A WATER SUPPLY SYSTEM STUDY AND ASSOCIATEDGAPS ON SANITATION OF THE DAYE TOWN, SIDAMA REGIONAL STATE, ETHIOPIA

MSC THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A WATER SUPPLY SYSTEM STUDY AND ASSOCIATEDGAPS ON SANITATION OF THE DAYE TOWN, SIDAMA REGIONAL STATE, ETHIOPIA

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A THESIS SUBMITTED TO THE

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This is to certify that the thesis entitled "A WATER SUPPLY SYSTEMSTUDY AND THE ASSOCIATED GAPS ON SANITATION OF THE DAYE TOWN, SIDAMA REGIONAL STATE, ETHIOPIA" submitted in partial fulfillment of the requirements for the degree of master'swith specialization in Water Resources Engineering and management the Graduate Program of the Department ofWATER RESOURCES AND IRRIGATION ENGINEERING, and has been carried out by ABERRA ELEFEW ID. No WREMW/024/12, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis proposal to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by ABERRA ELEFEWhave read and evaluated his MSc thesis entitled A WATER SUPPLY SYSTEMSTUDY AND THE ASSOCIATED GAPS ON SANITATION OF THE DAYE TOWN, SIDAMA REGIONAL STATE, ETHIOPIA", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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LIST OF ABBRIVATIONS

AWWA	American Water Work Association
CARL	Current Annual Real Loss
CSA	Central Statistics Agency
DTWSSO	Daye town water supply service office
DCI	Ductile Cast Iron
DEM	Digital Elevation Model
DMA	District Metered Area
DN	Nominal Diameter
ETB	Ethiopian Birr
GPS	Global Positioning System
GIS	Geographic Information System
HTU	House Tap Users
HDPE	High Density Polyethylene
HGL	Hydraulic Grade Line
ICPS	Inter-Censual population survey
ILI	Infrastructure Leakage Index
IWA	International Water Association
L/c/d	Liters Per capita per day
m.a.s.l	Meter above Sea Level
MoWIR	Ministry of Water, Irrigation, and Energy
NRW	Non – Revenue Water
PF	Peak Factor
PN	Nominal Pressure
PRV	Pressure Reducing Valve
PTU	Public Tap Users
PVC	Polyvinyl Chloride
RL	Real Loss
SNNPRS	South Nation Nationalities and PeoplesRegional State

SPSS	Statistical Package for Social Science
TWB	Town water Board
UARL	Unavoidable Annual Real Loss
UFW	Unaccounted for Water
UTM	Universal Traverse Mercator
UWDN	Urban Water Distribution Network
WDNs	Water Distribution Networks
WDS	Water Distribution System
WGS	World Geodetic System
WHO	World Health Organization
WSS	Water Supply System
WUAM	Water Utility Asset Management
YCU	Yard Connection Users

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DECLARATION

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

Name: Aberra Elefew Asaminew

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ABSTRACT

Safe and adequate delivery of water to a consumption node is an essential function of a water distribution network. Daye Town has experienced frequent and regular disruption of water because of hydraulic problems related to pressure and velocity during high consumption period and at night-time. The main aim of this study was to model the existing water distribution system for steady-state and evaluate hydraulic performance of the system and sanitation condition of the town. For conducting this study, both primary and secondary data were collected and tools such as WaterGEMS and SPSSwere used. Questionnaire was used for the sanitation assessment for the selected sample households. Pressure gauge was used and the pressure on the selected points on the water supply system measured and then validated with the result from hydraulic modeling analysis. The existing water sources studied, and the population of the town analyzed for the present and the forecasted, 20 years. Accordingly, the total average per capita consumption of the Town in the year 2022was 9.21 l/c/d which showed lower performance compared to 50 l/c/d which is set by GTP-II of the country for category 4 town and 34,714m^3/year (25.03%) of water is considered to be non-revenue (NRW) and the apparent losses and real losses of the town was 0.9% and 26.44% respectively. There is high gap between demand and supply in the town because the current (2022) and the future (2041) maximum day water demand of the town was 1741.04m^3/day and 4,581.81 m^3/day respectively and the current (2022) water production of the town was only 511.2 m^3/day which only satisfies 44% of the current demand (2022) and 17% of the future demand in year 2041. Therefore, securing additional water supplies becomes an essential issue to meet the current and future water demand of the town. The simulated result showed that 41.35% for pressure value (<10m) and 58.65% for pressure value with recommended value (11-70m) base *consumption and the velocity of pipe flow showed that 51.3% (<0.6m/s) and 48.7% the range of (0.6-2m/s). The performance of the model was evaluated using model evaluation statistics. The value of the coefficient of determination (R^2) for pressure calibration was 0.96. Moreover, potential causes of water losses in the town water supply system were assessed, water losses reduction strategies are designed, and the system pressure and velocity are adjusted. Finally, sanitation associated gapsmainly the latrine in household and selected institutions and excreta disposal and transportation was assessed. Percent of households with access to sanitation facility and percent of households with year-round access to improved water system for sanitation was27.52% and 15.5% respectively.*

Keywords:*Daye town, Hydraulic performance, WaterGEMS, Water distribution network, Sanitation*

1. INTRODUCTION

1.1.Background

Water is the primary need to maintain life; every man in the World has the right to have access to potable water (Garg, 2010). Condition of safe and adequate water supply services is necessary components for sustainable development. The prerequisite of adequate and reliable water supply in developing countries is becoming a challenge for most water utilities especially public service providers (KB Khatri, 2007). Water demand has been increasing drastically in developing nations due to population growth as a result of rural to urban migration. As a consequence, in many countries public water service utilities have failed to provide consumers with adequate water supply services. A partly from service coverage, there are other problems that affect public service providers such as low or high pressure, high unaccounted for water (UFW) and financial problems due to a combination of low tariff, poor services, poor consumer records and inefficient billing practices (Kimey, 2012). Models are used to predict pressures under specific demands conditions and a variety of scenarios to identify low pressures and to select infrastructure that will improve flow or less pressure deficiency. According to Candelieri, et al., (2013) Water losses (physical loss) in the urban water supply is accounted to more than 50% of the supplies that mainly arise from leakage of pipes, joints, and valves, overflowing service reservoir and waste of water through illegal connection and non-metered house connections. Although leakage is one of the major causes of loss of water in the network distribution system, the loss of water through illegal connections and non-functioning meters is also contributing a lot; that needs a proper management and monitoring system. The estimated water supply service level of Ethiopia in terms of coverage, quantity, quality and reliability is very low (Taha AL-Washali, et al., 2020). Water supply is an inevitable part of the urban infrastructure. The operational practices of large-scale water supply networks still continue to be a major engineering challenge (WHO, 2011). Water supply authorities are responsible to meet consistently the demand of different water consumer sectors including fire flows in the distribution system, to maintain reasonable flow velocities and service levels within the possible operational boundaries and to manage the available storage capacities for balancing the supply and demand in the pipe network. According to Ethiopian Water Sector Strategy (2001), condition of sustainable, professional, reliable, and reasonable and user 's acceptable water supply to the urban population is a major concern in Ethiopia in general and in South Nation Nationality and People Region in particular. The need on water supply increases due to the population growth rate, increasing standards of living and the increase in per capita consumption. As the result of demand increase in water supply, the additional water resources and infrastructure is growing.

The town is one of the developing towns in Ethiopia in which there is a growing demand for water and sanitation services in the town due to growing populations. The existing infrastructure of the town is old and in poor condition. There are frequent interruptions to the scheme due to the breakdown of equipment, shortage of technicians, and inefficient operation and maintenance practices. This caused the population to not get adequate water due to the shortage of water and also, one of the causes of this problem is that the existing water supply system has a design problem. There are many cases in the customers illegally tapping into a water main so as obtain water without paying for it. Beyond committing a crime (theft of water, thus depriving the water utility of revenue), people who make illegal connections to the water supply system also compromise the safety of the mains water through possible contamination. This event can be caused simply by making a break in the pipe without taking the necessary protections to prevent contamination. According to Candelieri, et al., (2013) Leakage is often a large source of unaccounted for water and is a result of either lack of maintenance or failure to renew aging systems. Leakage may also be caused by poor management of presser zones, which result in pipe or pipe joint failure. Although some leakage may go unnoticed for a long time, detection of visible leakage also requires good reporting which includes some level of public participation.

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

1.2.Statement of the Problem

The major gaps of urban water supply systems in developing countries are low water supply service coverage, unavailability of sufficient water at all times, occurrence of very high amount of water loss, due to it does not meet national or international drinking water standards, (World Bank, 2006). Concerning performance and water availability, the capacity of the water supply system which includes sources, transmission, storage facilities and distribution system should satisfy current and future demands. Daye Town is one of the medium level towns in the country with recent rapid urbanization and high population growth. The area has been experiencing frequent and regular disruption of water supplies for days to a week, high rate of water losses from the distribution systems, frequent pipe bursting in the water distribution network, water pressure and velocity variation, very old and outdated structures, and intermittent water flow. Although the town water supply and service office trying to control the problem, delivering sufficient water without any interruption to the dwellers remains a dream. First-time rate of population growth, urbanization and the need for repair and maintenance of very old and outdated structures widen the gap between demand and supply of water in the town. This study focused on the improvement of water supply system service through research-based estimation of water demand and appropriate hydraulic networking. Therefore, this research work evaluated the status of distribution system performance of the town and recommended possible measures for` problems in hand.

1.3.Study objective

1.3.1. General objective

The overallobjectiveofthisstudywasto evaluate the water Supply system performance of Daye Town using WaterGEMS and Study the associated gaps of the Towns' Sanitation system by SPSS.

1.3.2. Specific Objectives

- To evaluate the existing water demand as well as its supply, service coverage and forecast future water demand of the Town.
- To assess the existing associated gaps in sanitation using SPSS
- To evaluate the performance of the existing water supply system using WaterGEMS
- To quantify the water loss and identifying the causes of water loss in the distribution network
- To propose remedial measures for Water Supply and Sanitation associated gaps.

1.4.Research Questions

The study addressed the following research questions:

1. Is the present water supply satisfying the current and future demand of the Town?
2. What are the existing problems related to hydraulic parameters in the distribution system?
3. What are the associated causes for the Water supply and Sanitation gaps in the study area?

4. How much water is lost in the system comparing with the system production?
5. What are the causes for water loss in the area?
6. What are the remedial measures to be taken for Water Supply and Sanitation associated gaps of Daye Town?

1.5.Scope of the study

This study is limited to assess the existing Water supply system and access to safe water and sufficient water supply requirements with the perspective of the national guidelines using WaterGEMS analysis of Daye Town. The sanitation assessment of the Daye town will be analyzed using SPSS analysis with respect to the national water, hygiene, and environmental health communication-guidelines. Depending on the analysis, the factors associated with Sanitation and water supply accessibility will be described.

1.6.Significance of the Study

The study outcomes will help identify different factors that determine water supply schemes functionality and Water access in the community to plan and propose remedial actions. And the assessment of Sanitation facility with the associated factors for the gaps will be evaluated. The decision makers, government and NGOs which have interest in financial and technical support in the area can use the research outcomes as reference for their objective. Moreover, it will serve as the input for further study.

1.7.Thesis Organization

Generally, the thesis was structured into five chapters, a reference list and appendices. Chapter one introduces the study with its objective, statement of the problem, the significance of the study and scope of the study. Chapter two describes literature review related to the study.

Chapter three deals thematerials and methods that areused in the study. At this chapter the study area was described, the available data are collected and analyzed and the procedures to address the study objective were well-defined. Chapter four describes results and discussions and chapter five deals with conclusions and recommendations of the study. The reference list outlines the bibliography of the materials to which the respective citations refer. The Appendix provides supplementary information to the materials used and results in the study.

2. LITERATURE REVIEW

2.1.General about Water Supply

In water distribution system, the reliability of water with a constant flow rate should be available to customers throughout the design time. If water is not available in sufficient quantities it should be pumped for a short period of time and at high flow rate, to meet the various demand of customers. Accordingly, service reservoir/storage tanks usually provided in order to store water when the pumping rate is higher than the demand at low/night times. But this can be also used in the case that the pumping rate is below the needed demand, since to equalize the pressure in the network (Hussni, S. & Zyoud, A.R. , 2003).

In developing countries, many water authorities are facing the gaps in providing adequate water supply to the rapidly growing populations. Thereby, most of the existing water supply systems are unable to meet the various demands of water. Besides this; infrastructural aging problem, poor management of the existing system components/assets and utility capacity shortages increased the level of water losses in the distribution system (Welday, 2005).

Water utilities are facing a high level of water loss in their distribution networks. 'For many utilities, reducing loss should be the first option to pursue when addressing low service coverage levels and increased demand for piped water supply. But, expanding water distribution networks without addressing water losses will only lead to a cycle of waste and inefficiency'(HC, 1990).

Water distribution system Modelling has become a key tool in evaluating existing water networks and planning for future development. Modelling can show the weak links in a distribution system. The key part of water system Modelling is the use of field data to calibrate the computer model. Field data is gathered by flowing a city fire hydrant and measuring the flow rate, monitoring a nearby hydrant for static and residual pressures, and recording production and storage levels at the time of the test (Hussni & Zyoud, 2003a).

Zewdu (2014) has recognized as water supply distribution network system, which enables to obtain the existing water supply system and water loss in the distribution system is a growing management problem in Ethiopia, there are few studies conducted on the existing Modelling of urban water supply in the country related to water loss and coverage.

Mays (2004) stated pressure-reducing valves are often used to establish lower pressure in WDNs, with more than pressure zone. As upstream pressure increases, the valve will close, creating more head loss across the valve, until the target pressure is obtained. WDNs of technical management it is necessary to explore establishing an attained pipe network estimation of flow and pressure head in network pipe has been of the great amount and concern for those design construction, operation, maintenance, conservation of municipal water distribution system, so, it is not exaggerated to say that supplying and distributing of adequate water form the basis of water life is thus divided into several district pressure zones.

2.2.Water demand and Coverage

2.2.1. Water Demand

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

Types of water demand

i. Domestic Demand

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

ii. Institutional, commercial, and public demands

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

iii. Industrial Demand

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

2.2.2. Water supply Coverage

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

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

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

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

- Residential occupancy water consumption.
- Commercial occupancy water consumption.
- Industrial occupancy consumption.
- Municipal and educational building use; etc.
- Needed Fire Flows (NFFs) that are available from a planned location of fire hydrants throughout the municipality; and

- Water for special community needs that include parks and recreation, street cleaning, decorative water fountains, sale of water to contractors through metered water from fire hydrants, etc. (Harry, 2008).

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

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

2.3.Water Loss and Leakage in Distribution System

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

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

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

2.3.1. Non-Revenue Water (NRW)

According to Rudolf & Liemberger (2010) Until the early ’90s, there was no standard term to express and assess the water losses in the distribution system. The International Water Association (IWA) has acknowledged this problem and established the Water Loss Task Force (WLTF). The WLTF examined the international best practices and developed a standard terminology as “Non-Revenue Water is the difference between the volume of water put into the water distribution system and the volume that is billed to customers.”

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

A. Real losses

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

i. Reported or visible leaks

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

ii. Unreported or hidden leaks

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

iii. Background leakage

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

B. Apparent Losses

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

C. Unavoidable Annual Real Losses

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

2.4.Factors Causing Water Loss in the Water Distribution Networks

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

However, the purpose of hydraulic integrity in the water distribution system is to supply water at adequate/acceptable pressure and flow. But, according to (Chambers, et al., 2004). The most common factors for intermittent water supply and loss of hydraulic integrity in the distribution system are described in the following sections.

2.4.1. Low pressure

However, there is pressure loss by the action of friction at the pipe wall and its magnitude also dependent on the water demand, properties of the fluid that is passing through the pipe, the speed at which it is moving, and the internal roughness of the pipe, pipe length, gradient and diameter of the pipe. Such situations may occur where there are: properties on high ground, remote properties at the end of long lengths of pipe, demands that are greater than the design demand, pipes of inadequate capacity (too small diameter), rough pipes (e.g., corroding iron pipes or pipes with a build-up of sediment) and equipment failures such as pumps and valves. In general, poor pressures tend to be caused by inadequate capacity in a pipe or pump, high elevations, or some combination of the two' (Candelieri, et al., 2013).

2.4.2. High pressure during low demand conditions

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

2.4.3. Pump capacity

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

2.4.4. Demand Increase

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

2.4.5. Poor infrastructures

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

2.4.6. Operation and maintenance activities

Water distribution systems are occasionally subject to emergencies or planned maintenance activities in which certain components become not workable and the system can no longer provide the minimum level of service to customers. Planned maintenance activities include supplies going offline (e.g., reservoir shut down for inspection, cleaning, or repairs; installation of new pipe connections; pipe rehabilitation or brake repairs; and transmission main valve repairs.) while, emergencies include earthquakes, power failures, equipment failures, or transmission main failures. Therefore, all these activities can result in a reduction in system capacity and supply pressure, and changes to the flow paths of water within the distribution system' (NRC, 2006).

2.5. Strategy for water loss management in developing countries.

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

Due to time limitation all the strategy issues are not addressed, rather some of theremedialmeasures to be taken are discussed in this section. The following may be considered to beremedial actions to be taken to reduce water loss and leakage in a distribution system but not limited:

Setting leakage index

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

2.5.1. Water audit

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

2.5.2. Performance indicator and bench marking

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

2.5.3. Improving organizational management and provision of training

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

2.5.4. Proper maintenance and renewal

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

2.5.5. Regular inspection of the water network

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

2.5.6. Calibration and replacement of customer meters

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

2.6.Basic Principles of Hydraulic Modelling

The network hydraulic model provides the basis for Modelling water supply in distribution systems. This event provides a characteristic of hydraulic Modelling, an overview of model inputs, and general criteria for selection and application (Cincinnati, 2005). Using simulations, problems can be anticipated in proposed or existing systems and can be evaluated before time, money, and Materials are invested in a world (Hickey, 2008).When a water distribution system does not provide water 24 hours per day to their customers, but they are supplied by turns during some hours, such a system is named as intermittent. Therefore, these systems may have zones of the network with empty pipes, while some other zones receive water with low pressures.

Model-based simulation is a method for mathematically approximating the behavior of real water distribution systems. To effectively utilize the capabilities of distribution system simulation software and interpret the results produced, the modeler must understand the mathematical principles involved.

According to (Thomas, 2003). There are two most basic types of simulation that a model depends on.

Steady-State, Simulation

Computes the state of the system (hydraulic parameters such as flows, pressures, pump operating appearances, valve positions) by assuming that demands and boundary conditions were not changed to time (Thomas, 2003).

Extended Period Simulation

Computing the state of the system as the information required by a steady-state model, where the system can to provide the acceptable; levels of the model with the duration multiple of 24 hours with the hydraulic demand and boundary conditions do change to time (Lemma, 2011)

2.7.Hydraulic Modelling of Water Distribution System

According to Haestad (2003) States that several computer programs are available for Modelling, analyzing, performance evaluated under various physical and hydraulic condition including, EPANET, Bentley WaterCAD, and Bentley WaterGEMS for Modelling distribution network systems have been designed for each of the pressure zone based on the design top and bottom water levels of the associated reservoirs and the agreed design criteria using the hydraulic Modelling computer program

2.7.1. Use of Modelling Application

Modelling of water supply schemes is an excellent tool for qualifying real-world crucial problems, emergency response, planning, estimation, and understanding of different types of water losses. Also, a model is important for water supply distribution systems due to its complex topology, frequent maintenances, and changes. As a result, the way to develop a model is to break it down into its components and work through each step. Some tasks can be done in parallel while others must be done in series.

The undertaking of any Modelling project is to develop a consensus within the water utility regarding the need for the model and intended purpose for which the model will be used for both short- and long-term periods. Before these, there is no single correct way to use models on the case of how a model application used to last. For example, for design purposes, it differs depending on whether the model is being used for master planning, preliminary design, subdivision development, or system rehabilitation (Haestad, 2003). Also, every type of model has a specific goal, characteristics, and Modelling purposes interims of diverse application; therefore, it should not be viewed as an isolated endeavor by a single modeler but rather a utility wide effort with the modeler as the key worker.

2.7.2. Water Distribution Network Model Selection

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

The advantages of WaterGEMS CONNECT Edition Update 2 over other software's its tools for a simplified model building with geospatial modules like water quality modelling, fire flow analysis, optimization and scenario management, etc. WaterGEMS CONNECT Edition Update 2 is thus easy to use as a multipurpose water distribution scheme as well as quality Modelling. Also, the main advantage of WaterGEMS application is its various tools like Darwin designer for analyzing the cost of pipes and pipe catalog tools which are found to be very effective for

Modelling, design, and optimization of water distribution network concerning strong data management and integration along with AutoCAD, ArcGIS and other related software packages (Bentley Systems, 2014).Moreover, the choice of software's for Modelling distribution network is based on the overall cost of the project, data required by software's, specificity of the software related to types of distribution networks it can handle as well as its computational requirements.

Bentley Water GEMS CONNECT Edition Update 2

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

Input data for assembling the model.

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

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

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

(Source: Hussni & Zyoud, 2003a)

2.8.Estimation of Water Demand

According Melaku Abebaw, (2015), when determine the water supply scheme of a city or town we have to know the total yearly, monthly, daily as well as hourly demand variation in the demand rates. There are so many factors involved in determining demand that make the actual demand estimation unreliable. However, the demand for various purposes is divided under the following categories: Domestic water demand (the amount of water needed for drinking, food preparation, washing, cleaning, bathing, and other miscellaneous domestic purposes), Nondomestic demand, Business or commercial water demand, Industrial water demand and Fire demand. One of the difficulties faced by the water service office is determining the accurate water demand if the town as the consumption during the past years that have been used as a base is far below the actual demand due to shortage of water. There are two primary approaches to water demand Modelling: deterministic water demand estimation, and stochastic demand estimating. Within the deterministic approach, the actual water demand for all major users is evaluated certainly based on anticipated water consumption over the service time. Be that as it may, stochastic water demand estimating considers questionable changes on water demand over time and area ranges (Mays, 2004).

2.9.Water Supply System Distribution Networks

Water distribution networks are very important lifeline structure systems, where failures are inevitable. Typical WDNs consists of network pipes, nodes linking the pipes, storage tanks, reservoirs, pumps, additional appurtenances like valves.According to Belay (2020) The water distribution system represents a major portion of the investment in urban infrastructure and a critical component of public works. The main goal is to design a water distribution system to deliver potable water over spatially extensive areas in required quantities and under satisfactory pressures. has recognized as water supply distribution network system, which enables to obtain the existing water supply system and water loss in the distribution system is a growing management problem in Ethiopia, there are few studies conducted on the existing Modelling of urban water supply in the country related to water loss and coverage. For domestic consumption, the water demand in a community is estimated by per capita consumption, Per capita consumption of water distributed to the network separated by the number of residents connected to the network in 24 hours l/c/day.

2.9.1. Problems of the water distribution system

Water flow is the function of several things, including the size and shape of the opening, and the pressure at the opening (Rossman *et al*., 2003). Typically, city water supplies are at 40-70 m, (static pressure). The older private system is set to maintain water pressure between 20 m and 40 m which is too low for some lifestyles; plumbers can set systems higher if the pump is capable of delivering higher pressure (MoWR, 2002).

Water pressure drops due to gravity.

Tezera (2011) stated that gravity another source of pressure loss in a residential plumbing system. Energy is required to push the water uphill. For every 0.305 m of elevation increase in a pipe, approximately 0.434 m is lost. With no water flowing, the static pressure available at the street main may be 60 psi, but the static pressure at the second-floor basin would be 52 m.

Water pressure drops due to corrosion.

According to Hutton and Haller (2014) When the water pressure is poor in the distribution system, the most common cause is corroded galvanized steel piping. The common 12.7 mm diameter piping can close down so that the opening is only 3.18 mm diameter or even less. The only solution is to replace the pipe typically with copper. It is omen wise to replace with a large diameter size pipe on the main feeds to least to improve pressure. When galvanized steel pipe is present, and pressure is low, it is common for accessible pipes running across the basement ceiling to be replaced first

Water pressure drops due to distance from the source.

Hutton and Haller (2014) stated that if more water is flowing, the pressure drops more at each point along the pipe. The more fixtures flowing at once, the greater the pressure drop at all fixtures and the lower at each fixture.

Other causes of poor water pressure

The supply line from the street to the house may be undersized, damaged, or leaking. Long runs of relatively small (13 mm diameter) pipe within a house will result in considerable pressure drop. A clogged pipe within the house will adversely affect the pressure. Also, defective, undersized or poorly adjusted pump will result in poor pressure (RATA, 2018).

2.10. Sanitation and associated factors assessment

Water and sanitation improvements, in association with hygiene behavior change, can have significant effects on population and health by reducing a variety of disease conditions such as diarrhea, intestinal helminths, guinea worm, and skin diseases. These improvements in health can, in turn, lead to reduced morbidity and mortality and improved nutritional status (Patricia Billig et al., 1999). Basic Sanitation access was considered for latrines which are not shared and having a piped water supply system and safe disposal of human waste.

Sanitation status of clients is associated significantly with educational status and household latrineavailability; clients who do not have latrine availability were 10 times more likely to have unimprovedsanitation status as compared to thosewho do not have latrineavailability (Yallew et al. BMC Public Health 2012).

2.11. Review of Related Studies

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

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

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

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

3. MATERIALS AND METHODS

3.1.Description of the Study Area

Daye is the center of Bansa Woreda which is one of the 36 Woredas in Sidama Regional State of Ethiopia.Daye is found 403 km away from the Addis Ababa, 130 km away from regional capital, Hawassa.The town Daye lies between UTM of 485566.157 to 482430.845 latitude and 728349.974 to 726287.479 longitude, with the altitude range of 2083 to 2134 meters above sea level. The town gets a mean annual rainfall of 1050 mm and average temperature of 22^0C.

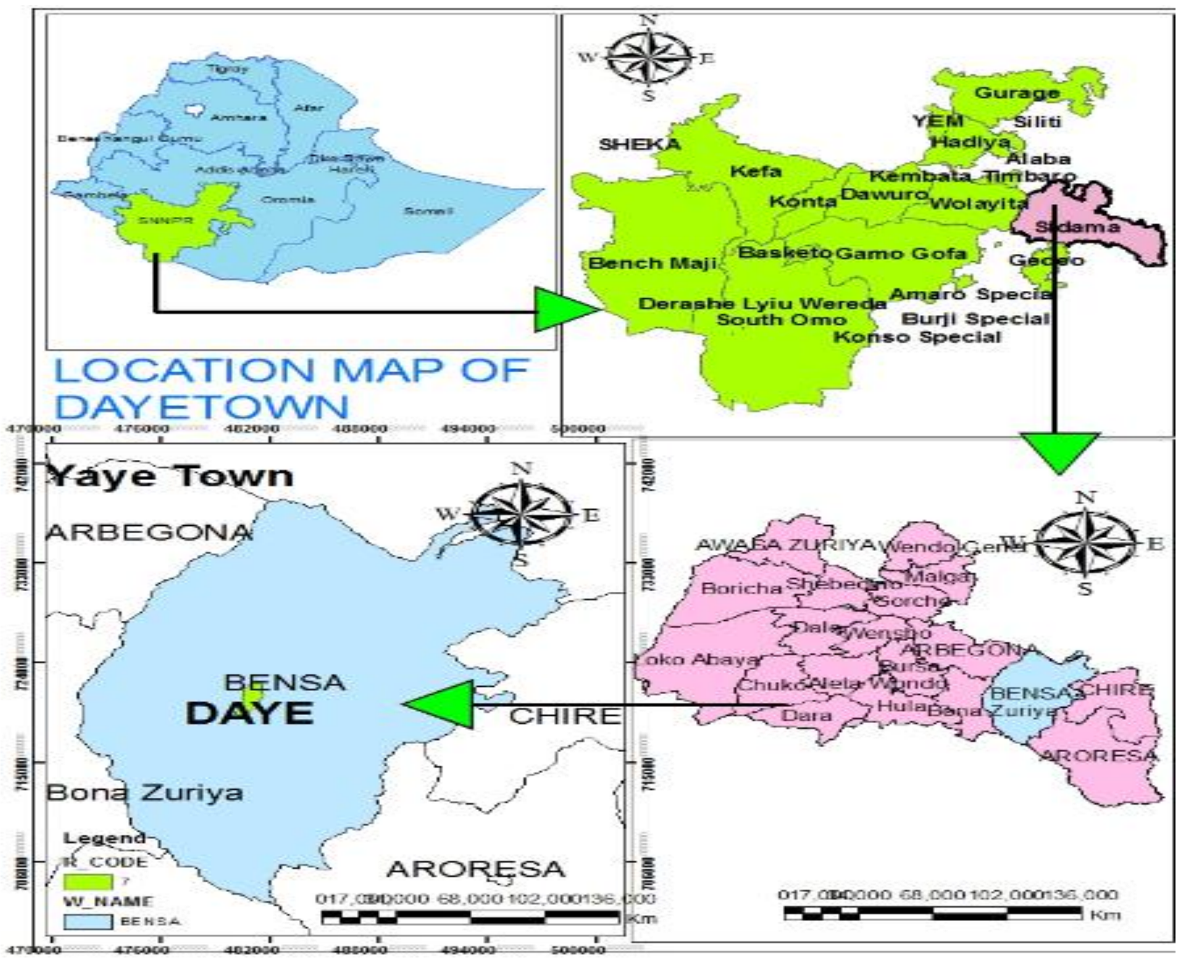


Figure 3.1: Location map of the study area

3.2.Methods

3.2.1. Study Work Steps

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

3.2.2. Materials and Tools Used

To achieve the goal of the research the materials that were used are a pressure gauge to measure the pressure at the nodes and pump outlet, GPS instrument used to collect the required coordinate and elevation data during pressure reading and Software tools that have been used are, BentleyWaterGEMS, AutoCAD 2016 etc.Pressure readings were done using pressure gauge which is commonly taken in the selected points of distribution system.To perform sanitation assessment SPSS analysis was used.

3.2.3. Data Collection and Source

The source of data was involved both primary and secondary data. For this study, the primary data were obtained from pressure reading, elevation surveying and made of discussion with water utility staff members to obtain additional relevant information on the subject matter.

While, secondary data were collected from different literature reviews, design report, the town water supply service office existing documents and annual reported papers.

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

i. Collected Primary Data

Primary data was collected through field survey and from key personnel of Daye Town WSSO. The data collection process included consultation and discussion with the respective officials of various agencies and institutes such as city administration, municipality, agriculture office and finance and economic office. Questionary survey conducted for the selected households to gather sanitation related primary data.

- ❖ By using GPS surveying instrument coordinate and elevation data of selected nodes were collected during pressure measurement on ten points by using pressure gauge.
- ❖ The type of pipe materials, fittings and valves has been collected from the site to identify whether the system have material quality problem or not.
- ❖ Pressure measurement is taken at different time and in different locations to perform calibration and validation. Pressure measurement throughout the entire day was conducted at Critical times were selected while pressure gauges were taken. According to the water services recommendation, these critical times were fixed based on the peak hour demand rate of the users which covers the time between 8:00-12:00 AM, 2:00-6:00

PM and 8:00- 12:00 PM. The operating performance indicator (unavoidable annual real loss) was calculated taking the average pressure in meter during nighttime.

- ❖ Discussion with the officials and experts in the concerned government office to acquire necessary information on WSS.
- ❖ Questionary survey to gather information on the existing sanitation situation in the Town.
- ❖ Site visit and observation on the key components of the water system to evaluate the functionality and physical appearance of the water system.

ii. Collected Secondary Data

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

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

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

The following data have been needed for implementation the modeling of thesystem:

Maps with layout of the existing distribution system.

- Contour maps determine the elevations of the consumption nodes.
- Capacity and elevation of the central storage reservoirs.
- Sources of water and available quantities of potable water.
- Demand Patterns for domestic consumption
- Commercial, industrial, public consumption
- Field measurements of pressure, flow and elevations and distances

Table 3.1: Quantity of pipe material in distribution system

Pipe Type	Length (m)	Coverage in System (%)
PVC	3,340	15.96
GI	8,930	42.69
HDPE	8,650	41.35
Total	20,920	

(Source: Daye Town Water Supply Service Enterprise)

3.3.Existing Water Supply System

The existing water supply system generally consists of three developed springs and two boreholes with pump and Generator (One serving the Hawassa University Daye Campus and Daye Industrial Park) the second one feed Daye Town. The main source of the Daye town water supply system is BH-2 located towards southeast part of the townMirado plain. The BHis constructed in 2006 E.C located about 6.4 km from the town and the discharge of the BHis8 l/s.

In addition, there are three springs, Debiso, Shalamo and Kimbichawith a yield of 1.5 liter/sec, 1.5 liter/sec, and 1 liter/sec respectively, which are conveyed via around 3km gravity main line to the 500m^3 concrete service reservoir.At downstream side of the Town there is a spring called Tsebel with 3.7 liter/sec yield and currently serving the Hawassa University Daye Campus. All spring sources and BH together cover 43% of the Town current standard demand.

Table 3.1: Existing water sources (DWSSO)

Source name	Lat	Long	Elevation	Yield (l/sec)
Debiso spring	6.56432	38.83337	2118.9	1.5
Kimbicha Spring	6.58705	38.84696	2149.0	1
Shalamo Spring	6.57805	38.84055	2140.9	1.5
BH-1	482288.1	718876.3	1871.150	8

Figure 3.2: Service Reservoir 500m^3

Figure 3.3: The existing water sources for Daye town and the neighboring villages

i. Operation & Maintenance Information of the Town

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

3.4.Water Supply Coverage

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

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

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

3.5.Analysis of Water Demand Coverage of Daye Town

3.5.1. Town population projection

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

Pn = Po* $(1+r)^n$ ……………………………………………………………… (3.3)

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

Pn = population after n years

r = Annual population growth rate in %

n = number of years of the concerned period.

Therefore, the future population of Daye town was projected by using the method for period of 2021 to 2042.

3.5.2. Present and Future Demand Forecasting

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

A. Domestic Water Demand

Estimation of water demand per mode of service and estimation of population by mode of service was used to calculate the average per capita water demand. The average per capita domestic water demand for each year was computed by combining water demand by mode of service and population percentage distribution by mode of service for the year 2021-2041.

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

i. Population percentage distribution by mode of service

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

ii. Per-capita domestic demand by mode of service

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

Adjustment to climate

In addition to per-capita water demand and mode of services which influence the quantity of water consumption, the climate also affected the water consumption, and the per-capita domestic demand was adjusted by factors which is given in table 3.3.

Table 3.2: Climate Adjustment factor (MoWR, 2006)

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

Adjustment for socio-economic activity

The domestic water demand also depends on the socio-economic situation of the area. Thus per-capita domestic water demand was modified using appropriate factor. The demand adjustment factors in socioeconomic situations were given in table 3.4.

Table 3.3: Demand adjustment factor for socioeconomic situation

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

B. Non-Domestic Water Demand

i. Institutional Water and Commercial Demand

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

ii. Industrial Water Demand

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

iii. Livestock Water Demand

Animal demand may be required if there are no water sources to the proximity of the town. From the existing information and observation made around the town there is a nearby river called Shama River. Therefore, it is believed that some of the animal demand will be meeting from Shama River and therefore about 5% of domestic demand is considered.

iv. Fire Demand

Fire demand is the quantity of water required for fighting a fire that may break out at commercial center, stores, etc. in the town. Fire demand can be expressed as a function of population, and it is estimated by using empirical formula. But, in Ethiopia, the demand is generally taken care of by increasing the size of service reservoirs by 10 % (MoWR, 2006).

v. Unaccounted water demand

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

Variation of Water Use

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

Table 3.4: Maximum daily coefficient and peak hour factor

Maximum daily coefficient	**Town population**	**Peak hour factor**
2.00	<20,000	**2**
1.55	20,000-50,000	1.9
1.45	50,001-100,000	1.8
1.15	>100,000	1.6

(Source: MoWR, 2006)

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

3.6.Water Loss Analysis

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

3.6.1. Quantifying Total Water Loss

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

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

i. Water Loss by Mathematical Calculation

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

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

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

ii. Water Loss by Water Balance Method

The AWWA Water Balance diagram shown in table 3.6 portrays all component volumes of water supplied, delivered to customers, or lost during the course of a reporting year. Each box represents an annual volume of water, and each column totals the same amount of water. Thus, all columns "balance" as water moves across the system, and all water is accounted for.

Accordingly, there is no "unaccounted-for" water, and AWWA recommends against use of the term "unaccounted-for water." Instead, AWWA recommends use of the term NRW. The water balance diagram provides accountability for water utilities by defining a clear path to quantify the loss volumes and demonstrate how those losses affect utility operations.

Table 3.5: Classification of water balanced method.

System input volume **A1**	Authorized Consumption **A2= A4 + A5**	Billed Authorized Consumption **A4= A8 + A9**	Billed Metered Consumption**A8**	Revenue Water **A18 =A8+A9**
			Billed Unmetered Consumption**A9**	
		Unbilled Authorized Consumption **A5= A10 + A11**	Unbilled Metered Consumption**A10**	Non-Revenue Water (NRW) **A19 = A1-A18**
			Unbilled Un metered Consumption**A11**	
	Water Loss **A3= A1-A2**	Apparent Losses (Commercial Losses) **A6 = A12 + A13 + A14**	Unauthorized consumption **A12**	
			Customer meter inaccuracies **A13**	
			Systematic data handling Errors **A14**	
		Real Losses (Physical Losses) **A7 = A15 +A16 +A17**	Leakage in Transmission and Distribution Mains **A15**	
			Storage Leaks and Overflows from water storage Tanks **A16**	
			Service Connection leaks up to the meter **A17**	

iii. Unavoidable annual real losses (UARL)

UARL represents the allowable volume of real losses from the system, which estimated a volume of leak that are undetectable or would be uneconomical to repair during the year. This can help to evaluate the feasibility of real loss minimization (provides better understanding of real loss component). The total length of main pipes was 20.92 km, number of service connections was 2,900and the average pressure 29.71 m from the result of Water GEMS was used in the calculation of UARL. Based on the analysis, unavoidable annual real losses of town were determined as:

UARL= (18*Lm+0.8*Nc+25*Lp) *P……………………………………………… (3.5)

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

Lm = length of main pipes (km)

Nc = number of service connections (main to meter)

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

P=average operating pressure (m)

3.7.Hydraulic Model Analysis

3.7.1. Modelling of water supply system

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

3.7.2. Data Organization

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

3.7.3. Nodal Demand Computation & Water Demand Analysis

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

Principles of Distribution Network Hydraulics

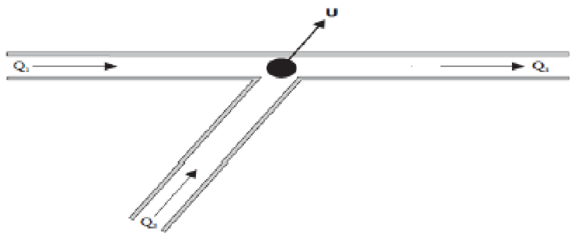
The two basic equations that govern in WaterGEMS modeling network of these interconnections are:

- Conservation of mass or continuity principle.
- Conservation of energy or energy principle.

Conservation of Mass

In network modeling, all outflowsare lumped at the nodes or junctions (Walski et al, 2003).

For steady incompressible flow:



Net flow into junction = Use at junction.

Mass in = Mass out

$$\sum_{pipes} Q_i - U - = 0$$

……………………………………………. eq. (3.6)

where Qi = inflow to node in i-th pipe (L3/T)

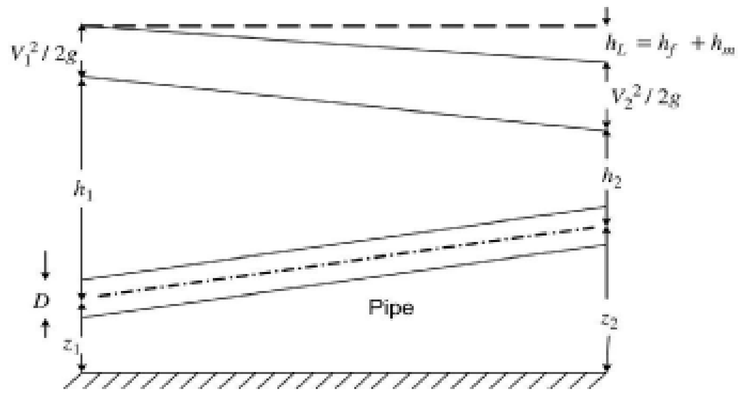
U = water used at node (L3/T)

Conservation of Energy

The Energy equation is known as Bernoulli'sequation and the principle of conservation of energy dictates that the difference in energy between two points must be the same regardless of the path is taken (Bernoulli, 1738 cited in Walski et. al., 2003). It consists ofthe pressure head, elevation head, and velocity head.

Head loss in pipeline

Energy is converted to energy per unit weight (ft-lb/lb) of water, reported in length units (ft) called "head".



Source: (Swamee, 2008)

Z1+P1/γ1+V12/2g+Σha=Z2+P2/γ2+V22/2g+Σhf+Σhm ______ Eq (3.7)

Where:

P= the pressure (Ib2/ft2)

γ = the specific weight of the fluid (Ib/ft3 or N/m3)

z = the elevation at the centroid (ft or m)

V = the fluid velocity (ft/s or m/s)

g = gravitational acceleration (ft/s or m/s2)

hL = the combined head loss (ft or m)

hf = friction loss(ft,m)

hm = head loss due to minor loss(ft,m)

hl = head loss due to pipe friction(hf+hm),(ft,m)

ha = head added by pumps

Pressure head - p / γ

Velocity head - V2 / 2g

Elevation head – z

Head loss in Water GEMS modeling

Head loss(hf)=10.67*C-1.85*D-4.87*Q1.85*L,

where, Head Loss,Hazen‑Williams Equation, Roughness Coefficient(C), Length of the Pipe(L), Inside Pipe Diameter(D), Volumetric Flow Rate(Q)

3.8.Model Calibration and Validation

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

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

3.9.Sanitation and associated gaps assessment

3.9.1. Existing Sanitation situation of Daye Town

There are 11 private and government owned schools (5-Kindergarten, 2-primary, 1-secondary, and preparatory schools) in the town. Damo Primary School (grade 1-8) having more than 3,000 students has three blocks of latrines with no water system working currently. One block for staff which is functional and two blocks for students not functioning (boys and girls). The students' blocks are not well managed and can't be used hence faces on the floor.

Figure 3. 1: Damo Primary School with Staffs Latrine block and water system

Figure 3.2: Daye Town Primary School existing students Latrine block

The only high school and preparatory school KewenaGata has 5 blocks of latrines with water system not functioning. The latrine blocks seem sufficient in stances for both gender with better appearance, except the nonfunctional water system near the blocks. Two elevated water tanks exist for the staff serving in irregular functioning time.

Figure 3.3: Kewena school existing Latrine blocks and the water system

3.9.2. Hygienic sanitation facilities

Percentage of population using hygienic sanitation facilities, where sanitation facility is defined as an excreta disposal facility, typically a toilet or latrine; and hygienic means there are no feces on the floor or seat and there are few flies (Patricia Billig, Diane Bendahmane and Anne Swindale 1999).

- **Households with year-round access to improved water Source**

  Calculation

Percent of households with year-round access to improved water source

$$= \frac{\text{Number of households in the sample with access to improved water source}}{\text{Total number of households in the sample}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

Households with access to a sanitation facility

Calculation

Percent of households with access to sanitation facility

$$= \frac{\text{Number of people in households in the sample using hyginic sanitation facilities}}{\text{Total number of people in the households in the sample}} \ldots\ldots\ldots\ldots\ldots\ldots (3.9)$$

3.9.3. SPSSAnalysis

Developing countries are facing unprecedented demographic, environmental, economic, social and spatial challenges. One of the major 21st century global challenges in public health is improving the urban sanitation related problems. SPSS (Statistical Package for the Social Sciences) statistics is a software package used for logical batched and non-batched statistical analysis. This software is one of the most popular statistical packages which can perform highly complex data manipulation and analysis with simple instructions. The SPSS software package was created for the management and statistical analysis of social science data. It was originally launched in 1968 by SPSS Inc. and was later acquired by IBM in 2009. Questionary was distributed to the selected households and analyzed for the sanitation coverage of the area depending on the availability of improved latrines and status.

3.10. Study design

The target population for this study is all the residents of the Daye Town including the school and health Center community. The current population number is forecasted for the next 20 years of design periods for the per-capita demand computation.

To determine the sample size for the study, three key factors such as confidence interval (it is also called level of precision or sampling error), confidence level, and the population size are considered. According to Israel (2009) considering the aforementioned factors Yamane (1967) simplified formula to calculate sample sizes will be used.

$$\mathbf{n} = \frac{\mathbf{N}}{\mathbf{1+N}(e)^{2}} \quad \text{(3.10)}$$

Where, n is the sample size, N is the population size, and e is the level of precision/ confidence interval. Systematic random sampling is used to select $\mathbf{k^{th}}$ individual from gridded population, i.e.

$$k = \frac{N}{n}$$

Where, k is $\mathbf{k^{th}}$ individual from gridded population.

4. RESULT AND DISCUSSION

4.1.Water Supply and Demand Coverage

4.1.1. Water Supply Coverage Analysis

To identify the gap between demand and supply three ways are followed, first by using annual domestic consumption identifying the level of per capital demand per person, second computing the per capital demand by level of connection and third by following the design criteria calculating the overall demand coverage. The current i.e., 2021 population number of Daye Town is 30,925 and the annual consumption was 103,986m^3. To evaluate the amount of water consumption, the annual water consumption is converted to average daily per capita consumption using the population data of the town and the number of domestic connections per family has been also used to analyze the level of connection. The volume of water consumed for domestic purposes has been distributed for all beneficiaries of the town to analyze the distribution of the water supply coverage.

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

$$= \frac{103{,}986 (m^3) * 1000 \text{ l}/m^3}{30{,}925 * 365 \text{ day}} = 9.21 \text{ l/c/d}$$

By using the above expression, the average daily per capita consumption became 9.21l/c/day. According to WHO (2008), the minimum quantity of domestic water required in urban areas of developing countries is taken as 20 l/c/day. Regarding this value, the domestic water supply of Daye Town only satisfies 46.05% of the standard value. In addition, according to GTP-II (Ethiopian Water Sector Strategy, 2015); the per capita consumption standard set for category-3 town like Daye is 50l/c/day. But the current water supply coverage is only satisfying almost 18.42% of the demand.

Level of water connection per family is one mechanism to evaluate the level of water coverage. The total number of connection or water meter within the town are about 2,900that among these 2000are for domestic users, according to the census of the 2007, average family size of 5 was used for calculating the average number of connections per family using the following expression.

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

$$= \frac{2000}{(30{,}925/5)} = 0.3234$$

The level of water connection as per the above expression became 0.3234; this implies that the current connection coverage is only 32.34%.

4.1.2. Analysis of overall Water Demand Coverage

A water supply system capable of supplying sufficient quantity of portable water is necessary for the town. In order to estimate as correctly as possible, the total demand of a particular community, all demands must be considered. Generally, speaking in design of water supply scheme for a town, it is necessary to determine the total quantity of water required for various proposes. This is done as follows.

Present and Future Domestic Water Demand

i. Population Forecasting

The water demand of a particular town is proportionally related with the population to be served. According to Municipal finance and economic development office, the current (2021) population of Daye Town is 30,925 and it was used as base population for current estimation. According to CSA, the regional level annual growth rate of urban population and applying geometric increase method, the estimated number of populations from 2021 to 2041 of the town were presented in table 4.1 below.

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

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

Pn = projected population after n years

r = annual growth rate

n = number of years or time horizon.

Table 4.1: Projected population of the town (2021-2041)

Year (G.C)	**2021**	**2026**	**2031**	**2036**	**2041**
Population growth rate	0.0351	0.0335	0.0315	0.0295	0.0290
Projected Population	30,925	35,227	40,739	46,208	52,921

(Source: CSA, 2007 National statistical census document, South Region, Daye town)

ii. Population distribution by mode of service

The percentage of population to be served by each mode of service will vary with time. The variation is caused by changes in living standards, improvement of the service level, changes in building standards and capacity of the water supply service to expand.

The mode of service is an important element to assess the level of water coverage of the town. Based on the available data obtained from the Water Supply Service during the field visit in 2021; four major modes of service were identified for domestic water consumers. These are house tap users (HTU), yard connections users (YCU), yard shared Connections users YCU(S) and public tap users (PTU). The number of population percentage in each mode of service was indicated below in table 4.2.

Table 4.2: Population Percentage Distributions by Mode of Service

Mode of service	Unit	2021	2026	2031	2036	2041
HTU	%	6.36	7.60	10.60	13.60	16.60
YCU	%	30.00	37.00	42.00	47.00	52.00
YCU(S)	%	16.14	15.80	14.80	13.80	12.80
PTU	%	47.50	39.60	32.60	25.60	18.60
Total	%	100	100	100	100	100

iii. Per-capital domestic demand by mode of service

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

Table 4.3: Projected Per Capita Demand by Mode of Service (2021 -2041)

Mode of service	Unit	2021	2026	2031	2036	2041
HTU	l/c/d	50.00	50.00	50.00	55.00	60.00
YCU	l/c/d	25.00	25.00	25.00	27.00	30.00
YCU(S)	l/c/d	30.00	30.00	30.00	35.00	40.00
PTU	l/c/d	20.00	20.00	20.00	23.00	25.00

(Source: MoWR, 2006)

By using tables 4.3 as the base of other water demand calculation the water domestic demand was projected for 2021-2041 by including non-revenue water and other factors. The average per capital domestic water demand for each year was computed by combining water demand by mode of service from the year 2021-2041. As shown the table 4.4 below the total domestic water demand was forecasted by each mode of service throughout the design period.

Table 4.4: Domestic water demand determination

Year (G.C)	Unit	2021	2026	2031	2036	2041
Population Growth Rate		0.0351	0.0335	0.0315	0.0295	0.0290
Forecasted Population	No	30,925	35,227	40,739	46,208	52,921
Population Projection by Mode of Services						
HTU	%	6.36	7.60	10.60	13.60	16.60
YCU	%	30.00	37.00	42.00	47.00	52.00
YCU(S)	%	16.14	15.80	14.80	13.80	12.80
PTU	%	47.50	39.60	32.60	25.60	18.60
HTU	No	1967	2677	4318	6284	8785
YCU	No	9277	13034	17111	21718	27519
YCU(S)	No	4991	5566	6029	6377	6774
PTU	No	14689	13950	13281	11829	9843
HTU	(l/c/d)	50.00	50.00	50.00	55.00	60.00

YCU	(l/c/d)	25.00	25.00	25.00	27.00	30.00
YCUS	(l/c/d)	30.00	30.00	30.00	35.00	40.00
PTU	(l/c/d)	20.00	20.00	20.00	23.00	25.00
HTU	(m^3/d)	98	134	216	314	527
YCU	(m^3/d)	232	326	428	543	826
YCUS	(m^3/d)	150	167	181	191	271
PTU	(m^3/d)	294	279	266	237	246
Total Domestic Water demand (TDWD)	m^3/d	**774**	**905.68**	**1,090.19**	**1,285.05**	**1870**
	l/s	8.96	10.48	12.62	14.87	21.64

Based on the table 4.4, the total domestic water in year 2021 was 773.80 m^3 /day and for the year 2041 was 1,869.71 m^3 /day.

iv. Socio-economic and climatic adjustment factor

Town is considered as a town of "high potential growing town under normal Ethiopia conditions and it is categorized with the towns of group C and its altitude was 1,900m which is found b/n 1500-2300m. Based on these values, the socio-economic and climatic adjustment factors of the town were 1.0for each.

Table 4.5: Climatic adjustment factors

Year (G.C)	**Unit**	**2021**	**2026**	**2031**	**2036**	**2041**
Total DWD	m^3/d	773.80	905.68	1,090.19	1,285.05	1,869.71
Socio-economic Factor	No	1	1	1	1	1
Climatic Factor	No	1	1	1	1	1
Adjusted Domestic Water Demand (ADWD)	m^3/d	773.80	905.68	1,090.19	1,285.05	1,869.71
	l/s	8.96	10.48	12.62	14.87	21.64

Sample Calculation:

Adjusted domestic water demand (2021) = socio-economic factor*total domestic demand

773.80 m^3/d *1= **773.80 m^3/d**

Adjusted domestic water demand (2041) = socio-economic factor*total domestic demand

1,869.71 m^3/d *1= **1,869.71m^3/d**

Based on the table 4.5 the domestic water demand of the study area was **773.80** m^3/day in the year 2021 and **1,869.71** m^3/day in year 2041. After the domestic water demand was projected, water loss, public and commercial and industrial water demand were computed to analyse the total water demand of the town.

v. Peak hour and maximum day factor

For this study the peak hour factor was taken 1.9 up to the year of 2021- 2038 because of the population of the town was b/n 20,001-50,000 and from 2039-2041 the peak hour factor was taken 1.8 because of the population of the study area was 50,001-100,000.Also, the maximum day demand factor was taken 2 and 1.15 for 2021-2038 and 2039-2041 respectively (MoWR, 2006).

Table 4.6: Recommended Peak hour Factors

Population Range	Peak hour factor
< 20,000	2
20,001 to 50,000	1.9
50,001 to 100,000	1.8
>100,000	1.6

(Source:MoWR, 2006)

Table 4.7: Summary of Water Demand Analysis

Year (G.C)	Unit	**2021**	**2026**	**2031**	**2036**	**2041**
Population Growth Rate		0.0351	0.0335	0.0315	0.0295	0.0290
Forecasted Population	No	30,925	35,227	40,739	46,208	52,921
Population Projection by Mode of Services						
HTU	%	6.36	7.60	10.60	13.60	16.60
YCU	%	30.00	37.00	42.00	47.00	52.00
YCU(S)	%	16.14	15.80	14.80	13.80	12.80
PTU	%	47.50	39.60	32.60	25.60	18.60
Population Served by Mode of Service						
HTU	No	1967	2677	4318	6284	8785
YCU	No	9277	13034	17111	21718	27519
YCU(S)	No	4991	5566	6029	6377	6774
PTU	No	14689	13950	13281	11829	9843
Per Capital Demand by Mode of Service						
HTU	(l/c/d)	50.00	50.00	50.00	55.00	60.00
YCU	(l/c/d)	25.00	25.00	25.00	27.00	30.00
YCUS	(l/c/d)	30.00	30.00	30.00	35.00	40.00
PTU	(l/c/d)	20.00	20.00	20.00	23.00	25.00
Domestic Water Demand by Mode of Service						
HTU	(m^3/d)	98	134	216	314	527
YCU	(m^3/d)	232	326	428	543	826
YCUS	(m^3/d)	150	167	181	191	271
PTU	(m^3/d)	294	279	266	237	246
Total Domestic Water demand	m^3/d	**774**	**905.68**	**1,090.19**	**1,285.05**	**1870**
	l/s	8.96	10.48	12.62	14.87	21.64
Socio-economic Factor		1	1	1	1	1
Climatic Factor		1	1	1	1	1
Adjusted Domestic Water Demand (ADD)	m^3/d	**774**	**905.68**	**1,090.19**	**1,285.05**	**1870**
	l/sec	8.96	10.48	12.62	14.87	21.64
Non-Domestic Water Demand (NDWD)						
Institutional & Commercial Water demand & (10% of ADD)	m^3/d	77.38	90.57	109.02	128.50	186.97
	l/sec	0.90	1.05	1.26	1.49	2.16
Small Industries demand (10% of ADD)	m^3/d	77.38	90.57	109.02	128.50	186.97
	l/sec	0.90	1.05	1.26	1.49	2.16
Livestock Water Demand (5% of ADD)	m^3/d	38.69	45.28	54.51	64.25	93.49
	l/sec	0.45	0.52	0.63	0.74	1.08

Total Demands (TD)	m^3/d	1044.63	1222.67	1471.75	1734.81	2524.10
	l/sec	12.09	14.15	17.03	20.08	29.21
UFW (15-25% of TD)	%	15	16.43	18.33	20.71	23.10
UFW or NRW	m^3/d	116.07	148.80	199.83	266.13	431.90
	l/sec	1.34	1.72	2.31	3.08	5.00
Average Day Demand	m^3/d	1160.69	1371.48	1671.58	2000.95	2956.01
	l/sec	13.43	15.87	19.35	23.16	34.21
Max. Day Factor		1.5	1.5	1.5	1.5	1.55
Max. Day Demand	m^3/d	1741.035	2057.22	2507.37	3,001.43	4,581.81
	l/sec	20.15	23.81	29.02	34.74	53.03
Peak Hour Factor		1.9	1.9	1.9	1.9	1.8
Peak Hour Demand	m^3/d	2,205.32	2,605.81	3,176.01	3,801.80	5,320.81
	l/sec	25.52	30.16	36.76	44.00	61.58

The total water demand of the town was determined by summing up the adjusted domestic water demand and non-domestic water demands as shown in the above table. Therefore, the total maximum water demand is 1741.04m^3/day and 4,581.81 m^3/day in the year 2021 and 2041respectively.

4.1.3. Finding and conclusion

From the water supply analysis as per level of average per capital consumption of the town found to be 9.21 l/c/d l/day. This average per capital consumption which only satisfies 18% of the minimum urban water consumptionwhich only satisfies 18% of the requirement of domestic demand which is 50 l/c/d, hence the town category C. The other way followed to evaluate the town water coverage was the level of connection per family. The average level of connection in house is about 22.7%, which is relatively low 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 showed the total average current demand was 1,160.69m^3/day. However, the amount of water production in 2021showed as 511.20m^3/day, which have only 44% coverage of the demand. Therefore, the result shows there is high gap between demand and supply which means the current supply only satisfies 44% of the current demand (2021) and 17% of the future demand in year 2041. From this, we concluded that the utility should have to supply additional water to satisfy the current and the future demand of Daye town by searching additional water sources.

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 (real) losses, commercial (apparent) losses, and unbilled authorized consumption.

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

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

A. Total Water loss Computation

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

$$NRW (\%) = \frac{(production \ - metered \ \ use)*100\%}{Production} \text{.. (4.4)}$$

Table 4.8: Computed Total Water Loss

Year	Production (m^3/year)	Consumption (m^3/year)	Loss (m^3/year)	Loss (%)
2018/19	131,400	89,950	41,450	31.54%
2019/20	136,875	99,389	37,486	27.39%
2020/21	138,700	103,986	34,714	25.03%

B. Water loss expressed as per number of connections.

The total number of connections in the study area is 2,000 the water loss per connection computed by using this expression:

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

From the year2021 computed total annual water loss value of 34,714 m^3 is used.

Water loss =34,714*1000/ (2000 *365) =47.5 lit/connection/day

C. Water loss expressed as per length of pipes.

Expressing water loss as per km of main pipe is one way to indicate the loss. The total length of pipes is 26.498Km,and this total pipe length is used to express the water loss.

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

Water loss =34,714/ (26.498km *365) = 3.6m^3/km/day

4.2.2. Determining the water balance and Water Loss components

Annually water produced and distributed to the supply system and the water billed that was aggregated from the individual customer meter readings of one-year 2021 was used to quantify the total water loss for the entire town. The entire annual production and billed water consumption of scheme are shown below in table4.9.

Table 4.9: Water balance method

<table>
<tr><td rowspan="10">System input volume
138,700</td><td rowspan="4">Authorized Consumption
103,986
74.97 %</td><td rowspan="2">Billed Authorized Consumption
103,986</td><td>Billed Metered Consumption
103,986</td><td rowspan="2">Revenue Water
103,986</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non-Revenue Water (NRW)
34,714</td></tr>
<tr><td>Unbilled Un metered Consumption</td></tr>
<tr><td rowspan="6">Water Loss
34,714
(<u>312,426</u> birr fiscal year loss)
25.03 %</td><td rowspan="3">Apparent loss (Commercial Losses)
0.9%
1,248.30
<u>11,234.70birr</u></td><td>Unauthorized consumption
0.1% 138.70
<u>1,248.30birr</u></td></tr>
<tr><td>Customer meter inaccuracies
0.3% 416.10
<u>3,744.90birr</u></td></tr>
<tr><td>Systematic data handling Errors =**0.5%**
693.50 <u>6,241.50birr</u></td></tr>
<tr><td rowspan="3">Real loss (Physical Losses)
26.44%
36,672.28
<u>330,050.52 birr</u></td><td>Leakage in Transmission and Distribution Mains (**Not brokendown)**</td></tr>
<tr><td>Storage Leaks and Overflows from water storage Tanks (**Not broken down)**</td></tr>
<tr><td>Service Connection leaks up to the meter (**Not brokendown)**</td></tr>
</table>

i. Apparent loss

This component of the total water loss volume includes the loss due to unauthorized consumption, customer metering inaccuracies and data handling errors and is aggregated to 1,248.30m^3/year. This loss amount covers 0.9% of the total system loss. This result signifies less of the loss in the system as real loss which is mainly caused due to deterioration of the existing distribution system.

ii. Unauthorized Consumption

This volume of water includes theft and illegal connections. As there is not any means to determine this quantity of water, its volume is estimated based on the system input volume. Accordingly, the unauthorized consumption amounts to 138.70m3/year which is 0.1% of system input volume.

iii. Customer Metering Inaccuracies

The total volume of loss due to meter in accuracy in the system is 416.10m3/year. This apparent loss of water accounts for approximately 0.3% of the system input volume for the fiscal year and translates to lost revenue of approximately 3,744.9 Ethiopian Birr. Generally, in the case of Daye the main reason for this high meter under registration is the deterioration of water meters with age, resulting in inaccurate readings. This is highly influenced by the lack of water meter testing and replacement programme and unlimited service year for meters in the distribution system.

iv. Real loss

This category includes the volume of water lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering. In this specific study the real loss volume is found to be 36,672.28m^3/year. This apparent loss of water accounts for approximately 26.44 % by breakdown the two Loss categories of the system input volume for the fiscal year and translates to lost revenue of approximately 330,050.52 Birr.

So, in this figure indicates the deterioration of water supply system, water supply management problem and urgent need of a leakage of main and distribution (transition lines) and overflows in tanker area control program.

v. Unavoidable Annual Real Losses (UARL)

This category represents the allowable volume of real losses from the system, which estimates a volume of leaks that are undetectable or would be uneconomical to repair during the year. This can help to evaluate the feasibility of real loss minimization provides better understanding of real loss components.

Non-revenue or total loss is the sum of real loss and apparent loss. To know the value of both real and apparent losses, the unavoidable real loss is computed by using IWA expression before. Total length of service connections from the edge of the street to customer meters average of 6 m for individual, Lp (km)=6*2,000 =12,000 m=12km. The length of main line was 5.910km, number of service connections was 2,000and the average pressure value of 29.71 m is taken from model result and the value of UARL is estimated as follows.

UARL= (18*Lm+0.8*Nc+25*Lp) *P

UARL= (18*5.910+0.8*2000+25*12) *29.71 = 59,609.55 lit/day

59.61m^3/day = 21,757.49m^3/year

4.2.3. Possible Causes of Water Loss

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

i. Age of Pipe Network

The age of a pipe section can appear to be the most significant factor for leakage. It is estimated that nearly 60% of the pipe network was laid over 20 years ago. Except the newly installed customer pipe all the pipes are galvanized, HDP and steel pipes. All these materials suffer by new road construction time due to operational measures, environmental conditions and general wear and tear and result in increased leakage in the network. It is therefore necessary to replace older mains so that leakage occurs.

ii. Poor and Unscheduled maintenance of network

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

iii. Customer Meter inaccuracies

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

iv. Data Handling Error

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

v. Poor record keeping

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

vi. Community Behavior

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

vii. Operation and maintenance

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

Lack of assets and inadequate data on Operation & Maintenance

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

4.2.4. Possible Water Loss Reduction Strategies

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

i. Old Pipes and Fittings replacement and repair

In Daye town water supply system part of the pipe network were long aged and deteriorated to repair. In this case, it may be necessary to replace one or more length of pipe and fittings. While pipe replacement is best done using the same material as the existing pipe, lack of pipe stock or desire to upgrade to a less corrosive pipe material may dictate that the replacement material be another material. Aging infrastructure in the system means failing joints, leaking valve seals and corroded pipes, all contributing for water loss must be replaced by new one and repaired as required.

ii. Effective maintenance

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

iii. Water Balance check-up

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

iv. Assessing meter testing and replacement

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

v. Improving Organizational Management and Provision of Training

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

4.3.Hydraulic Modelling of the Town water Supply System

4.3.1. Pipe Type and Length of Town

The distribution system consists of a network of rising mains with total length 5,910m and distribution main with a total of 4,618 meters. The system contains pipe ranging from 32 to 100 mm in internal diameter of pipe. The distribution network in material type 395.25mm diameter of the pipe was the major pipes used in the distribution system, while 43.8mm diameter of the pipe was the least quantity used in the distribution system.

4.3.2. Demand pattern of town

The proposed distribution pipe network was carried out using Bentley WaterGEMS and the adequacy of the system to meet the water demands for current situation has been performed under steady state scenario.

Therefore, a great care has been taken into consideration in order to bring the model output result within acceptable range as per the design criteria.

4.3.3. Model Calibration and Validation

In this research, the pressure data measured at the near to node home faucet of the system is used to assess the model performance. The model performance measure such as the degree of accuracy (error of difference) and the coefficient of determination (R^2) are two techniques to be considered for the calibration of model check as mentioned below the results. The observed and simulated pressure giving a correlation coefficient of determination which ranges between 0 and 1, describes the proportion of the variance in the measured data which is explained by the model with higher values indicating less error variance. The diagonal line on the plot represents the line of perfect correlation as indicated in figure 8 generally, all the points should align themselves on this line, and all observed pressure should be equal to computed pressure giving a relationship coefficient of 1 that is the best correlation between observed and simulated (Tsegay, 2019) All observed pressures were equal to the simulated pressures, giving a link coefficient of one that is the best correlation between observed and simulated. The coefficient of determination (R^2) value was 0.96, it indicates that observed and simulated relation is strong as values tend to one. The observed and simulated pressure relationship plot is shown in the figure 4.10.

Table 4.10: Junction pressure calibration based on degree of accuracy criteria.

Sample Location	Observed pressure (m H2O)	Simulated pressure (m H2O)	Difference in pressure error	Measured time	X (m)	Y (m)	Elevation (m)
J-256	6.98	3.98	-3	8:40 AM	481919	723104	1975.8
J-352	8.9	6.24	2.66	10:00 AM	481210	721519	1932.26
J-362	5.6	7.22	-1.62	10:30 AM	481262	721132	1916.32
J-391	9.15	8.96	0.19	11:25 AM	481014	721317	1916.03
J-425	17.3	16.46	0.84	11:50 AM	480634	720008	1892.84
J-323	22	27.62	-5.62	2:00 PM	481494	722205	1920.79
J-349	39	33.51	5.49	3:20 PM	481356	721935	1912.13
J-329	46	44.25	1.75	4:00 PM	481406	722021	1902.59
J-329	59	55.16	3.84	5:10 PM	481408	721749	1889.51
J-344	60	48.18	11.82	4:40 PM	481389	721795	1897.58
		Average	**1.635**				

As shown in table 4.10 the computed pressure values within an average error of 1.635m pressure from simulated to observed values. Hence the model is acceptable calibrated which is satisfied the criteria that pressure calibration under average level (average ±1. 5m to maximum ±5m).

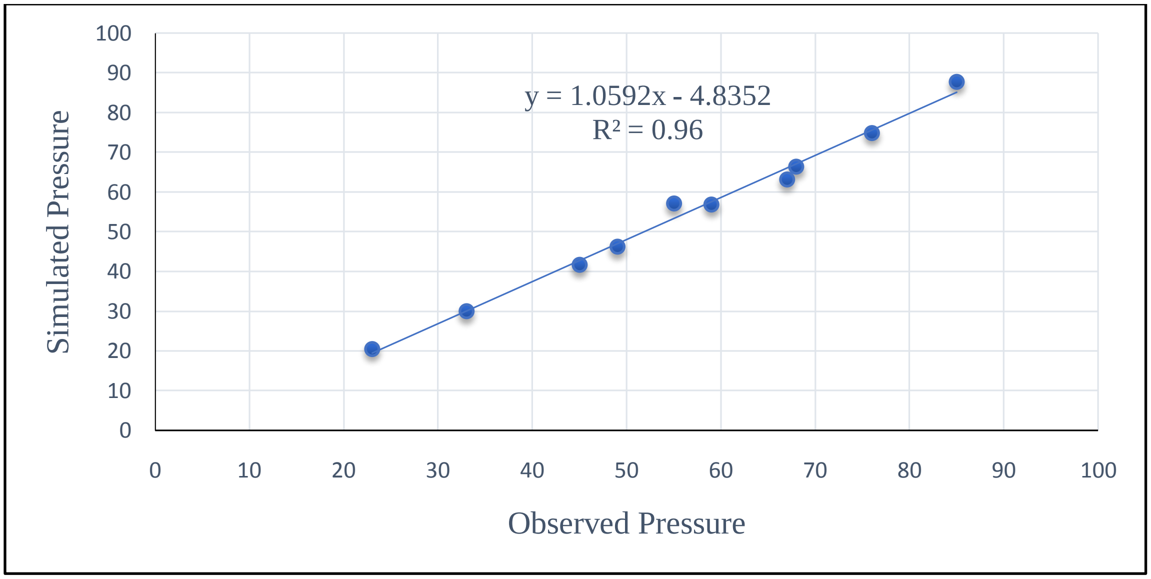


Figure 4. 1: Correlation between observed and simulated pressure relationship plot

4.3.4. Major challenges on Existing Water Supply System of the Daye Town

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

(a.) The Existing Water Supply System of the Town has been modeled with the help of WaterGEMS in which the result of the analysis showed that the overall performance of existing water distribution of the town shown that velocity and pressure were not in permissible range.

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

(c.) Most parts of the central network being suffered by lower flow velocities of less than 0.6m/s due to unnecessarily congestion of pipe network. This is to the extent of occurring zero (no) flow conditions in some of the pipes.

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

4.3.5. Methods used to improve the existing water supply network of the Town.

i. Adding pressure reducing valve in the network

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

ii. Using higher PN class of pipe in the network

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

iii. Improving pipe size

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

4.4.Hydraulic Performance Evaluation

4.4.1. Pressure analysis

Minimum pressures at peak hour consumption: appropriate to assist the maximum supply idea in the system classically mains, pressures not less than 15 m would be required (MoWR, 2006).

Maximum pressure during low consumption hour:The maximum pressure in mains is considered not to exceed 70 m to limit leakage and stress on pipes (MoWR, 2006).

Considering the Pressure reducing valve requirement at Borehole site, a small system with no zones and distribution mains close to reservoir the exceptional condition is taken as the pressure range to be 10mH_2O and 70 mH_2O (MoWR, 2006)

During hydraulic modelling of the distribution system of town, 133 nodes and 152 pipes were identified. With regard to current simulation the result of pressure at distribution systemsummarized in table 4.11 blew.

Table 4.11:pressure at distribution System

Pressure (m of H2O)	Number of nodes	Percentage
<=10	55	41.35%
10 -75	78	58.65%
>70	0	0%
Sum	133	100%

Table 4.11 indicates that 41.35% of the distribution system was with pressure of less than the minimum recommended level and the rest 58.65% is with in recommended level (10 -70 m H20).

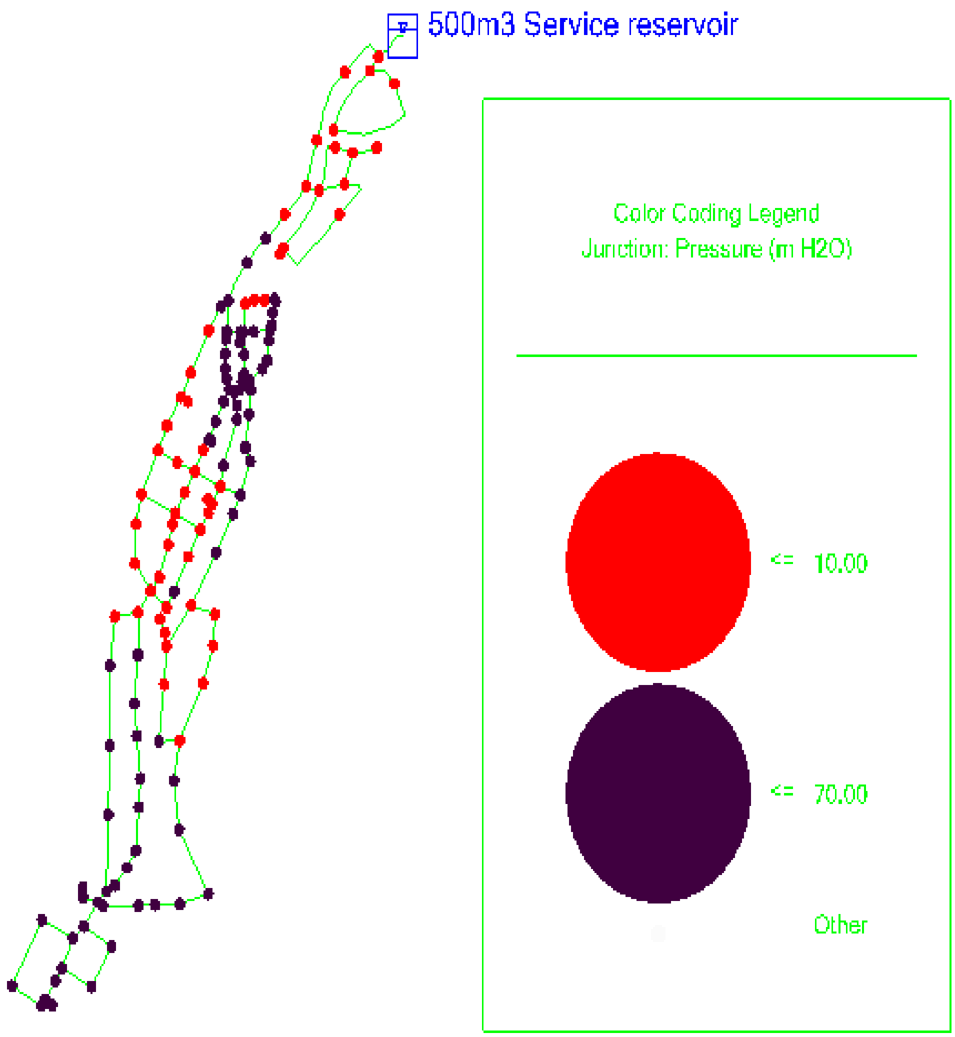


Figure 4. 2: Pressure Colour coding properties

In existing system there is no pressure zoneclassification. But based the current study hydraulic modelling, the entire distribution system of the Town has two pressure zones (one low pressure zone and the other high-pressure zone).

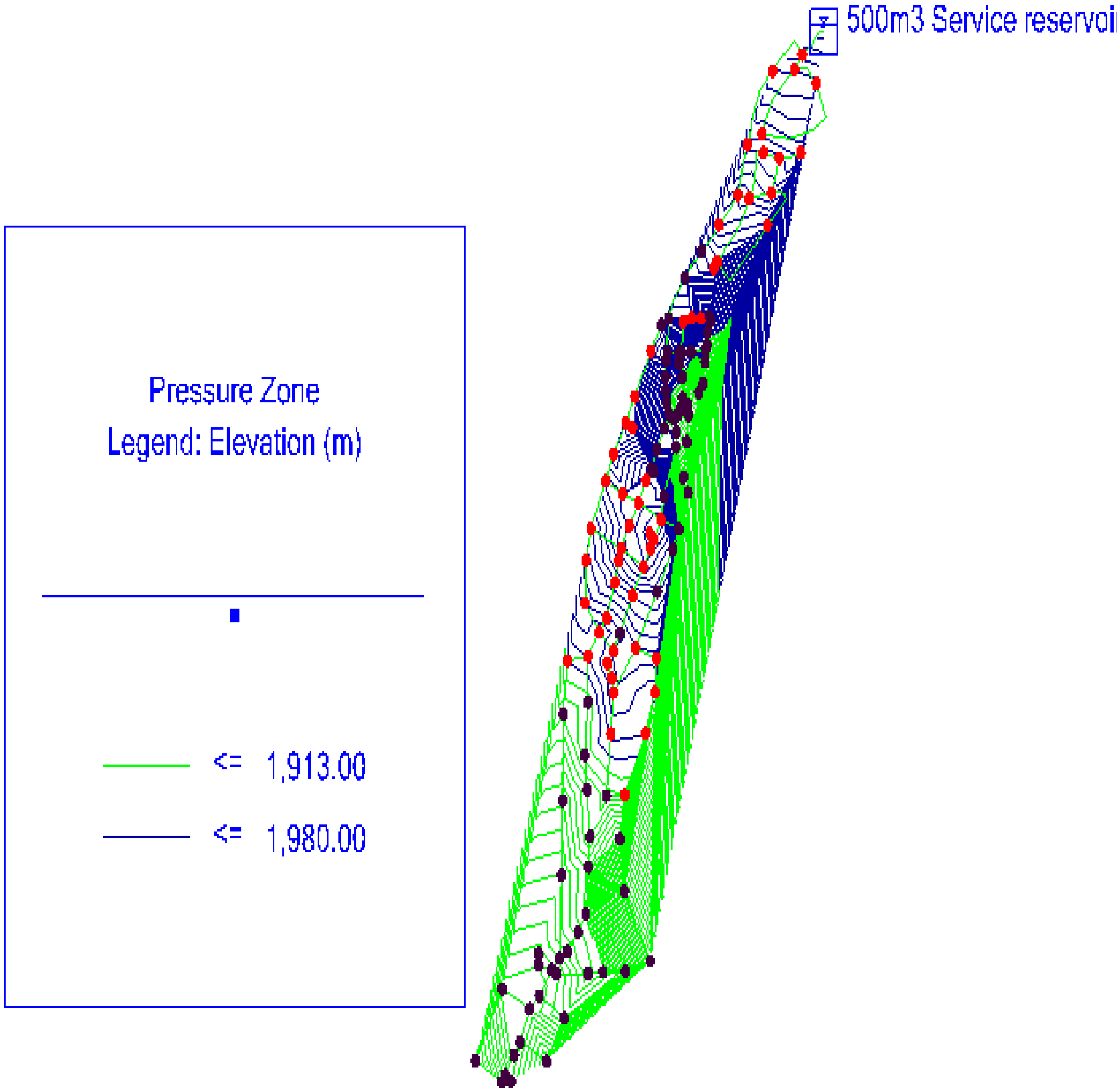


Figure 4.1: Pressure Zone contour map of the Town

4.4.2. Velocity analysis

The velocity of water flow in a pipe is also one of the important parameters in hydraulic modelling performance evaluation of the efficiency of water supply distribution and transmission line. According to MoWR, (2006) the velocity ranges can also be adopted as the design criteria, low velocities for hygienic, while too high-velocity cause exceptional head loss reason are not preferred velocity distribution is also varying with demand pattern changes. There are specific standards for velocity and head loss in WDS. According to (MOWR, 2006). velocity of flow in the pipe below 0.6m/s causes‟ water stagnation, sediment accumulation and bacteriological growth in the pipe, on the other hand velocity of flow in the pipe above 2m/s causes head loss as well as water hammer. Velocity in water distribution system was varied with the demand pattern change. At peak consumption time the values are different as compare low consumption time. The town water supply distribution system of velocities was summarized in table 4.12.

As indicated table 4.12, 51.3% of the pipes are below the recommended velocity range of minimum 0.6 m/s and the rest of pipes, 48.7%, are within the recommended velocity range (0.6 m/s to 2 m/s) velocities based on Ethiopia urban water supply design guideline criteria.

Table 4.12: Velocities fordistribution system

Velocity (m/s)	Number of pipes	Percentage
<0.6	78	51.3%
0.6-2	74	48.7%
>2	0	0
Total	152	100%

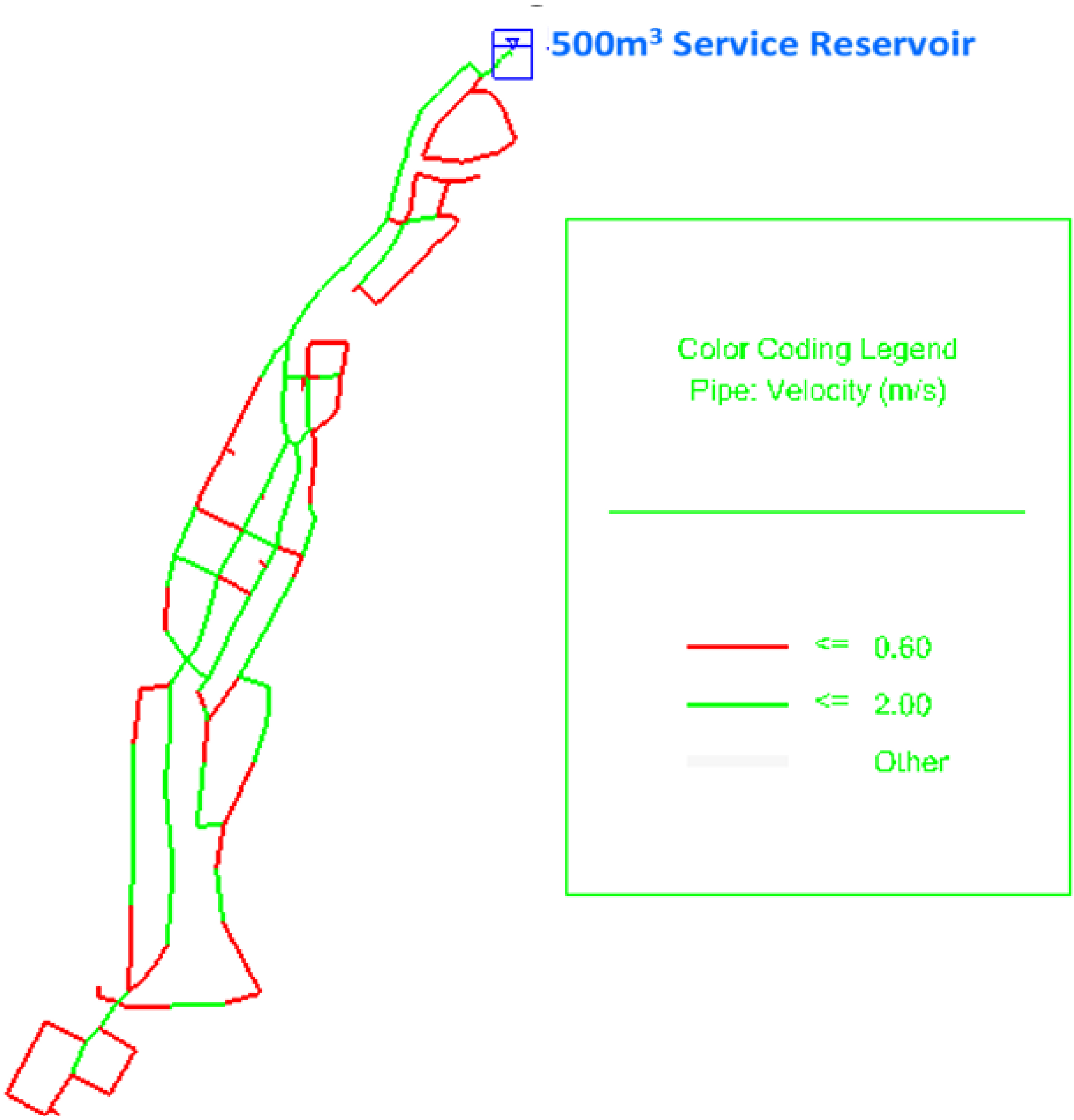


Figure 4.2: Velocity Colour coding properties for distribution system

Table 4. 16: Head loss for distribution system

Head loss (m/km)	Number of pipes	Percentage
<1	7	4.6%
1-5	20	13.1%
>5	125	82.3%
Total	152	100%

As indicated in table 4.16, 4.6% of the pipes are below the recommended minimum head loss range of 1m/km, 13.1% are within the recommended head loss range (1 to 5m/km) and the rest of pipes, 82.3% head loss is above the recommend range based on Ethiopia urban water supply design guideline criteria.

Figure 4.3: Head loss gradient Colour coding

4.5.Sanitation assessment

4.5.1. Households with access to a sanitation facility

Considering 95 per cent confidence level and p = .05 are assumed for this equation

$$n = \frac{N}{1+N(e)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4.5.1$$

$$n = \frac{8{,}811}{1+8{,}811(0.05)^2} = 382.63,$$

where, N=Number of households=30,925/3.51=8,811 (30,925 current population and 3.51 average population size)

From the formula, the sample size for this study was 383 households, however 407 households were conducted for the questionnaire. The respondents were chosen based on their availability during visit to respond to the survey.

Accordingly, 95.5% of the latrine type was dry pit latrine, whereas the rest 4.5% were Flush/Pour flush latrines.

Currently, about 27.52% of the households have access to basic sanitation, where the households having any type of latrine is 100%. The latrine type is mainly two, dry pit latrine and Flush/pour flush, with 88.6% and 11.4% respectively.

Percent of households with access to sanitation facility =

$$\frac{\text{Number of people in households in the sample using hyginic sanitation facilities}}{\text{Total number of people in the households in the sample}} \ldots\ldots\ldots\ldots \quad 4.5.2$$

Sample calculation

Percent of households with access to sanitation facility $=\frac{112}{407}=27.52\%$

Table 4.13: Latrine status in household level (own survey)

Latrine Type	Latrine Type		With water		Without water		With water in bucket	
	Frequency	Percent (%)	Frequency	Percent	Frequency	Percent	Frequency	Percent
Dry pit latrines	391	96.07	55	13.51	295	72.48	41	10.07
Flush/pour flush	16	3.93	8	1.97	0	0	8	1.97
Total	407	100.0	63	15.48	295	72.48	49	12.04

According to the result obtained from the sample survey 18.43% of the latrines shared with the other households.

Table 4.14: Latrine types and shared with households.

Type of Latrine	**Shared with other HHs**				**Total**
	No		**Yes**		
	Number of Cases	**%**	**Number of Cases**	**%**	
Total	332		75	18.43	407
Dry pit latrines	316	95.50%	75	100%	391
Flush/pour flush	16	4.50%	0	0%	16

Of the 407 total respondents taken during the interviews 348 (85.50%) responded that their latrine never emptied. Only 12.53% mentioned that their toilet emptied.

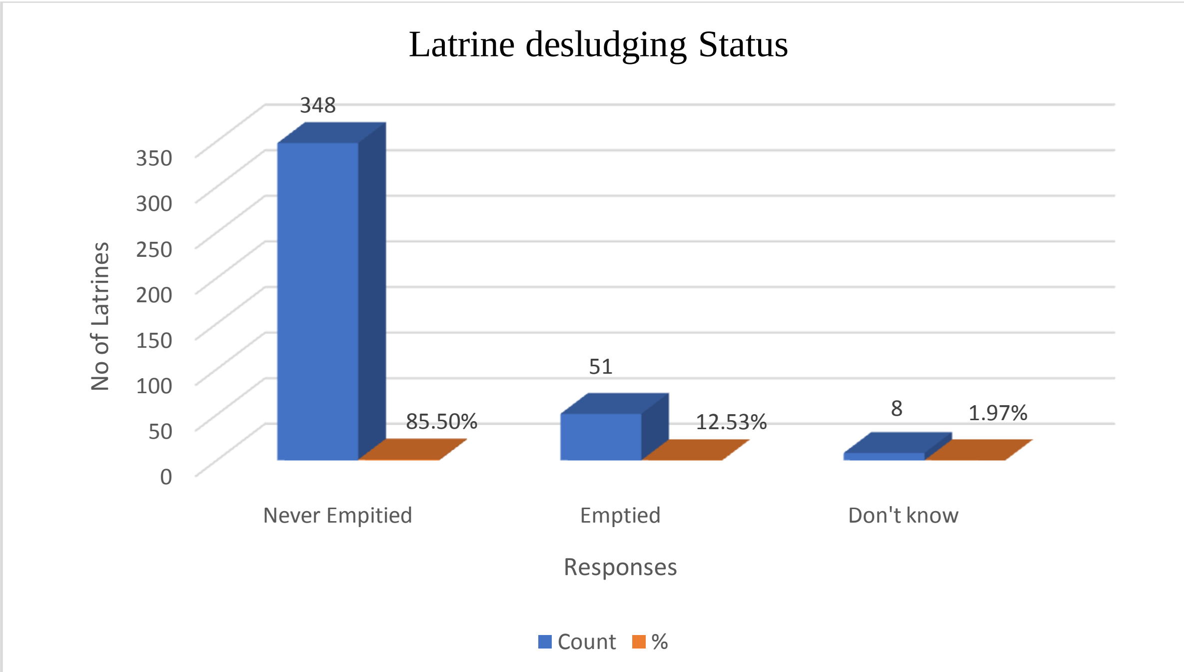


Figure 4.4: Latrine emptying status.

Table 4.15: Latrine emptying with households.

Pit Latrine Emptying Practices

emptying done by	Frequency	Percent	Place of disposal
Removed by service provider	6	75.00%	Don't know
Emptied by household	2	25.00%	Buried in a covered pit
			To uncovered pit, open ground, farmlands
Total	8	100.00%	

75% of the disposal of feces was mainly by service providers from Hawassa, and the respondents have no information where they dispose. There is also a practice of emptying by households and the survey result shows that 25% of the respondents have this custom. The place and method of disposal was being buried in a covered pit and to uncovered pit or open ground in farms.

4.5.2. Households with year-round access to improved water Source

According to the respondents 59.9% of the current latrine lacks water supply for sanitation and only 27.85% have water supply. Out of which 12.66% practiced using bucket water for sanitation purposes.

Sample Calculation

Percent of households with year-round access to improved water source

$$= \frac{\text{Number of households in the sample with access to improved water source}}{\text{Total number of households in the sample}} \ldots\ldots\ldots\ldots (3.1)$$

Percent of households with year-round access to water for sanitation = $\frac{63}{407}$ = 15.5%

Table 4.16: Latrine with water for sanitation and shared with households.

		Is there water for latrine						Total
		No water for sanitation		Yes, there is piped system		Yes, but manually filled		
		Count	%	Count	%	Count	%	
shared with other HH	No	245	60.2%	44	10.8%	43	10.6%	332
	Yes	50	12.3%	19	4.7%	6	1.5%	75
Total		295	72.5%	63	15.5%	49	12.0%	407

The main reason for lack of water for latrines near latrine block, as in table 28, isdue to the house holds lack of attitude towards the water importance for the sanitation according to the response mentioned by 128 (25.3%) respondents. Absence of water system in their compound or nearly and also lack of water continuously was the second reason according to 110 (32%) of the respondents.

Table 4.17: Cause lack of water for sanitation

Reason for no water for sanitation	Frequency	Percent
No water supply in the nearby area	110	32%
Only toilet is available	103	30%
Water is not considered important	128	38%
Total	341	100%

4.5.3. Finding and conclusion

The sanitation situation of the Daye town requires great integral effort and coordination of the government sectors in the town. The health, water, education and the administration offices should give attention to improving the efficiency of the water supply system as well as to increase the community attitude towards the sanitation packages implementation.

The households with better latrines (lined and covered with slab) showed their interest to desludging and excreta transportation by their own expenses. Therefore, the town should have its own service to dispose wastes. Proposed remedial measures for Water Supply and Sanitation gaps.

The findings in the research conducted by the survey show that, water supply is not sufficient, and the distribution is irregular. This shows that the water supply system efficiency, especially in the electromechanical part (pump and Generator) has to be studied in detail. In the rural area of the spring sources tap stands have not a controlling mechanism and were flowing continuously during the site visit. Therefore, minor maintenance requirements such as faucet and gate valve repair need attention both in public and house connections, which is considered will increase the system efficiency and reduction in loss.

The hydraulic performance evaluation indicates that velocity in the pipeline and pressure on nodes in minimum and peak consumption scenarios are not in the acceptable limits. Moreover, the water supply service staffs also mentioned that the water pumping to the reservoir is not effective nowadays. Due to this they usually pump the water from BH to the nearly existing reservoir. Therefore, the water well inspection and checking for drawdowns in water table has to be done. There should be installed with appropriate valves such as air release valves to regulate the flow.

The water supply and sanitation situation need to be improved in the town and hence, collaboration of government development sectors (offices) is more important, so it needs the effort of all stake holders in the town.

Further investigation should be done to assess the enabling factors and constraints for the provision, use, and maintenance of water supply and Sanitation infrastructure at institutions in Daye town.

5. CONCLUSIONS AND RECOMMENDATION

5.1.Conclusions

The findings of this study revealed that the current (2021) and the future (2041) maximum day water demand at study area was 1741.04m^3/day and 4,581.81 m^3/day respectively and the average per capita domestic water consumption of the town was found to be 9.21 l/c/d for the base year which only satisfies 18% of the minimum urban water consumption value set by (MOWIE, 2015) and 46% value set by (WHO,2008). The study has confirmed that there is high gap between demand and supply in the town because the current water supply (production) of the town was only 511.20 m3/dayand this showed that the current supply only satisfies 44% of the current demand (2021) and 17% of the future demand in year 2041.The annual water loss in the study area in year 2021 was 34,714 m^3 (25.03%) and due to this the water supply service lost 312,426 ETB in 2021. The causes for water loss were age of pipe network, poor and unscheduled maintenance of network, customer meter inaccuracies, data handling error, community behavior, and low operation and maintenance attention and some the proposed strategies to reduce water loss were improving organizational management and provision of training, assessing meter, testing and replacement water balance check-up, effective maintenance, old pipes and fittings replacement and repair.

During hydraulic modelling, 41.35% of the lower pressures in the town (>10 m) were observed at 55 junctions due to high elevation. 58.65% of the areas have pressure within the recommended limit (10 to70 m) during base consumption. During peak hour consumption, parts of the distribution system receive water with low pressure and under some circumstances risk of obtaining no water is observed because of the pressure in the distribution system is below permissible minimum requirement.For the parts of the system that are located far away from the service reservoir and have low elevation; it is clearly obvious that they are exposed to high-pressure values. 48.7% of the velocity in distribution network was in recommended range at base consumption time and 51.3% of Velocity of water in the town was (<0.6m/s).

Currently, about 27.52% of the households have access to basic sanitation, where all the households have any type of latrines and 18.43% of the latrines share with the other households. 59.9% of the current latrine lacks water supply for sanitation and only 27.85% have water supply. Out of which 12.66% practiced using bucket water for sanitation purposes. This indicates that only 15.5% have access to water supply for sanitation year-round. The main reason for lack of water for latrines near latrine block was due to the house holds lack of attitude towards the water importance for the sanitation according to the response mentioned by 128 (25.3%) respondents.

5.2.Recommendation

In general, it was concluded that the current water distribution network systems of the town categorized under high water loss, unsatisfactory hydraulic performance situation and were not supply adequate water for the current and future water demand of the town. Particularly, the distribution system is not maintaining the minimum and maximum pressure and velocity. After modifying the existing water distribution system, the excessive pressure in the system (pressure head greater than 70m) can be solved by using pressure reducing valve and using higher PN class of pipe which can resist the excessive pressure.

High Pressures during low demand conditions are usually caused by serving customers at too low an elevation for the pressure zone or due to oversized piping main. This problem can be mitigated by establishing a new pressure zone for the lower elevation areas using system PRVs and/or downsizing the pipe main by re-running the model for the critical condition for that oversized piping. In areas where low velocity occurs, especially near collection points, lower pipe diameters need to be replaced.

The current trend increasingly urbanization due to the newly established administration in the Sidama Regional state, the town's population number expected to increase dramatically. This will lead to the gaps in the sanitation status remain, as there is no improved sewerage system in the town. Water supply system efficiency should be improved by connecting the existing drilled wells to satisfy the current and future water demand for domestic use including water for sanitation.

Based on the findings, the following recommendations are made:

The development ofwater sources having a production capacity at least 1,160.69 m^3/day and expansion of the existing sources should be done to meet increasing water demand.

Manage the demand by controlling water loss from pipe leakage and consumption usingmeters and tariffs that are set in accordance with the volume of water consumption.

In order to achieve (15- 70 m), the use of pressure sustaining valves are recommended to control the occurrences of minimum pressures. These valves start closing if the pressure falls below the preset value to guarantee allowable minimum pressure for isolated parts of area. Pressure reducing valve devices which decrease pressure are recommended as solution to control occurrences of maximum pressures for parts of high elevation network.

Equitable water supply across the households in the town has to be maintained for water systems for latrines.

- A planned and scheduled supply system should be implemented to supply water equally for residents of the town. Besides the knowledge on the sanitation and Hygiene practices the towns community attitude needs improvement in the latrine and water for sanitation.

- According to the survey result there is unequitable water supply and inefficiency in the towns water supply system.

- There is a need on the latrine desludging service from the community. Creating a service providers market link will contribute to the towns waste disposal management improvement. But there are no sufficient service providers in the town.

- The towns old system is not performing well and the sources from springs are not well managed and used effectively. There is a wastage in remote areas near the spring sources, hence uncontrolled flows on tap stands.

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APPENDEX

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

Label	X (m)	Y (m)	Elevation (m)	Hydraulic Grade (m)	Pressure (m H2O)
WP-2	481911.9	722799.9	1968.48	1965.33	-3.14
WP-3	481161	721949.3	1940	1937.21	-2.79
J-412	481172.5	722045.8	1940.24	1937.51	-2.73
J-410	481132.5	721963.9	1939.24	1937.51	-1.72
J-413	481244.4	722186.5	1939.23	1937.5	-1.72
J-398	480953.8	721538.9	1921.36	1921.2	-0.16
J-285	481815.8	722783.3	1965.59	1966.27	0.68
J-283	481745.2	722800.8	1965.71	1966.83	1.12
J-399	480949.8	721407.4	1919.26	1920.96	1.7
J-409	481078.2	721868	1935.71	1937.54	1.83
J-271	481786.1	723053.7	1973.78	1976.57	2.78
J-289	481783	722676.7	1963.89	1967.08	3.18
J-256	481918.9	723103.7	1975.8	1979.79	3.98
J-266	481981	723013.9	1973.22	1977.49	4.26
J-258	481885	723057.7	1973.96	1978.69	4.72
J-361	481269	721236.4	1919.76	1924.55	4.78
J-274	481673.2	722825.2	1967.23	1972.16	4.92
J-397	480977	721637.7	1923.02	1928.03	5
WP-4	481238.2	721621.7	1935.29	1940.45	5.15
J-358	481174.8	721266.7	1920.32	1925.66	5.33
J-350	481257	721604.7	1934.95	1940.49	5.53
J-318	481425.1	722288.7	1943.28	1948.85	5.56
J-400	481147.2	721645.9	1931.62	1937.33	5.7
J-396	481110.9	721575	1930.67	1936.7	6.02
J-351	481241.8	721575.2	1933.55	1939.79	6.23
J-352	481210.4	721519.5	1932.26	1938.51	6.24
J-401	481189.2	721715.8	1931.73	1938.02	6.28
J-402	481118.4	721745	1931.33	1937.79	6.45
J-363	481220.5	721004.6	1916	1922.49	6.48
J-294	481763	722575.9	1956.6	1963.47	6.86
J-346	481290.1	721665.4	1935.28	1942.47	7.17
J-362	481261.5	721131.7	1916.32	1923.55	7.22
J-393	481047.4	721360	1918.63	1926.01	7.37

J-403	481042.6	721785.8	1930.07	1937.58	7.5
J-394	481082.9	721470.8	1924.74	1932.35	7.6
J-357	481076.8	721130.2	1918.59	1926.6	8
J-395	481100.4	721537.5	1928.29	1936.4	8.09
J-297	481540.7	722463.3	1953.51	1961.76	8.24
J-386	480962.8	721242.9	1916	1924.29	8.28
WP-1	481525.1	722443.1	1953.09	1961.52	8.41
J-279	481682	722657.8	1960.8	1969.26	8.44
J-392	481077.2	721259.4	1919	1927.9	8.89
J-356	481069.2	721174.5	1918.31	1927.27	8.95
J-391	481013.7	721316.7	1916.03	1925	8.96
J-302	481546.5	722576.2	1958.56	1967.55	8.97
J-353	481161.6	721430.1	1925.01	1934.04	9.02
J-319	481467.5	722287.8	1939.36	1948.43	9.05
J-316	481389	722277.2	1940.56	1949.66	9.09
J-262	481739.6	722858	1968.11	1977.29	9.16
J-355	481050.3	721220.9	1918.33	1927.58	9.23
J-277	481631.8	722670.4	1960.2	1969.47	9.25
J-366	481066.1	721002.6	1916.4	1925.67	9.25
J-364	481127.5	720813.5	1911.53	1921.1	9.55
J-404	481221	721786	1931.55	1941.17	9.6
J-387	480871	721228.6	1914.43	1924.21	9.76
J-354	481105.7	721312.6	1918.38	1928.74	10.33
J-306	481394.6	722414.3	1948.82	1959.5	10.66
J-382	480972	720685.8	1908.45	1919.36	10.89
J-308	481322.7	722287.5	1943.25	1954.27	11
J-359	481272.9	721442	1926.96	1938.01	11.02
J-304	481470.9	722495	1952.1	1963.5	11.38
J-384	480947.8	720937.3	1911.81	1923.26	11.43
J-385	480962.4	721100.4	1912.04	1923.79	11.72
J-365	481045.9	720810.3	1910.52	1922.99	12.44
J-347	481302.2	721735.7	1930.78	1943.26	12.45
J-414	481292.1	722267.5	1940.46	1953.11	12.63
J-371	481030.3	720264.4	1903.21	1917	13.76
J-388	480852.2	721064.3	1910.04	1923.85	13.79
WP-5	481255.1	721815.8	1929.07	1942.93	13.83
J-360	481341.6	721573.1	1928.31	1942.41	14.08
J-383	480957.9	720829	1908.1	1922.34	14.21
J-380	480953.5	720445	1904	1918.44	14.41
J-381	480965.3	720590.4	1904.1	1918.72	14.59
J-372	480963.9	720260.4	1901.6	1916.38	14.75

J-422	480578.9	719924.8	1893	1908.12	15.09
J-423	480594.1	719946	1892.9	1908.19	15.26
J-416	480857	720124.7	1896.3	1912.19	15.86
J-379	480919	720388.5	1901.62	1917.53	15.88
WP-9	480620.8	719927.3	1891.63	1907.86	16.19
J-425	480634.1	720008.3	1892.84	1909.33	16.46
J-378	480870.2	720329.2	1899.58	1916.64	17.02
J-389	480850.6	720796.3	1902.07	1919.52	17.42
J-405	481244.6	721822.5	1925.38	1943.05	17.64
J-390	480844.4	720565.6	1899	1916.82	17.79
J-418	480660.7	720049.3	1891.48	1909.37	17.86
J-321	481509.7	722283.7	1929.4	1947.88	18.45
J-320	481505	722292	1929.4	1947.99	18.55
J-420	480581.5	720213.2	1892.3	1911.29	18.96
J-340	481313	722158.9	1933.14	1952.21	19.03
J-309	481315.6	722183.8	1933.14	1952.8	19.62
J-377	480837.1	720308.5	1896.15	1916.25	20.06
WP-8	480741.9	720321.8	1893.9	1914.08	20.14
J-419	480703.5	720151.2	1891.53	1912.67	21.1
J-373	480823	720259.9	1894.1	1915.5	21.35
J-374	480802.4	720272.6	1894	1915.41	21.36
J-367	481105	720678.1	1899.17	1920.65	21.43
J-375	480743.2	720287.2	1893.05	1914.53	21.44
J-415	480747.2	720192	1892.16	1913.72	21.51
J-370	481129.1	720267.5	1895.31	1917.36	22
J-322	481498.3	722245.8	1925.34	1948.24	22.86
J-339	481309.1	722107.1	1926.89	1951.01	24.07
J-312	481382.4	722182.8	1923.67	1950.65	26.92
J-311	481370.1	722182.8	1923.67	1951.02	27.3
J-323	481494.3	722205.4	1920.79	1948.47	27.62
J-345	481368.6	721636.2	1914.92	1942.67	27.7
J-324	481487	722190.2	1920.79	1948.7	27.85
J-417	480778.1	719989.4	1881.91	1911.01	29.04
J-421	480461	719991.1	1877.95	1908.56	30.55
J-407	481272.1	721881.8	1915.46	1946.26	30.74
J-348	481355.8	721889.6	1913.97	1945.15	31.12
J-338	481309.5	722061.8	1918.66	1950	31.27
J-408	481302.9	721948	1915.89	1947.53	31.57
WP-6	481368.1	722149.1	1918.24	1950.66	32.36
J-325	481422.9	722183	1917.64	1950.22	32.52
J-337	481314.6	722023.9	1915.91	1949.17	33.19

J-349	481356.4	721935.3	1912.13	1945.7	33.51
J-332	481383.7	722105.7	1913.54	1948.93	35.31
J-335	481346	721977.2	1910.5	1946.25	35.68
J-342	481403.7	721906.1	1909.71	1946.67	36.89
J-326	481485.1	722153.5	1910.98	1948.16	37.11
J-336	481326.2	721989	1910.5	1948.39	37.81
J-334	481365.4	721988.7	1906.19	1946.51	40.23
J-333	481377.6	722014.1	1905.91	1946.84	40.85
J-331	481384.8	722040.7	1904.29	1947.52	43.14
J-329	481405.8	722021	1902.59	1946.93	44.25
J-330	481394.4	722021.6	1902.59	1947.07	44.39
J-341	481410.5	721988.3	1902.4	1946.93	44.44
J-343	481389.3	721795	1897.58	1945.86	48.18
J-369	481241.3	720299.9	1868.61	1917.92	49.21
J-368	481125.8	720515.6	1869.35	1919.41	49.96
J-328	481457.2	722058.2	1892.61	1946.33	53.62
J-344	481408	721748.7	1889.51	1944.78	55.16
J-327	481476.3	722085.3	1890.26	1946.73	56.36

APPENDEX B: Hydraulic Modelling Analysis of Pipe flex table for distribution network

Label	**Length (Scaled)** (m)	**Diameter (mm)**	**Material**	**Hazen-Williams C**	**Flow (L/s)**	**Velocity (m/s)**	**Head loss Gradient (m/km)**
P-341	158	100	Galvanized iron	120	0.17	0.02	0.011
P-373	414	15	Galvanized iron	120	-0.01	0.05	0.477
P-340	91	100	Galvanized iron	120	0.41	0.05	0.059
P-343	84	15	Galvanized iron	120	0.02	0.12	2.464
P-423	132	20	Galvanized iron	120	0.04	0.12	1.792
P-339	110	100	Galvanized iron	120	0.96	0.12	0.287
P-438	90	100	Galvanized iron	120	1.2	0.15	0.435
P-408	135	25	Galvanized iron	120	-0.09	0.19	3.232
P-407	26	32	Galvanized iron	120	0.16	0.19	2.529
P-405	49	80	Galvanized iron	120	1	0.2	0.917
P-372	252	20	Galvanized iron	120	0.07	0.22	5.557
P-397	93	100	Galvanized iron	120	1.8	0.23	0.922
P-347	25	65	Galvanized iron	120	0.78	0.23	1.588
P-331	63	15	Galvanized iron	120	-0.04	0.24	9.339
P-379	317	25	Galvanized iron	120	0.12	0.25	5.394
P-322	10	15	Galvanized iron	120	0.05	0.27	11.363
P-401	257	65	Galvanized iron	120	0.93	0.28	2.209
P-323	40	20	Galvanized iron	120	-0.09	0.29	9.108
P-365	112	25	Galvanized iron	120	-0.14	0.29	7.206
P-324	41	32	Galvanized iron	120	-0.24	0.3	5.573
P-355	117	20	Galvanized iron	120	-0.1	0.31	10.293
P-398	165	80	Galvanized iron	120	1.58	0.31	2.152
P-384	24	50	Galvanized iron	120	0.62	0.32	3.751
P-330	33	20	Galvanized iron	120	0.1	0.33	12.075
P-429	86	80	Galvanized iron	120	1.68	0.33	2.411
P-391	146	100	Galvanized iron	120	-2.7	0.34	1.95
P-363	73	32	Galvanized iron	120	0.28	0.35	7.688
P-381	99	65	Galvanized iron	120	1.21	0.37	3.617
P-357	69	65	Galvanized iron	120	1.24	0.37	3.786
P-321	38	25	Galvanized iron	120	0.18	0.38	11.691
P-428	76	80	Galvanized iron	120	1.91	0.38	3.052
P-339	82	80	Galvanized iron	120	1.93	0.38	3.124

P-360	52	65	Galvanized iron	120	1.28	0.39	4.002
P-332	11	25	Galvanized iron	120	-0.19	0.39	12.309
P-304	26	32	Galvanized iron	120	0.32	0.39	9.546
P-344	32	32	Galvanized iron	120	0.32	0.39	9.547
P-364	99	32	Galvanized iron	120	0.32	0.39	9.548
P-377	137	80	Galvanized iron	120	1.99	0.4	3.301
P-320	42	32	Galvanized iron	120	0.32	0.4	9.825
P-386	35	25	Galvanized iron	120	0.2	0.4	13.189
P-414	33	32	Galvanized iron	120	0.33	0.41	10.112
P-437	12	32	Galvanized iron	120	0.33	0.41	10.111
P-386	36	32	Galvanized iron	120	0.33	0.41	10.113
P-383	141	50	Galvanized iron	120	0.82	0.42	6.257
P-338	37	80	Galvanized iron	120	2.1	0.42	3.643
P-409	253	32	Galvanized iron	120	-0.34	0.42	10.834
P-380	117	65	Galvanized iron	120	1.41	0.42	4.784
P-395	164	100	Galvanized iron	120	-3.53	0.45	3.204
P-370	128	50	Galvanized iron	120	0.89	0.45	7.272
P-412	157	50	Galvanized iron	120	0.9	0.46	7.557
P-360	168	65	Galvanized iron	120	-1.54	0.46	5.635
P-410	137	40	Galvanized iron	120	-0.59	0.47	10.063
P-377	182	32	Galvanized iron	120	0.38	0.47	13.313
P-396	143	100	Galvanized iron	120	-3.73	0.48	3.563
P-387	95	40	Galvanized iron	120	0.6	0.48	10.383
P-325	17	32	Galvanized iron	120	-0.38	0.48	13.631
P-379	245	65	Galvanized iron	120	1.61	0.48	6.099
P-378	191	25	Galvanized iron	120	0.24	0.49	18.827
P-385	61	32	Galvanized iron	120	0.39	0.49	14.304
P-350	57	25	Galvanized iron	120	0.24	0.49	19.273
P-328	37	32	Galvanized iron	120	0.4	0.5	14.621
P-373	213	65	Galvanized iron	120	-1.67	0.5	6.533
P-329	69	25	Galvanized iron	120	0.25	0.51	20.74
P-382	67	50	Galvanized iron	120	1.01	0.52	9.343
P-425	114	32	Galvanized iron	120	-0.42	0.52	15.904
P-413	132	40	Galvanized iron	120	0.66	0.52	12.4
P-340	112	65	Galvanized iron	120	1.77	0.53	7.261
P-378	164	65	Galvanized iron	120	1.8	0.54	7.559
P-327	40	50	Galvanized iron	120	-1.08	0.55	10.472
P-362	50	80	Galvanized iron	120	-2.78	0.55	6.126
P-371	193	40	Galvanized iron	120	0.7	0.56	13.889

P-374	134	65	Galvanized iron	120	-1.86	0.56	7.958
P-388	43	32	Galvanized iron	120	0.46	0.57	18.967
P-392	96	80	Galvanized iron	120	-2.9	0.58	6.63
P-400	231	50	Galvanized iron	120	1.15	0.58	11.709
P-411	129	50	Galvanized iron	120	1.15	0.59	11.823
P-363	47	80	Galvanized iron	120	-2.96	0.59	6.868
P-406	74	40	Galvanized iron	120	0.74	0.59	15.435
P-424	111	20	Galvanized iron	120	-0.19	0.61	36.447
P-366	103	32	Galvanized iron	120	-0.49	0.61	21.267
P-375	105	65	Galvanized iron	120	-2.04	0.62	9.511
P-388	39	65	Galvanized iron	120	-2.07	0.62	9.774
P-372	82	32	Galvanized iron	120	0.51	0.64	23.1
P-380	242	25	Galvanized iron	120	-0.31	0.64	30.966
P-343	36	25	Galvanized iron	120	-0.32	0.65	31.7
P-394	109	80	Galvanized iron	120	-3.32	0.66	8.493
P-376	99	65	Galvanized iron	120	-2.23	0.67	11.189
P-389	77	65	Galvanized iron	120	-2.28	0.69	11.661
P-399	268	50	Galvanized iron	120	1.36	0.69	16.151
P-420	39	100	Galvanized iron	120	-5.69	0.72	7.768
P-403	60	50	Galvanized iron	120	1.42	0.72	17.455
P-431	113	25	Galvanized iron	120	-0.36	0.73	39.399
P-342	119	50	Galvanized iron	120	1.43	0.73	17.657
P-404	111	32	Galvanized iron	120	0.59	0.73	29.84
P-426	80	100	Galvanized iron	120	-5.74	0.73	7.91
P-415	90	100	Galvanized iron	120	-5.75	0.73	7.927
P-326	64	40	Galvanized iron	120	-0.93	0.74	23.657
P-390	66	65	Galvanized iron	120	-2.49	0.75	13.702
P-427	82	100	Galvanized iron	120	-5.97	0.76	8.499
P-421	148	20	Galvanized iron	120	0.25	0.78	58.648
P-430	162	20	Galvanized iron	120	0.25	0.78	58.986
P-361	45	65	Galvanized iron	120	-2.6	0.78	14.909
P-341	50	50	Galvanized iron	120	1.6	0.81	21.671
P-358	148	40	Galvanized iron	120	1.06	0.84	29.782
P-387	50	65	Galvanized iron	120	-2.79	0.84	16.99
P-422	101	20	Galvanized iron	120	0.26	0.84	67.351
P-402	98	65	Galvanized iron	120	2.82	0.85	17.302
P-364	60	80	Galvanized iron	120	-4.31	0.86	13.777
P-344	71	100	Galvanized iron	120	-6.89	0.88	11.097
P-342	94	10	Galvanized iron	120	-0.07	0.89	165.89

P-348	23	100	Galvanized iron	120	-6.99	0.89	11.378
P-345	163	100	Galvanized iron	120	-7.06	0.9	11.602
P-416	85	40	Galvanized iron	120	-1.13	0.9	33.916
P-349	28	100	Galvanized iron	120	-7.14	0.91	11.854
P-346	46	100	Galvanized iron	120	-7.23	0.92	12.114
P-350	18	100	Galvanized iron	120	-7.3	0.93	12.347
P-393	144	65	Galvanized iron	120	-3.11	0.94	20.718
P-347	43	100	Galvanized iron	120	-7.4	0.94	12.643
P-417	55	80	Galvanized iron	120	-5.02	1	18.314
P-367	64	80	Galvanized iron	120	-5.26	1.05	19.927
P-359	201	32	Galvanized iron	120	0.87	1.08	61.474
P-368	33	80	Galvanized iron	120	-5.44	1.08	21.194
P-435	73	100	Galvanized iron	120	-8.79	1.12	17.4
P-436	47	100	Galvanized iron	120	-9.03	1.15	18.28
P-351	23	25	Galvanized iron	120	-0.57	1.15	92.919
P-333	21	100	Galvanized iron	120	-9.74	1.24	21.049
P-352	37	100	Galvanized iron	120	-9.75	1.24	21.086
P-334	65	100	Galvanized iron	120	-9.9	1.26	21.682
P-353	38	100	Galvanized iron	120	-9.91	1.26	21.725
P-369	69	80	Galvanized iron	120	-6.39	1.27	28.598
P-335	77	100	Galvanized iron	120	-10.1	1.28	22.327
P-354	45	100	Galvanized iron	120	-10.1	1.28	22.369
P-312	104	150	Galvanized iron	120	22.84	1.29	14.157
P-355	52	100	Galvanized iron	120	-10.2	1.3	23.02
P-356	25	100	Galvanized iron	120	-10.4	1.32	23.723
P-381	127	150	Galvanized iron	120	23.66	1.34	15.11
P-365	130	65	Galvanized iron	120	-4.49	1.35	40.816
P-366	102	65	Galvanized iron	120	-4.66	1.41	43.857
P-376	160	150	Galvanized iron	120	25.04	1.42	16.779
P-374	261	150	Galvanized iron	120	-25.1	1.42	16.888
P-375	190	150	Galvanized iron	120	-25.2	1.43	16.997
P-371	127	150	Galvanized iron	120	25.52	1.44	17.386
P-315	12	100	Galvanized iron	120	11.87	1.51	30.358
P-432	77	80	Galvanized iron	120	-7.75	1.54	40.861
P-385	55	100	Galvanized iron	120	12.32	1.57	32.544
P-418	116	65	Galvanized iron	120	-5.24	1.58	54.469
P-433	44	80	Galvanized iron	120	-7.99	1.59	43.211
P-419	69	65	Galvanized iron	120	-5.46	1.65	58.728
P-434	65	80	Galvanized iron	120	-8.55	1.7	49.042

P-384	147	125	Galvanized iron	120	23.29	1.9	35.662
P-383	111	125	Galvanized iron	120	23.41	1.91	36.025
P-382	111	125	Galvanized iron	120	23.54	1.92	36.389

APPENDEX C: Hydraulic Modelling AnalysisJunctions flex table for transmission pipes

Label	X (m)	Y (m)	Elevation (m)	Hydraulic Grade (m)	Pressure (m H2O)
J-125	482070	723259	1983.66	1985.11	1.45
J-250	482184	723346	1986.92	1988.63	1.7
J-199	483032	727994	2156.76	2158.82	2.05
J-251	482080	723253	1982.57	1984.86	2.29
J-129	482182	723359	1986.92	1989.31	2.38
J-126	482091	723279	1983.43	1985.91	2.47
J-200	483050	728012	2156.76	2159.52	2.76
J-123	482026	723217	1980.41	1983.41	2.99
J-92	481998	723186	1979.02	1982.13	3.1
J-124	482054	723244	1981.28	1984.48	3.2
J-127	482115	723301	1983.6	1986.82	3.22
J-130	482207	723386	1987.05	1990.35	3.29
J-249	482247	723411	1987.33	1991.08	3.74
J-252	482021	723195	1978.83	1982.65	3.81
J-122	482010	723195	1978.83	1982.65	3.82
J-131	482258	723440	1988.46	1992.42	3.95
J-128	482158	723337	1984.08	1988.38	4.29
J-201	483043	728099	2157.64	2161.95	4.31
J-132	482264	723496	1989.51	1993.98	4.46
J-248	482273	723439	1987.46	1992.11	4.65
J-91	481958	723147	1977.6	1982.45	4.84
J-90	481946	723137	1977.6	1982.54	4.93
J-247	482277	723518	1989.26	1994.24	4.97
J-133	482267	723532	1989.96	1995	5.03
J-94	481999	723204	1978.83	1983.95	5.11
J-246	482207	723538	1989.7	1996.23	6.52
J-134	482220	723544	1989.7	1996.35	6.64
J-202	482456	727099	2130.77	2137.57	6.79
J-244	482227	723661	1992.64	1999.61	6.96

J-89	481911	723112	1975.8	1982.79	6.98
J-245	482212	723602	1990.94	1997.96	7
J-135	482230	723588	1990.49	1997.63	7.12
J-137	482254	723702	1993.16	2000.87	7.69
J-136	482241	723640	1991.21	1999.09	7.87
J-144	482536	724109	2007.83	2016.17	8.33
J-138	482270	723776	1994.62	2003	8.36
J-238	482659	724204	2011.53	2020.5	8.95
J-237	482729	724297	2014.57	2023.63	9.04
J-88	481865	723067	1973.94	1983.16	9.2
J-243	482262	723836	1995.1	2004.43	9.32
J-239	482555	724131	2007.27	2017.04	9.75
J-95	481965	723226	1976.36	1986.21	9.83
J-145	482592	724132	2007.96	2017.87	9.89
J-97	482025	723307	1981.52	1991.77	10.23
J-143	482487	724081	2004.32	2014.59	10.25
J-87	481819	723018	1973.24	1983.55	10.29
J-146	482650	724168	2009.39	2019.78	10.37
J-198	483151	727891	2143.84	2154.41	10.55
J-147	482717	724249	2011.74	2021.72	10.95
J-139	482290	723870	1994.35	2005.68	11.31
J-148	482776	724330	2013.91	2025.5	11.57
J-240	482434	724077	2000.39	2013.46	13.05
J-96	481985	723259	1975.25	1988.33	13.05
J-86	481772	722968	1970.33	1983.95	13.59
J-98	482113	723373	1983.97	1997.84	13.84
J-236	482775	724357	2010.31	2025.69	15.35
J-85	481740	722900	1968.96	1984.38	15.39
J-82	481667	722856	1969.31	1984.96	15.62
J-142	482422	724053	1996.25	2012.62	16.34
J-84	481726	722861	1968.11	1984.62	16.47
J-99	482178	723466	1987.45	2004.07	16.59
J-203	482612	727139	2116.07	2133.22	17.12
J-83	481702	722854	1967.51	1984.76	17.21
J-81	481653	722822	1967.54	1985.17	17.59
J-216	483694	726172	2066.64	2085.23	18.55
J-217	483628	726131	2063.76	2083.1	19.31
J-80	481646	722780	1965.88	1985.42	19.5
J-218	483557	726056	2060.77	2080.32	19.51

J-120	481677	725362	2128.01	2147.74	19.69
J-181	483641	726112	2065.3	2085.41	20.07
J-219	483553	726021	2059.24	2079.36	20.08
J-101	482201	723579	1990.29	2010.53	20.2
J-215	483758	726213	2066.98	2087.26	20.24
J-184	483774	726183	2069.32	2089.67	20.31
J-183	483721	726151	2067.5	2087.94	20.4
J-79	481638	722758	1965.11	1985.55	20.4
J-182	483685	726140	2066.32	2086.88	20.52
J-204	482704	727107	2109.14	2130.57	21.38
J-180	483584	726066	2061.32	2083.39	22.02
J-179	483560	725974	2058.04	2080.72	22.64
J-140	482308	723984	1985.92	2008.88	22.92
J-223	483502	725577	2044.15	2067.27	23.08
J-149	482819	724390	2003.8	2027.57	23.72
J-103	482122	723647	1992.47	2016.46	23.94
J-185	483781	726226	2066.57	2090.88	24.27
J-224	483475	725452	2039.09	2063.8	24.66
J-222	483519	725665	2044.88	2069.69	24.76
J-78	481629	722715	1960.99	1985.81	24.77
J-241	482353	724064	1986.03	2011.25	25.17
J-77	481614	722671	1960.8	1986.07	25.22
J-141	482367	724023	1985.34	2010.87	25.47
J-220	483545	725934	2051.21	2077	25.74
J-154	483050	724580	2010.17	2035.98	25.76
J-76	481575	722625	1960.5	1986.42	25.87
J-155	483086	724622	2011.49	2037.52	25.98
J-205	482707	726943	2098.77	2126.13	27.31
J-175	483509	725534	2040.64	2068.31	27.61
J-233	483005	724578	2006.62	2034.39	27.71
J-176	483535	725640	2043.5	2071.37	27.81
J-153	483010	724558	2006.62	2034.7	28.02
J-156	483120	724680	2011.1	2039.38	28.23
J-174	483494	725473	2037.61	2066.57	28.9
J-173	483487	725425	2035.98	2065.22	29.18
J-165	483435	724923	2021.35	2050.77	29.36
J-166	483462	724969	2021.58	2052.27	29.63
J-164	483398	724893	2019.38	2049.45	30.01
J-228	483432	724958	2019.9	2050.2	30.24

J-75	481531	722585	1955.83	1986.77	30.87
J-104	482044	723693	1990.47	2021.43	30.9
J-197	483184	727625	2115.9	2146.93	30.97
J-242	482306	724013	1978.09	2009.39	31.23
J-229	483367	724899	2016.04	2047.85	31.75
J-157	483167	724739	2009.42	2041.5	32.02
J-232	483085	724660	2005.38	2037.47	32.03
J-221	483536	725818	2041.77	2073.86	32.03
J-163	483368	724876	2016.04	2048.49	32.38
J-186	483751	726267	2058.97	2092.32	33.28
J-74	481496	722543	1953.71	1987.08	33.3
J-206	482886	726872	2086.79	2120.92	34.06
J-167	483485	725032	2019.52	2054.16	34.57
J-150	482857	724431	1994.41	2029.15	34.67
J-73	481453	722499	1952.1	1987.44	35.26
J-214	483645	726272	2055.24	2090.71	35.4
J-235	482823	724417	1990.46	2027.77	37.23
J-158	483189	724775	2005.21	2042.68	37.4
J-162	483318	724857	2009.52	2047.01	37.41
J-177	483552	725763	2036.71	2074.84	38.05
J-172	483500	725345	2024.44	2062.96	38.44
J-178	483556	725863	2038.46	2077.62	39.08
J-71	481372	722412	1948.86	1988.12	39.18
J-105	481957	723708	1986.91	2026.28	39.29
J-231	483157	724775	2000.62	2041.14	40.44
J-72	481412	722457	1947.15	1987.77	40.54
J-160	483243	724821	2002.57	2044.68	42.02
J-151	482895	724472	1987.88	2030.68	42.71
J-161	483281	724840	2002.97	2045.87	42.82
J-70	481347	722366	1945.17	1988.42	43.16
J-227	483477	725088	2010.26	2053.93	43.59
J-225	483483	725327	2016.69	2060.4	43.63
J-69	481311	722318	1944.25	1988.77	44.43
J-230	483219	724834	1997.49	2043.48	45.89
J-159	483208	724798	1997.49	2043.5	45.92
J-68	481311	722276	1940.46	1989.01	48.45
J-152	482966	724526	1984.6	2033.19	48.5
J-171	483504	725278	2011.96	2061.08	49.02
J-168	483496	725097	2006.6	2056	49.3

J-207	483017	726558	2060.72	2111.72	50.9
J-226	483487	725208	2005.44	2057.21	51.66
J-67	481308	722216	1936.96	1989.35	52.29
J-192	483131	726652	2064.82	2117.98	53.05
J-196	483283	727452	2087.51	2141.36	53.74
J-170	483509	725203	2004.67	2058.98	54.2
J-169	483505	725165	2003.35	2057.91	54.45
J-208	483030	726469	2053.97	2109.28	55.2
J-213	483510	726303	2039.01	2094.48	55.35
J-58	481275	721665	1935.28	1992.66	57.27
J-191	483065	726509	2055.74	2113.6	57.75
J-59	481290	721727	1934.27	1992.3	57.91
J-57	481237	721592	1934.95	1993.14	58.08
J-195	483293	727149	2073.61	2132.89	59.17
J-66	481302	722140	1929.97	1989.79	59.7
J-234	482873	724479	1969.66	2029.91	60.13
J-56	481191	721506	1930.95	1993.7	62.63
J-190	483116	726441	2047.47	2111.23	63.63
J-193	483207	726749	2056.77	2121.44	64.54
J-109	481738	724092	1987.59	2052.43	64.71
J-60	481315	721793	1925.45	1991.89	66.31
J-65	481299	722068	1921.65	1990.21	68.42
J-187	483467	726353	2031.51	2100.6	68.95
J-55	481147	721432	1925.01	1994.2	69.05
J-110	481740	724159	1986.78	2056.12	69.2
J-106	481859	723749	1962.48	2032.1	69.48
J-209	483141	726384	2035.83	2105.52	69.55
J-212	483385	726317	2027.63	2097.87	70.1
J-194	483225	726917	2055.64	2126.14	70.36
J-188	483310	726355	2033.4	2104.99	71.45
J-61	481346	721877	1918.64	1991.37	72.59
J-54	481131	721385	1920.32	1994.48	74.01
J-64	481309	722012	1915.91	1990.54	74.48
J-52	481083	721294	1919.33	1995.08	75.6
J-112	481926	724297	1993.18	2069.26	75.93
J-51	481064	721259	1919	1995.31	76.16
J-111	481841	724268	1987.87	2064.29	76.27
J-62	481350	721931	1914.55	1991.06	76.36
J-53	481109	721341	1918.04	1994.77	76.57

J-49	481055	721187	1918.6	1995.83	77.08
J-211	483287	726328	2023.08	2100.53	77.3
J-48	481059	721146	1918.59	1996.07	77.32
J-50	481032	721211	1917.09	1995.64	78.39
J-113	481991	724370	1996.03	2074.66	78.47
J-63	481327	721975	1910.5	1990.78	80.12
J-47	481051	720969	1914.87	1997.09	82.05
J-114	482021	724457	1995.9	2079.68	83.61
J-189	483220	726357	2021.23	2107.5	85.1
J-210	483228	726302	2016.97	2102.28	85.14
J-119	482002	725130	2040.22	2125.77	85.38
J-46	481034	720803	1910.52	1998.05	87.36
J-15	481687	719274	1920.14	2010.86	90.53
J-115	482073	724554	1992.77	2085.77	92.81
J-45	481040	720673	1905.03	1998.8	93.58
J-13	481868	719287	1916.76	2011.9	94.95
J-108	481766	723945	1949.04	2044.2	94.97
J-16	481619	719299	1913.78	2010.44	96.47
J-39	481062	720288	1904.14	2001.06	96.72
J-40	481071	720326	1903.2	2000.83	97.43
J-38	481084	720255	1900.75	2001.28	100.33
J-107	481803	723825	1934.98	2037.3	102.12
J-41	481081	720357	1896.27	2000.64	104.16
J-18	481608	719467	1904.98	2009.43	104.24
J-17	481592	719359	1905.23	2010.06	104.62
J-20	481616	719686	1902.7	2008.16	105.25
J-37	481126	720249	1895.16	2001.53	106.16
J-19	481623	719591	1901.32	2008.71	107.18
J-12	481950	719292	1904.82	2012.38	107.34
J-42	481082	720396	1892.68	2000.42	107.52
J-44	481052	720565	1888.64	1999.43	110.56
J-116	482141	724670	1982.28	2093.13	110.63
J-43	481068	720478	1887.59	1999.94	112.12
J-36	481179	720255	1882.86	2001.84	118.74
J-21	481535	719824	1887.38	2007.24	119.61
J-22	481483	719871	1886.69	2006.83	119.9
J-8	482155	719267	1893.31	2013.64	120.08
J-11	482033	719303	1890.98	2012.86	121.64
J-7	482178	719225	1891.3	2013.91	122.37

J-9	482128	719295	1889.66	2013.41	123.5
J-6	482215	719161	1889.07	2014.34	125.02
J-23	481398	719945	1880.65	2006.18	125.28
J-5	482240	719109	1886.09	2014.67	128.32
J-117	482222	724806	1970.99	2101.82	130.57
J-2	482274	718931	1883.72	2015.73	131.74
J-4	482263	719046	1882.77	2015.06	132.02
J-118	482242	724922	1973.8	2108.33	134.26
J-3	482265	718999	1880.47	2015.33	134.59
J-35	481245	720262	1866.91	2002.22	135.04
J-24	481337	719988	1864.51	2005.75	140.96
J-33	481289	720324	1854.15	2002.67	148.22
J-34	481275	720291	1852.42	2002.46	149.74
J-27	481211	720065	1849.92	2004.78	154.55
J-28	481274	720136	1844.64	2004.24	159.28
J-29	481294	720208	1843.73	2003.8	159.75
J-32	481330	720345	1840.95	2002.93	161.65
J-31	481345	720311	1840.54	2003.15	162.28
J-30	481324	720267	1839.59	2003.43	163.51
J-25	481278	720001	1840.29	2005.41	164.78
J-26	481221	720018	1836.68	2005.06	168.04

APPENDEX D: Hydraulic Modelling Analysis of Pipe flex table for transmission line

Pipe flex table for transmission pipes							
Label	Length (Scaled) (m)	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)	Headlos s Gradient (m/km)
P-2	69	100	Galvanized iron	120	5	0.62	5.765
P-3	46	100	Galvanized iron	120	5	0.62	5.766
P-4	68	100	Galvanized iron	120	5	0.62	5.766
P-5	58	100	Galvanized iron	120	5	0.62	5.767
P-6	73	100	Galvanized iron	120	5	0.62	5.765
P-7	48	100	Galvanized iron	120	5	0.62	5.768
P-8	39	100	Galvanized iron	120	5	0.62	5.766
P-11	84	100	Galvanized iron	120	5	0.62	5.767
P-12	82	100	Galvanized iron	120	5	0.62	5.765
P-15	72	100	Galvanized iron	120	5	0.62	5.767
P-16	66	100	Galvanized iron	120	5	0.62	5.766
P-17	109	100	Galvanized iron	120	5	0.62	5.766
P-18	125	100	Galvanized iron	120	5	0.62	5.766
P-19	96	100	Galvanized iron	120	5	0.62	5.766
P-20	160	100	Galvanized iron	120	5	0.62	5.767
P-21	70	100	Galvanized iron	120	5	0.62	5.767
P-22	113	100	Galvanized iron	120	5	0.62	5.766
P-23	74	100	Galvanized iron	120	5	0.62	5.767
P-24	60	100	Galvanized iron	120	5	0.62	5.766
P-25	60	100	Galvanized iron	120	5	0.62	5.766
P-26	48	100	Galvanized iron	120	5	0.62	5.766
P-27	95	100	Galvanized iron	120	5	0.62	5.766
P-28	75	100	Galvanized iron	120	5	0.62	5.767
P-29	66	100	Galvanized iron	120	5	0.62	5.766
P-30	49	100	Galvanized iron	120	5	0.62	5.766
P-31	37	100	Galvanized iron	120	5	0.62	5.767
P-32	46	100	Galvanized iron	120	5	0.62	5.764
P-33	35	100	Galvanized iron	120	5	0.62	5.767
P-34	42	100	Galvanized iron	120	5	0.62	5.768

P-35	66	100	Galvanized iron	120	5	0.62	5.765
P-36	53	100	Galvanized iron	120	5	0.62	5.767
P-37	43	100	Galvanized iron	120	5	0.62	5.765
P-38	39	100	Galvanized iron	120	5	0.62	5.766
P-39	40	100	Galvanized iron	120	5	0.62	5.768
P-40	32	100	Galvanized iron	120	5	0.62	5.763
P-41	38	100	Galvanized iron	120	5	0.62	5.766
P-42	83	100	Galvanized iron	120	5	0.62	5.768
P-43	89	100	Galvanized iron	120	5	0.62	5.765
P-44	108	100	Galvanized iron	120	5	0.62	5.767
P-45	130	100	Galvanized iron	120	5	0.62	5.766
P-46	167	100	Galvanized iron	120	5	0.62	5.767
P-47	176	100	Galvanized iron	120	5	0.62	5.766
P-48	41	100	Galvanized iron	120	5	0.62	5.765
P-49	33	100	Galvanized iron	120	5	0.62	5.77
P-50	57	100	Galvanized iron	120	5	0.62	5.764
P-51	40	100	Galvanized iron	120	5	0.62	5.769
P-52	54	100	Galvanized iron	120	5	0.62	5.767
P-53	50	100	Galvanized iron	120	5	0.62	5.766
P-54	49	100	Galvanized iron	120	5	0.62	5.766
P-55	86	100	Galvanized iron	120	5	0.62	5.767
P-56	97	100	Galvanized iron	120	5	0.62	5.766
P-57	83	100	Galvanized iron	120	5	0.62	5.767
P-58	63	100	Galvanized iron	120	5	0.62	5.767
P-59	71	100	Galvanized iron	120	5	0.62	5.765
P-60	90	100	Galvanized iron	120	5	0.62	5.767
P-61	53	100	Galvanized iron	120	5	0.62	5.768
P-62	50	100	Galvanized iron	120	5	0.62	5.765
P-63	42	100	Galvanized iron	120	5	0.62	5.764
P-64	57	100	Galvanized iron	120	5	0.62	5.768
P-65	72	100	Galvanized iron	120	5	0.62	5.766
P-66	76	100	Galvanized iron	120	5	0.62	5.767
P-67	59	100	Galvanized iron	120	5	0.62	5.766
P-68	42	100	Galvanized iron	120	5	0.62	5.768
P-69	60	100	Galvanized iron	120	5	0.62	5.766
P-70	53	100	Galvanized iron	120	5	0.62	5.765
P-71	60	100	Galvanized iron	120	5	0.62	5.767
P-72	59	100	Galvanized iron	120	5	0.62	5.766
P-73	62	100	Galvanized iron	120	5	0.62	5.767

P-74	54	100	Galvanized iron	120	5	0.62	5.766
P-75	60	100	Galvanized iron	120	5	0.62	5.765
P-76	60	100	Galvanized iron	120	5	0.62	5.766
P-77	47	100	Galvanized iron	120	5	0.62	5.766
P-78	43	100	Galvanized iron	120	5	0.62	5.768
P-79	23	100	Galvanized iron	120	5	0.62	5.768
P-80	43	100	Galvanized iron	120	5	0.62	5.764
P-81	37	100	Galvanized iron	120	5	0.62	5.768
P-82	35	100	Galvanized iron	120	5	0.62	5.766
P-83	24	100	Galvanized iron	120	5	0.62	5.767
P-84	42	100	Galvanized iron	120	5	0.62	5.765
P-85	75	100	Galvanized iron	120	5	0.62	5.767
P-86	69	100	Galvanized iron	120	5	0.62	5.766
P-87	67	100	Galvanized iron	120	5	0.62	5.767
P-88	64	100	Galvanized iron	120	5	0.62	5.766
P-89	43	100	Galvanized iron	120	5	0.62	5.766
P-90	16	100	Galvanized iron	120	5	0.62	5.769
P-91	56	100	Galvanized iron	120	5	0.62	5.766
P-92	22	100	Galvanized iron	120	5	0.62	5.764
P-1(1)	3	100	Galvanized iron	120	5	0.62	5.804
P-1(2)	53	100	Galvanized iron	120	5	0.62	5.767
P-347	182	100	Galvanized iron	120	5	0.62	5.767
P-348	96	100	Galvanized iron	120	5	0.62	5.766
P-202	83	100	Galvanized iron	120	11	1.42	27.05
P-203	161	100	Galvanized iron	120	11	1.42	27.051
P-204	98	100	Galvanized iron	120	11	1.42	27.05
P-205	164	100	Galvanized iron	120	11	1.42	27.052
P-206	193	100	Galvanized iron	120	11	1.42	27.051
P-207	340	100	Galvanized iron	120	11	1.42	27.051
P-208	90	100	Galvanized iron	120	11	1.42	27.052
P-209	139	100	Galvanized iron	120	11	1.42	27.05
P-210	120	100	Galvanized iron	120	11	1.42	27.051
P-211	65	100	Galvanized iron	120	11	1.42	27.05
P-212	98	100	Galvanized iron	120	11	1.42	27.051
P-213	126	100	Galvanized iron	120	11	1.42	27.051
P-214	139	100	Galvanized iron	120	11	1.42	27.051
P-215	127	100	Galvanized iron	120	11	1.42	27.051
P-216	75	100	Galvanized iron	120	11	1.42	27.05
P-217	78	100	Galvanized iron	120	11	1.42	27.052

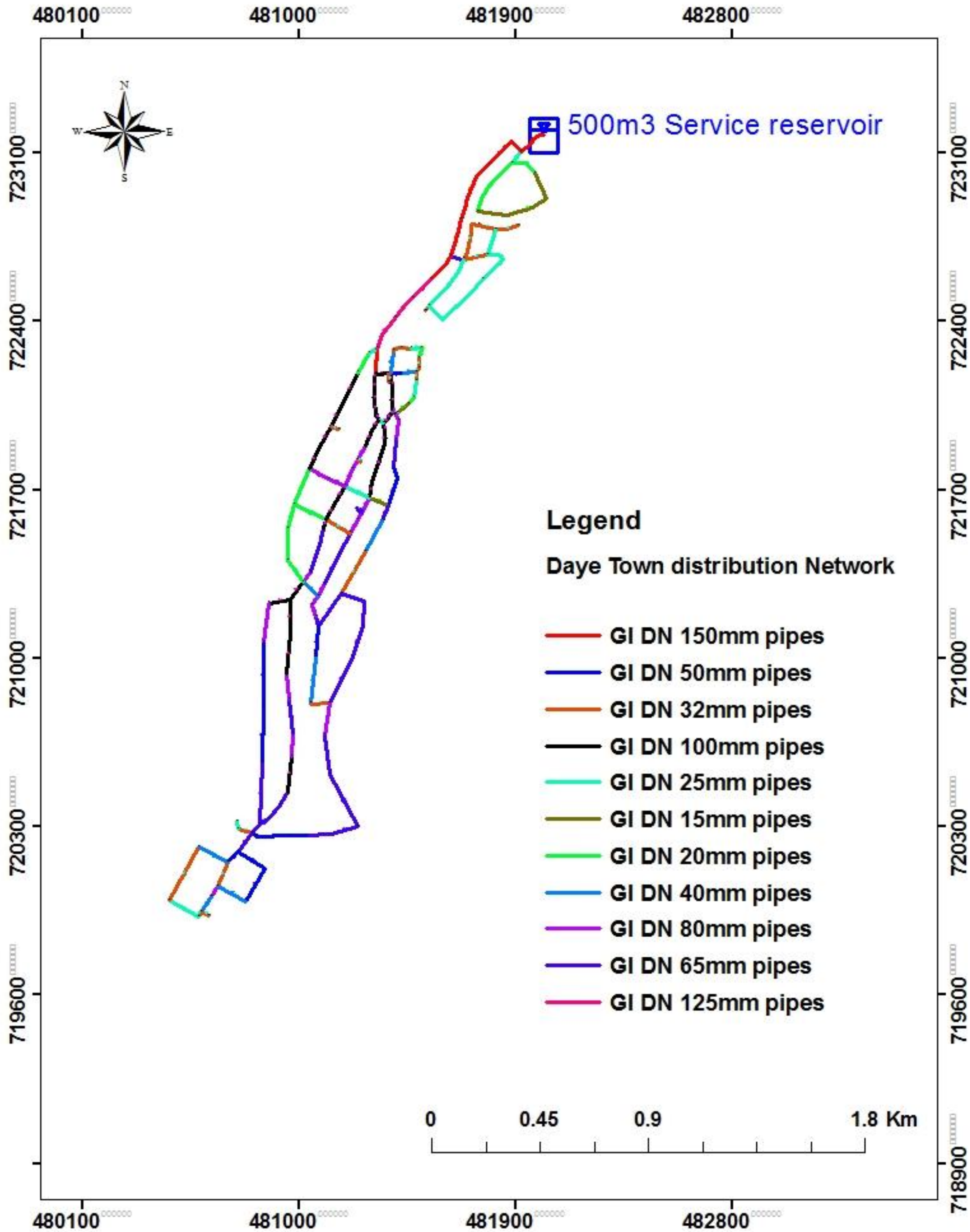
P-218	103	100	Galvanized iron	120	11	1.42	27.051
P-219	35	100	Galvanized iron	120	11	1.42	27.051
P-220	87	100	Galvanized iron	120	11	1.42	27.051
P-221	116	100	Galvanized iron	120	11	1.42	27.051
P-222	154	100	Galvanized iron	120	11	1.42	27.051
P-223	89	100	Galvanized iron	120	11	1.42	27.051
P-224	129	100	Galvanized iron	120	11	1.42	27.05
P-225	125	100	Galvanized iron	120	11	1.42	27.051
P-226	118	100	Galvanized iron	120	11	1.42	27.052
P-227	121	100	Galvanized iron	120	11	1.42	27.05
P-228	138	100	Galvanized iron	120	11	1.42	27.051
P-229	87	100	Galvanized iron	120	11	1.42	27.051
P-230	162	100	Galvanized iron	120	11	1.42	27.051
P-231	86	100	Galvanized iron	120	11	1.42	27.049
P-232	136	100	Galvanized iron	120	11	1.42	27.051
P-233	114	100	Galvanized iron	120	11	1.42	27.051
P-234	166	100	Galvanized iron	120	11	1.42	27.051
P-235	79	100	Galvanized iron	120	11	1.42	27.051
P-236	77	100	Galvanized iron	120	11	1.42	27.05
P-237	76	100	Galvanized iron	120	11	1.42	27.051
P-238	116	100	Galvanized iron	120	11	1.42	27.052
P-239	128	100	Galvanized iron	120	11	1.42	27.05
P-240	132	100	Galvanized iron	120	11	1.42	27.051
P-241	82	100	Galvanized iron	120	11	1.42	27.051
P-242	69	100	Galvanized iron	120	11	1.42	27.05
P-243	183	100	Galvanized iron	120	11	1.42	27.051
P-244	178	100	Galvanized iron	120	11	1.42	27.051
P-245	61	100	Galvanized iron	120	11	1.42	27.051
P-246	64	100	Galvanized iron	120	11	1.42	27.052
P-247	73	100	Galvanized iron	120	11	1.42	27.05
P-248	79	100	Galvanized iron	120	11	1.42	27.051
P-249	38	100	Galvanized iron	120	11	1.42	27.05
P-250	90	100	Galvanized iron	120	11	1.42	27.051
P-251	139	100	Galvanized iron	120	11	1.42	27.051
P-252	82	100	Galvanized iron	120	11	1.42	27.051
P-253	24	100	Galvanized iron	120	11	1.42	27.053
P-121	23	100	Galvanized iron	120	-11	1.44	27.92
P-122	27	100	Galvanized iron	120	-11	1.44	27.924
P-123	38	100	Galvanized iron	120	-11	1.44	27.922

P-124	22	100	Galvanized iron	120	-11	1.44	27.917
P-125	29	100	Galvanized iron	120	-11	1.44	27.922
P-126	33	100	Galvanized iron	120	-11	1.44	27.922
P-127	56	100	Galvanized iron	120	-11	1.44	27.923
P-128	33	100	Galvanized iron	120	-11	1.44	27.921
P-129	37	100	Galvanized iron	120	-11	1.44	27.922
P-130	74	100	Galvanized iron	120	-11	1.44	27.921
P-131	56	100	Galvanized iron	120	-11	1.44	27.92
P-132	36	100	Galvanized iron	120	-11	1.44	27.925
P-133	48	100	Galvanized iron	120	-11	1.44	27.92
P-134	46	100	Galvanized iron	120	-11	1.44	27.921
P-135	52	100	Galvanized iron	120	-11	1.44	27.924
P-136	64	100	Galvanized iron	120	-11	1.44	27.92
P-137	76	100	Galvanized iron	120	-11	1.44	27.922
P-138	96	100	Galvanized iron	120	-11	1.44	27.922
P-139	115	100	Galvanized iron	120	-11	1.44	27.922
P-140	71	100	Galvanized iron	120	-11	1.44	27.92
P-141	63	100	Galvanized iron	120	-11	1.44	27.924
P-142	70	100	Galvanized iron	120	-11	1.44	27.921
P-143	57	100	Galvanized iron	120	-11	1.44	27.922
P-144	61	100	Galvanized iron	120	-11	1.44	27.92
P-145	68	100	Galvanized iron	120	-11	1.44	27.922
P-146	105	100	Galvanized iron	120	-11	1.44	27.922
P-147	100	100	Galvanized iron	120	-11	1.44	27.921
P-148	74	100	Galvanized iron	120	-11	1.44	27.922
P-149	56	100	Galvanized iron	120	-11	1.44	27.922
P-150	55	100	Galvanized iron	120	-11	1.44	27.92
P-151	90	100	Galvanized iron	120	-11	1.44	27.922
P-152	54	100	Galvanized iron	120	-11	1.44	27.922
P-153	46	100	Galvanized iron	120	-11	1.44	27.921
P-154	55	100	Galvanized iron	120	-11	1.44	27.923
P-155	67	100	Galvanized iron	120	-11	1.44	27.922
P-156	76	100	Galvanized iron	120	-11	1.44	27.922
P-157	42	100	Galvanized iron	120	-11	1.44	27.922
P-158	29	100	Galvanized iron	120	-11	1.44	27.919
P-159	42	100	Galvanized iron	120	-11	1.44	27.924
P-160	43	100	Galvanized iron	120	-11	1.44	27.921
P-161	41	100	Galvanized iron	120	-11	1.44	27.92
P-162	53	100	Galvanized iron	120	-11	1.44	27.923

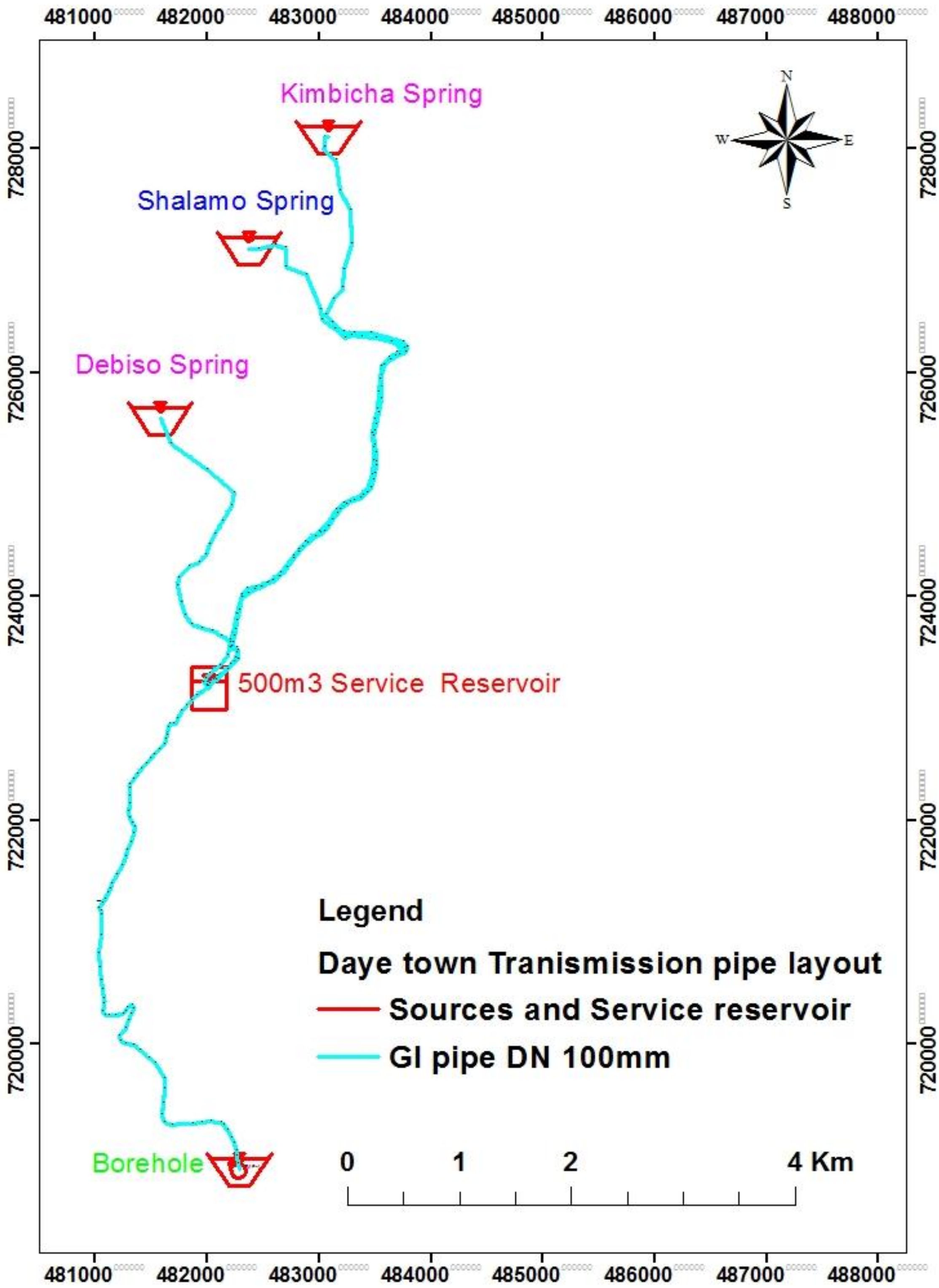
P-163	34	100	Galvanized iron	120	-11	1.44	27.92
P-164	47	100	Galvanized iron	120	-11	1.44	27.921
P-165	54	100	Galvanized iron	120	-11	1.44	27.923
P-166	67	100	Galvanized iron	120	-11	1.44	27.921
P-167	66	100	Galvanized iron	120	-11	1.44	27.922
P-168	68	100	Galvanized iron	120	-11	1.44	27.922
P-169	38	100	Galvanized iron	120	-11	1.44	27.92
P-170	75	100	Galvanized iron	120	-11	1.44	27.922
P-171	67	100	Galvanized iron	120	-11	1.44	27.922
P-172	81	100	Galvanized iron	120	-11	1.44	27.92
P-173	48	100	Galvanized iron	120	-11	1.44	27.923
P-174	62	100	Galvanized iron	120	-11	1.44	27.922
P-175	110	100	Galvanized iron	120	-11	1.44	27.921
P-176	124	100	Galvanized iron	120	-11	1.44	27.922
P-177	100	100	Galvanized iron	120	-11	1.44	27.921
P-178	111	100	Galvanized iron	120	-11	1.44	27.922
P-179	95	100	Galvanized iron	120	-11	1.44	27.922
P-180	72	100	Galvanized iron	120	-11	1.44	27.92
P-181	53	100	Galvanized iron	120	-11	1.44	27.922
P-182	38	100	Galvanized iron	120	-11	1.44	27.922
P-183	62	100	Galvanized iron	120	-11	1.44	27.922
P-184	44	100	Galvanized iron	120	-11	1.44	27.921
P-185	51	100	Galvanized iron	120	-11	1.44	27.921
P-186	296	100	Galvanized iron	120	-11	1.44	27.922
P-187	157	100	Galvanized iron	120	-11	1.44	27.921
P-188	90	100	Galvanized iron	120	-11	1.44	27.922
P-189	133	100	Galvanized iron	120	-11	1.44	27.921
P-190	85	100	Galvanized iron	120	-11	1.44	27.922
P-191	157	100	Galvanized iron	120	-11	1.44	27.922
P-192	124	100	Galvanized iron	120	-11	1.44	27.921
P-193	168	100	Galvanized iron	120	-11	1.44	27.922
P-194	242	100	Galvanized iron	120	-11	1.44	27.921
P-195	303	100	Galvanized iron	120	-11	1.44	27.921
P-196	199	100	Galvanized iron	120	-11	1.44	27.922
P-197	268	100	Galvanized iron	120	-11	1.44	27.922
P-198	158	100	Galvanized iron	120	-11	1.44	27.921
P-199	25	100	Galvanized iron	120	-11	1.44	27.923
P-200	87	100	Galvanized iron	120	-11	1.44	27.92
P-201	39	100	Galvanized iron	120	-11	1.44	27.923

P-93	36	100	Galvanized iron	120	-16	2.08	55.004
P-94	41	100	Galvanized iron	120	-16	2.08	55.002
P-95	39	100	Galvanized iron	120	-16	2.08	55.001
P-96	63	100	Galvanized iron	120	-16	2.08	55.004
P-97	110	100	Galvanized iron	120	-16	2.08	55.003
P-98	113	100	Galvanized iron	120	-16	2.08	55.003
P-103	90	100	Galvanized iron	120	-16	2.08	55.004
P-104	88	100	Galvanized iron	120	-16	2.08	55.002
P-105	106	100	Galvanized iron	120	-16	2.08	55.004
P-106	95	100	Galvanized iron	120	-16	2.08	55.002
P-107	125	100	Galvanized iron	120	-16	2.08	55.003
P-108	149	100	Galvanized iron	120	-16	2.08	55.003
P-109	67	100	Galvanized iron	120	-16	2.08	55.002
P-110	149	100	Galvanized iron	120	-16	2.08	55.003
P-111	90	100	Galvanized iron	120	-16	2.08	55.003
P-112	98	100	Galvanized iron	120	-16	2.08	55.003
P-113	91	100	Galvanized iron	120	-16	2.08	55.004
P-114	111	100	Galvanized iron	120	-16	2.08	55.003
P-115	134	100	Galvanized iron	120	-16	2.08	55.003
P-116	158	100	Galvanized iron	120	-16	2.08	55.003
P-117	118	100	Galvanized iron	120	-16	2.08	55.004
P-118	317	100	Galvanized iron	120	-16	2.08	55.003
P-119	400	100	Galvanized iron	120	-16	2.08	55.003
P-120	248	100	Galvanized iron	120	-16	2.08	55.003
P-349	117	100	Galvanized iron	120	-16	2.08	55.003
P-350	108	100	Galvanized iron	120	-16	2.08	55.002

APPENDEX E: Daye Town Existing Water Supply Distribution System



APPENDEX F: Daye Town Existing Water Supply Transmission Line



481000
482000
483000
484000
485000
486000
487000
488000
728000
726000
724000
722000
720000
Kimbicha Spring
Shalamo Spring
Debiso Spring
500m3 Service Reservoir
Borehole
N
S
E
W
Legend
Daye town Tranismission pipe layout
Sources and Service reservoir
GI pipe DN 100mm
0
1
2
4 Km

APPENDEX G: Questionaries for Sanitation situation Survey (Latrine availability, waste disposal and water for sanitation)

Name ________________________________, Age______ Sex _____, Kebele ____________

1. Do the household have a Latrine block?

Yes_______________, No_________________

2. What was the (main) reason that household members were unable to use the toilet at all times of the day or night? (Ask only if 'No' answered in Q- 1)

- Limited mobility prevents members from using the toilet.
- Distance/barriers prevent members from reaching the toilet.
- Toilet is not always available to all household members.
- Toilet is not always safe for all household members to use,
- Other (specify)

____

____

3. What kind of toilet facility do members of your household usually use? (Ask only if 'Yes' answered in Q-1)

- Flush/pour flush,
- Dry pit latrines
- Composting toilets
- Other (specify) ____
- Bucket
- Container based sanitation,
- Hanging toilet / hanging latrine
- No facility / Bush / Field

____

____

4. Where does it flush to? (Ask only if 'Flush' or 'Pour flush' answered in Q-3)

- Flush to piped sewer system,
- Flush to septic tank

- Flush to pit latrine,
- Flush to don't know where,
- Flush to open drain

5. Do you share this facility with others who are not members of your household?

Yes_______________, No_________________

6. Where is this toilet facility located?
   - In own dwelling
   - In own yard / plot
   - Elsewhere
7. Has your (pit latrine or septic tank) ever been emptied?
   - Yes emptied,
   - Never emptied,
   - Don't know,
8. The last time it was emptied, who did it? (Ask only if "yes emptied" answered in Q-7)

   Removed by service provider,

   Emptied by household,
   - Other (specify)

   ____

   ____
   - Don't know,
9. If removed by service providers, where were the contents emptied to?

   (Ask if "removed by service providers" answered in Q-8)
   - To a leach field, soak pit
   - To a sewer
   - To an open drain

- To open ground or watercourse
- Other (specify)

- Don’t know,

10. If emptied by household, where were the contents emptied to? (Ask if "Emptied by household" answered in Q-8)

    - buried in a covered pit,
    - to uncovered pit, open ground, water body or elsewhere,

11. Is water available near the toilet for hand washing/MHM? (Ask if "Emptied by household" answered in Q-8)

    - Yes
    - Yes, but manually filled Buckets,
    - No

12. What was the cause for the absence of water supply near the toilet? (Ask if "No" answered in Q-11)

    - Only toilet is available,
    - No water supply in the nearby area
    - Water is not considered as important,
    - Other (specify)

APPENDEX H: Summary of Sanitation Status (SPSS-report)

Type of Latrine

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid			1.0	1.0	1.0
	Dry pit latrines	391	95.1	95.1	96.1
	Flush/pour flush	16	3.9	3.9	100.0
	Total	407	100.0	100.0	

Where to flush

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		391	96.1	96.1	96.1
	To Pit latrine	7	1.7	1.7	97.8
	To Septic tank	9	2.2	2.2	100.0
	Total	407	100.0	100.0	

Status of emptied

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid			1.0	1.0	1.0
	Don't know	8	1.9	1.9	2.9
	Never emptied	348	84.7	84.7	87.6
	Yes emptied	51	12.4	12.4	100.0
	Total	407	100.0	100.0	

Who did empty

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		356	87.6	87.6	87.6
	Emptied by household	35	8.5	8.5	96.1
	Removed by service p	16	3.9	3.9	100.0
	Total	407	100.0	100.0	

Place of emptying

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		356	87.6	87.6	87.6
	buried in a covered pit	33	8.0	8.0	95.6
	Don’t know	16	3.9	3.9	99.5
	to uncovered pit, open ground, water body	2	.5	.5	100.0
	Total	407	100.0	100.0	

Water system for latrine

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid			1.0	1.0	1.0
	No water nearly	295	72.48	72.48	73.48
	Yes, there is water	63	15.3	15.3	90.0
	Yes, but manually fi	49	12.04	12.04	100.0
	Total	407	100.0	100.0	

Reason for not water for sanitation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		66	17.0	17.0	17.0
	No water supply in the nearby area	110	26.8	26.8	43.8
	Only toilet is available	103	25.1	25.1	68.9
	Water is not considered important	128	31.1	31.1	100.0
	Total	407	100.0	100.0	