Water supply system Improvement

4.5.1. Water demand projection

The design document shows as the demand of the town as well as rural community is forecasted from 2007 to 2017 for 10 years. Hence, the design period remains only one year. In addition, the forecasted population and demand of 2015 on design document is almost reduced by half when compared to the existing situation. From this perspective it is clear to judge that planning such kind of big project just only for 10 years is not economical. Therefore, this study tray to identify the demand need by forecasting the current population and demand for next 10 years.

4.5.1.1. Population Forecasting

From various methods used to forecast the population the method used by the Central statistic Authority selected for this study.

Pn = P0 eG.R*n Where: - Pn = population at n years

n = number of years

GR = growth rate

P0 = population at present

Table.21. Growth rate for Urban and Rural population

Year	Urban Growth rate %	Rural Growth rate %
1995-2000	4.3	3.1
2000-2005	4.1	2.8
2005-2010	4.06	2.5
2010-2015	3.88	2.3
2015-2020	3.69	2.1
2020-2025	3.51	1.8
2025-2030	3.35	1.7

Source. CSA's Country Level Population Growth Rates

Sample calculation for urban

P2021 = P2016 e0.035 (2021 – 2016)

=50,189 e0.035 (5) = **59,787**

Sample calculation for rural

P2021 = P2016 e 0.035 (2021 – 2016)

= 28,000 *e0.018* (5) = **30,637**

Table .22. Forecasted Population

Years	Urban Population	Rural Population	Total
2016	50,189	28,000	78,189
2021	59,787	30,637	90,424
2026	70,689	33,355	104,044

Table.23. Demand Projection

Description	Unit	Year		
		2016	**2021**	**2026**
Population(Welkite town)	No.	50,189	59,787	70,689
Domestic demand (urban)				
Proportion of Population Served by		1	1	1
Private house connection		0.07	0.08	0.09
Private yard connection		0.46	0.47	0.48
private yard shared		0.47	0.45	0.43
Population using different service level				
Private house connection	No.	3513	4,783	6362.01
Private yard connection	No.	23589	28,100	33,931
private yard shared	No.	23087	26,904	30396.27
Per capita Water Demand by Categories				
Private house connection	l/c/day	60	65	70
Private yard connection	l/c/day	30	32	34
private yard shared	l/c/day	40	41	42
Water Demand by Categories				
Private house connection	m^3/day	210.78	310.8924	445.3407
Private yard connection	m^3/day	707.67	899.1965	1153.644
private yard shared	m^3/day	923.48	1103.07	1276.643
Total Urban Domestic Water Demand	m^3/day	1841.93	2313.159	2875.629
Rural Domestic Demand				
Population		28,000	30,637	33,355
Public Tap (Proportion)		100%	100%	100%

Per capita Water Demand	l/c/day	20	21	22
Rural Domestic Water demand	m3/day	560	643.377	733.81
Total Urban and Rural Domestic demand	m3/day	2401.93	2956.536	3609.439
Non Domestic Water Demand	m^3/day	627	627	627
Average day demand	**m^3/day**	**3028.93**	**3583.536**	**4236.439**
Losses and Leakage (25-30%)	m^3/day	908.679	895.884	1059.11
Average day demand including loss(ADD)	m3/day	3937.609	4479.42	5295.548
Total Maximum Day demand(ADD *1.2)	m^3/day	4725.131	5375.304	6354.658
Total Maximum Day demand	**l/sec**	**54.66976**	**62.19227**	**73.52339**
Peak Hour Demand(1.8 *ADD)	m3/day	7087.696	7346.249	8684.699
Peak Hour Demand	**l/sec**	**82.00465**	**84.9961**	**100.482**
Storage Capacity (33% MDD)		1559.293	1773.85	2097.037

From the water demand analysis as shown in the table above to satisfy maximum day demand until end of design period needs a discharge of 73.5l/s and to satisfy the peak hour demand needs 100.48 l/sec. This means, the pressure main pipe should have a capacity to deliver 73.5l/s and the pump should have a capacity to lift 73.5 l/sec. In addition the main distribution pipe should have a capacity to deliver 100.48 l/sec.

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

The potential of Bozebar spring is more than 130 l/s and no difficulty to up grad the discharge. The existing two pumps have a maximum capacity of lifting 40 l/s, 20l/s form each and to satisfy the average day demand additional 33.5 l/s discharge needed. To fill this gap two options are recommended. The first is adding one more pump with the same capacity of the one of the existing pump which has a capacity of 20 l/s and the second is rehabilitation of the existing three bore which have a cumulative discharge of 15l/s.

During upgrading of the spring discharge capacity from 40 to 60 l/s need checking whether the capacity of pressure main pipe can able or not. From model out put the two existing pump has a capacity of 40 l/s with 88m pressure head and velocity of 0.55m/s. Moreover, when the discharge became 60 l/s the head and the velocity as computed by Hazan William equation became 93m and 0.82m/sec (See table below). Hence, the PN-16 PVC pressurized existing pipe has capacity to resist pressure of more than this value and the velocity also on it is recommended limit. There for the system doesn’t affect by additional pump. Using hassen willion formula the head loss due to pipe friction (hf) computed the result shown on table 24 below .

$$^{H}f = 10.675 \frac{(Q)}{C} * 1.852 \times \frac{L}{D*4.87}$$

Where Q = Discharge (m 3/S)

L = Length of pipe (m)

D = Diameter of pipe

C = Pipe material coefficients

Table.24. Hydraulic calculation of main pressure pipe line for improved discharge

	EASTING	NORTHING	ALTITUDE	STATIC	L	DIA	CUM L	Q	V	LOSS	CUMLOSS	HEAD
Spring	376757	900953	1934	0	0	0	0		0.00	0.00	0.00	0.00
PH	377034	900941	1931	3	277	12	277	60.00	0.82	0.74	0.74	2.26
	377333	900877	1949	-15	306	12	584	60.00	0.82	0.82	1.56	-16.56
	377639	900814	1961	-27	313	12	896	60.00	0.82	0.84	2.40	-29.40
	379283	900109	2007	-73	1789	12	2686	60.00	0.82	4.79	7.19	-80.19
	379345	900049	2008	-74	86	12	2772	60.00	0.82	0.23	7.42	-81.42
500m3 RSV	379427	900271	2019	-85	237	12	3009	60.00	0.82	0.63	8.06	-93.06

4.5.3. Design of separate pipe line for rural community

Along the gravity main line between balancing and service reservoir about 26,500 communities has been gain access of drinking water by direct connection from gravity main line. So far, this is one factor which affects the demand of the town. Therefore here is design separate main line and reservoir to serve around 15,000 of rural community and this have additional advantage by reducing the load of gravity main pipe to resist the increasing of discharge. For analysis water demand forecasted by following the step shown above and the hydraulic analysis done by using Hazan William expression, the result as shown the tables below.

Table.25 .Demand projection for rural community

S/N	Parameter	Unit	Year 2016	2021	2026
1	Population	No	15000	17389	20159
2	Per capital demand	l/c/day	20	20.00	20.00
3	Domestic demand	l/day	300,000.00	347,782.22	403,174.91
4	Average daily demand	l/day	300,000.00	347,782.22	403,174.91
5	Average daily demand(ADD)	$m^{3/day}$	300.00	347.78	403.17
6	Max. day demand(MDD)= ADD*1.2 factors/For 12hr Service	m3/day	360.00	417.34	483.81
		l/s	8.28	9.60	11.13
7	Peak hour demand= ADD*1.8 factor/For 12 Hour service	m3/day	540.00	626.01	725.71
		l/s	12.42	14.40	16.69

Table.26. Hydraulic Calculation for Separate pipe line

Pt	X	Y	Z	STATIC	L	DIA	CUM L	Q	V	LOSS	CUM LOSS	HEAD	Village
RSV	379427	899971	2019	0		6	0	11.00		0.00	0.00	0.00	
	379436	899979	2017	2	12	6	12	11.00	0.60	0.03	0.03	1.97	
J1	379345	900049	2008	11	115	6	127	11.00	0.60	0.26	0.28	10.72	Emdebera
	379282	900109	2007	12	87	4	214	9.00	1.11	0.97	1.26	10.74	
	379038	900375	1990	29	361	4	575	9.00	1.11	4.01	5.27	23.73	
	379019	900395	1988	31	32	4	608	9.00	1.11	0.36	5.63	25.37	
	378765	900695	2001	18	393	4	1001	9.00	1.11	4.37	10.00	8.00	
J2	378718	900747	1998	21	71	4	1072	9.00	1.11	0.79	10.79	10.21	Yefek Terk
	378614	900794	1995	24	114	4	1186	7.20	0.89	0.84	11.63	12.37	
	378547	900821	1991	28	72	4	1259	7.20	0.89	0.53	12.16	15.84	
	375988	902984	1961	58	3351	4	4609	7.20	0.89	24.64	36.80	21.20	
	375580	903084	1951	68	421	4	5031	7.20	0.89	3.10	39.90	28.10	
	375011	903095	1948	71	569	4	5600	7.20	0.89	4.19	44.08	26.92	
J3	374744	903110	1951	68	267	4	5867	7.20	0.89	1.97	46.05	21.95	Werer ber
	374622	903115	1946	73	122	4	5989	5.50	0.68	0.55	46.59	26.41	
	374521	903115	1950	69	101	4	6090	5.50	0.68	0.45	47.04	21.96	
	373804	903140	1949	70	717	4	6808	5.50	0.68	3.20	50.25	19.75	
	372940	903183	1950	69	865	4	7673	5.50	0.68	3.86	54.11	14.89	
J4	372325	903219	1945	74	616	4	8289	5.50	0.68	2.75	56.86	17.14	Sise Ena Emateye
	370567	903459	1944	75	1774	4	10063	3.00	0.37	2.58	59.44	15.56	
	369564	903967	1939	80	1124	4	11188	3.00	0.37	1.63	61.07	18.93	

	369356	904070	1943	76	232	4	11420	3.00	0.37	0.34	61.41	14.59	
J5	369198	904157	1937	82	180	4	11600	3.00	0.37	0.26	61.67	20.33	Other ena sise

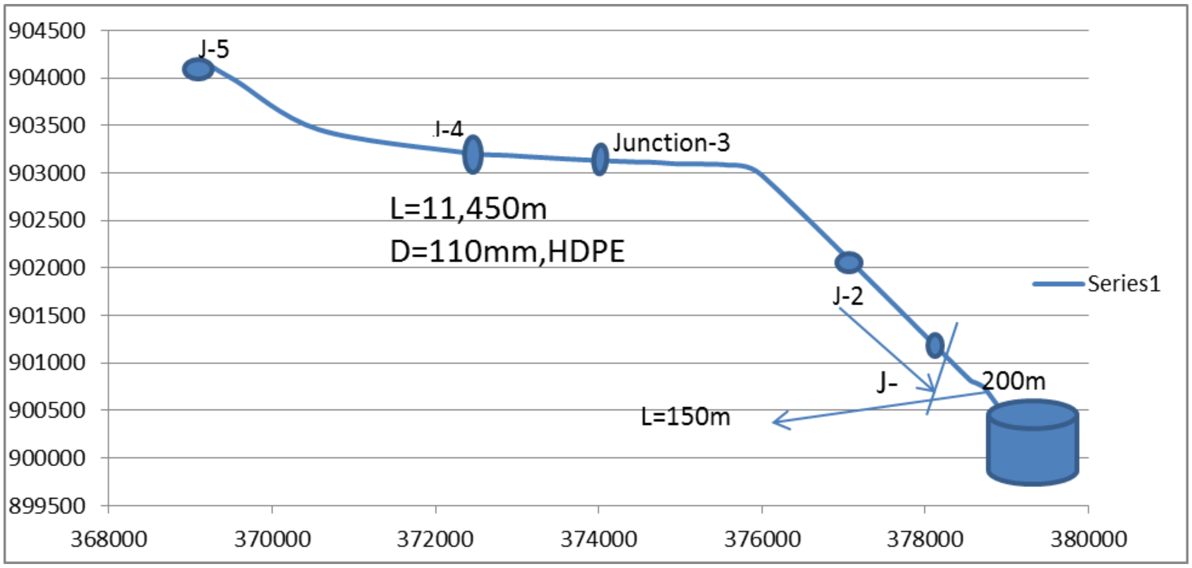


Figure.14. Lay out of separate pipe line

4.5.4. Improvement on distribution system

The distribution pipe system of the study area was not improved during new source development and the old distribution system has no capacity to satisfy the existing demand. Furthermore, the model result confirmed that their is oversized and undersized pipes shown on the system. For example, Jun- 47 to Jun-51 there is high demand but small pipe size (63mm and 50mm) should be improved to 110mm or parallel pipe of 63mm.See Figure 15.

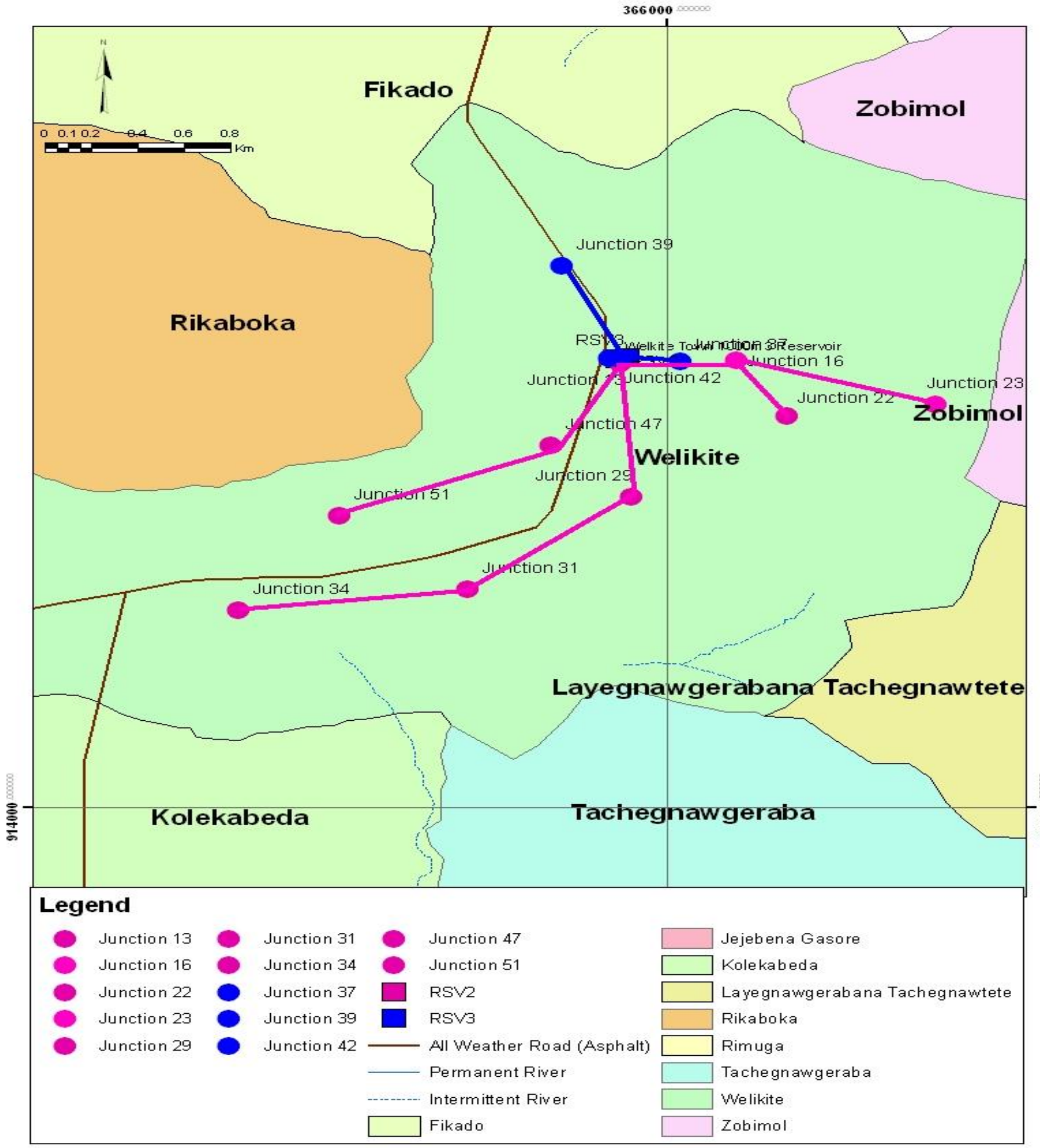


Figure.15.Map of study area with Main Junction of Distribution network

4.5.5. Alternative route selection

To prevent the gravity main pipe line from bursting, unable to recommend pressure reduction components like Pressure reduce valve (PRV) or break pressure tank. The reason is the available free head in service reservoir is only 17m and if the pressure reduced on this critical location the water cant inter in to service reservoir. Therefore, for long run changing the pipe line route to upstream location is one option to fix the problem. Changes made after Junction 4 of existing pipe line and at critical location the pressure reduced from 284m to 210m even if detailed investigation made there is probability of finding safe value than the obtained. The hydraulic calculation for proposed gravity pipe line result shown in table 27 below.

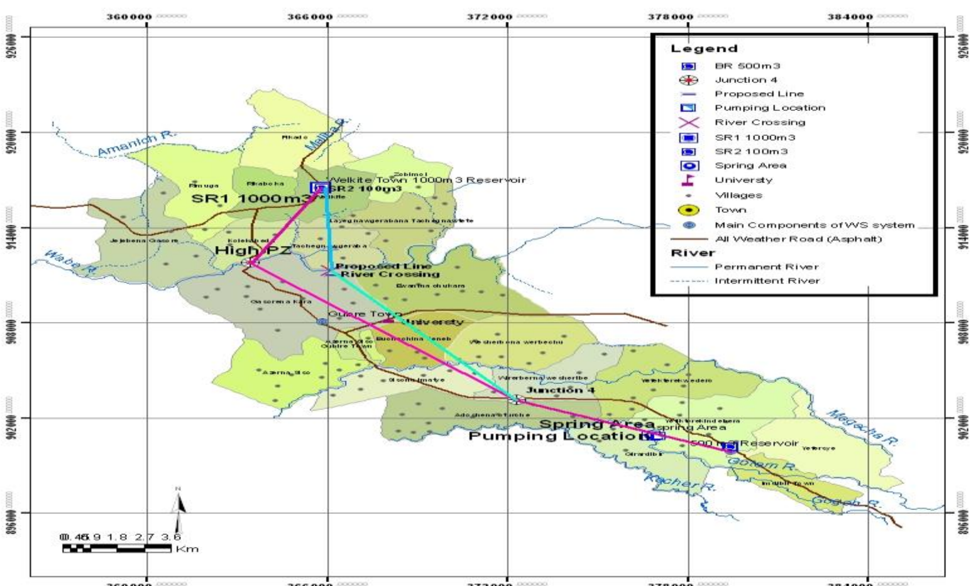


Figure.16. Map with alternative gravity pipe selection

Table. 27. Hydraulic Calculation for Proposed Gravity main line

Pt	X	Y	Z	STATIC	L	DIA	CUM L	Q	V	LOSS	CUM LOSS	HEAD	Village
RSV	379427	899971	2019	0		4	0	9.00		0.00	0.00	0.00	
	379436	899979	2017	2	12	4	12	9.00	1.11	0.14	0.14	1.86	
J1	379345	900049	2008	11	115	4	127	9.00	1.11	1.28	1.41	9.59	Emdebera
	379282	900109	2007	12	87	4	214	7.50	0.92	0.69	2.11	9.89	
	379038	900375	1990	29	361	4	575	7.50	0.92	2.86	4.97	24.03	
	379019	900395	1988	31	32	4	608	7.50	0.92	0.26	5.23	25.77	
	378765	900695	2001	18	393	4	1001	7.50	0.92	3.12	8.34	9.66	
J2	378718	900747	1998	21	71	4	1072	7.50	0.92	0.57	8.91	12.09	Yefek Terk
	378614	900794	1995	24	114	4	1186	6.20	0.76	0.64	9.54	14.46	
	378547	900821	1991	28	72	4	1259	6.20	0.76	0.40	9.95	18.05	
	375988	902984	1961	58	3351	4	4609	6.20	0.76	18.68	28.62	29.38	
	375580	903084	1951	68	421	4	5031	6.20	0.76	2.35	30.97	37.03	
	375011	903095	1948	71	569	4	5600	6.20	0.76	3.17	34.14	36.86	
J3	374744	903110	1951	68	267	4	5867	6.20	0.76	1.49	35.64	32.36	Werer ber
	374622	903115	1946	73	122	4	5989	5.00	0.62	0.46	36.09	36.91	
	374521	903115	1950	69	101	4	6090	5.00	0.62	0.38	36.47	32.53	
	373804	903140	1949	70	717	4	6808	5.00	0.62	2.69	39.16	30.84	
	372940	903183	1950	69	865	4	7673	5.00	0.62	3.24	42.39	26.61	
J4	372325	903219	1945	74	616	3	8289	5.00	1.10	9.36	51.75	22.25	Sise Ena Emateye
	368091	908418	1865	154	6705	4	14994	6.00	0.74	35.17	86.93	67.07	Welkite University
	367701	908966	1830	189	677	5	15671	7.00	0.55	1.59	88.52	100.48	
	367274	909442	1774	245	640	6	16312	8.00	0.44	0.79	89.31	155.69	
	366596	910021	1781	238	893	7	17205	9.00	0.36	0.65	89.97	148.03	
	366277	910446	1779	240	531	8	17737	10.00	0.31	0.25	90.21	149.79	
	366223	910625	1718	301	187	9	17923	11.00	0.27	0.06	90.27	210	
	365795	916602	1907	112	5993	10	23916	12.00	0.24	1.31	91.58	20.42	Service Reservoir

CHAPTER FIVE

5. Conclusion and Recommendation

5.1. Conclusion

The water supply of adequate quantity and acceptable quality is one of the basic needs of human beings, but the provision of potable water for Welkite Town is inefficient. The situation is getting worse due to the population growth, spatial expansion of the town and number of technical and management problem which outstripped its ability to supply sufficient water for its inhabitants.

- ❖ The existing sources of potable water are Large Spring found 29km away from the town with good potential. However, due to availability of high problem in Production, in main as well as distribution pipe system and poor operation and maintenance unable to use this potential.
- ❖ Moreover, the state of water supply in the town in terms of coverage both in spatial and Population, reliability, accessibility, and sustainability is not at the required standard. The rate of meter connection is low and the distribution system is inefficient. The major Constraints of distribution systems identified are low density of pipeline networks, and their unfair distribution, inadequate pressure in the pipe, low pumping capacity and no well-established distribution network. As a result, water consumption is affected in the town due to these physical factors.
- ❖ As per the computed existing water supply in Welkite town the coverage is 33% as per current domestic Consumption compared with the current per capital demand, 60% as per the level of Connection and 52% as per the Domestic and Non-Domestic consumption, the result indicates that there is high gap between Demand and supply and need more work.
- ❖ The research has confirmed that there is high gap between demand and supply. This gap is due to not only low water production, but also urban expansion. Moreover, a lot of unplanned connection along the gravity main line, poor water

management and under estimation of the demand during the construction of the water system has contributed enormously to the shortage of potable water in the town. Besides, the model Water Cad output indicates that the old distribution pipe network doesn't have capacity to satisfy the demand. In addition, there is high pressure along the gravity main pipe line which is result bursting of pipe and water loss.

5.2. Recommendation

- Depend on the available data of production and consumption the average computed NRW is 19.27% .However, as per the research made for different seven town of the country by water aid in 2010 the loss of Welkite town is 43% .Without following any leakage detection mechanism the loss can't reduce to such level with short period. Therefore, need further investigation to analysis the real level of NRW.
- The new system as well as the old distribution system doesn't follow the technical procedure for example, along the 29km gravity main line a lot of connection made for rural community as well as for different institution along the line and during the peak period these affects the amount of water delivered by service reservoir. In addition the water line connected for Gubre sub cities from gravity main line as well as the 1000 m3 service reservoir also have no water meter. Their for, on this area have no information to know the amount of released water to compare with consumption for identification of loss per Zone. So, the office should immediately install gate valves for junctions and water meter in different critical area to help them for safe operation and also to know were high leakage found.
- To cover the gap of water demand the system should have use different alternative like, depend on the availability of enough spring water source and ability of the pressure main line pipe delivering more water additional pump recommended increasing the production. In addition, building separate reservoir & pipe line for rural community to separate the connection from gravity main line, this helps to deliver more amount of water to town service reservoir. However, depend on the demand still there is a gap in town. There for, the remaining gap should be covered by existing non-functional three boreholes which have sum of 15 l/s by finalizing already started rehabilitation work.
- For distribution network, need controlling the water flow by gate valve for location of high pressure and fixing air release valve for low pressure zone. Moreover, to increase the capacity of the distribution network by considering

from economical point of view, it is better to use parallel pipe line installation which has a capacity to cover the demand gap.

- To prevent the gravity main pipe line from bursting, unable to recommend pressure reduction components like PRV or break pressure tank. The reason is the available free head in service reservoir is only 17m and if the pressure broke along the line the water cant inter in to service reservoir. This research put here two recommendation, the 1st is applying activities like, suitable anchoring, treating the system by using quality joints, changing pipe in same critical points and fixing air release valves. The 2nd is in long run changing the pipe line route to upstream location.
- Management of Welkite town water supply totally need improvement to maximize the overall performance of the utility. Locally there are a number of Water Supply Services that operate efficiently with the principle of cost recovery and full autonomy. Visiting such institutions would be helpful to improve the performance of the board, management and staffs. Timely upgrading and acquaintance of staffs with innovative ideas, new technologies with clear purpose and change is a tool for improvement.

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Appendix 1. Surveyed Pipe Line Data for Junction

Label	X (m)	Y (m)	Elevation (m)
J-1	379,345.00	900,049.00	2,008.00
J-2	376,718.00	902,608.00	1,954.00
J-3	374,744.00	903,110.00	1,951.00
J-4	372,325.00	903,219.00	1,945.00
J-5	369,198.00	904,157.00	1,937.00
J-6	366,691.00	907,194.00	1,944.00
J-7	366,671.00	907,215.00	1,945.00
J-8	365,830.00	908,132.00	1,912.00
J-9	365,374.00	908,930.00	1,849.00
J-10	364,030.00	911,157.00	1,816.00
J-11	363,042.00	913,098.00	1,808.00
J-12	365,805.00	916,592.00	1,906.00
J-13	365,805.00	916,578.00	1,907.00
J-14	365,847.00	916,590.00	1,906.00
J-15	366,063.00	916,587.00	1,906.00
J-16	366,305.00	916,595.00	1,894.00
J-17	366,444.00	916,823.00	1,898.00
J-18	366,593.00	916,830.00	1,892.00
J-19	366,985.00	916,323.00	1,872.00
J-20	367,169.00	916,346.00	1,867.00
J-21	366,866.00	915,235.00	1,879.00
J-22	366,964.00	916,235.00	1,878.00
J-23	366,524.00	917,015.00	1,895.00
J-24	366,148.00	916,699.00	1,901.00
J-25	366,805.00	917,550.00	1,883.00
J-26	366,391.00	916,825.00	1,905.00
J-27	365,858.00	916,567.00	1,905.00
J-28	365,863.00	916,319.00	1,901.00
J-29	365,885.00	915,828.00	1,882.00

J-30	365,822.00	915,733.00	1,892.00
J-31	365,595.00	915,620.00	1,885.00
J-32	365,223.00	915,333.00	1,880.00
J-33	364,405.00	915,195.00	1,870.00
J-34	364,156.00	915,191.00	1,871.00
J-35	365,746.00	916,248.00	1,899.00
J-36	365,836.00	916,603.00	1,906.00
J-37	365,821.00	916,756.00	1,908.00
J-38	366,148.00	916,699.00	1,901.00
J-39	365,758.00	916,607.00	1,904.00
J-40	365,723.00	916,588.00	1,903.00
J-41	365,508.00	917,117.00	1,893.00
J-42	365,384.00	917,336.00	1,893.00
J-43	365,666.00	916,769.00	1,900.00
J-44	365,612.00	916,580.00	1,904.00
J-45	365,567.00	916,387.00	1,901.00
J-46	365,549.00	916,318.00	1,898.00
J-47	365,447.00	915,924.00	1,896.00
J-48	365,436.00	915,670.00	1,890.00
J-49	365,408.00	915,573.00	1,889.00
J-50	365,250.00	915,516.00	1,886.00
J-51	365,172.00	915,485.00	1,886.00
J-52	364,158.00	915,214.00	1,867.00
J-53	364,143.00	915,210.00	1,863.00
J-54	365,440.00	916,582.00	1,885.00

J-55	365,686.00	916,385.00	1,904.00
J-56	365,475.00	915,554.00	1,891.00
J-57	365,396.00	915,917.00	1,895.00
J-58	364,662.00	915,457.00	1,873.00
J-59	364,231.00	915,324.00	1,872.00

Appendix 2. Pump Data

Label	X (m)	Y (m)	Discharge(l/s)	Head(M)
Pump 1&2	376718	900985	40	89

Appendix 3. Tank Data

Label	X (m)	Y (m)	Base Elevation (m)	Minimum Elevation (m)	Initial HGL (m)	Maximum Elevation (m)
T-1	379,427.00	899,971.00	2,019.00	2,019.20	2,023.20	2,024.20
T-2	365,795.00	916,602.00	1,907.00	1,907.20	1,911.20	1,912.20
T-3	365,836.00	916,603.00	1,921.00	1,921.20	1,923.70	1,924.70

Appendix. 4. Pipe Data

Leble	Start node	End Node	Material	Diameter(mm)	Length(m)
p-1	source	PMP		300	50
p-2	Pump	R-1	PVC	300	2894
p-3	R-1	J-1	Ductile Iron	300	114
P-4	J-1	J-2	PVC	300	3668
P-5	J-2	J-3	Ductile Iron	300	2037
P-6	J-3	J-4	PVC	300	2421
P-7	J-4	J-5	PVC	300	3265
P-8	J-5	J-6	PVC	300	3938
P-9	J-6	J-7	Ductile Iron	300	50
P-10	J-7	J-8	PVC	300	1245
P-11	J-8	J-9	Ductile Iron	300	921
P-12	J-9	J-10	Ductile Iron	300	3521
P-13	J-10	J-11	Ductile Iron	300	2182
P-14	J-11	J-12	Ductile Iron	300	4449
P-15	J-12	R-2	Ductile Iron	300	12
P-16	J-12	R-3	Ductile Iron	300	33

P-17	R-3	J-36	Ductile Iron	110	12
P-18	J-36	J-37	PVC	63	157
P-19	J-37	J-38	PVC	63	344
P-20	J-36	J-39	PVC	110	145
P-21	J-39	J-40	PVC	110	140
P-22	J-40	J-41	PVC	110	568
P-23	J-41	J-42	PVC	110	300
P-24	J-39	J-43	PVC	110	190
P-25	R-2	J-13	PVC	300	35
P-26	J-13	J-14	PVC	200	26
P-27	J-14	J-15	PVC	200	757
P-28	J-15	J-16	PVC	200	499
P-29	J-16	J-17	PVC	110	242
P-30	J-17	J-18	PVC	110	267
P-31	J-18	J-19	PVC	90	149
P-32	J-19	J-20	PVC	63	641
P-33	J-17	J-23	PVC	110	185
P-34	J-15	J-24	PVC	110	155
P-35	J-24	J-25	PVC	110	1216
P-36	J-24	J-26	PVC	110	835
P-37	J-16	J-21	PVC	110	1450
P-38	J-21	J-22	PVC	110	1200
P-39	J-14	J-27	PVC	150	45
P-40	J-27	J-28	PVC	150	850
P-41	J-28	J-29	PVC	150	800
P-42	J-29	J-30	PVC	150	655
P-43	J-30	J-31	PVC	110	114
P-44	J-31	J-32	PVC	90	1500
P-45	J-32	J-33	PVC	90	800
P-46	J-33	J-34	PVC	63	1200
P-47	J-28	J-35	PVC	63	500
P-48	J-13	J-44	PVC	150	55
P-49	J-44	J-45	PVC	150	250
P-50	J-45	J-46	PVC	150	300
P-51	J-46	J-47	PVC	110	150
P-52	J-47	J-48	PVC	63	478
P-53	J-48	J-49	PVC	63	800
P-54	J-49	J-50	PVC	63	890
P-55	J-50	J-51	PVC	63	550
P-56	J-51	J-52	PVC	63	750
P-57	J-44	J-54	PVC	110	193

P-58	J-44	J-55	PVC	63	950
P-59	J-55	J-56	PVC	63	1800
P-60	J-47	J-57	PVC	110	200
P-61	J-48	J-58	PVC	110	1100
P-62	J-50	J-59	PVC	63	955
P-63	J-52	J-53	PVC	50	1250

Appendix .5. Base Demand Computation

Lebel	No Connection	Residential Connection	Commercial /Institution	Population	Unit Residential Demand	Residential demand	Commercial Demand	Base Demand
J-1	3.00	3.00	0	3002	0.00021	0.69	0.00	0.69
J-2	4.00	3.00	1.00	2673	0.00021	1.11	0.01	1.12
J-3	5.00	4	1	2623	0.00021	1.09	0.01	1.10
J-4	7.00	5	2	4814	0.00021	2.01	0.01	2.02
J-5	59.00	54	5	3917	0.00021	1.63	0.13	1.76
J-6	697.00	607	90	2428	0.00021	2.91	0.54	3.45
J-7	2.00		2			0.00	6.25	6.25
J-8	2.00		2			0.00		0.00
J-9	14.00	13	1	5191	0.00021	2.16	0.01	2.17
J-10	2.00	2		1000	0.00021	0.42	0.00	0.42
J-11	3.00	3		1250	0.00021	0.52	0.00	0.52
J-12	0.00						0.00	0.00
J-13	0.00						0.00	0.00
J-14	-						0.00	0.00
J-15	37.00	28	9	112	0.00120	0.13	0.05	0.19
J-16				0	0.00120	0.00	0.00	0.00
J-17	18.00	17	1	68	0.00120	0.08	0.01	0.09
J-18	145.00	145		580	0.00120	0.70	0.00	0.70
J-19	150.00	150		600	0.00120	0.72	0.00	0.72
J-20	115.00	115		460	0.00120	0.55	0.00	0.55
J-21	214.00	198	16	792	0.00120	0.95	0.10	1.05
J-22	430.00	405	25	1620	0.00120	1.94	0.15	2.09
J-23	50.00	48	2	192	0.00120	0.23	0.01	0.24
J-24	44.00	35	9	140	0.00120	0.17	0.05	0.22
J-25	125.00	114	11	456	0.00120	0.55	0.07	0.61
J-26	10.00		10	0	0.00120	0.00	0.06	0.06
J-27	88.00	70	18	280	0.00120	0.34	0.11	0.44
J-28	158.00	136	22	544	0.00120	0.65	0.13	0.78
J-29	125.00	120	5	480	0.00120	0.58	0.03	0.61
J-30	90.00	40	50	160	0.00120	0.19	0.30	0.49
J-31	155.00	125	30	500	0.00120	0.60	0.18	0.78
J-32	185.00	125	65	500	0.00120	0.60	0.39	0.99
J-33	205.00	190	15	760	0.00120	0.91	0.09	1.00
J-34	390.00	365	25	1460	0.00120	1.75	0.15	1.90
J-35	250.00	203	47	812	0.00120	0.97	0.28	1.26
J-36				0	0.00120	0.00	0.00	0.00
J-37	50.00	27	5	108	0.00120	0.13	0.61	0.73
J-38	58.00	43	15	172	0.00120	0.21	0.09	0.30

J-39	35.00	15	20	60	0.00120	0.07	0.12	0.19
J-40	65.00	44	21	176	0.00120	0.21	0.13	0.34
J-41	75.00	61	14	244	0.00120	0.29	0.08	0.38
J-42	150.00	135	15	540	0.00120	0.65	0.09	0.74
J-43	255.00	250	5	1000	0.00120	1.20	0.03	1.23
J-44	88.00	81	7	324	0.00120	0.39	0.04	0.43
J-45	45.00	18	33	72	0.00120	0.09	0.20	0.28
J-46	252.00	198	54	792	0.00120	0.95	0.32	1.27
J-47	218.00	175	43	700	0.00120	0.84	0.26	1.10
J-48				0		0.00	0.00	0.00
J-49	168.00	56	115	224	0.00120	0.27	0.69	0.96
J-50	78.00	18	60	72	0.00120	0.09	0.36	0.45
J-51	50.00	30	20	120	0.00120	0.14	0.12	0.26
J-52	165.00	155	10	620	0.00120	0.74	0.06	0.80
J-53	78.00	67	11	268	0.00120	0.32	0.07	0.39
J-54	128.00	110	18	440	0.00120	0.53	0.11	0.64
J-55	35.00	20	15	80	0.00120	0.10	0.09	0.19
J-56	255.00	10	245	40	0.00120	0.05	1.47	1.52
J-57	315.00	195	120	780	0.00120	0.94	0.72	1.66
J-58	259.00	255	4	1020	0.00120	1.22	0.02	1.25
J-59	281.00	231	50	924	0.00120	1.11	0.30	1.41

Appendix 6 . Demand at different Scenarios

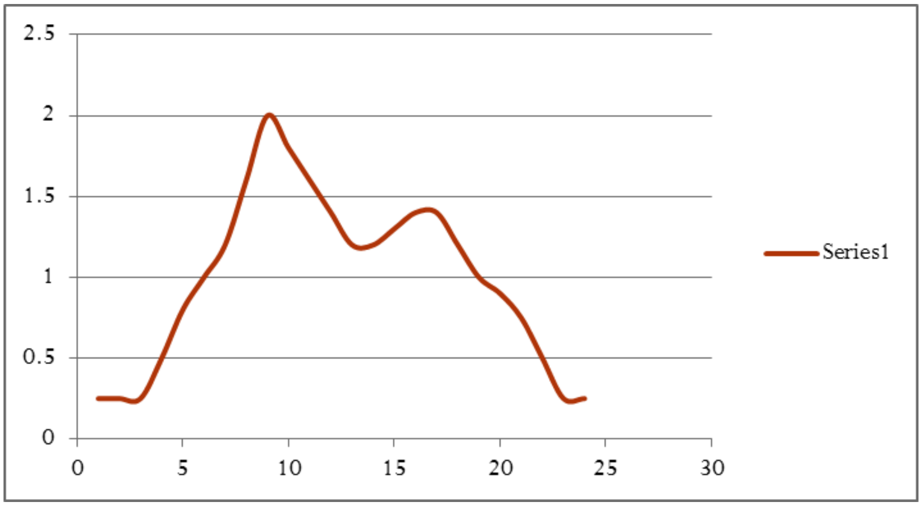
Lebel	Base Demand(A)	Maximum Day Demand(A*1.2)	Peak Hour Demand(A*2)	Low Demand(A*0.25)
J-1	0.69	0.83	1.38	0.17
J-2	1.12	1.34	2.24	0.28
J-3	1.10	1.32	2.20	0.27
J-4	2.02	2.42	4.04	0.50
J-5	1.76	2.12	3.53	0.44
J-6	3.45	4.14	6.91	0.86
J-7	6.25	7.50	12.49	1.56
J-8	0.00	0.00	0.00	0.00
J-9	2.17	2.60	4.34	0.54
J-10	0.42	0.50	0.83	0.10
J-11	0.52	0.63	1.04	0.13
J-12	0.00	0.00	0.00	0.00
J-13	0.00	0.00	0.00	0.00
J-14	-	0.00	0.00	0.00
J-15	0.19	0.23	0.38	0.05
J-16	0.00	0.00	0.00	0.00
J-17	0.09	0.11	0.18	0.02
J-18	0.70	0.84	1.39	0.17
J-19	0.72	0.86	1.44	0.18
J-20	0.55	0.66	1.10	0.14
J-21	1.05	1.26	2.09	0.26
J-22	2.09	2.51	4.19	0.52
J-23	0.24	0.29	0.48	0.06
J-24	0.22	0.27	0.44	0.06
J-25	0.61	0.74	1.23	0.15
J-26	0.06	0.07	0.12	0.02
J-27	0.44	0.53	0.89	0.11
J-28	0.78	0.94	1.57	0.20
J-29	0.61	0.73	1.21	0.15
J-30	0.49	0.59	0.98	0.12

J-31	0.78	0.94	1.56	0.20
J-32	0.99	1.19	1.98	0.25
J-33	1.00	1.20	2.00	0.25
J-34	1.90	2.28	3.80	0.48
J-35	1.26	1.51	2.51	0.31
J-36	-	0.00	0.00	0.00
J-37	0.73	0.88	1.47	0.18
J-38	0.30	0.36	0.59	0.07
J-39	0.19	0.23	0.38	0.05
J-40	0.34	0.40	0.67	0.08
J-41	0.38	0.45	0.75	0.09
J-42	0.74	0.89	1.48	0.18
J-43	1.23	1.48	2.46	0.31
J-44	0.43	0.52	0.86	0.11
J-45	0.28	0.34	0.57	0.07
J-46	1.27	1.53	2.55	0.32
J-47	1.10	1.32	2.20	0.27
J-48	-	0.00	0.00	0.00
J-49	0.96	1.15	1.92	0.24
J-50	0.45	0.54	0.89	0.11
J-51	0.26	0.32	0.53	0.07
J-52	0.80	0.96	1.61	0.20
J-53	0.39	0.47	0.78	0.10
J-54		0.76	1.27	0.16

	0.64			
J-55	0.19	0.22	0.37	0.05
J-56	1.52	1.82	3.04	0.38
J-57	1.66	1.99	3.31	0.41
J-58	1.25	1.50	2.50	0.31
J-59	1.41	1.69	2.82	0.35

Appendix.7. Hourly demand factor

Time	Factor	Time	Factor	Time	Factor
00-01	0.25	08-09	2	16-17	1.4
01-02	0.25	09-10	1.8	17-18	1.2
02-03	0.25	10-11	1.6	18-19	1
03-04	0.5	11-12	1.4	19-20	0.9
04-05	0.8	12-13	1.2	20-21	0.75
05-06	1	13-14	1.2	21-22	0.5
06-07	1.2	14-15	1.3	22-23	0.25
07-08	1,6	15-16	1.4	23-24	0.25



Appendix .8. Model Output of Pressure junction at night Flow Demand

Label	X (m)	Y (m)	Night Flow demand (l/s)	Elevation (m)	Pressure Head (m)	Zone
J-1	366,235.07	913,292.38	0.31	2,008.00	14.67	Zone - 1
J-2	366,075.61	913,375.56	0.28	1,954.00	54.36	Zone - 1
J-3	365,823.92	913,471.82	0.27	1,951.00	47.96	Zone - 1
J-4	365,607.49	913,555.98	0.5	1,945.00	44.67	Zone - 1
J-5	365,461.41	913,632.83	0.44	1,937.00	40.32	Zone - 1
J-6	365,372.27	913,763.43	0.86	1,944.00	18.62	Zone - 1
J-7	365,327.42	913,883.79	1.56	1,945.00	17.4	Zone - 1
J-8	365,331.02	914,072.12	0	1,912.00	46.07	Zone - 1
J-9	365,388.40	914,191.14	0.54	1,749.00	205.26	Zone - 1
J-10	365,468.62	914,314.93	0.1	1,716.00	223.9	Zone - 1
J-010	365,489.89	914,368.28	0	1,708.00	229.45	Zone - 1
J-0010	365,529.21	914,460.16	0	1,650.00	283.18	Zone - 1
J-11	365,548.78	914,506.37	0.13	1,808.00	123.04	Zone - 1
J-12	367,337.30	916,061.48	0	1,906.00	17.03	Zone - 1
J-13	367,417.39	916,037.35	0	1,907.00	14.2	Zone - 2
J-14	367,442.56	916,078.44	0	1,906.00	5.19	Zone - 2
J-15	367,642.38	916,076.74	0.05	1,906.00	5.17	Zone - 2
J-16	367,884.38	916,084.74	0	1,894.00	17.16	Zone - 2
J-17	367,969.23	916,201.10	0.02	1,898.00	13.14	Zone - 2
J-18	368,097.40	916,243.93	0.17	1,892.00	19.12	Zone - 2
J-19	368,117.51	916,062.94	0.18	1,872.00	39.11	Zone - 2
J-20	368,183.95	916,098.38	0.14	1,867.00	44.05	Zone - 2
J-21	367,849.67	915,882.29	0.26	1,879.00	31.95	Zone - 2
J-22	367,994.09	915,951.59	0.52	1,878.00	32.87	Zone - 2
J-23	368,067.56	916,344.78	0.06	1,895.00	16.14	Zone - 2
J-24	367,725.68	916,193.70	0.06	1,901.00	10.17	Zone - 2
J-25	367,865.05	916,357.29	0.15	1,883.00	28.16	Zone - 2
J-26	367,970.38	916,314.74	0.02	1,905.00	6.17	Zone - 2
J-27	367,467.73	916,032.86	0.11	1,905.00	6.19	Zone - 2
J-28	367,442.38	915,808.74	0.2	1,901.00	10.04	Zone - 2
J-29	367,464.38	915,317.74	0.15	1,882.00	28.96	Zone - 2
J-30	367,401.38	915,222.74	0.12	1,892.00	18.9	Zone - 2
J-31	367,174.38	915,109.74	0.2	1,885.00	25.87	Zone - 2
J-32	366,802.38	914,822.74	0.25	1,880.00	30.37	Zone - 2
J-33	365,994.06	914,694.37	0.25	1,870.00	40.1	Zone - 2

J-34	365,744.10	914,652.84	0.48	1,871.00	38.03	Zone - 2
J-35	367,325.38	915,737.74	0.31	1,899.00	11.84	Zone - 2
J-36	367,483.47	916,095.87	0	1,906.00	17.7	Zone - 3
J-37	367,469.53	916,218.25	0.18	1,908.00	15.66	Zone - 3
J-38	367,685.83	916,208.54	0.07	1,901.00	22.65	Zone - 3
J-39	367,334.96	916,202.77	0.05	1,904.00	19.68	Zone - 3
J-40	367,279.48	916,074.46	0.08	1,903.00	20.67	Zone - 3
J-41	367,229.20	916,306.29	0.09	1,893.00	30.66	Zone - 3
J-42	367,176.90	916,345.84	0.18	1,893.00	30.66	Zone - 3
J-43	367,273.27	916,293.92	0.31	1,900.00	23.67	Zone - 3
J-44	367,191.38	916,069.74	0.11	1,904.00	7.18	Zone - 2
J-45	367,146.38	915,876.74	0.07	1,901.00	10.11	Zone - 2
J-46	367,128.38	915,807.74	0.32	1,898.00	13.04	Zone - 2
J-47	367,026.38	915,413.74	0.27	1,896.00	14.92	Zone - 2
J-48	367,015.38	915,159.74	0	1,890.00	18.27	Zone - 2
J-49	366,987.38	915,062.74	0.24	1,889.00	18.27	Zone - 2
J-50	366,829.38	915,005.74	0.11	1,886.00	20.83	Zone - 2
J-51	366,751.38	914,974.74	0.07	1,886.00	20.77	Zone - 2
J-52	365,765.28	914,719.43	0.2	1,867.00	39.72	Zone - 2
J-53	365,718.90	914,727.64	0.01	1,863.00	43.72	Zone - 2
J-54	367,105.27	916,067.98	0.16	1,885.00	26.15	Zone - 2
J-55	367,265.38	915,874.74	0.05	1,904.00	7.16	Zone - 2
J-56	367,054.38	915,043.74	0.38	1,891.00	19.7	Zone - 2
J-57	366,975.38	915,406.74	0.41	1,895.00	15.79	Zone - 2
J-58	366,241.38	914,946.74	0.31	1,873.00	35.24	Zone - 2
J-59	365,810.38	914,813.74	0.35	1,872.00	34.36	Zone - 2

Appendix .9. Model Out Put Velocity in Pipe at Night Flow Demand

Label	Length (m)	Diameter (mm)	Material	Discharge (l/s)	Velocity (m/s)	Control Status	C Value	Pressure Pipe Head loss (m)	Start Node	Stop Node
P-1	50	300	PVC	31.62	0.45	Open	110	0.05	R-1	Pump 1
P-2	2,894.00	300	DCI	31.62	0.45	Open	100	3.58	Pump 1	T-1
P-3	114	300	DCI	64.76	0.92	Open	100	0.53	T-1	J-1
P-4	3,668.00	300	PVC	64.61	0.91	Open	110	14.3	J-1	J-2
P-5	2,037.00	300	DCI	64.33	0.91	Open	100	9.4	J-2	J-3
P-6	2,421.00	300	PVC	64.06	0.91	Open	110	9.29	J-3	J-4
P-7	3,265.00	300	PVC	63.56	0.9	Open	110	12.35	J-4	J-5
P-8	3,938.00	300	PVC	63.12	0.89	Open	110	14.71	J-5	J-6
P-9	50	300	DCI	62.26	0.88	Open	100	0.22	J-6	J-7
P-10	1,245.00	300	PVC	60.7	0.86	Open	110	4.32	J-7	J-8
P-11	921	300	DCI	60.7	0.86	Open	100	3.82	J-8	J-9
P-12	3,521.00	300	DCI	60.16	0.85	Open	100	14.35	J-9	J-10
P-0012	1,050.65	300	DCI	60.06	0.85	Open	100	4.27	J-010	J-0010
P-012	603.81	300	DCI	60.06	0.85	Open	100	2.45	J-10	J-010
P-14	4,449.00	300	DCI	59.93	0.85	Open	100	18.01	J-11	J-12
P-15	12	300	DCI	59.5	1.02	Open	100	1.83	J-12	T-2
P-16	92.66	300	DCI	59	1,17	Open	100	10.67	J-12	T-3
P-17	12	110	DCI	0.96	0.1	Open	100	0	T-3	J-36
P-18	157	63	PVC	0.25	0.08	Open	110	0.04	J-36	J-37
P-19	344	63	PVC	0.07	0.02	Open	110	0.01	J-37	J-38
P-20	145	110	PVC	0.71	0.07	Open	110	0.02	J-36	J-39
P-21	140	110	PVC	0.35	0.04	Open	110	0	J-39	J-40
P-22	568	110	PVC	0.27	0.03	Open	110	0.01	J-40	J-41
P-23	300	110	PVC	0.18	0.02	Open	110	0	J-41	J-42
P-24	190	110	PVC	0.31	0.03	Open	110	0.01	J-39	J-43
P-25	35	300	PVC	0.76	0.1	Open	110	0	J-13	T-2
P-26	26	200	PVC	3.7	0.12	Open	110	0	J-13	J-14
P-27	757	200	PVC	1.63	0.05	Open	110	0.02	J-14	J-15
P-28	499	200	PVC	1.35	0.04	Open	110	0.01	J-15	J-16
P-29	242	110	PVC	0.57	0.06	Open	110	0.02	J-16	J-17
P-30	267	110	PVC	0.49	0.05	Open	110	0.02	J-17	J-18
P-31	149	90	PVC	0.32	0.05	Open	110	0.01	J-18	J-19
P-32	641	63	PVC	0.14	0.04	Open	110	0.06	J-19	J-20

P-33	185	110	PVC	0.06	0.01	Open	110	0	J-17	J-23
P-34	155	110	PVC	0.23	0.02	Open	110	0	J-15	J-24
P-35	1,216.00	110	PVC	0.15	0.02	Open	110	0.01	J-24	J-25
P-36	835	110	PVC	0.02	0	Open	110	0	J-24	J-26
P-37	1,450.00	110	PVC	0.78	0.08	Open	110	0.21	J-16	J-21
P-38	1,200.00	110	PVC	0.52	0.05	Open	110	0.08	J-21	J-22
P-39	45	150	PVC	2.07	0.12	Open	110	0.01	J-14	J-27
P-40	850	150	PVC	1.96	0.11	Open	110	0.15	J-27	J-28
P-41	800	150	PVC	1.45	0.08	Open	110	0.08	J-28	J-29
P-42	635	150	PVC	1.3	0.07	Open	110	0.05	J-29	J-30
P-43	114	110	PVC	1.18	0.12	Open	110	0.04	J-30	J-31
P-44	850	90	PVC	0.98	0.15	Open	110	0.5	J-31	J-32
P-45	800	90	PVC	0.73	0.11	Open	110	0.27	J-32	J-33
P-46	1,200.00	63	PVC	0.48	0.15	Open	110	1.07	J-33	J-34
P-47	500	63	PVC	0.31	0.1	Open	110	0.2	J-28	J-35
P-48	55	150	PVC	3.06	0.17	Open	110	0.02	J-13	J-44
P-49	250	150	PVC	2.36	0.13	Open	110	0.06	J-44	J-45
P-50	300	150	PVC	2.29	0.13	Open	110	0.07	J-45	J-46
P-51	150	110	PVC	1.97	0.21	Open	110	0.12	J-46	J-47
P-52	478	63	PVC	1.29	0.41	Open	110	2.65	J-47	J-48
P-53	300	63	PVC	0.98	0.31	Open	110	1	J-48	J-49
P-54	220	63	PVC	0.74	0.24	Open	110	0.44	J-49	J-50
P-55	175	63	PVC	0.28	0.09	Open	110	0.06	J-50	J-51
P-56	250	63	PVC	0.21	0.07	Open	110	0.05	J-51	J-52
P-57	193	63	PVC	0.16	0.05	Open	110	0.02	J-44	J-54
P-58	320	110	PVC	0.43	0.05	Open	110	0.02	J-44	J-55
P-59	800	63	PVC	0.38	0.12	Open	110	0.46	J-55	J-56
P-60	200	63	PVC	0.41	0.13	Open	110	0.13	J-47	J-57
P-61	1,100.00	110	PVC	0.31	0.03	Open	110	0.03	J-48	J-58
P-62	955	63	PVC	0.35	0.11	Open	110	0.47	J-50	J-59
P-63	1,250.00	50	PVC	0.01	0.01	Open	110	0	J-52	J-53
P-66	527.61	300	DCI	60.06	0.85	Open	100	2.14	J-0010	J-11

Appindex 10. Model out Put of Pressure Junction at peak hour Demand

Label	X (m)	Y (m)	Peak hour demand (l/s)	Elevation (m)	Pressure Head (m)	Zone
J-1	366,235.07	913,292.38	2.5	2,008.00	14.52	Zone - 1
J-2	366,075.61	913,375.56	2.24	1,954.00	50.65	Zone - 1
J-3	365,823.92	913,471.82	2.2	1,951.00	42.14	Zone - 1
J-4	365,607.49	913,555.98	4.04	1,945.00	37	Zone - 1
J-5	365,461.41	913,632.83	3.53	1,937.00	30.77	Zone - 1
J-6	365,372.27	913,763.43	6.91	1,944.00	7.41	Zone - 1
J-7	365,327.42	913,883.79	12.49	1,945.00	6.18	Zone - 1
J-8	365,331.02	914,072.12	4.34	1,912.00	35.32	Zone - 1
J-9	365,388.40	914,191.14	0	1,749.00	195.37	Zone - 1
J-0010	365,529.21	914,460.16	0	1,650.00	277.94	Zone - 1
J-010	365,489.89	914,368.28	0	1,708.00	223.21	Zone - 1
J-10	365,468.62	914,314.93	0.83	1,716.00	217.09	Zone - 1
J-11	365,548.78	914,506.37	1.04	1,808.00	118.3	Zone - 1
J-12	367,337.30	916,061.48	0	1,906.00	6.97	Zone - 1
J-13	367,417.39	916,037.35	0	1,907.00	3.29	Zone - 2
J-14	367,442.56	916,078.44	0	1,906.00	4.11	Zone - 2
J-15	367,642.38	916,076.74	0.38	1,906.00	3.02	Zone - 2
J-16	367,884.38	916,084.74	0	1,894.00	14.5	Zone - 2
J-17	367,969.23	916,201.10	0.18	1,898.00	9.56	Zone - 2
J-18	368,097.40	916,243.93	1.39	1,892.00	14.79	Zone - 2
J-19	368,117.51	916,062.94	1.44	1,872.00	34.28	Zone - 2
J-20	368,183.95	916,098.38	1.1	1,867.00	36.63	Zone - 2
J-21	367,849.67	915,882.29	2.09	1,879.00	19.5	Zone - 2
J-22	367,994.09	915,951.59	4.19	1,878.00	16.59	Zone - 2
J-23	368,067.56	916,344.78	0.48	1,895.00	12.55	Zone - 2
J-24	367,725.68	916,193.70	0.44	1,901.00	7.91	Zone - 2
J-25	367,865.05	916,357.29	1.23	1,883.00	25.5	Zone - 2
J-26	367,970.38	916,314.74	0.12	1,905.00	3.91	Zone - 2
J-27	367,467.73	916,032.86	0.89	1,905.00	4.7	Zone - 2
J-28	367,442.38	915,808.74	1.57	1,901.00	1.72	Zone - 2
J-29	367,464.38	915,317.74	1.21	1,882.00	16.97	Zone - 2
J-30	367,401.38	915,222.74	0.98	1,892.00	4.54	Zone - 2
J-31	367,174.38	915,109.74	1.56	1,885.00	9.9	Zone - 2
J-32	366,802.38	914,822.74	1.98	1,880.00	-8.26	Zone - 2
J-33	365,994.06	914,694.37	2	1,870.00	-10.91	Zone - 2
J-34	365,744.10	914,652.84	3.8	1,871.00	-61.2	Zone - 2

J-35	367,325.38	915,737.74	2.51	1,899.00	-5.81	Zone - 2
J-36	367,483.47	916,095.87	0	1,906.00	17.55	Zone - 3
J-37	367,469.53	916,218.25	1.41	1,908.00	13.59	Zone - 3
J-38	367,685.83	916,208.54	0.59	1,901.00	20.14	Zone - 3
J-39	367,334.96	916,202.77	0.38	1,904.00	18.71	Zone - 3
J-40	367,279.48	916,074.46	0.67	1,903.00	19.48	Zone - 3
J-41	367,229.20	916,306.29	0.75	1,893.00	28.9	Zone - 3
J-42	367,176.90	916,345.84	1.48	1,893.00	28.76	Zone - 3
J-43	367,273.27	916,293.92	2.46	1,900.00	22.48	Zone - 3
J-44	367,191.38	916,069.74	0.86	1,904.00	-23.93	Zone - 2
J-45	367,146.38	915,876.74	0.57	1,901.00	-24.08	Zone - 2
J-46	367,128.38	915,807.74	2.55	1,898.00	-24.67	Zone - 2
J-47	367,026.38	915,413.74	2.2	1,896.00	-28.9	Zone - 2
J-48	367,015.38	915,159.74	0	1,890.00	-64	Zone - 2
J-49	366,987.38	915,062.74	1.92	1,889.00	-18.7	Zone - 2
J-50	366,829.38	915,005.74	0.89	1,886.00	-41.3	Zone - 2
J-51	366,751.38	914,974.74	0.53	1,886.00	-45.7	Zone - 2
J-52	365,765.28	914,719.43	1.61	1,867.00	-31	Zone - 2
J-53	365,718.90	914,727.64	0.78	1,863.00	-35	Zone - 2
J-54	367,105.27	916,067.98	127	1,885.00	-45.00	Zone - 2
J-55	367,265.38	915,874.74	0.37	1,904.00	-24.64	Zone - 2
J-56	367,054.38	915,043.74	3.04	1,891.00	-33.38	Zone - 2
J-57	366,975.38	915,406.74	3.31	1,895.00	-34.26	Zone - 2
J-58	366,241.38	914,946.74	2.5	1,873.00	-49	Zone - 2
J-59	365,810.38	914,813.74	2.82	1,872.00	-49.88	Zone - 2