



ASSESSMENT OF URBAN WATER SUPPLY SYSTEM  
PERFORMANCE:  
ARBA MINCH TOWN: ETHIOPIA

M.Sc. THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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ASSESSMENT OF URBAN WATER SUPPLY SYSTEM  
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## ACRONYMS

AutoCAD	Automatic Computer Aided Design
AWWA	American Water Work Association
CSA	Central Statistics Agency
DCI	Ductile Cast Iron
EPA	Environmental Protection Agency
EPANET	Environmental Protection Agency Network Evaluation Tool
EPS	Extended Period Simulation
GIS	Geographical Information System
HDPE	High Density Polyethylene
IBNET Sanitation	International Benchmarking Network for Water and Utilities
Ins.ESRI	Interfaces with Environmental System Research Institute
m.a.s.l.	Meters above sea level
MDD	Maximum Day Demand
MDGs	Millennium Development Goals
MPC	Minimum Pressure Criterion
NMA	National Meteorology Agency
NRW	Non-Revenue Water
PHD	Peak Hour Demand
PN	Nominal Pressure
SCADA	Supervisory control and data acquisition
SEAWUN	Southeast Asian Water Utilities Network
SNNPR	South Nation National People Region
uPVC	unplasticised polyvinyl chloride
UNICEF	United Nations Children's Emergency Fund
WaterCAD	Water Computer-Aided Design

WaterGEMS	Water Geospatial Engineering Modeling System
WDF	Water Duty Factor
WDN	Water Distribution Network
WDS	Water Distribution System
WHO	World Health Organization

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## DECLARATION

I declare that the work of the thesis entitled by “**Assessment of Urban Water Supply System Performance**”, **The Case of Arba Minch Town, Ethiopia** has been performed by me for the Faculty of Bio-Systems and Water Resources Engineering Department of Water Resources and Irrigation Engineering. This thesis has not been submitted to any other University or Institution.

Name: Mesay Mulu Uta

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## **ABSTRACT**

*Water distribution systems are the most important urban infrastructure in the world and require huge construction investments. Arba Minch Town has been experiencing failure of the water distribution system due to poor system design and system deterioration. Therefore, this study aimed to model optimal water distribution network by modifying the existing distribution network of Arba Minch Town using WaterGEMS software. The population of the town in 2032 expected to reach 201,814 with an average daily demand of average daily demand of 67.34l/c/d and 36.8 % of water production lost in the distribution system before reaching to the end customers. The town's master plan made it possible to optimally modify the layout of the network, change the pressure zones and change the position of some supply tanks in the existing water networks. It is observed that existing water distribution systems did not cover the existing community like Gurba and Woze kebele due to design problems and pipe size. The modified distribution network has improved the minimum and maximum water flow velocity through providing appropriate pressure in the ranges of 10-70 m head of water. It has been noticed that maximum pressure criteria violation percent was reduced from 35.62 percent to 1.5 percent during minimum flow hours and it also diminished from 32.3percent to 1.08 percent during peak flow. The results also showed that the minimum velocity criteria violation reduced from 17.08percent to 0.07percent during peak flow rate condition. The study concluded that the existing water distribution network in the study area needs to be done of optimal approach by modifying the system to ensure efficient water distribution for the community.*

**Keywords:** *Arba Minch Town, Demand, Distribution network, WaterGEMS*

# 1 INTRODUCTION

## 1.1 Background

According to Kapa(2021), water is the most essential resource to sustain life not only for human life but also for all the living things in this world. Urban water supply is defined as a survival factor for development, and that limits sustainable development of the city, which is a necessary material base that ensures people's life production and is directly related to social and economic stability development.

The water distribution system (WDS), the infrastructure required worldwide, is of paramount importance to modern man presence of all social, industrial and environmental aspects(Suribabu, 2019). The water has become increasingly scarce resources in the world due to rapid urbanization, climate patterns of change considering dynamic population and economic growth(Nkiaka et al., 2021).

The center of any healthy population is access to safe drinking water. At the end of the Millennium Development Agenda in 2015, the results achieved by the Millennium Development Goals (MDGs) were mixed. According to the United Nations(WHO, 2005),the water-related MDG target had been achieved, yet in 2015 there were still 663 million people without access to an improved drinking water source. Furthermore, even where a water point is deemed to be ‘improved’, this is no guarantee that the water point is operational, or that water is available and is safe to drink. Thus, it is estimated that at least 1.8 billion people around the world are using water sources contaminated with faecal bacteria in 2015 (Génevaux, 2018).

Basic component for sustainable development is delivery of safe and adequate water supply service for the consumers. In developing countries, the need of adequate potable water supplies for use in urban areas is an essential for well-being of the people. The recent awareness and concern of safe drinking water in developing country is increased from ever. This awareness focus on water supply sector like adequate water supply coverage, losses control, infrastructures renew and replacement, observing existing scheme and planning the future. In sustainable world, sufficient and safe water is made accessible to meet every person’s basic needs(WWDR, 2015). According to(UNICIEF, 2014) Ethiopia has

improved water supply by 57% (97% in urban areas and 42% in rural areas). Despite the progress seen in Ethiopia, 43% of the population does not have access to an improved water source.

Aim of the WDS project is based on the uninterrupted supply of water in sufficient quantity the right engraving of acceptable quality, as economically as possible to consumers(Access et al., 2022). WDS is a complex system that consists of tanks, pipes, pumps, fittings (nodes), valves and fittings for transportation of water from a wastewater treatment plant (WTP) or source to the end users(Dandy et al., 2022). This puts pressure on the water organizations to provide sustainable water supply to end users in the required quantity and quality, within the required time, subject to the series delivery requirements and operating restrictions.

Studies have shown that WDS generally does not serve its purpose due to system reliability limitations(Rai & Lingayat, 2019).The term reliability reveals ability to offer WDS satisfactory end-user services for several abnormal operations location. It is often considered based on two general classes of failure activities, such as mechanical and hydraulic failures. Mechanical failures include system failures such as pipe bursts and pump failures; while the hydraulic failures include inconsistency of demands and pipe hydraulic resistance (Darvini et al., 2020). Such events can lead to significant changes in the WDS terms and thus to reducing flow rates and residual pressure at points of use.

Nevertheless, difficulties in maintaining system reliability, there is also a degree of flexibility in WDS what allowed to provide the necessary water more or less economically depending on the operating time(Constraints & Dai, 2021). This flexibility gives an opportunity to evaluate the performance of the WDS.

Miscellaneous location; namely, pipe breakers and pumps blockages cause a pressure drop in the distribution system and therefore the actual flow consumed can decrease significantly(Abdulaziz et al., 2022). However, the network is under too little pressure conditions. On the other hand, under normal conditions when the requirements are fully met filled when the pressure in the house connection and thus in the consumer connection increases attrition and losses can easily increase(HJ Van Zyl, and Ilemobade, 2017). Conventional simulation models often do this ignores him circumstances and requirements are considered to be

constant and independent of pressure, this is an important limitation (Gebremedhin, 2020). That's why realistic hydraulics is so important in simulation models behavior net in all operating pressure conditions.

Therefore, the present study focuses on the assessment of water distribution network modeling and hydraulic performance evaluation of the water distribution network of Arba Minch Town.

## **1.2 Statement of the Problem**

The main goal of water supply was to provide enough water without interruption at a reasonable cost, in use of water networks. The core causes of failure for the water distribution systems are poor system design and system deterioration. Also, because it's complicated and costly, it's reassuring the problems are hard for cities in poor countries like Ethiopia. As a result, much water supply projects in Ethiopian cities have failed after investing a lot of capital in design and construction. Arba Minch Town, the study area of this research, also has the same problem although it uses piped water supply system with good quality source. In defiance of delivery system covers most of the city, except for new extensions, the system is not efficient. Does not deliver water everywhere town at a time, which means the existing system delivers water intermittently with zone difference.

The problems of the water supply distribution system in the town of Arba Minch include: too old the water supply system, which increases water loss, is broken diameter of supply lines, frequent failures in existing electricity supply and limited water pressure in the water supply. Due to the above issues, the locals are struggling with water supply issues.

To alleviate and improve the prevailing major drinking water shortages living conditions of the residents by rehabilitating the existing systems and expansion of water supply for new expansion areas, Arba Minch Town Water Supply and Sewerage Enterprise in collaboration with South Nations Nationalities and Peoples of Ethiopia Water Resource office prepared a design in 2011.

However, from the beginning, the design of the new rehabilitation project has its own problems, which encounter it to solve the problem it is set for. The main limitations of this new design include improper sitting of service reservoirs which expels some areas from getting water from distribution system and unreasonable

demand allocation which after effects pipe size, flow velocity, power requirement, and pressure in distribution system and size of any water supply system structures. In addition to give the inefficiency services, the country is subject to large capital investments.

Therefore, this research aims to assess the performance of the distribution system, which will be the solution to the problem of Arba Minch Town water supply system.

### **1.3 Objective of the Study**

#### **1.3.1 General Objective**

The main objective of this study was to assess the water distribution system performance of Arba Minch Town.

#### **1.3.2 Specific Objective**

- To compute water demand of the town.
- To quantify the water loss in the distribution network.
- To assess the hydraulic performance of existing water supply distribution system using WaterGEMS.

### **1.4 Research Questions**

- How much is the demand of water required for the town?
- How much water is lost in the water distribution network while compared with the water produced?
- What are the key hydraulic parameters affecting the performance of the existing water supply system of the Town?

### **1.5 Significance of the Study**

The performance of Arba Minch Town water supply networks became one of the most critical issues in the town that requires instant action as the system repeatedly supplies the intermittent supply of water. The study of the system performance of the water distribution system contributes to identify the problems, possible cause of identified problem, preventive measure to improve the performance and to offer background facts for people who desire to conduct in additional applicable research in the water supply system.

This paper is mainly focused on evaluating the existing system of water supply and loss management situation of Arba Minch town to provide the efficient loss management and adequate water supply system, and also it is expected to increase the knowledge and up to date information on limitations of water supply service provision in the town. In addition to that, it is also important as an input to the future studies; as well as, help responsible body to be aware to put policy in order to satisfy the water demand and to achieve good hydraulic performance of water distribution system.

### **1.6 The Scope of the Study**

This study focuses on the assessing performance of urban water supply distribution system in Arba Minch Town based on ten years of water consumption data (2011 to 2020). Water GEMS hydraulic model was used to analyze water distribution network of the town. This study is specifically focus to evaluate the hydraulic performance of the existing water supply distribution system starting from the source of production up to end users in terms of pressure, flow or velocity, demand fulfillment (supply-demand), urban physical water loss in distribution system and their efficiency, and excluded pump assessment and water quality due to lack of recorded data and financial limitation.

## **2 LITERATURE REVIEW**

### **2.1 Urban Water Distribution System**

Water distribution systems are urban water supply systems that needs-based transport of drinking water from the discharge treatment plant to the consumers. Water association around the world face growing environmental challenges the hydraulic integrity and water quality of their water distribution networks. These challenges arise from population growth and migration to urban cities. They further increase the burden of aging, are inefficient and already overburdened infrastructure(AWWA, 2010).

Several studies have been conducted to study the behavior of water distribution systems and reach at optimal solutions and assumption to improve hydraulic performance and network efficiency. Anore, (2020) and Zyoud,(2004) studied hydraulic performance of water distribution system under the action of cyclic pumping; the results show it the network under consideration is exposed to relatively high-pressure values along the entire route. The velocity of the water in the network has; also attained high values. These high values of pressure and velocity negatively affect network performance. (Zyoud, 2004) assessed the hydraulic behavior and evaluate the global performance of Bani Suhila City water distribution network by developing a computer model for a distribution network under actual existing and alternative conditions, especially involving intermittent supply. The performance of the network was evaluated from a hydraulic point view using a systematic engineering approach, and the results indicated that the performance was adequate and the system provided an acceptable level of service based on pressure considerations.

Water distribution networks are very important vital infrastructure where failures are inevitable. Typical WDNs consists of a network of pipes, nodes linking the pipes, storage tanks, reservoirs, pumps, additional appurtenances like valves. Water distribution systems represent a major portion of the investment in urban infrastructure and a critical component of public works. The main goal is to design water distribution systems to deliver potable water over spatially extensive areas in required quantities and under satisfactory pressures.

Therefore, hydraulic models of water distribution networks have become essential tools for understanding system behavior by simulating pressures and flows at different locations and

times in the networks. The design of water distribution systems in general based on the assumption of continuous supply. However, in most of the developing countries, the water supply system is not continuous but intermittent (Khatri & Vairavamoorthy, 2008)

A well-planned water supply network is very important for the development of urban areas. The network is built to meet the diverse needs of consumers while meeting minimum pressure requirements at specific nodes (Atiquzzaman, 2004). Water cannot be pumped at lower pressures and excessive leakage may occur at higher pressures

### **2.1.1 Demand for Water**

Safe, reliable, an accessible and readily available water supply is essential to good health (Williams et al., 2020). However, for several decades about a billion people in developing countries lacked safe and sustainable water deliver. According to (Howard & Bartram, 2003)estimated a minimum of 7.5 liters of water per person per day is needed at home for drinking, preparing food and for personal use hygiene, the most basic requirements for water; at least 50, liters per person per day is necessary to ensure the overall personal hygiene, food hygiene, household hygiene cleaning and laundry.

The public water requirement for the demand is made up of authorized consumption by domestic, non-domestic consumers and water losses. The water distribution networks should meet demands for potable water. If designed correctly, the network of interconnected pipes, storage tanks, pumps, and regulating valves provides adequate pressures, adequate supply, and good water quality throughout the system. If incorrectly designed, some areas may have low pressures, poor fire protection, and even health risks(Don D. Ratnayaka, Alan C. Twort, 2009).

Water demand shows your current and/or projected water consumption in any area at any time(Munialo et al., 2015). While several studies on improvement have been conducted in developed countries to understand the characteristics of urban water applications, this may not be the case in developing countries (Espey et al., 2015). This knowledge is the same least understood in Africa. In general, water needs vary and should be taken into account the probabilistic nature of the variation leads to more meaningful assessment of the performance and reliability of water distribution systems(Tom Tietenberg, 2011).

As stated by Baumberger et al.( 2007)the main purpose of water demand forecasting in water management plans, the process involves determining an adequate water supply to meet the expected total demand curve. Projection of water demand through the final construction guarantees the series procurement targets to be achieved in the coming years. The identify existing and anticipated needs for the future it is a precocious and critical step, and one miscalculation can derail everything master planning process (Baumberger et al., 2007).

The main purpose of water demand forecasting in the water planning process, know enough water supply to meet the expected aggregate demand curve. Projection of water demand through its eventual expansion, it provides a set of procurement objectives that must be met in the coming years. According to Munialo et al.(2015), the need for water forecasting has become a necessity, an integral part of effective planning and management of water resource. The water forecasting and assessment of existing deliveries are invaluable triggers to determine when or new water source should be tapped.

Demands have many uses besides distribution system modeling, including supply planning and setting treatment plant and transmission main capacities(Świtnicka et al., 2017); therefore, it is important that demands are consistent with accepted water use characteristics and available data and those they undergo a thorough review process.

Analyzing and predicting water demand in cities is a complex but necessary task, it is important that cities meet the water needs of their residents. Ability to estimation of water needs in different climate zones, population growth, protection scenarios are closely related to urban and hydrological processes modeling (Peters & Chang, 2011). Further development of infrastructure and drinking water use has highlighted the importance of accurately determining water needs estimates for effective municipal water infrastructure planning and design (HJ Van Zyl and AA Ilemobade, 2008). Accurate water demand forecast it depends on the availability of reliable population and water use data and understanding of the distribution of different user types in the community (Munialo et al., 2015).

### **2.1.2 Water Demand Projection Using Customer Billing Records**

According to the study of Espey et al.(2015), plenty of water demand estimation approaches have been practiced since the history of urban water supply planning. However, they all

have their own defects; the commonly used methods were population-based water demand projection, water consumption history-based approach and water usage category approach.

The consumption measurement data is actual meter readings logged approximately every month or bimonthly. These readings are recorded and stored as the main value for year's information on planning the future of water approvals. The account registration details are treated as water consumption history of water management desks. In addition to future water demand estimation, historical billing data as well as very important when calculating the actual water losses in the water supply system. History of water use is relatively the best input for an accurate estimation of the future water requirements (HJ Van Zyl and AA Ilemobade, 2008). Fixes some limitations in others methods, such as estimating water needs based on population. For example, in contrast to the population-related water demand, this is taken into account in the customer's billing standard of living from the development of water consumption. According to the study of Temesgen Mekuriaw(2020) to evaluate the existing water supply systems and water demand scenario analysis and future water demand forecast have been done for the town of Yejube in Ethiopia. The analysis is done focused on the evaluation of existing water supply coverage in the town based on produced and billed water consumption forecasting the future water demand estimation using time series water consumption.

### **2.1.3 Water Usage Category-based Water Demand**

Water consumption models, they generally forecast water usage for utility planning purposes. Estimates the water consumption forecast contains water consumption for the sector and a measuring its size during the planning period(Morales et al., 2009). The water consumption rate or water consumption factor per activity is the sum water consumption of all customers in this area standardized by sum the measurement of its size and usage information is used to characterize the water present utilization patterns for different types of water usage category (single-family house, apartment buildings, commercial and industrial buildings, etc.).

Florida Water Resources Journal, published in December 2007, highlights a study by Baumberger et al. (2007). The aim of the study is to compare the forecast water requirements information about population, water usage category and customer billing data.

Olathe was a city given due consideration as a subject. The evaluation result indicates different values obtained and compared by each method with the actually recorded water consumption of the Olathe city in the year 2005. Therefore, the city's water demand in million gallon per day (mgd) was 13.21, 13.24 and 13.33 for approaches based on population, water usage category and settlement data while the water was actually produced for the city in the same year was 13.20 mgd. As the result shows, the percent errors for approaches based on population, water usage category and bill data-base are 13, 4 and 1 as a result.

Investigation performed by Baumberger et al. (2007) defines it as a population approach overestimates the water needs of towns. There are no limits to this approach it's just an overestimate, but it also assumes an average water requirement for everyone a person in town who neglects the norm of life, the main factor makes the difference between personal water consumption. In addition, the method does not provide any indication of the spatiality localization of demand in the distribution area. These are consequences of the efficiency of water distribution networks, both in terms of costs and hydraulics features.

## **2.2 Non-Revenue Water and Causes of Water Losses**

As defined by Rudolf, F., and Roland, (2011), Non-Revenue Water is the difference between the amount of water poured into the water distribution system and volume billed to customers.

According to World Bank group, (2017)on Water Supply and Sanitation Sector Council Report, NRW consists of three elements: physical losses (or real), commercial (or apparent) and unaccounted for losses are allowed consumption. Physical losses include losses from all parts of the system and overflows in storage tanks. They are caused by wrong operations and maintenance, no active leak control and poor-quality underground resources.

Commercial losses are caused by under-registration of customer counters, data processing errors and theft of water in different forms. Authorized unbilled consumption includes water consumption of for operational purposes, extinguishing water and water made available free of charge to certain consumer groups. Jalalkamali & Eftekhari, (2012)reduce, split into two as real and apparent losses. Real losses are covered by losses of pipes, fittings and accessories as well as leaking tanks etc. Apparent losses are due to unauthorized connections

(theft and illegal) and measurement errors (Jalalkamali & Eftekhari, 2012). Most real losses are often due to leaks, and it is usually due to lack of maintenance or lack of renewal and replacement systems. Leaks in water distribution systems are a serious problem, impacts on water companies and their consumer's worldwide(Dighade et al., 2014).

Therefore, apparent losses can amount to a large volume of water than physical losses and often have a greater value, since reducing apparent losses increases revenue, whereas physical losses reduce production costs. For any profitable utility, the water tariff will be higher than the variable production cost and sometimes up to four times higher. Thus, even a small volume of apparent loss will have a large financial impact(Farley et al., 2008).

One of the most important issues affecting water supply in developing countries is important the difference between the amount of water introduced into the distribution system and the amount of water billed to consumers called Non Revenue Water (NRW) (Dighade et al., 2014). Current statistical studies have shown that NRW makes up half of the developing countries, with around 45-50% total input volume of the system (Lambert, 2012). Although it is very popular recognized that NRW values are very high in developing countries, in fact, very little data on real numbers is available in the literature. It's largely because most of the water public services in developing countries lack adequate oversight water loss rating systems and national reports are lacking in many countries systems that collect and consolidate information about the efficiency of water supply systems. Currently, the water supply system in developing countries does not meet the requirements to the needs of people and industry. This results in a high loss of water mismanagement and poor physical condition of WDS (Wu et al., 2010).

According to Ewa Ociepa,( 2019) the amount of water lost in water distribution systems vary greatly by country, region and planting from only 3-7% to approximately up to 50% of incoming dispensed volume on well-maintained systems in developed countries and less well maintained systems in developing countries respectively.

### **2.3 Hydraulic Modeling for Distribution Network Evaluation**

The water distribution system (WDS) is a roadside hydraulic transport system in which the topology and topography are known and which can transport the water from the source to the consumer; it consists of components such as pipes, valves, pumps and tanks, flow

regulation and control devices (Świtnicka et al., 2017).

The reliability of the water distribution system of the utility depends on the combination of different factors that play an important role in the design and management of the system: Variability of water needs, size and maintenance of pipes, volume of urban reservoirs(Fontanazza et al., 2014).

Second examined by Ostfeld, (2012), reliability in general and in water distribution system in particular, is a measure of probabilistic performance. A system is considered reliable when it works properly for a specific time interval and within limits conditions. No system, it's pretty reliable. Adverse events and failures can occur in any system, to cause downtime or system failures. Failures are by nature a stochastic in nature and are the result of unpredictable events in the year of the system itself and/or its environment.

However, serious problems when analyzing the reliability of the water supply systems to define meaningful, relevant and computationally feasible measures of reliability(Ostfeld, 2012). While the question "Is the system reliable?" is generally understandable and easy to understand, the question "is it reliable enough?" no has a simple answer because it requires both quantification and assessment of reliability measures. Much effort has been made to analyze the reliability of water supplies. However, these studies are still common to follow heuristic guidelines, such as providing two alternative routes to each requesting node of at least one source or all pipe diameters larger than the recommended minimum.

Reliability considerations are an integral part of all decisions about the planning, design and operational phases of water distribution systems. Quantitative can be the reliability of the water distribution system defined as the complement of the probability of the system failing, where failure is defined as the inability of a system to meet consumer demands (Ostfeld, 2012). Studies on the efficiency of water distribution networks (WDN) are a central topic as an instrument decision-making process of water management authorities (Laucelli et al., 2015).

According to Hugo J and Bartolin, (2015), hydraulic simulation models are commonly used by planners, water utility workers, consultants and many others involved in the analysis, design, operation or maintenance of water systems. The reliable and efficient operation of modern water supply systems in large cities and the management of energy flows in large

and long pipelines require a specific approach based on the intensive use of models (Hurgin, 2018). Velocity and pressure are the most important hydraulic parameters that show the reliability of a water distribution system. In the hydraulic simulation of the water distribution, modeling software that determines the maximum and minimum allowable values for velocity and pressure increases the efficiency of the system.

There are no fixed criteria for the maximum velocity of main (Walski et al., 2003), but usually when the velocity reaches 3 m/s, the pressure starts to decrease and the water hammer increases. To avoid accumulation of scale in drinking water distribution networks, it is recommended to design self-cleaning networks (Vreeburg et al., 2012). Despite the constructive velocity threshold for the self-cleaning drinking water distribution system if the system is set to 0.4 m/s, this value is considered conservative, so a constant velocity of 0.2 m/s or less may be sufficient (Vreeburg et al., 2012). Therefore, a maximum flow value of 2 m/s and a minimum value of 0.3 m/s were assumed for flow velocities in the distribution mains for this study.

The minimum pressure criteria actually available vary widely around the world. The wide range of minimum allowable pressure criteria means that water supplied at the same pressure may be acceptable in some countries and unacceptable in others. Therefore, the cost of providing water (both capital and operational) to meet the same flow demand will inevitably vary from region to region. The pressure required is usually given as the minimum allowable pressure at which the system is considered healthy. Most insurance companies care less about people's comfort and more about the risk of fire. Insurance companies often require that the minimum allowable pressure achieve a specific fire flow rate, which often corresponds to 14 m (20 psi) residual pressure at the vent point.

Ghorbanian, V., Karney, B. W., & Guo, ( 2015) recommended five pressure targets (i.e. above 0 m for emergencies such as major power outages/main breaks and power outages; more than 14 m (20 psi) below the maximum daily demand and fire flow; more than 25 m (35 psi) under normal conditions; less than 70 m (100 psi) under normal conditions; within +7 m (+10 psi) of average pressure greater than 95% of the time) to assess WDS and reduce unnecessary water loss, major failures and/or energy consumption.

### **2.3.1 Various Hydraulic Modeling Tools**

The widespread introduction of personal computers has improved the hydraulic design of distribution networks. Commercial programs available on the market, sometimes even free of charge, enable a very precise and quick calculation, which makes them equally suitable for the design of simple rural systems or large urban networks of a few thousand pipes. Accessibility of such software and PCs to the engineers of developing countries has been significantly improved since the mid-nineties. There are different types of hydraulic models available for water supply distribution analysis and evaluation(Walski et al., 2003)

#### **EPANET**

EPANET, the least expensive of the models presented and, it is a free software package developed by the United States Environmental Protection Agency (EPA) that was originally and primarily intended for use as an assessment tool by any interested party in a distribution system.

EPANET runs in a Windows environment to view and edit the model output. Although EPANET only performs extended period simulations, the program is equipped with tools for modeling water quality phenomena such as mass flow responses and pipe wall responses. The program solution algorithms are extremely fast, and the slow convergence problems inherent in node-oriented systems have been solved, at least in part, by a hybrid approach. The main disadvantage of EPANET as compared to commercial modeling programs is the use of a text editor for data entry. While EPANET doesn't offer any graphical input options, the program does offer attractive color-coded output maps. Despite its limitations, EPANET works reasonably well as a general modeling package for predicting pressure drops, pressures, and water quality in a distribution system.

#### **WaterCAD**

Water CAD, manufactured and distributed by Haestad Methods of Waterbury, Connecticut, is a standalone hydraulic modeling program that includes its own graphical editor and extensive modeling capabilities with a Windows interface to the EPANET network. WaterCAD can create a network of distribution systems to scale or schematic, with or without DXF base maps. The resulting network can be color-coded to reflect the modeling

results, and WaterCAD also provides adequate annotation capabilities.

WaterCAD's modeling capabilities include a scenario management tool, fire flow and water quality analysis capabilities, and graphing and profiling of model results and water properties. WaterCAD can also create contour plots to demonstrate areas of high pressure, low fire flow availability, hydraulic level rise and many other important system attributes. WaterCAD provides what-if steady-state and extended-term analysis.

Unlike a word processing program, WaterCAD uses tables for input and output that are contained directly in the modeling environment. The data to populate the model can be written to and generated from these tables using WaterCAD's database connectivity. WaterCAD also interfaces with Environmental Systems Research Institute; Inc. (ESRI) GIS programs that use SHAPEFILE to import and export model data.

### **Cybernet**

Cybernet, also manufactured and sold by Haestad Methods, includes the same hydraulic modeling capabilities as WaterCAD but runs in AutoCAD for Windows. Cybernet is essentially WaterCAD with the ability to run in an AutoCAD environment. This mode of operation provides the user with all the functionality of AutoCAD version 14, allowing for graphical compatibility with other drawings created in the organization. The AutoCAD environment gives the software greater graphic flexibility to achieve high quality graphic output and modeling results.

### **H2ONET**

H2ONET is a modeling program provided by MW Soft, Inc., a subsidiary of Montgomery-Watson of Pasadena, California, that includes a Windows-based AutoCAD interface to EPANET. Like Cybernet, H2O NET uses the AutoCAD version 14 environment to create network model drawings with full AutoCAD capabilities; However, H2ONET requires AutoCAD and cannot run as a standalone program.

H2ONET provides a large range of modeling capabilities, including scenario management, fire flow modeling and fire hydrant analysis, and water quality analysis. Some of the features that set H2ONET apart include a supervisory control and data acquisition (SCADA) interface, which allows for the extraction of real-time modeling data directly from a SCADA

system in an ASCII format for use in model calibration and operator emergency response training; and an energy management module for use in identifying the most energy-efficient and cost-effective operational policies.

### **SynerGEE Water**

SynerGEE Water is the water modeling software from Stoner Associates, out of Carlisle, Pennsylvania, does not use the hybrid method of equations for solving the network analysis. SynerGEE uses the Newton-Raphson method and nodal (or H) equations. Because SynerGEE products have the ability to effectively model large, complex systems in excess of 100,000 pipes, the program historically has been used mostly by clients with large distribution systems. However, the advanced modules in SynerGEE 3.0 make the program attractive to a utility system of any size.

### **WaterGEMS**

Hydraulic models are useful decision-making aids in the real-world management of water distribution systems (Kara et al., 2016). Public domain applications such as EPANET, Branch, and Loop, as well as commercial software such as Water GEMS and Water CAD, are all available to model the distribution system (Sonaje & Joshi, 2015). The Water GEMS software would be used to evaluate the evaluation or simulation software of the water distribution system in this report. Previous studies that have used Water GEMS for modeling include those that have used it to model all the components of a distribution system (Mehta et al., 2017; Menten et al., 2020). According to Salunke et al., (2018), Bentley Systems in the United States created the Water GEMS program. It's strong but simple software that helps in the analysis of complex pumping systems and piping networks as they transition from one steady state to the next. Water GEMS is an integrated interoperability, geospatial model-building, evaluation, and asset management solution for water distribution systems. Engineers can use Water GEMS to evaluate, design, and evaluate the performance of water distribution systems in an easy-to-use environment (Świtnicka et al., 2017).

Sumithra et al., (2013) compared the Water GEMS and loop software's abilities. The studies found that Water GEMS is more reliable, effective, and changeable. Additionally, with a variety of hydraulic and graphical analysis options, Water GEMS was found to be highly user-friendly. It takes less time to renovate and re-analyze the network as well. Finally, the

authors found that using the Water GEMS for modeling and evaluation would help to improve the water distribution system. Computer simulations in Water GEMS software are used in the hydraulic model of evaluation and operating solutions of analyzing systems. Water GEMS can be used to provision the model process of new distribution systems, assess water flow capacity, detect water losses, and manage water losses, among other things(Dhumal et al., 2018; Świtnicka et al., 2017).

Water GEMS can generate, evaluates, and recalls an infinite number of model variants, such as situations and options. The goal of situations and options is to provide accurate control over model changes for the present and future water distribution system (Świtnicka et al., 2017).Bentley Water GEMS has a universal data interface, can connect to other GIS systems directly, and can import data from Arc GIS, AutoCAD DWG, DXF, and shape files. It's also compatible with Microsoft Excel.

Nodal elements in water distribution models include junction nodes, which link pipes, storage tank and reservoir nodes, pump nodes, and control valve nodes. Link elements are used in models to describe the pipes that connect these nodes. Table 2-1 shows each model element, as well as the type of element that was used to represent it in the model and the primary modeling purpose(Walski, 2003).

Table 2-1: Common Network Modeling Elements

Element	Type	Primary modeling purpose	Input Data
Reservoir	Node	Provide water to the system	Hydraulic Grade line, water surface elevation
Tank	Node	Store excess water within the system and release that water at times of high usage	Base, maximum and minimum elevation and also Diameter
Juntion	Node	Removes(demand)or adds(inflow) water from/to the system	Elevation
Pipe	Link	Conveys water from one node to another	Elevation, Diameter, material and roughness coefficient
Pump	Node or Link	Raise the hydraulic grade to over come elevation differences and friction losses	Elevation, pump definition)
Control Valves	Node or Link	Controls flow or pressure in the system based on the specified criteria	Elevation, diameter, valve type

Sourece:(Walski, 2003)

### **3 MATERIALS AND METHODS**

#### **3.1 Description of the Study Area**

Arba Minch town is one of the fast-growing towns in Ethiopia. ArbaMinch town is bordered by Kola Shara village to the north, Lake Chamo, Ganta Kanchama and Ocholo Kebele to the south, Nechisar National Park and Lake Abaya to the east, and Ganta Meyche and Zigiti Bakole Kebele to the west. Geographically Arba Minch town is located between 337,200 and 344,900 degrees latitude and between 662,000 and 671,500 degrees longitude. It is found in Gamo zone and used as the zonal capital in Southern Nations Nationalities and Peoples Regional State of Ethiopia. It is about 505 km south of Addis Ababa and 275 km from Hawassa, the capital of the region.

Arba Minch town consists of eleven administrative kebeles namely Kulfo, Gurba, Menharia, Woze, Ediget Ber, Mehal Ketema, Wuha Minch, Bere, Chamo, Doissa and Dulfana kebeles. According to CSA, (2007) Arba Minch has a total population of 74,879, from which 39,208 were male and 35,671 female. Currently (2022) the town has a population of about 201,028 out of which 103,953(51.71%) were males and 97,075(48.29%) were females. The population of town is estimated to grow at an average rate of 4.8% per annual( SNNRP Finance Bureau, 2022).The total area of the town covers about 55.57 square kilometers or 5557 hectare. The town is located between 1300m – 1500m above sea level. The minimum and maximum temperature of the town is 17.37°C and 30.30°C respectively and receives a mean annual rainfall of 887.5mm (NMA, 2017).

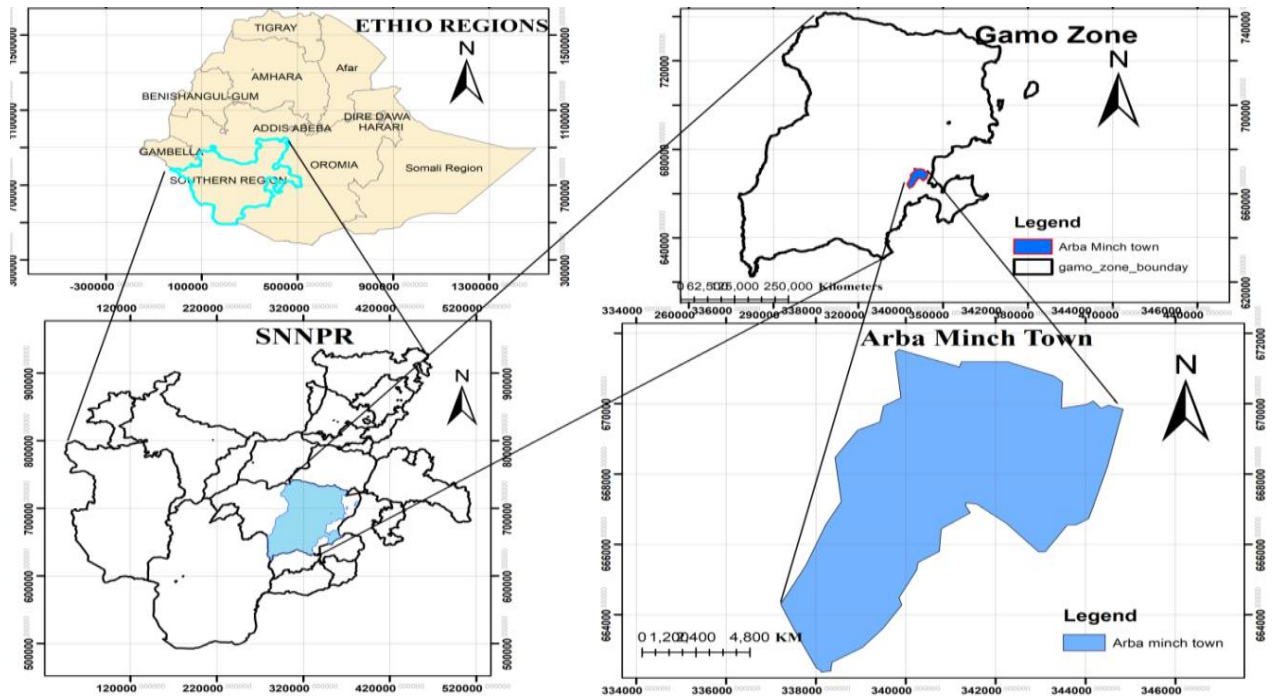


Figure 3-1: Location Map of the Study Area

### 3.2 Existing Water Supply System of the Town

The Town of Arba Minch has a long history of practicing piped water distribution system. It was first built and launched in 1964 and updated in 1969 and 1988 due to the growth and expansion of the town's population. A distribution system was designed in 2010 to alleviate the current acute shortage of drinking water.

Therefore, the system has been designed for the targeted design periods of phase I (2012-2022) and phase II (2022-2032), and the system was introduced at the end of year 2012. According to the designed report, the maximum daily demand was 8,726.7m<sup>3</sup>/d for phase I and 17,971.7m<sup>3</sup>/d for phase II. The existing water supply network was divided into four self-propelled pressure zones. Zone-I include the upper part of the Secha sub town. Zone -II and III cover the central part of the town, zone -IV covers the lower part of the town (Sikela sub town) and where more expansion of the town will be expected during phase II of the project. Proposed water source designed to draw 100l/s from forty springs and the left between three wells each with a capacity of 18l/s located along the Kulfo river bank for the phase I investigate. Additional wells have been suggested with their Phase II requirements.

Table 3-1: The Existing Water Source of the Arba Minch Town and their Geographical Location

Water source	Easting(m)	Northing(m)	Elevation(m)	Depth (m)	Yield(l/s)
Spring	340405	664271	1200	-----	100
Borehole 1	341100	667592	1214	300	18
Borehole 2	340706	667772	1217	300	18
Borehole 3	340324	668053	1223	300	18

Source: Arba Minch Town Water Supply and Sewerage Enterprise (2021)

The project also includes a storage tank with capacity to meet fluctuations in water demand, fire safety, other emergencies during power outages or mechanical failures in the supply and to equalize pressure in the distribution system. The design report shows that a total volume of 2,800 m<sup>3</sup> (phase I) and 5,000 m<sup>3</sup> (phase II) tank capacity is required. The locations and number of reservoirs were determined by the town's topography and the pressure zones to be served.

Table 3-2: Location of the Recommended Service Reservoirs with their Storage Capacities

Zones	Recommended service reservoirs for Phase-I and Phase-II				
	Location		Elevation (m.a.s.l)	Existing Storage	Proposed
	X(m)	Y(m)			
1	337,582	664,310	1,465	300 m <sup>3</sup>	100m <sup>3</sup>
2	337,801	663,745	1,420	500 m <sup>3</sup>	100 m <sup>3</sup>
3	339,975	664,332	1,350	1000 m <sup>3</sup>	500 m <sup>3</sup>
4	340,569	665,470	1,286	1000 m <sup>3</sup>	1500m <sup>3</sup>

Source: Arba Minch Town Water Supply and Sewerage Enterprise (2021)

The existing system for all areas includes 53 km of pipes of various sizes and materials. The diameters of the pipes ranged from 50 mm to 400 mm, using HDPE for pipes with a minimum diameter of up to 100 mm, uPVC for pipes with a diameter of 150 mm and DCI for pipes with a larger diameter. A summary of the water network profile is shown in Table 3-3.

Table 3-3: The Required Pipes in the Distribution Network with their Length

Diameter (mm)	Pressure zone length(m)				Pipe Material	Pipe Class	
	1	2	3	4			
50	2313	1991	1388	4422	HDPE	PN10	
80	1085	2409	496	3673			
100	549	3688	2964	3305			
50	2281				HDPE	PN16	
80	344						
100	593						
150	146	2669	2912	1856	uPVC	PN10	
200	305	859	417	643			
250			149	1010			
300		629	572	2814	DCI	PN10	
400				2559			
Sub total	7615	12245	8888	24282			
Total	53030						

Source: Arba Minch Town Water Supply and Sewerage Enterprise (2021)

### 3.3 Computation of Water Demand for Proposed Model

Water demand analysis is the first step in modeling the distribution system. In the draft of the present document, the water needs have been estimated based on the population using the average per capita water consumption, without taking into account the standard of living and the geographical location - needs. In this study, however, water needs were estimated using two methods, bill data and water usage category. It was chosen because it could

identify a gap in the previously used method (population forecast method during design time of the system) for estimating water needs. Estimating water needs using bill data and water usage category takes into account living standards and the location of needs (Baumberger et al., 2007; Makhtoumi et al., 2020). The water requirement was calculated in the study area for the existing buildings and the area for future expansion. See the next section for detailed calculation methods.

### **3.3.1 Computation of Water Demand Using Bill Data Method**

Billing records are usually used to quantify water consumption. This is equivalent to the consumption that can be used for water balance calculations. The yearly water consumption has been aggregated from the private connected, public taps, and in house connected, institutional and commercial center meters. While water consumption data was reviewed, differences in some consecutive months were observed. Forecasting water demand is component based and the demand is broken down in to different components and a base line demand in every component is assessed from a base year to a particular year in the future. Water demand forecast is the amount of water needed to supply population that is the assessment requires data collection on existing water consumption patterns, potential demand for future upgrading (Gisha et al., 2016).

The accuracy of the water demand forecast based on customer billing data increases with the length of the period of data used (Espey et al., 2015). The longer years the data used, the more accurate the result will become. To estimate future water demand by this method, first, the water consumption data should be represented graphically and then the future nearby decades' water need will be found simply by extending the graph.

Therefore, customer billing approach is the primary demand forecasting method used in the study. This method uses the town's water usage history as input to predict future water needs. Customer billing report for the years 2011 to 2020 were obtained from the town's water and sewerage enterprise and summarized in Table 3-4. Ten years of customer billing data were then used as inputs, and an exponential micro-soft excel spreadsheet based on a smoothing algorithm was used to predict the future needs of each area. The subtotal water usage results were then aggregated to determine the town's overall water demand forecast. This approach was used to estimate water consumption in already developed areas of the

town by the year 2032.

Table 3-4: Water Consumption Data

Yearly water consumption data(m <sup>3</sup> /year)										
Kebele	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bere	64974	79398	71537	70720	93567	86830	10570	10107	118832	96850
							3	9		
Chamo	11706	14304	12888	12741	16857	15643	19044	18211	193243	17336
	3	9	6	4	8	9	3	2		4
Dilfana	77466	94662	85290	84316	11155	10352	12602	12051	140516	11648
					6	3	5	2		3
Doissa	11522	14080	12685	12541	16592	15397	18744	17924	189358	15977
	2	0	9	1	6	9	8	8		8
Ediget Ber	58850	71914	64794	64054	84748	78646	95740	91552	92678	90665
Gurba	41336	50513	45511	44992	59527	55241	67248	64306	65428	61895
Kulfo	60901	74421	67053	66287	87702	81387	99077	94743	95754	94286
Mehal	14406	17604	15861	15680	20745	19252	23436	22411	235243	20120
Ketema	3	3	3	2	9	1	7	5		8
Menharia	47395	57916	52182	51586	68251	63337	77104	73731	75954	73416
Woze	29016	35457	31946	31581	41784	38776	47204	45139	46240	44183
Wuha	24788	30291	27292	26980	35697	33127	40327	38563	397762	36256
Minch	9	7	6	9	5	1	6	5		2
Total	1,004,	1,227,	1,105,	1,092,	1,446,	1,341,	1,633,	1,562,	1,651,0	1,474,
	174	090	598	972	072	948	635	172	08	690

(Source: Arba Minch Town Water Supply and Sewerage Enterprise, 2021)

### 3.3.2 Computation of Water Demand Using Water Usage Category Method

For those covered by the town's spatial plan and not yet developed and not included in the plan, but at the beginning of settlement, the water demand assessment method was based on the water usage category. To estimate the current and future requirements for this method

water usage category and accurate water use records are essential. According to the town master plan, the town expands to the north and agricultural land near Woze kebele will be occupied in the coming decades. The second expected extension zone is uphill towards Gurba kebele to west, where the occupation had already begun, although not included in the master plan. For these two locations, a water usage category-based approach was used because data on water consumption is not yet available. According to the water usage category-based water demand forecasting method, the water demand is estimated based on historical water-use patterns, water usage classifications, and water duty factor.

Customer billing relationship history for 2011 to 2020, every kebele was obtained from the municipal water supply and sewage enterprise. In addition, the water usage category data, the estimated area for each water usage category type for each kebeles, received from town municipality.

Table 3-5 shows information about water usage category in the town. According to the data, the town has been divided into nine types of water usage category, only five of which are: residential, commercial, government, public and industrial areas are included as the others did not use water from the municipal water supply like forest land, agriculture land, green area and special function.

Table 3-5: Data of Different water usage category and their duty Factor

Kebeles	Water usage category area(m <sup>2</sup> )				
	Residential	Commercial	Industrial	Admin	Service
Bere	380686	94143	0	0	89314
Chamo	566354	153431	0	91318	0
Dilfana	175159	56889	438755	2842	92628
Doissa	493270	155516	0	0	90316
Edget ber	570044	18889	1252	2209	1252
Gurba	231036	0	168614	37145	168614
Kulfo	471723	16398	18508	6813	18508
Mehal- ketema	239985	127327	24734	36647	24734
Menharia	194438	22195	0	3846	0
Woze	365758	56394	12820	3201	88004
Wuha Minch	791593	320623	19753	0	19753
Sub-total Area(m <sup>2</sup> )	4480046	1021804	684437	92702	684440

. Source: Arba Minch Town municipality (2021)

### 3.3.2.1 Water duty factor

The water usage category-based method utilizes water demand factors (WDF) and water usage category plans to estimate the water demand of certain towns. According to Morales et al.(2009), WDF is defined as the estimated amount of water consumption per area for a certain water usage type. The WDFs are as a rule determined from a combination of geocoded billing record and water usage category records information. After drawing the water usage category for each parcel, meter with consumption data is applied to parcel to link consumption to types of water usage category and the acreage of each property. WDFs are typically quoted in gallons per day per acre (gpd/ac) or cubic meter per day per area (m<sup>3</sup>/d/m<sup>2</sup>). These factors are used to estimate the average daily requirement for existing and

potential development areas by multiplying the WDF by the total number of acres of each water usage category. Water duty factors are combined with water usage category data to generate future water demand estimates. After generating the water duty factor using the above approach, future development areas were calculated by taking a shape file generated by Google Earth Pro as input. According to Morales et al., (2009) water duty factor is defined as the estimated amount of water consumption per area for a certain water usage type. Finally, the generated duty factor was multiplied by the corresponding area to calculate the water demand.

### **3.4 Non-Revenue Water Analysis**

To understand the non-revenue water for the town of Arba Minch, ten years of water production and consumption data were used. The water production and consumption reports for the years 2011-2020 were received from the municipality. The water production report provides monthly information about pumping raw water from water supplies, while the water consumption report shows the amount of water billed. From these two data, water production and consumption, the unbilled water was calculated for the current water supply system of the city as the difference between the amount of water produced and consumed. The difference is expressed as a percentage divided by the amount of water produced.

$$NRW(\%) = \frac{Q_{in} - Q_{revenue}}{Q_{in}} * 100 \quad 3.1$$

Where NRW is Non-Revenue,  $Q_{in}$  is annual system input volume;  $Q_{revenue}$  is annual billed volume consumption

### **3.5 Hydraulic Model Analysis of the Distribution Network**

In order to understand how each section works within the modeling and modifying the processes, it is important to understand each step, as well as what data are used and how they integrate into Water GEMS. The network of distribution pipelines obtained from the Arba Minch Town Water Supply and Sewage Authority is in AutoCAD layer format. The data includes the layout of pipe, the location of the reservoirs, the crossings (locations of junctions') and all infrastructures of the cities included in the spatial plan with their spatial coordinates. Given the topographical layout of Arba Minch Town water distribution system, and the configuration of the existing distribution network, rezoning the existing pressure

zones of the study area is done in this research work. After rezoning the existing pressure zone, allocating nodes to their appropriate pressure zoning would give the chance to the nodes getting better flow and pressure head. As a result, the system shows better improvement. In this study, rezoning of the existing distribution pressure zones and relocation of reservoir site were done. According to the study, four pressure distribution zones were reduced three. The components of water distribution data were imported in to Water GEMS using Model Builder based on Microsoft Excel. In such a way shape file of water lines, appurtenance and reservoirs were projected with respect to the coordinate system of Arba Minch Town. The shape file was overlapped on the Water GEMS background used to check the pipeline and junction coordinates. In addition to this, arrange the water demand pattern and tank (limited level of all tanks those are base, minimum, initial and maximum).

The modeling process of the WDS is used to determine the pressure, velocity, head loss, hydraulic grade, and flow. In this study, head loss in distribution can be determined based on the Hazen-Williams formula. This formula (Eq. 3.2) was several successfully used by(Rai & Tetu, 2016) as follows below;

$$h_L = \frac{10.674LQ^{1.852}}{C^{1.852}D^{4.87}} \quad (3.2)$$

Where;  $h_L$  is a head loss in meters (water) over the length of pipe; L-is the length of pipe (m); Q- is volumetric flow rate ( $m^3/s$ ); C- is Hazen-Williams friction coefficient; and D-is nominal pipe diameter (m).

### 3.5.1 Water Demand Variations

Water demand variations throughout a day are influenced by the customer base and the daily lifestyles of the customers. The hydraulic modeling and evaluation of the distribution network in Water GEMS are simulated through Extended Period Simulation (EPS) and steady state of time analysis type. In this study EPS analysis was used to provide a specific pattern for giving demands with respect to hourly variation in water demand. Hourly demand fluctuation factors have to be estimated in service reservoir. These factors are fractions of the daily water demand in each hour of a day, which exhibits a peak hour demand during rush hour especially in the morning hours when most people use water for

bathing, cooking and could also occur towards the end of the day due to peoples need of water for the same purpose after working hours and low demand around the mid-night when the most people stop their day activities. The demand balancing volume depends on the demand variation over 24-hours and constant production from the boreholes feeding the tank period of the day. The analysis of the distribution network was carried out using WaterGEMS and the adequacy of the system to meet the water demands has been performed to assess the system by considering the peak hourly water consumption pattern, which is 1.6 and recorded from 8:00am to 9:00am. The peak hour demand was used for sizing of the distribution pipelines that can deliver the required maximum flow at minimum established pressure on all consumers tap while the minimum water demand is used to analyze the maximum pressure in the system so as to select the pipe material and also to manage excessive pressure in the system.

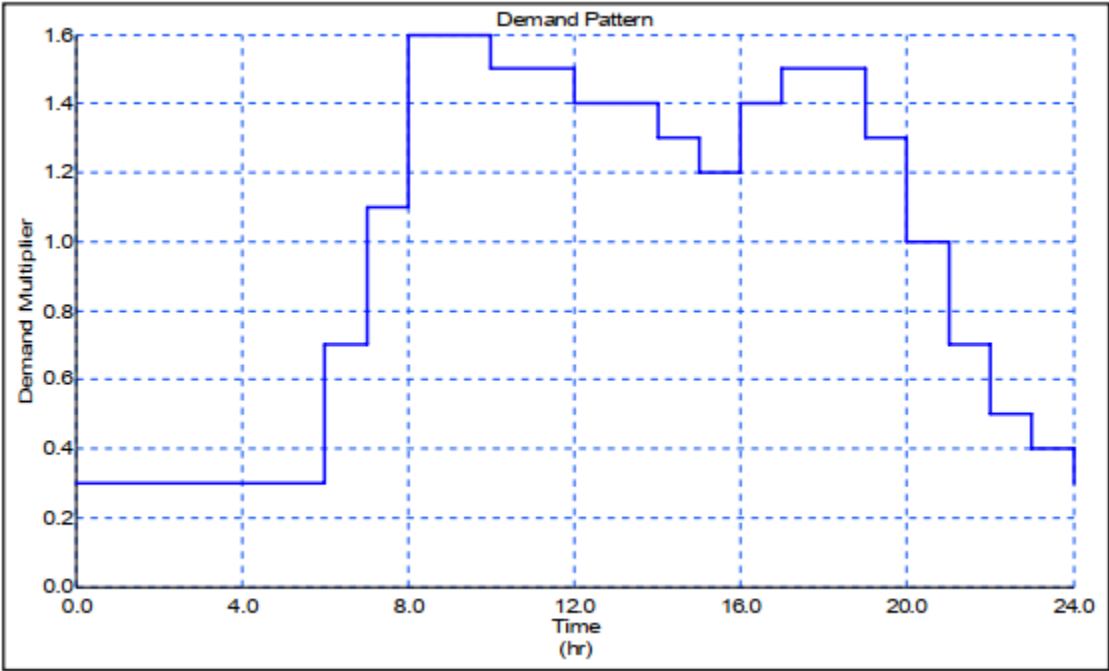


Figure 3-2: Hourly Variation of Water Demand pattern of Arba Minch Town

Source: Planning and Implementation of Town Water Supply and Sanitation Improvement Program, Arba Minch

**3.5.2 Assigning Nodal Water Demand Allocation**

A historical bill data approach and water usage category method were used to estimate the

town's water needs over the intended planning period of the town's water supply system. The estimated demand at the end of the planning period in 2032 was then distributed across all nodes. The nodal demand load was carried out according to the zone method, taking into account the pressure zones as sub-zones of the entire municipal water distribution system.

The spatial distribution of water consumption across the entire water network model was a key component of the water distribution modeling. The water demand must therefore be geographically distributed in order to represent and simulate a water system correctly. The spatial distribution of water consumption in the water network model was commonly referred to as demand distribution or allocation. Among the different approaches to needs allocation, the area method was used in this analysis.

Area methods use areas as the basis for demand distribution. For the purposes of this analysis, the water needs of each urban area were determined. Then the total distribution area was divided into sub-areas, pressure areas, which were assigned to the model nodes. The node influence zone was understood as an area that is drawn around each request node, and all requests generated within this area are assigned to this node.

After finding the distribution sub-zone, the pressure zones, the nodes of this pressure zone, were uniformly loaded. It refers to the total flow contained within the bounding polygon; the flow evenly allocated to nodes located within the bounding polygon.

### **3.5.3 Model Calibration and validation**

Before any use, the model must be calibrated to establish its reliability and allow decisions about physical and operational developments in the real system to be made with as high a degree of confidence as possible. This information, once discovered through the calibration process, can explain operational difficulties and identify distribution system problems that require the development of solutions to resolve and improve system operation (AWWA, 2015). Once developed and calibrated, a water distribution model can predict the behavior of a water distribution system, providing an effective tool to help utility service providers meet goals. Ideally, during the water distribution model calibration process is adjusted for each link and each node. However, only a small percentage of representative sample measurements can be made available for the use of model calibration due to the limited financial and labor requirements for data collection.

### 3.5.3.1 Sampling size of Pressure Calibration

To select the sampling size of the junction and pressure reading first specify the intended use. According to the international proposed pressure calibration standard for this study, the entire numeral of junctions in the network system of Arba Minch town is 150 junctions. Hence as per as(AWWA, 2015) the number of pressures reading ranges from 2% to 10% of all nodes.

### 3.5.3.2 Model Validation

#### A. Degree of Accuracy (Error of Difference):

The degree of accuracy varies depending on the size of the system and the amount of field data and testing available to the modeler. Sefiu.A .et.al,( 2010) states that the average difference of  $\pm 1.5$  m to maximum of  $\pm 5$  m represents for good data set and  $\pm 3$  m to 10 m far bad data set would be a reasonable target. This is in terms of comparing the observed versus the calculated pressure heads in the system.

#### B. Coefficient of Determination ( $R^2$ ):

The coefficient of determination describes the degree of linearity between simulated and observed pressure. ( $R^2$ ) describes the proportion of variance in measured data explained by the model.  $R^2$  ranges from Zero to one, with higher values indicating less error variance and typically value greater than 0.5-1 (1 inclusive) are considered acceptable. The model performance was taken manually using coefficient of determination ( $R^2$ ) method.

$$R^2 = \frac{\Sigma(x - xavg)(y - yavg)}{\sqrt{\Sigma(X - Xavg)^2 \Sigma(y - yavg)^2}}$$

Where:  $R^2$  is the Correlation coefficient, X and Y are measured and simulated values, X mean and Y mean are the average value of measured and simulated data respectively

## 4 RESULTS AND DISCUSSION

### 4.1 Water Demand for Developed Areas Using Bill Data

Table 4.1 show the existing water consumption and forecasted water demand for the three zones in the study area in cubic meter per year. Using historical bill data of the water consumption of the three zones (2011-2020) the future water demand for those zones were estimated and the values were presented in tabular and graphical form as shown below in Table-4.1 and Figure 4.1.

Table 4-1: Existing water consumption and forecasted water demand of the three zones

Year	Existing water consumption(m3/yr.)			Year	Forecasted water demand(m3/yr.)		
	Zone-I	Zone-II	Zone-III		Zone-I	Zone-II	Zone-III
2011	391,651	600,000	669,615	2021	566,618.5	1,615,200.9	971,176.6
2012	400,956	721,564	678,785	2022	584,917.0	1,728,421.8	1,003,986.1
2013	415,980	741,653	689,952	2023	603,215.4	1,841,642.7	1,036,795.5
2014	431,784	764,459	698,715	2024	621,513.9	1,954,863.6	1,069,605.0
2015	452,724	942,452	729,687	2025	639,812.4	2,068,084.5	1,102,414.5
2016	479,685	807,398	859,993	2026	658,110.9	2,181,305.4	1,135,224.0
2017	489,928	961,282	868,812	2027	676,409.4	2,294,526.3	1,168,033.4
2018	518,032	985,703	897,785	2028	694,707.9	2,407,747.2	1,200,842.9
2019	536,052	1,573,200	906,639	2029	713,006.3	2,520,968.1	1,233,652.4
2020	542,976	1,827,148	907,262	2030	731,304.8	2,634,189.0	1,299,271.3
				2031	749,603.3	2,747,409.9	1,299,271.3
				2032	767,901.8	2,860,630.8	1,332,080.8

Figure 4-1 presents predicted water demand for developed areas in the WDS of the study site.

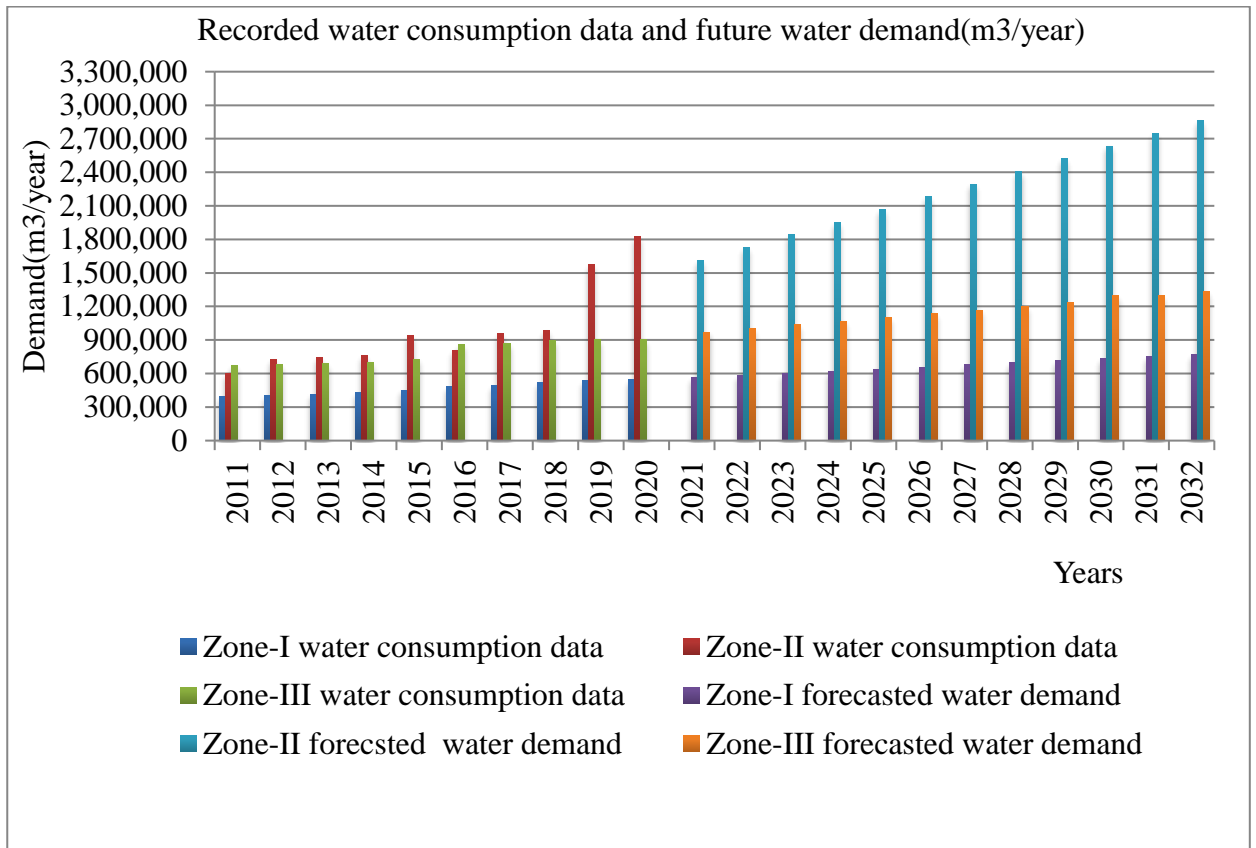


Figure 4-1: Predicted Zonal Water Requirement for Developed Areas

The result in Figure 4-1 shows that the water demand in zone-I have slowly increased due to the zone containing the older kebeles, whose land is near saturation. There was no free land in the area for further expansion. The small change itself is the result of the expected change in the residents' standard of living. The amount of water needed in zone I (i.e. Chamo, Bere and Doissa Kebele) should be around an average of 2,103, 840l/day taking into account the 36.8% unaccounted for water at the end of 2032. Likewise, the water volume was forecast for a maximum daily demand of 2,419,200 l/day and a peak hour demand of 3,366,144l/day based on a peak factor of 1.15 and 1.6 for the maximum day and peak hour respectively.

Zone II showed a moderate change in increased water demand. This is because the zone covers a large part of the town with different categories of water consumption (house connection, yard connection etc.). It also has open spaces that will be used in the near future. Taking into account about 36.8% of the water produced for non-revenue water, the total

water demand for this area in 2032 was estimated at about 7,837,344l/day, 9,000,288l/day, 12,540,096l/day for the average, maximum and peak demand of the day respectively.

Zone III includes areas that are less developed but have high potential for future development. It contains Woze and part of Dulfana kebeles. In this area, a large area is earmarked for agricultural land (11.5 km<sup>2</sup>), which will now be integrated into the city through a new master plan. Thus, the average daily water demand in zone III was estimated at approximately 3,649,536l/day, the maximum daily demand at 4,197,312l/day and the peak demand at approximately 5,838,912l/day, covering 36.8% of the water produced to non-revenue purposes.

#### 4.2 Water Demand for Future Expansion Areas Using Water Usage Category

Table 4-2 shows information about water usage category in the town. According to the data, it also shows how water duty factor is computed, percentage of area coverage and existing water usage in each category.

Table 4-2: Data of different water usage category type and their duty factor

Arba Minch Town	Water usage category Area(m <sup>2</sup> )				
	Residential	Commercial	Industrial	Admin	Service
Sub-total Area(m <sup>2</sup> )	4480046	1021804	684437	92702	684440
Total Area(m <sup>2</sup> )	6963429				
% From total area	64.34	14.67	9.83	1.33	9.83
Water demand (m <sup>3</sup> /d)	2327.99	976.33	202.34	423.53	623.21
Duty factor (m <sup>3</sup> /d/m <sup>2</sup> )	0.00052	0.000955	0.000296	0.00457	0.00091

. Source: Arba Minch Town municipality (2021)

Table 4-3 shows the water requirements for future expansion areas. The study identified two areas that will be included before the end of the project period, namely Area-I in zone- III and Area-II in zone II. In zone-II human settlements are already started.

Table 4-3: Expected water requirement for future expansion areas (2032)

Usage Category	Duty factor	% of Area	Area-I(m <sup>2</sup> ) (Zone-III)	Demand (m <sup>3</sup> /d)	Area-II(m <sup>2</sup> ) (Zone-II)	Demand( m <sup>3</sup> /d)
Residential	0.00052	64.34	173677.78	90	80960	42
Commercial	0.000955	14.67	39681.35	38	18497	17
Institutional	0.00091	9.83	92589.81	84	43161	39
Government	0.00457	1.33	3450.55	15	1608	7
Industry	0.000296	9.83	26454.23	8	12332	4
Total			575092.40	235	268078	109

Overall, the total water demand in Arba Minch Town will be an average of 13,590,720l/day by 2032. The average water demand at the end of 2032 will be about 2,103,840 l/day, 7,837,344 l/day and 3,649,536l/day each for zone I, zone II and zone III respectively. The existing Arba Minch Town water supply project utilized the estimated needs of the population. According to the existing design project, the town's water demand using population projection method was average 15,629,760 l/day by 2032. However, the results of this study indicate that the town's water demand will be 13,590,720l/day by 2032. This study takes into account the spatial location of water needs; the need for each zone is calculated separately and population projection method over estimate bill record and water usage category method by 2039040l/day (15%).

### 4.3 Non-Revenue Water Quantity

Figure 4-2 shows the amount of unbilled water in the entire distribution network. The average water loss rate is 606521.2m<sup>3</sup>/year, which is approximately 30.6% of the system's flow rate.

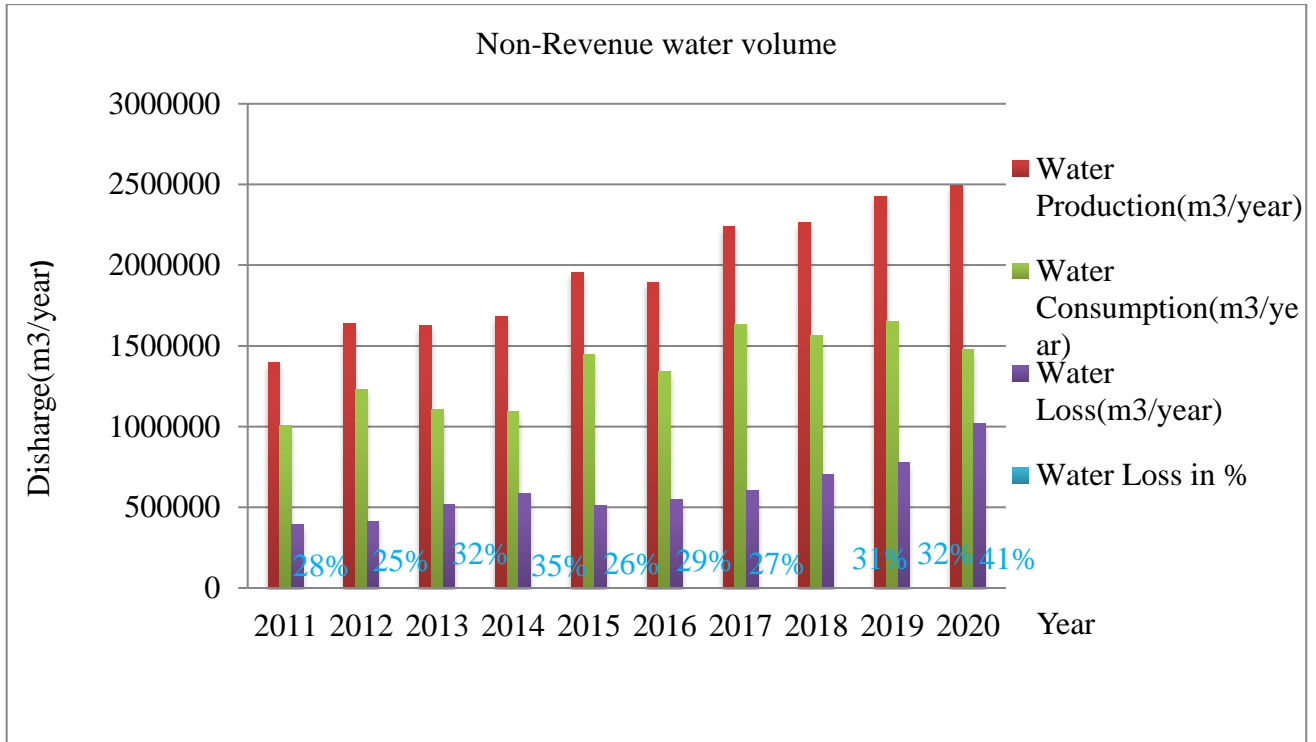


Figure 4-2: Non-Revenue Water Quantity

Non-Revenue water (unbilled quantity) includes unbilled authorized usage and water losses (apparent and actual). While the actual allowable volume of unbilled authorized and water loss amount of non-revenue water has not been clearly defined, it is expected that a higher percentage of the non-revenue water be due to water loss from the system (Ewa Ociepa, 2019).

According to Kingdom et al., (2006) more than 32 billion cubic meters of treated water physically leak from municipal water systems worldwide each year. Half of this water loss occurs in developing countries, where utilities are starving for additional revenue to fund service expansion and where most connected customers are suffering intermittent supply and poor water quality (Kingdom et al., 2006). A Southeast Asian Water Utilities Network (SEAWUN) study found that NRW content accounts for an average of 30% of water

produced. The World Bank's IBNET (International Benchmarking Network for Water and Sanitation Utilities) database also confirms these results and even increases the leakage rate to 40 % in developing countries.

Compared to the above standards in developing countries, the percentage of unbilled water in the town of Arba Minch is fair but from year 2013 to 2014 and recently 2018 up to 2020 the loss is highly increased. However, given the country's economic level, it is frightening to hear about the loss of this immense capital for nothing. This increase in non-revenue volume is due to reduced monitoring, premature replacement of old lines, and the unprotected build-out of infrastructure such as roads and buildings. Especially in the old kebeles record mains water distribution system in the early days of municipal water supply history, the correct route of the buried pipes is not even well known. The old distribution system also uses a direct pump system, particularly in the sub-town of Secha. The discharge was pumped directly from a booster station at the entrance of Paradise Lodge and distributed in the sub-town of Secha. These conditions are causing an increase in the percentage of water loss in the Arba Minch Town Municipality's water distribution system.

Figure 4-3 describes the worst-case scenario for NRW up to the year 2032 in the study area. According to the result, there is a probability of non-revenue water percent is expected to be kept at about 36.8 %. The graph was projected based to exponential smoothing.

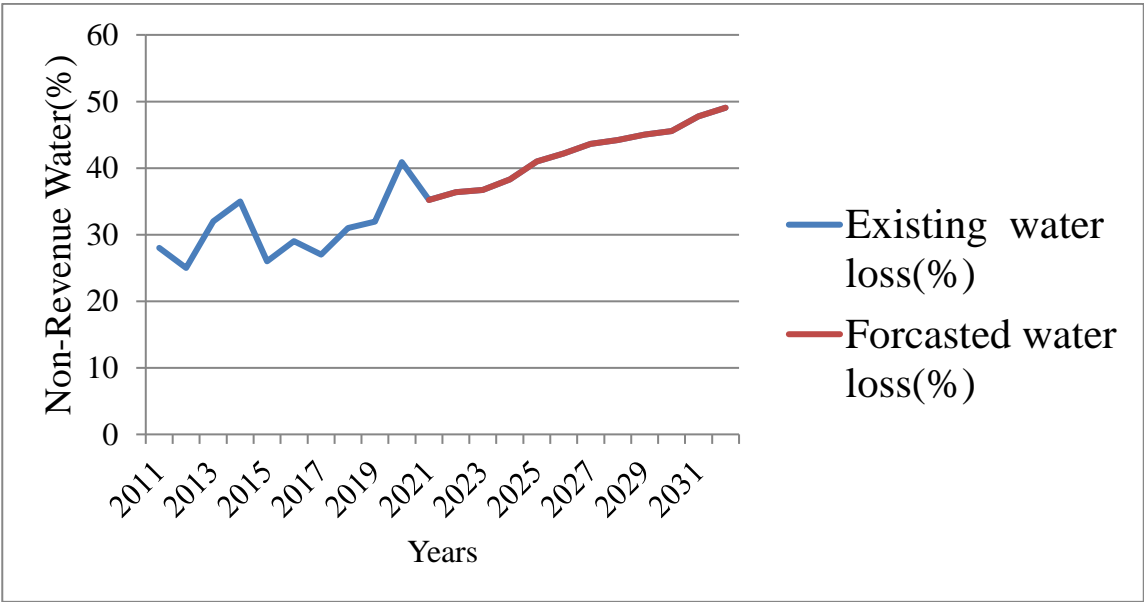


Figure 4-3: Worst Case Scenario for Non -Revenue Water

In contrast to the higher share of water with no revenue, another sustainable outcome for the worst-case scenario was also observed in Figure 4-3. While the water loss rate has been high over the past ten years, the probability to retain the non-revenue percent from rising high is there in the next near future decades because the new pipes will replace the old distribution network, build strong monitoring system and needs early communication with stakeholders before starting other infrastructural building.

#### **4.4 Hydraulic Analysis of the Distribution Network Results**

##### **4.4.1 Model Calibration and Validation**

Model calibration is the most important in the evaluation problem of the WDS to reflect the actual behavior from the different model simulation. Table 4.4 indicates the pressure values which were measured and simulated for fifteen consecutive days at fifteen junctions in the selected time i.e., 10% of total junction used in the study. These data were used for WaterGEMS performance evaluation of the Arba Minch Town. The model performance measure techniques; 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 model check as mentioned below the results.

**A. The degree of accuracy (error of difference)**

The comparison of simulated pressure results with field-measured data are presented in the table 4.4 below based on degree of accuracy criteria.

Table 4-4: Comparison of Measured and simulated pressure for selected nodes

Date (2021)	Time	Name of junction	Measured pressure(m)	Simulated junction(m)	Error of Difference (m)
Oct.2	9:00AM	J-24	16	17	-1
Oct.3	9:00AM	J-30	35	34	1
Oct.4	9:00AM	J-42	69	70	-1
Oct.5	9:00AM	J-48	69	68	1
Oct.6	9:00AM	J-52	70	70	0
Oct.7	9:00AM	J-54	16	14	2
Oct.8	9:00AM	J-67	67	68	-1
Oct.9	9:00AM	J-72	70	71	-1
Oct.10	9:00AM	J-74	68	67	1
Oct.11	9:00AM	J-79	70	71	-1
Oct.12	9:00AM	J-82	69	71	-2
Oct.13	9:00AM	J-87	63	64	-1
Oct.14	9:00AM	J-97	69	70	-1
Oct.15	9:00AM	J-125	34	34	0
Oct.16	9:00AM	J-130	32	30	2

Average		-2
---------	--	----

The average pressure error of difference is (-2) from the table 4.4 where, measured pressure value to predicted or simulated pressure value. Hence the model is acceptable with in criteria under average level of ( $\pm 1.5$  mand maximum difference  $\pm 5$  m). Therefore, based on the results the estimated pressure indicates that the Water GEMS model is a very good performance evaluation of pressure in the study area.

**B. The coefficient of determination (R<sup>2</sup>)**

Model calibration was determined based on the results of model pressure and measured pressure in the selected nodes (junctions) has been used for calibration. The pressure gauge was used to measure the pressure of water at fifteen nodes (J-24, J-30, J-42, J-48, J-52, J-54, J-67, J-72, J-74, J-79, J-82, J-87, J-97, J-125, and J-130) from 150 junctions in peak hour demand for fifteen consecutive days to check the simulation results. Fig 4.4 shows variation of simulated pressure results with field-measured data sample size of 15 junction out of 150.

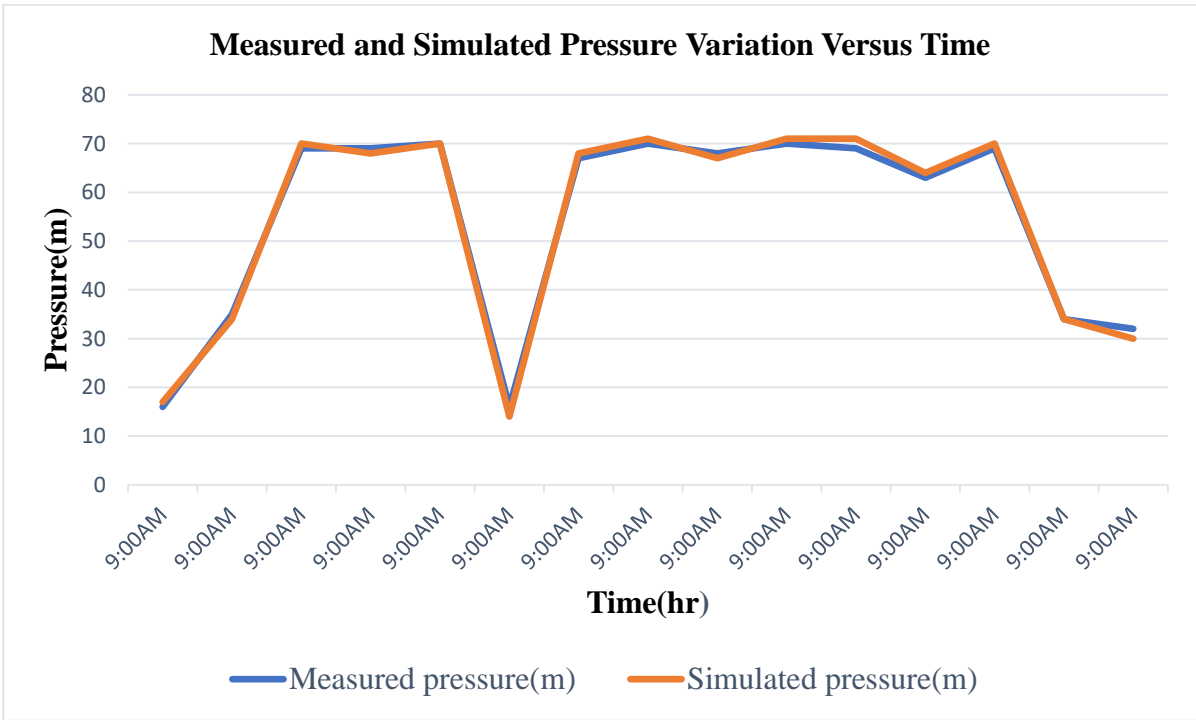


Figure 4-4: Variation of measured and simulated pressure at sample point

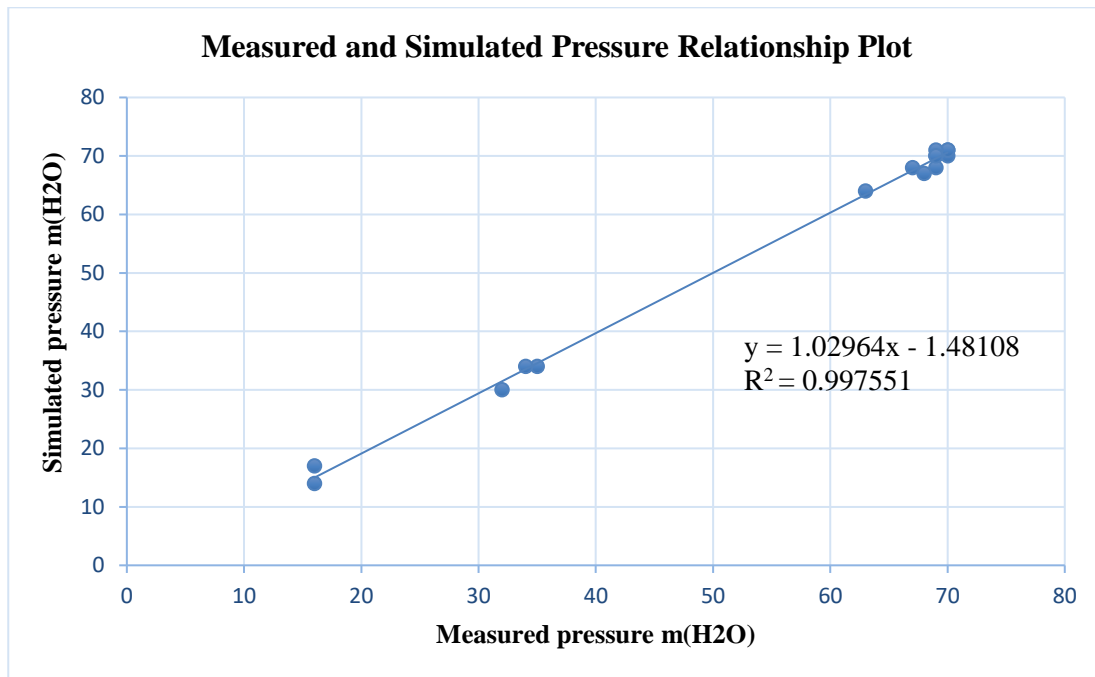


Fig 4.5 Correlation between measured and simulated pressure relationship plot

Figure 4-5: Correlation between measured and simulated pressure relationship plot

The measured and simulated pressure give a correlation coefficient of the determination which ranges between 0 and 1, describing 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 in Figure 4.5. Generally, all the points should align themselves on this line, and all measured pressure should be equal to computed pressure, giving a relationship coefficient of 1, which is the best correlation between observed and simulated.

It is necessary to validate every model before applying the model to new problem identification. And shows there is no problems were found in order to use the model for analysis. From the figure 4.5, the coefficient of determination ( $R^2$ ) value was 0.9975. Since the value of  $R^2$  approaches 1, which indicates that there is a good correlation between fields measured pressure and simulated pressure, and shows the observed pressure and simulated pressure relationship is strong as values tend to one.

#### 4.4.1. Modification of Pressure Zones

Distribution zoning, which divides the entire distribution system into subsystems, is a way to

effectively manage larger distribution systems. In this model, the entire urban distribution system is reduced from four to three subsystems. This reduction in the number of zones aims to increase coverage and assess the distribution network. Zone-I and zone-II of the previously planned facility were merged into zone- I. Zone- IV was split in two and partially merged with zone- III to form core area, zone- II and the left area as a new zone- III. As part of this zoning, the proposed zone -II reservoir for the second phase of the existing project has been relocated to the new zone- II zone to meet the maximum water demand of that zone and to create a new area within this previously foreclosed area of supply because of its height. Differences in altitude, the proximity to the reservoir and water sources were taken into account.

According to the study, zone-I should include the southern part of the town, including Chamo, Bere and Doissa Kebeles. The elevation changes observed in this zone ranged from 1299 m to 1437 m. The water source considered for zone -I was forty springs. The amount of water calculated as the maximum daily requirement is pumped into the reservoir located at the entrance of the Paradise Lodge Hotel. Using this reservoir as a booster station, the water will be pumped to a service reservoir located at near Bere Mariam, where it is distributed by gravity. Taking into account all storage requirements (balance, fire protection and emergency reserve), the required reservoir volume was calculated at 800 m<sup>3</sup>.

Zone II includes the central part of the town. This area consists of a large area and a large amount of water and the longest pipeline network. The elevation difference between the distribution nodes ranged from 1,221 m to 1,341 m. To meet the needs of consumers, an optimal system of three interconnected reservoirs and two water sources was proposed for this area. The total containment requirement for this area is a reservoir with a capacity of 3000 m<sup>3</sup>. There are already two 1000m<sup>3</sup> reservoirs and the third one is planned to be placed at the maximum height of the area in the new expansion area. In addition to supplying nearby junctions, the first reservoir called the T-1 in the distribution network was also used as a booster station for the reservoir-II and reservoir III. This area takes the required flow from two water sources, forty springs and wells. According to the feasibility study report and drilling history, the safe flow rate of each well is 18 l/s.

The third area is zone- III which covers the northern part of the town; includes the smaller

built-up area of Woze kebele and part of Dulfana but vast lands set aside for future expansion. For this area the required capacity of the service reservoir is 1500 m<sup>3</sup>. The water source for zone -III is a well near the Arba Minch textile area. A total of four wells are required, one of which has already been tapped. The level difference of the crossings in this area varies between 1206 m and 1271 m. The classification was based on the topography of the area, the source and location of the water and the distance to the service reservoir. Depending on the layout, each area has its own water source and service reservoir. Below this division, the upper zone, zone-I, includes three kebeles: Chamo, Bere and Doissa with elevations ranging from 1294 to 1441m. The core area, zone -II, includes Wuha Minch, Edget Ber, Mehal Ketema, Gurba, Menharia, Kulfo, Parts of Dulfana and open land in this area, while Woze, part of Dulfana and agricultural land near Woze Kebele have been declared zone- III. Zone -II and Zone III elevations range from 1218m to 1345m and 1208m to 1259 m, respectively.

#### **4.4.2. Skeletonization of the Distribution Network Using WaterGEMS Models**

The second phase concerns the Skeletonization of the pipeline network. This phase includes activities such as pipe structuring, which includes rezoning of existing distribution pressure areas and reservoir site relocation. According to the study, the four pressure zones in distribution networks have been reduced to three.

The new Zone I was created by merging the existing Zone I and Zone II pipeline networks. This was done by combining Zone-I and Zone-II into one zone and was called Zone-I.

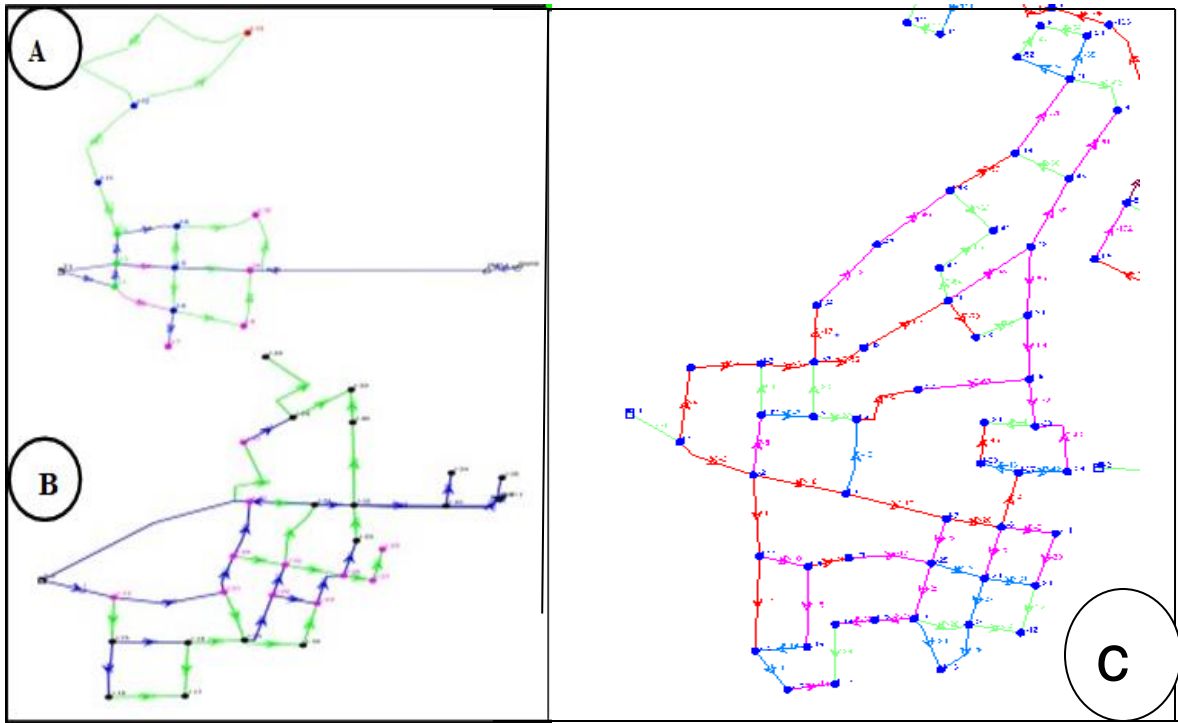


Figure 4-6: Existing Zone-I(A), Existing Zone-II(B), Modified Zone-I(C) pipe distribution network

Figure 4-6 shows the pipe skeleton in existing Zone-I, existing Zone II and modified Zone I. The core zone of the modified system, Zone II, was created by merging the existing Zone III and portions of Zone IV.

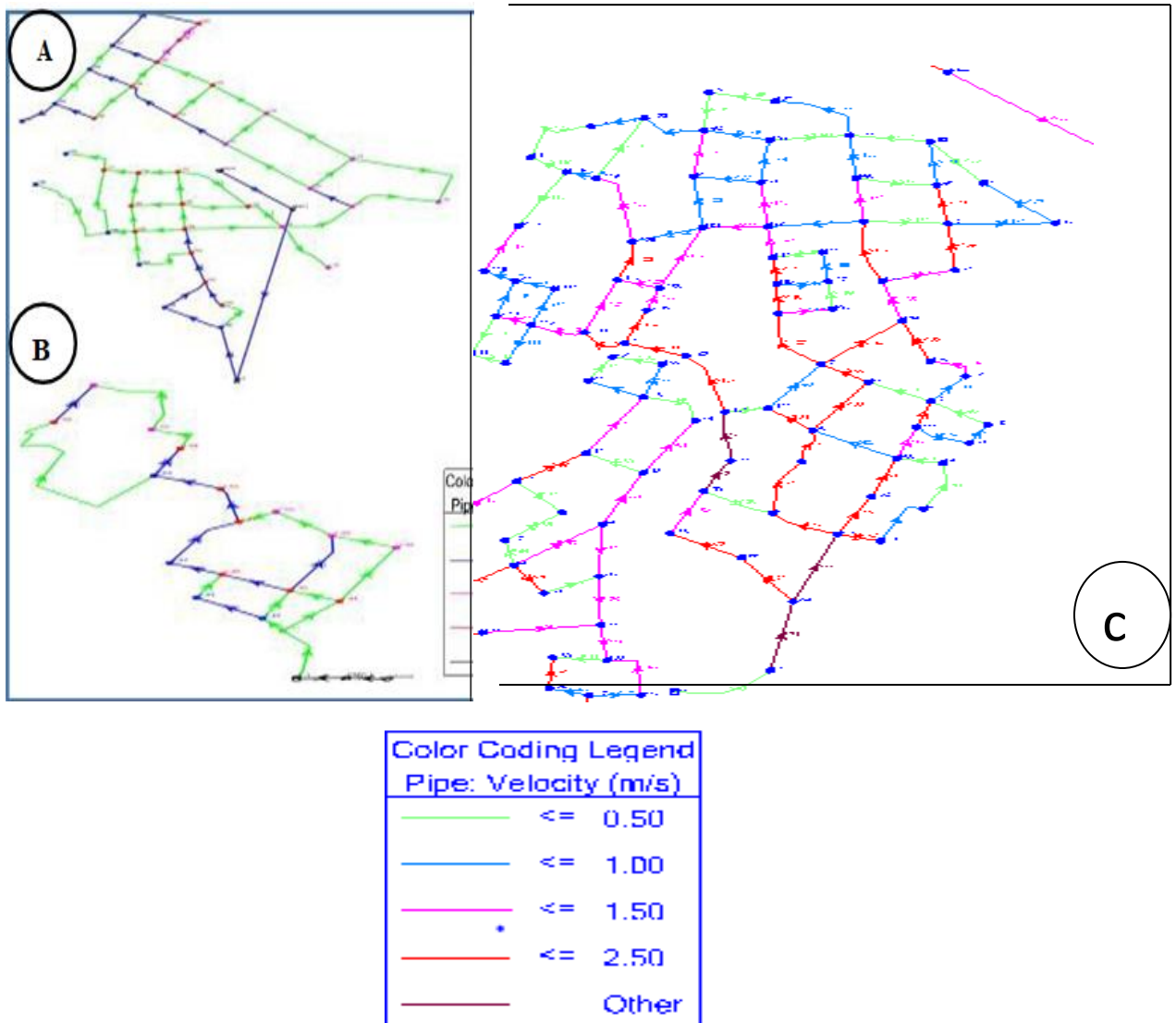


Figure 4-7: Existing Zone-IV (A), Existing Zone-III (B), Modified Zone-II(C) Distribution Network

Figure 4-7 shows the existing network from part of Zone IV and existing zone-III, forming the modified Zone II pipe skeleton.

The left portion of Zone IV of the existing network was designated Zone III of the new, modified system. Figure 4-8 shows the existing network from Zone IV and the modified Zone III pipe skeleton.

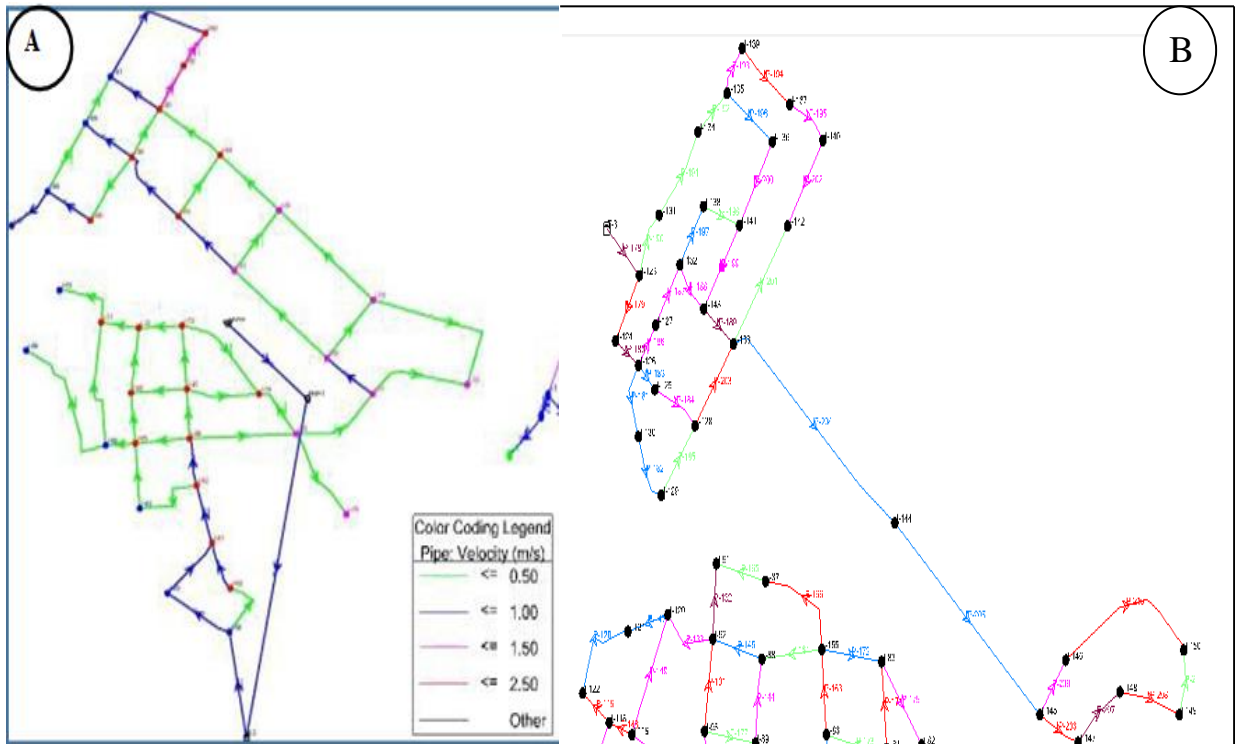


Figure 4-8: Existing Zone-IV (A), Modified Zone-III (B) Distribution network

Figure 4-8 shows the existing network from part of Zone IV and the modified Zone III pipe skeleton.

During the design modification by re-zoning, the reservoir proposed or Zone-II in the existing design of the distribution system is shifted to Zone II to meet demand of zone II and feeding new expansion areas on the uphill of Sikela sub-town in western direction. An AutoCAD layer file obtained from Water Supply and Sewerage Enterprise of the town was used to construct the distribution networks. The data includes the lengths of the poly-lines, the connection points of the various lines, and the diameters of the poly-lines.

The study showed that there were flow and pressure differences at the connections in the existing and modified systems. The varieties are distinguished by a color code, and their connotations are given in the legends. A detailed comparison is made in the following sections.

#### 4.4.3. Flow Velocity Variation at Minimum Flow Condition

Figure 4-9 shows the variation in the existing and modified network at minimum flow hours.

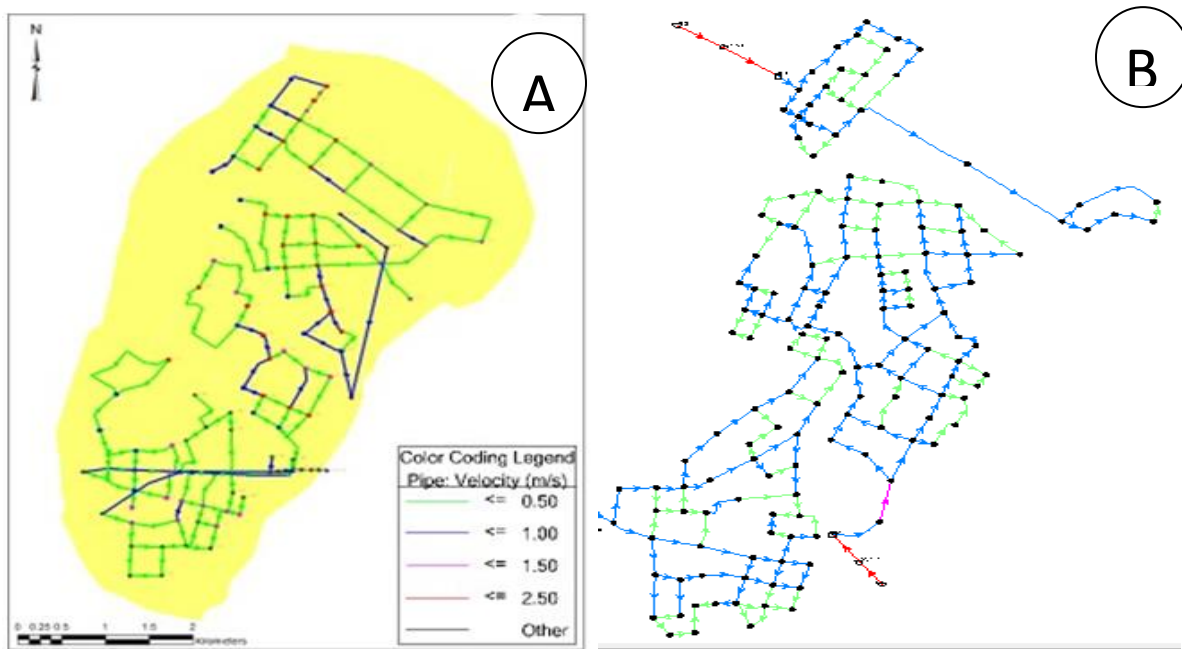


Figure 4-9: Layout of the water distribution Network flow velocity during minimum flow condition: Existing (A), and Modified (B)

As shown in Figure 4-9, more pipes in the existing distribution network (A) were colored green with minimum flow, while after the change (B) more pipes were colored blue. This shows the flow rate change in the distribution system. One of the basic conditions of properly working is to ensure that the water flow velocity is adequate. This parameter is relevant for the dimensioning the water supply system including the diameter selection of the water pipes. Ensuring the water velocity in the installation in accordance with the recommendations for pipes is important. Because the speed of the water affects the degree of the corrosion of the pipe, the noise level of the system, hydraulic impacts, developments of bio-films, linear and local pressure losses in the system and stagnation of water (Zabnieńska-Góra & Dudkiewicz, 2018). The minimum recommended velocity is recommended to ensure a permanent water flow in the distribution network so as not to affect the water quality the water supplied to the consumer. According to the model simulation result, most pipe velocity values before modification was below the minimum recommended velocity constraints (0.3m/s) during minimum flow rate where as it shows increment for the modified system because thus may case lower water quality due to increase in the age of water in the pipe line.

#### 4.4.4. Flow Velocity Variation at Peak Flow Condition

Figure 4-10 shows the flow velocity profile of the entire pipe network for the existing and modified system at peak flow. The hydraulic evaluation of existing WDS was carried out in order to evaluate hydraulic behaviors by considering pressure and velocity into account. Figure 4.10 and 4.12 shows the skeletonized pipe diameter within Arba Minch Town's velocity and pressure results of existing and modified WDN respectively, which includes 71 pipes and 52 junctions in zone-I, 98 pipes and 70 junctions in zone-II, and 34 pipes and 28 junctions in zone-III.

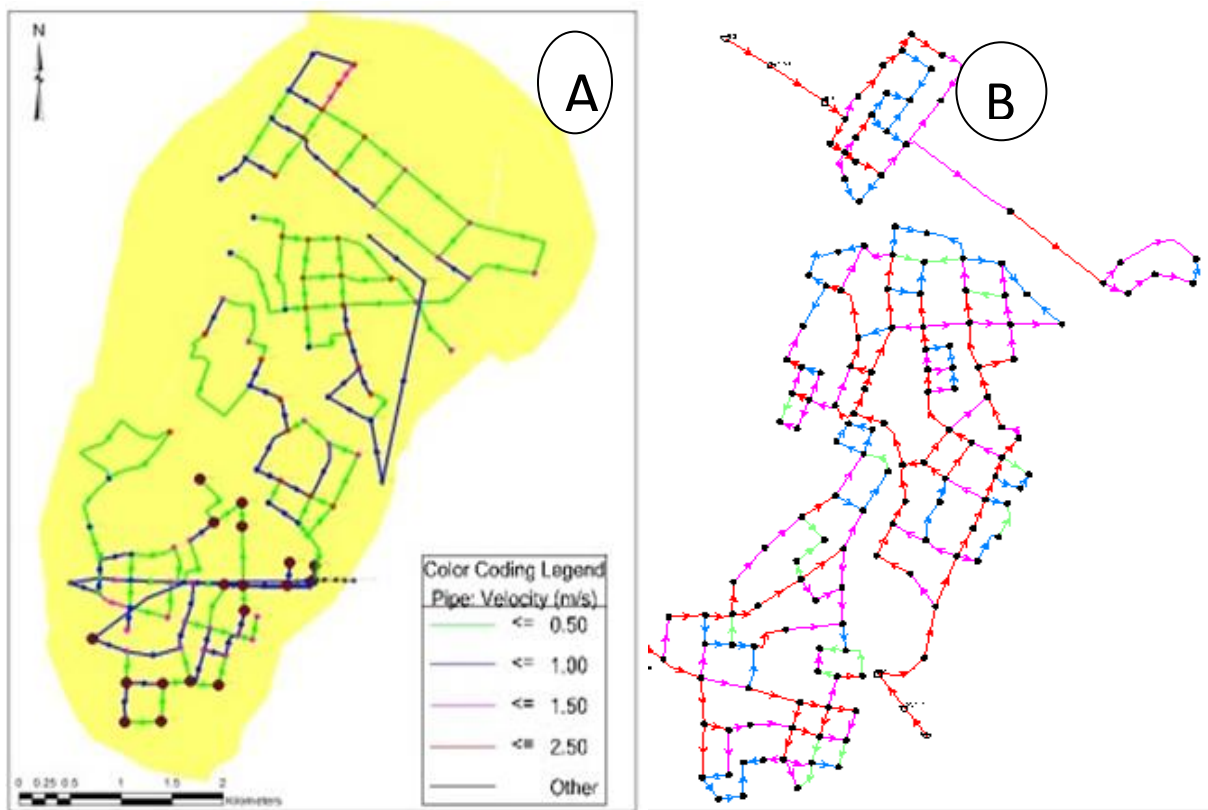


Figure 4-10: Layout of the water distribution network flow velocity during peak hour demand: Existing (A), and modified (B)

Figure 4-10 shows color variation for pipes in existing (A) and modified (B) distribution network. The variation in pipes color indicated that there was variation in flow velocity in the pipes. During peak periods, the flow velocity in most pipes decreases slightly, even before modification. After modification, almost all pipes (96.1%) achieve the permissible value of flow velocity (between 0.3 m/s and 2 m/s) only four pipes (P-65, P-113, P-164, P-

173) and four pipes (P-74, P-76, P-93, and P-205) have below the minimum and maximum permissible velocity respectively as shown the result in the appendix-A. The velocity value indicates the increase in maximum flow time compared to the minimum flow time without changing the pipe diameter. This variability was observed due to the increase in releases in the distribution network. Also, for the same pipes in the network, flow rates were higher after modification than before modification, which may be due to the reduction in pipe diameters. The hydraulic model result for velocity in the pipes at the peak hour demand in the WDS is presented.

Table 4-5: Hydraulic model results of velocity

Velocity(m/s)	Number of pipes	Percentage (%)
<=0.5	18	8.87
0.5-1	50	24.63
1-1.5	63	31.03
1.5-2.5	72	35.47
Total	203	100

**4.4.5. Junction Pressure Variation at Minimum Flow Condition**

Figure 4-11 shows the hydraulic model results of the nodal pressures the distribution system at minimum flow. High pressure usually caused by serving customers is located too low elevations (high elevation difference) in the pressure zone. From model output and site observation, most of the Sikela sub-town and some part of Secha areas have the maximum pressure occurred above 70m of water to much the recommended value and it is the reason for high elevation difference in the pressure zone.

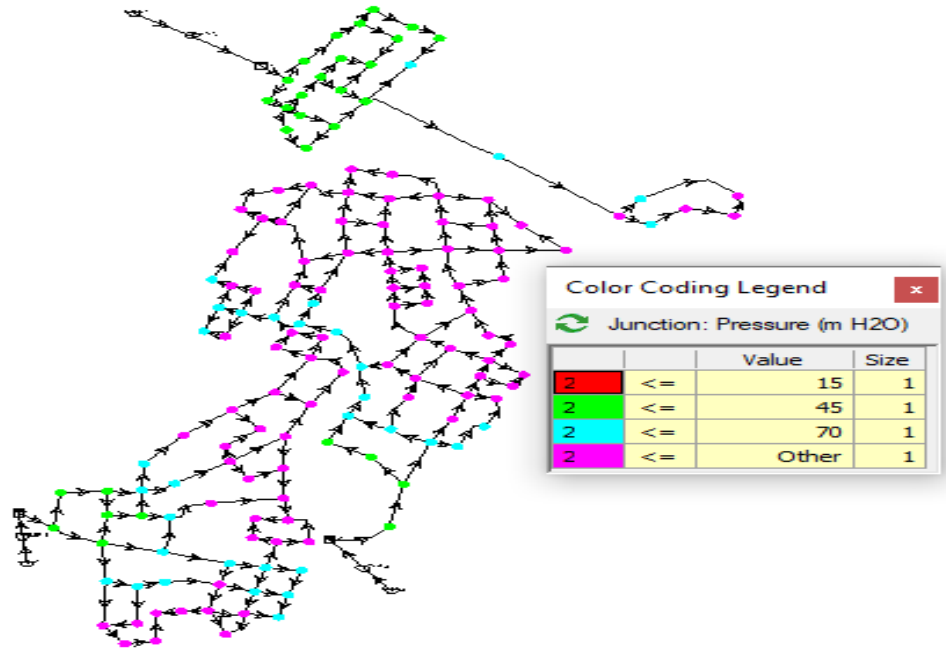


Figure 4-11: Junctions pressure in distribution network during minimum flow hours

It was observed that the high elevation difference is not only the consequence of high pressure. However, during the time of pump operation and the balancing reservoir outlet open same time the pump stopped due to the light off or pump stack and some check valves were un-functional. Since the outlet is, open until the reservoir is empty. Consequently, the reservoir and the pipeline filled with air. Since, the next pump operation starts without air releasing this leads to atmospheric pressure in pipe greater than hydrostatic pressure and results pipe collapse.

When designing the distribution network, the pressure in the system must generally be kept between the minimum and maximum allowable values to ensure safe, reliable and economical operation. High-pressure systems cause more frequent pipe ruptures and increase energy consumption and losses(Lambert, 2012). The maximum allowable pressure is determined by the resistance of the pipe, which is related to its material, wall thickness and general condition. Low pressure systems cause consumer complaints, make the system more sensitive to negative pressure and possible contaminant ingress during transient events. The overall goal of establishing the Minimum Pressure Criterion (MPC) is to balance these opposing trends to ensure safe, reliable, and cost-effective operation of the WDS. However, there are no generally accepted or established rules or guidelines for a specific MPC for

WDS design(Ghorbanian, V., Karney, B. W., & Guo, 2015). However, according to the Ethiopian Ministry of Water Resources, it is recommended to keep the pressure in the distribution network between 10 and 70 m head of water.

**4.4.6. Junction Pressure Variation at Peak Flow Condition**

In addition to the diameter, flow changes also affected the pressure. Due to flow fluctuations, the pressure recorded at low flow conditions was not similar to the pressure at peak flow conditions. It was observed that during the peak flow times, the pressure was lower than the minimum flow time. The reason for these fluctuations may be related to the relationship between pressure and flow. The Hagen-Poiseuille equation briefly describes the relationship between volume flow and pressure drop in a pipe flow system. Therefore, the pressure drop is directly proportional to the flow rate. The differential pressure across the same nodes shows variations at minimum flow and peak flow due to the change in volumetric flow rate; As a result, the pressure value under peak flow conditions was lower than the minimum flow value.

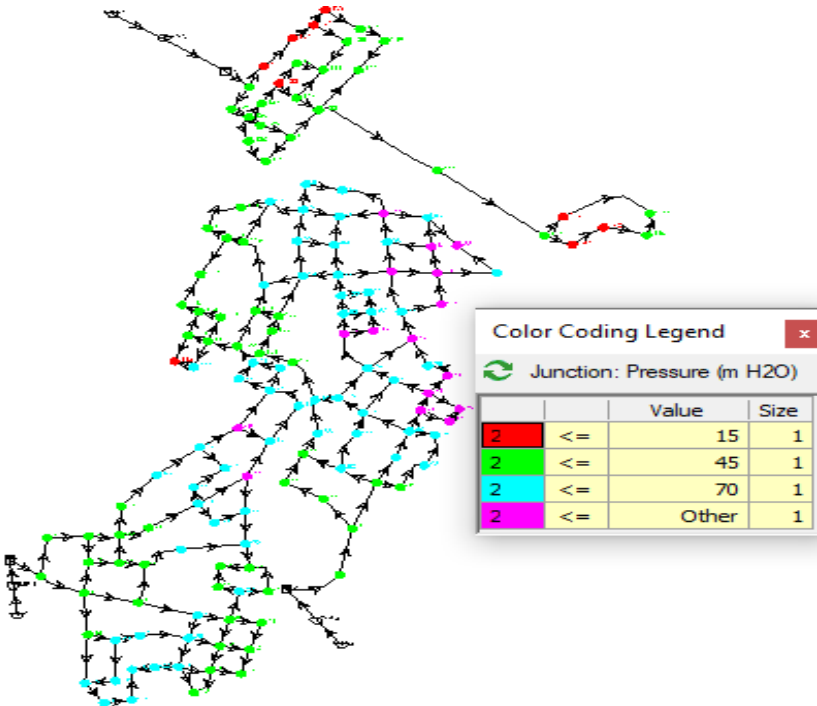


Figure 4-12: Junction pressures in the distribution network at peak hour demand

According to the results of the study, by modifying the existing water distribution network of the town of Arba Minch, a significant improvement in the hydraulic reliability of the

pipelines was observed. The hydraulic reliability of the distribution network was expressed in terms of flow rate and pressure. After the modification of the system, the pressure and velocity are within the recommended minimum and maximum limits worldwide and in the country of Ethiopia. Before the modification, the recommended value violation of for both velocity and pressure were observed and then corrected. As a result, the percentage of exceeding the maximum pressure criterion was reduced by 35.62 to 1.5 at low flow and 32.3 to 1.08 during peak flow hours. The model result was displayed during the peak hours, from all pipelines in the distribution network 17.08% violates the minimum velocity value in an existing design, which later reduced to zero for modified system.

The hydraulic model result for pressure at the peak hour demand in the WDS is illustrated Table 4.6.

Table 4-6: Hydraulic model results of pressure

Pressure(mH <sub>2</sub> O)	Number of Nodes	Percentage (%)
<=15	10	6.63
15-45	64	42.38
45-70	73	48.34
>70	4	2.65
Total	151	100

The results of the pressure values in the whole system as it is mentioned in the Appendix-B show the ability of the system to satisfy the needed pressures; only 2.65% (four junctions from the total junctions) of junction nodes (J-72, J-78, J-79 and J-82) in the given alternatives experience pressures above the permissible as shown in Table 4.6 above.

## **5. CONCLUSION AND RECOMMENDATIONS**

### **5.1. Conclusion**

This thesis covers the modeling of water supply network effectiveness assessment using the WaterGEMS model. Its goal was to find an effective solution to deliver water at the right volume and pressure and to increase the flow rate of the distribution network by modifying the existing distribution network. Since the water demand affects all systems of the water distribution network, the quantity including unbilled water for 2032 was estimated at 13,590,720l/day, a value that represents a reduction of 2,039,040l/day compared to the previous demand estimate 15,629,760l/day project estimation by using population projection. The change in demand shows how the population-based method of estimating water demand overestimates water demand by 15%. The water loss in the study area was 36.8% from the total water production.

Most pipe diameters in the distribution network have been reduced and flow rates and pressures have been kept within the recommended range. Reducing of the minimum and maximum percentage of exceeding the criteria for pressure and flow velocity at nodes was done. As a result, the maximum pressure injury rate was reduced from 35.62% to 1.5% at minimum flow and from 32.3% to 1.08% during peak flow hours. During peak periods, 17.08 % of all piping in the distribution system violated the existing design's minimum velocity criteria, which were then reduced to zero for the assessment system.

Overall, this study satisfies the need for assessment by satisfying users with the efficiency of the water supply system. Therefore, the implementation of this modern finding will go a long way in providing a solution to ensure adequate water supply in Arba Minch Town by improving the effectiveness of the existing system.

## 5.2. Recommendations

Based on the results of the study, the following recommendations were made.

- In order to overcome the problems of overestimation in determining the amount of water, in addition to the population projection approach, an approach based on the history of water use (accounting data) and the estimation of water based on water usage category should be applied.
- The reason for increase in non-revenue volume is due to reduced monitoring, premature replacement of old lines, and the unprotected build-out of infrastructure such as roads and buildings. Therefore, for reduction of NRW in the system, pressure modification, replacing the old distribution network, building strong monitoring system and need of early communication with stakeholders before starting other infrastructural expansion or building is mandatory to reduce loss and system effectiveness.
- As the problem identified and the result obtained the town enterprise should make an optimal change of layout of the network, change the pressure zones, and change the position of modified pressure zone II supply tank in the existing water networks before end of the project period to increase the effectiveness of existing water supply system; particularly, re-zoning of pipes network should be carried on in model skeletonization, some links which shall be split and some joined. Accordingly, J-45, J-48, J-49 and J-52 of Zone I should be connected with J-44, J-50, and J-43 and J-51 of Zone II respectively to form new Zone I. In the same way, P-174 and P-175 of Zone IV also should be connected with P-168 and P-172 of Zone III respectively.
- To control and minimize risks related with variation of pressure, it should be installing the necessary valves and accessories in the distribution system

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## APPENDICES

### Appendix A: Model out of the distribution network during peak flow hour

#### 1. Results of the WDN of pipes at peak demand

##### I. Zone-I pipe report

Label	Length (m)	Diameter (mm)	Material	Length (m)	Hazen-Williams C	Flow (l/s)	Velocity (m/s)
P-1	265	325	HDPE	265	150	163.9	1.98
P-3	347	250	HDPE	347	150	90.76	1.85
P-4	368	250	HDPE	368	150	69.99	1.43
P-5	288	220	uPVC	288	150	66.84	1.76
P-6	251	63	HDPE	251	150	1.69	0.54
P-7	214	100	HDPE	214	150	6.92	0.88
P-8	298	100	HDPE	298	150	8.39	1.07
P-9	400	150	uPVC	400	150	32.59	1.84
P-10	202	125	HDPE	202	150	20.24	1.65
P-11	465	80	HDPE	465	150	9.2	1.83
P-12	231	100	HDPE	231	150	6.73	0.86
P-13	195	80	HDPE	195	150	3.58	0.71
P-14	212	40	HDPE	212	150	-0.68	0.54
P-15	394	60	HDPE	394	150	3.84	1.36
P-16	172	110	HDPE	172	150	13.25	1.39
P-17	340	100	HDPE	340	150	10.1	1.29
P-18	385	200	DCI	385	130	46.64	1.48
P-19	427	160	HDPE	427	150	37.95	1.89
P-20	227	125	HDPE	227	150	23.62	1.92
P-21	222	63	HDPE	222	150	4.82	1.54
P-22	227	90	HDPE	227	150	11.17	1.76
P-23	261	60	HDPE	261	150	5	1.77
P-24	228	60	HDPE	228	150	-5.08	1.8
P-25	284	100	HDPE	284	150	13.04	1.66
P-26	275	50	HDPE	275	150	2.01	1.02
P-27	236	90	HDPE	236	150	2.7	0.42
P-28	237	50	HDPE	237	150	-2	1.02
P-29	272	60	HDPE	272	150	1.14	0.4
P-30	269	40	HDPE	269	150	1.66	1.32
P-31	210	60	HDPE	210	150	-4.23	1.5
P-32	239	100	HDPE	239	150	2.74	0.35
P-33	215	32	HDPE	215	150	-0.41	0.84
P-34	162	80	HDPE	162	150	5.88	1.17
P-35	157	60	HDPE	157	150	2.73	0.96
P-36	292	32	HDPE	292	150	-0.42	0.53
P-37	223	200	uPVC	223	150	62	1.97

P-38	173	63	HDPE	173	150	2.18	0.7
P-39	270	80	HDPE	270	150	1.59	0.32
P-40	371	100	HDPE	371	150	5.53	0.7
P-41	277	100	HDPE	277	150	10.65	1.36
P-42	199	50	HDPE	199	150	3.7	1.89
P-43	340	40	HDPE	340	150	0.55	0.44
P-44	206	90	HDPE	206	150	2.51	0.39
P-45	201	32	HDPE	201	150	-0.64	1.31
P-46	159	100	HDPE	159	150	-3.79	0.48
P-47	277	150	uPVC	277	150	27.33	1.55
P-48	387	150	uPVC	387	150	24.18	1.37
P-49	399	150	HDPE	399	150	21.03	1.19
P-50	322	100	HDPE	322	150	14.86	1.89
P-51	426	100	HDPE	426	150	11.38	1.45
P-52	239	90	HDPE	239	150	4.72	0.74
P-53	182	63	HDPE	182	150	1.56	0.5
P-54	194	63	HDPE	194	150	-1.59	0.51
P-55	224	90	HDPE	224	150	4.74	0.74
P-56	225	150	uPVC	225	150	33.1	1.87
P-57	414	150	uPVC	414	150	29.95	1.69
P-58	428	125	uPVC	428	150	19.07	1.55
P-59	368	80	HDPE	368	150	7.21	1.43
P-60	253	32	HDPE	253	150	0.33	0.67
P-61	392	100	HDPE	392	150	4.38	0.56
P-62	289	60	HDPE	289	150	-1.23	0.44
P-63	264	110	HDPE	264	150	3.02	0.32
P-64	162	110	HDPE	162	150	3.28	0.35
P-65	285	32	HDPE	285	150	0.13	0.16
P-66	347	60	HDPE	347	150	4.57	1.61
P-67	453	40	HDPE	453	150	1.41	1.12
P-68	314	80	HDPE	314	150	-6.85	1.36
P-69	337	90	HDPE	337	150	-8.71	1.37
P-70	214	63	HDPE	214	150	4.44	1.42
P-71	236	40	HDPE	236	150	1.29	1.03
P-72	232	90	HDPE	232	150	-5.11	0.8

## II. Zone-II pipe report

Label	Length (m)	Diameter (mm)	Material	Length (m)	Hazen-Williams C	Flow (l/s)	Velocity (m/s)
P-73	422	400	HDPE	422	150	247.61	1.97
P-74	455	355	HDPE	455	150	244.06	2.47
P-75	347	250	uPVC	347	150	69.78	1.42
P-76	312	200	uPVC	312	150	66.22	2.11
P-77	469	350	uPVC	469	150	170.73	1.77
P-79	286	150	uPVC	286	150	24.69	1.4
P-80	299	100	HDPE	299	150	9.3	1.18
P-81	222	225	HDPE	222	150	68.42	1.72
P-82	319	225	HDPE	319	150	64.87	1.63
P-83	166	125	HDPE	166	150	-19.42	1.58
P-84	221	180	HDPE	221	150	-38.55	1.51
P-85	364	125	HDPE	364	150	11.84	0.96
P-86	216	110	HDPE	216	150	8.28	0.87
P-87	170	90	HDPE	170	150	8.42	1.32
P-88	305	90	HDPE	305	150	4.87	0.77
P-89	319	63	HDPE	319	150	1.32	0.42
P-90	276	300	uPVC	276	150	134.07	1.9
P-91	266	300	uPVC	266	150	130.51	1.85
P-92	368	250	uPVC	368	150	72.86	1.48
P-93	218	180	HDPE	218	150	51.87	2.04
P-94	232	90	HDPE	232	150	5.7	0.9
P-95	136	63	HDPE	136	150	2.15	0.69
P-96	264	63	HDPE	264	150	-1.4	0.45
P-97	174	180	HDPE	174	150	42.61	1.67
P-98	350	110	HDPE	350	150	15.57	1.64
P-99	211	180	HDPE	211	150	-42.57	1.67
P-100	378	160	HDPE	378	150	39.05	1.94
P-101	270	90	HDPE	270	150	-7.07	1.11
P-102	179	63	HDPE	179	150	2.23	0.72
P-103	211	160	HDPE	211	150	30.58	1.52
P-104	205	160	HDPE	205	150	27.03	1.34
P-105	284	125	HDPE	284	150	23.48	1.91
P-107	401	250	HDPE	401	150	80.74	1.64
P-108	248	225	HDPE	248	150	77.18	1.94
P-109	211	160	HDPE	211	150	36.03	1.79
P-110	220	160	HDPE	220	150	26.43	1.31
P-111	268	90	HDPE	268	150	6.87	1.08
P-112	145	63	HDPE	145	150	3.32	1.07
P-113	267	32	HDPE	267	150	-0.23	0.29
P-114	146	90	HDPE	146	150	-11.93	1.88
P-115	240	90	HDPE	240	150	8.15	1.28

P-116	134	63	HDPE	134	150	5.11	1.64
P-117	321	40	HDPE	321	150	1.56	1.24
P-118	395	63	HDPE	395	150	-1.99	0.64
P-119	165	90	HDPE	165	150	4.1	0.64
P-120	373	32	HDPE	373	150	0.55	0.68
P-121	363	80	HDPE	363	150	6.06	1.2
P-122	260	110	HDPE	260	150	17.86	1.88
P-123	466	110	HDPE	466	150	16.32	1.72
P-124	230	160	HDPE	230	150	37.6	1.87
P-125	151	160	HDPE	151	150	34.05	1.69
P-126	169	110	HDPE	169	150	15.35	1.62
P-127	425	110	HDPE	425	150	15.14	1.59
P-128	282	63	HDPE	282	150	-2.01	0.64
P-129	246	80	HDPE	246	150	-5.09	1.01
P-130	334	110	HDPE	334	150	14.67	1.54
P-131	303	90	HDPE	303	150	10.47	1.65
P-132	245	63	HDPE	245	150	3.09	0.99
P-133	273	63	HDPE	273	150	-3.43	1.1
P-134	415	110	HDPE	415	150	11.73	1.23
P-135	269	160	HDPE	269	150	31.66	1.57
P-137	402	110	HDPE	402	150	16.49	1.74
P-138	402	180	HDPE	402	150	42.86	1.68
P-139	210	40	HDPE	210	150	1.42	1.13
P-140	192	160	HDPE	192	150	33.74	1.68
P-141	173	160	HDPE	173	150	25.9	1.29
P-142	200	125	HDPE	200	150	21.55	1.76
P-143	289	63	HDPE	289	150	5.99	1.92
P-144	276	63	HDPE	276	150	3.08	0.99
P-145	259	32	HDPE	259	150	-0.4	0.49
P-147	211	63	HDPE	211	150	-3	0.96
P-148	122	90	HDPE	122	150	9.64	1.52
P-149	431	63	HDPE	431	150	3.12	1
P-150	248	63	HDPE	248	150	4.07	1.3
P-151	158	32	HDPE	158	150	-0.52	0.64
P-152	304	225	HDPE	304	150	62.67	1.58
P-153	210	60	HDPE	210	150	4.14	1.46
P-154	200	63	HDPE	200	150	4.29	1.38
P-155	192	63	HDPE	192	150	2.75	0.88
P-156	180	63	HDPE	180	150	2.01	0.65
P-157	192	32	HDPE	192	150	0.8	0.99
P-158	370	90	HDPE	370	150	6.92	1.09
P-159	282	90	HDPE	282	150	12.12	1.91
P-163	278	90	HDPE	278	150	8.76	1.38
P-164	306	32	HDPE	306	150	-0.07	0.09
P-165	257	32	HDPE	257	150	0.57	0.71

P-166	423	63	HDPE	423	150	-2.98	0.96
P-167	287	90	HDPE	287	150	11.61	1.83
P-168	320	90	HDPE	320	150	7.74	1.22
P-169	302	90	HDPE	302	150	8.06	1.27
P-170	253	90	HDPE	253	150	8.13	1.28
P-171	283	63	HDPE	283	150	4.39	1.41
P-172	308	63	HDPE	308	150	2.15	0.69
P-173	313	32	HDPE	313	150	-0.19	0.24
P-174	410	63	HDPE	410	150	4.11	1.32
P-175	338	63	HDPE	338	150	2.99	0.96
P-176	378	32	HDPE	378	150	-0.56	0.7
P-177	261	32	HDPE	261	150	0.65	0.81

### III. Zone-III Pipe report

Label	Length (m)	Diameter (mm)	Material	Length (m)	Hazen-Williams C	Flow (l/s)	Velocity (m/s)
P-178	225	280	HDPE	225	150	119.62	1.94
P-179	244	250	HDPE	244	150	78.8	1.61
P-180	142	225	HDPE	142	150	74.53	1.87
P-181	253	90	HDPE	253	150	7.39	1.16
P-182	241	63	HDPE	241	150	3.11	1
P-183	114	160	HDPE	114	150	37.2	1.85
P-184	239	160	HDPE	239	150	32.92	1.64
P-185	284	50	HDPE	284	150	-1.16	0.59
P-186	156	160	HDPE	156	150	25.67	1.28
P-187	232	125	HDPE	232	150	21.4	1.74
P-188	190	125	HDPE	190	150	12.27	1
P-189	189	110	HDPE	189	150	7.18	0.76
P-190	227	180	uPVC	227	150	36.54	1.44
P-191	337	160	uPVC	337	150	32.27	1.61
P-192	194	150	uPVC	194	150	28	1.58
P-193	171	110	HDPE	171	150	16.59	1.75
P-194	303	90	HDPE	303	150	12.31	1.94
P-195	212	90	HDPE	212	150	8.04	1.26
P-196	279	110	HDPE	279	150	7.14	0.75
P-197	225	90	HDPE	225	150	4.86	0.76
P-198	194	32	HDPE	194	150	0.59	0.74
P-199	327	40	HDPE	327	150	0.81	0.65
P-200	319	63	HDPE	319	150	-2.87	0.92
P-201	472	32	HDPE	472	150	0.5	1.02
P-202	331	63	HDPE	331	150	-3.77	1.21
P-203	329	160	HDPE	329	150	-27.5	1.37
P-204	1,036	160	HDPE	1,036	150	29.9	1.49

P-205	966	125	HDPE	966	150	25.63	2.09
P-206	216	110	HDPE	216	150	13	1.37
P-207	269	90	HDPE	269	150	8.73	1.37
P-208	312	63	HDPE	312	150	4.46	1.43
P-209	221	90	HDPE	221	150	8.36	1.31
P-210	718	63	HDPE	718	150	4.09	1.31
P-211	215	32	HDPE	215	150	-0.18	0.58

## 2. Results of the WDN of nodal pressure

### I. Zone-I junction report

Label	Elevation(m)	X(m)	Y(m)	Pressure(mH <sub>2</sub> O)	Demand(l/s)	Zone
J-1	1,432.00	337,935.65	664,406.13	17	3.15	Zone - 1
J-2	1,414.00	338,233.91	664,243.68	31	3.15	Zone - 1
J-3	1,417.00	338,265.91	664,790.73	26	3.15	Zone - 1
J-4	1,420.00	337,978.41	664,771.98	26	3.15	Zone - 1
J-5	1,400.00	338,608.43	664,152.99	41	3.15	Zone - 1
J-6	1,399.00	338,652.37	664,518.68	40	3.15	Zone - 1
J-7	1,387.00	339,017.64	664,030.10	46	3.15	Zone - 1
J-8	1,385.00	339,241.13	663,988.14	43	3.15	Zone - 1
J-9	1,377.00	339,109.48	663,508.78	38	3.15	Zone - 1
J-10	1,369.00	338,885.53	663,536.42	51	3.15	Zone - 1
J-11	1,388.00	339,461.00	663,956.68	32	3.15	Zone - 1
J-12	1,386.00	339,320.68	663,469.09	21	3.15	Zone - 1
J-13	1,370.00	338,995.68	663,286.78	44	3.15	Zone - 1
J-14	1,398.00	338,259.09	663,844.51	40	3.15	Zone - 1
J-15	1,370.00	338,241.20	663,379.46	51	3.15	Zone - 1
J-16	1,359.00	338,565.60	663,218.49	59	3.15	Zone - 1
J-17	1,365.00	338,372.91	663,190.03	54	3.15	Zone - 1
J-18	1,369.00	338,568.04	663,510.36	46	3.15	Zone - 1
J-19	1,368.00	338,451.77	663,399.79	54	3.15	Zone - 1
J-20	1,382.00	338,454.21	663,793.29	52	3.15	Zone - 1
J-21	1,386.00	338,620.88	663,837.19	46	3.15	Zone - 1
J-22	1,367.00	338,724.13	663,530.69	50	3.15	Zone - 1
J-23	1,382.00	339,172.11	663,736.38	33	3.15	Zone - 1
J-24	1,392.00	339,379.42	663,700.61	16	3.15	Zone - 1
J-25	1,375.00	338,956.66	663,811.18	52	3.15	Zone - 1
J-26	1,378.00	339,509.51	664,259.96	32	3.15	Zone - 1
J-27	1,377.00	339,310.32	664,256.71	46	3.15	Zone - 1
J-28	1,367.00	339,377.80	664,483.54	41	3.15	Zone - 1
J-29	1,379.00	339,157.47	664,301.42	44	3.15	Zone - 1

J-30	1,372.00	339,172.92	664,501.43	35	3.15	Zone - 1
J-31	1,407.00	338,479.42	664,529.88	33	3.15	Zone - 1
J-32	1,418.00	338,265.59	664,539.64	24	3.15	Zone - 1
J-33	1,404.00	338,481.04	664,799.80	36	3.15	Zone - 1
J-34	1,396.00	338,490.80	665,077.04	40	3.15	Zone - 1
J-35	1,351.00	339,353.41	664,714.44	58	3.15	Zone - 1
J-36	1,350.00	339,347.72	665,028.26	66	3.15	Zone - 1
J-37	1,379.00	338,903.00	664,664.03	46	3.15	Zone - 1
J-38	1,391.00	338,680.33	664,868.67	45	3.15	Zone - 1
J-39	1,366.00	339,137.65	664,920.50	57	3.15	Zone - 1
J-40	1,369.00	339,023.17	665,101.27	60	3.15	Zone - 1
J-41	1,360.00	339,208.13	665,443.75	69	3.15	Zone - 1
J-42	1,352.00	339,359.56	665,365.50	70	3.15	Zone - 1
J-43	1,346.00	339,515.71	665,698.73	68	3.15	Zone - 1
J-44	1,345.00	339,714.42	666,036.39	67	3.15	Zone - 1
J-45	1,345.00	339,519.28	666,190.25	66	3.15	Zone - 1
J-46	1,367.00	338,736.51	665,376.26	65	3.15	Zone - 1
J-47	1,363.00	338,990.58	665,260.40	66	3.15	Zone - 1
J-48	1,361.00	339,033.33	665,642.19	68	3.15	Zone - 1
J-49	1,349.00	339,297.13	665,826.39	70	3.15	Zone - 1
J-50	1,345.00	339,589.04	666,403.44	65	3.15	Zone - 1
J-51	1,340.00	339,400.68	666,451.31	69	3.15	Zone - 1
J-52	1,340.00	339,304.94	666,296.77	70	3.15	Zone - 1

## II. Zone-II junction report

Label	Elevation(m)	X(m)	Y(m)	Pressure(mH <sub>2</sub> O)	Demand(l/s)	Zone
J-53	1,341.00	340,000.53	664,417.66	18	3.55	Zone - 2
J-54	1,338.00	340,088.52	664,864.36	16	3.55	Zone - 2
J-55	1,319.00	339,889.54	665,148.67	33	3.55	Zone - 2
J-56	1,320.00	339,620.22	665,305.60	27	3.55	Zone - 2
J-57	1,309.00	340,256.59	665,302.37	42	3.55	Zone - 2
J-58	1,299.00	340,010.46	665,438.32	49	3.55	Zone - 2
J-59	1,304.00	339,749.27	665,580.42	40	3.55	Zone - 2
J-60	1,282.00	340,482.61	665,793.43	64	3.55	Zone - 2
J-61	1,312.00	340,420.82	665,257.65	36	3.55	Zone - 2
J-62	1,291.00	340,387.48	665,545.46	57	3.55	Zone - 2
J-63	1,297.00	340,584.95	665,466.53	49	3.55	Zone - 2
J-64	1,283.00	340,658.22	665,760.91	62	3.55	Zone - 2
J-65	1,280.00	340,120.96	665,773.03	65	3.55	Zone - 2
J-66	1,295.00	339,850.08	665,777.98	47	3.55	Zone - 2

J-67	1,276.00	340,162.38	665,975.65	68	3.55	Zone – 2
J-68	1,272.00	340,560.66	665,996.68	70	3.55	Zone – 2
J-69	1,270.00	340,760.30	665,892.99	70	3.55	Zone – 2
J-70	1,269.00	340,828.78	666,010.24	70	3.55	Zone – 2
J-71	1,270.00	340,613.50	666,162.54	70	3.55	Zone – 2
J-72	1,267.00	340,745.21	666,326.77	71	3.55	Zone – 2
J-73	1,268.00	340,374.48	666,288.56	69	3.55	Zone – 2
J-74	1,267.00	340,196.43	666,402.38	67	3.55	Zone – 2
J-75	1,266.00	340,611.34	666,421.73	70	3.55	Zone – 2
J-76	1,259.00	340,502.12	666,683.68	70	3.55	Zone – 2
J-77	1,257.00	340,428.14	666,942.22	69	3.55	Zone – 2
J-78	1,246.00	340,705.46	667,014.77	71	3.55	Zone – 2
J-79	1,241.00	340,677.73	667,315.40	71	3.55	Zone – 2
J-80	1,231.00	341,087.49	667,317.02	70	3.55	Zone – 2
J-81	1,237.00	340,635.45	667,564.99	70	3.55	Zone – 2
J-82	1,223.00	340,812.69	667,577.19	71	3.55	Zone – 2
J-83	1,234.00	340,609.44	667,847.11	65	3.55	Zone – 2
J-85	1,246.00	340,358.22	667,330.03	70	3.55	Zone – 2
J-86	1,238.00	340,327.32	667,610.52	69	3.55	Zone – 2
J-87	1,232.00	340,018.38	668,108.09	63	3.55	Zone – 2
J-88	1,234.00	339,999.68	667,856.05	67	3.55	Zone – 2
J-89	1,242.00	339,966.34	667,582.88	64	3.55	Zone – 2
J-90	1,256.00	339,989.92	667,295.07	65	3.55	Zone – 2
J-91	1,233.00	339,767.97	668,165.00	67	2.52	Zone – 2
J-92	1,236.00	339,749.27	667,921.09	68	3.55	Zone – 2
J-93	1,245.00	339,707.80	667,621.09	67	3.55	Zone – 2
J-94	1,258.00	339,743.58	667,288.57	60	3.55	Zone – 2
J-95	1,259.00	340,030.09	666,731.61	70	3.55	Zone – 2
J-96	1,252.00	340,237.89	666,760.92	70	3.55	Zone – 2
J-97	1,251.00	340,222.44	666,939.78	70	3.55	Zone – 2
J-98	1,258.00	340,026.51	666,923.52	69	3.55	Zone – 2
J-99	1,250.00	340,199.68	667,130.03	68	3.55	Zone – 2
J-100	1,258.00	340,010.25	667,095.88	67	3.55	Zone – 2
J-101	1,292.00	339,828.48	666,094.13	47	3.55	Zone – 2
J-102	1,283.00	339,992.38	666,117.55	59	3.55	Zone – 2
J-103	1,303.00	339,678.23	666,456.41	33	3.55	Zone – 2
J-104	1,308.00	339,445.38	666,540.32	25	3.55	Zone – 2
J-105	1,297.00	339,530.59	666,753.65	32	3.55	Zone – 2
J-106	1,286.00	339,578.07	666,897.39	40	3.55	Zone – 2
J-107	1,278.00	339,417.42	666,950.73	45	3.55	Zone – 2
J-108	1,269.00	339,475.95	667,198.53	47	3.55	Zone – 2
J-109	1,301.00	339,293.19	666,609.91	28	3.55	Zone – 2
J-110	1,297.00	339,089.80	666,659.80	30	3.55	Zone – 2
J-111	1,260.00	338,992.70	666,410.23	64	3.55	Zone – 2

J-112	1,310.00	338,859.36	666,466.82	11	3.55	Zone – 2
J-113	1,299.00	338,954.97	666,716.58	23	3.55	Zone – 2
J-114	1,289.00	339,028.47	666,944.87	29	3.55	Zone – 2
J-115	1,286.00	339,177.41	666,892.19	35	3.55	Zone – 2
J-116	1,291.00	338,910.09	667,006.66	22	3.55	Zone – 2
J-117	1,275.00	339,039.53	667,300.00	25	3.55	Zone – 2
J-118	1,264.00	339,222.29	667,649.92	39	3.55	Zone – 2
J-119	1,265.00	339,337.41	667,609.59	40	3.55	Zone – 2
J-120	1,249.00	339,521.48	667,999.84	49	3.55	Zone – 2
J-121	1,259.00	339,317.90	667,945.21	36	3.55	Zone – 2
J-122	1,261.00	339,087.01	667,744.88	41	3.55	Zone – 2
J-155	1,231.00	340,304.28	667,887.46	70	3.55	Zone – 2

### III. Zone-III junction report

Label	Elevation(m)	X(m)	Y(m)	Pressure(mH <sub>2</sub> O)	Demand(l/s)	Zone
J-123	1,259.00	339,376.22	669,099.66	17	4.27	Zone – 3
J-124	1,251.00	339,254.55	668,887.63	24	4.27	Zone – 3
J-125	1,237.00	339,454.55	668,729.91	34	4.27	Zone – 3
J-126	1,241.00	339,371.62	668,807.96	32	4.27	Zone – 3
J-127	1,249.00	339,458.61	668,938.04	23	4.27	Zone – 3
J-128	1,236.00	339,659.43	668,612.84	32	4.27	Zone – 3
J-129	1,237.00	339,487.88	668,386.82	29	4.27	Zone – 3
J-130	1,239.00	339,370.81	668,577.06	30	4.27	Zone – 3
J-131	1,260.00	339,476.50	669,295.77	14	4.27	Zone – 3
J-132	1,254.00	339,582.19	669,133.98	13	4.27	Zone – 2
J-133	1,237.00	339,854.55	668,877.88	28	4.27	Zone – 3
J-134	1,260.00	339,674.06	669,565.69	10	4.27	Zone – 3
J-135	1,256.00	339,822.03	669,690.89	11	4.27	Zone – 3
J-136	1,245.00	340,052.93	669,533.98	21	4.27	Zone – 1
J-137	1,237.00	340,141.66	669,653.90	15	4.27	Zone – 3
J-138	1,244.00	339,702.52	669,324.22	21	4.27	Zone – 3
J-139	1,249.00	339,900.08	669,836.42	14	4.27	Zone – 3
J-140	1,233.00	340,311.00	669,537.60	16	4.27	Zone – 3
J-141	1,244.00	339,886.05	669,262.24	18	4.27	Zone – 3
J-142	1,215.00	340,130.40	669,260.53	26	4.27	Zone – 3
J-143	1,245.00	339,703.01	668,991.57	21	4.27	Zone – 3
J-144	1,223.00	340,676.54	668,297.45	30	4.27	Zone – 3
J-145	1,206.00	341,415.15	667,674.95	20	4.27	Zone – 3
J-146	1,208.00	341,546.54	667,852.05	14	4.27	Zone – 3
J-147	1,209.00	341,610.54	667,585.64	14	4.27	Zone – 3
J-148	1,206.00	341,822.83	667,749.02	11	4.27	Zone – 3
J-149	1,182.00	342,124.62	667,675.14	26	4.27	Zone – 3
J-150	1,172.00	342,147.33	667,884.81	31	4.27	Zone – 3

## Appendix B: Water consumption data (m<sup>3</sup>/year)

### 1. Year 2011

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Tot
1.Kulfo	Private	3657	3918	3239	4145	3555	5099	4772	4280	4378	4036	4079	4156	49315
	commerci	1010	943	1176	864	658	767	760	674	780	797	768	832	10028
	Institutional	53	42	35	51	47	111	64	55	76	50	94	96	774
	governme	103	78	108	68	58	120	12	36	37	49	59	55	784
	<b>Total</b>	<b>4823</b>	<b>4981</b>	<b>4558</b>	<b>5129</b>	<b>4318</b>	<b>6098</b>	<b>5607</b>	<b>5045</b>	<b>5271</b>	<b>4932</b>	<b>5000</b>	<b>5139</b>	60901
2.Gurba	Private	1970	2039	2271	2385	2130	3021	2318	3016	2055	2414	1964	2566	28148
	commerci	0	0	0	0	0	1	7	0	6	4	2	5	24
	Institutional	1018	862	975	1025	523	964	496	971	698	1051	695	1073	10350
	governme	143	229	337	238	394	262	218	49	51	314	258	319	2814
	<b>Total</b>	<b>3130</b>	<b>3130</b>	<b>3584</b>	<b>3647</b>	<b>3047</b>	<b>4248</b>	<b>3039</b>	<b>4036</b>	<b>2810</b>	<b>3783</b>	<b>2918</b>	<b>3964</b>	41336
3.Menharia	Private	1241	1745	1703	2144	1818	2762	2157	2099	2357	2099	1893	2099	24117
	commerci	1261	1735	1829	2088	1412	2413	1599	1776	1937	1507	1727	1798	21082
	Institutional	22	1	3	186	244	226	109	266	182	172	120	147	1679
	governme	24	34	38	17	38	34	51	55	45	58	62	61	517
	<b>Total</b>	<b>2549</b>	<b>3515</b>	<b>3573</b>	<b>4436</b>	<b>3511</b>	<b>5436</b>	<b>3916</b>	<b>4196</b>	<b>4521</b>	<b>3836</b>	<b>3801</b>	<b>4105</b>	47395
4.Woze	Private	1601	931	1100	1612	2632	1896	2383	2684	2295	2547	1912	1597	23190
	commerci	0	41	13	16	20	6	0	21	25	37	40	32	251
	Institutional	125	60	359	566	273	156	418	735	616	627	1065	566	5567
	governme	0	0	0	0	1	1	1	2	1	1	1	1	8
	<b>Total</b>	<b>1727</b>	<b>1032</b>	<b>1473</b>	<b>2193</b>	<b>2926</b>	<b>2060</b>	<b>2802</b>	<b>3442</b>	<b>2938</b>	<b>3211</b>	<b>3018</b>	<b>2196</b>	29016
5.Edgetber	Private	4113	4064	3616	4503	4057	4862	4646	4669	4176	3602	3722	3653	49685
	commerci	341	291	337	316	208	398	438	438	352	255	262	205	3841
	Institutional	546	577	559	506	555	428	471	388	418	353	222	258	5281
	governme	3	3	6	5	3	3	3	2	3	4	5	5	44
	<b>Total</b>	<b>5002</b>	<b>4935</b>	<b>4518</b>	<b>5330</b>	<b>4822</b>	<b>5691</b>	<b>5558</b>	<b>5497</b>	<b>4948</b>	<b>4214</b>	<b>4212</b>	<b>4122</b>	58850
6.M/ketema	Private	3094	2909	2581	3078	4406	2735	3934	3445	3444	3912	2613	3401	39553
	commerci	4676	4775	4338	5047	6156	3310	5354	4911	5526	5624	3773	5625	59114
	Institutional	1655	1327	1140	1492	2207	1027	2471	1567	1149	1156	616	1155	16962
	governme	4049	2771	1181	4397	4989	370	2292	2363	798	1034	1813	2376	28434
	<b>Total</b>	<b>13474</b>	<b>11783</b>	<b>9240</b>	<b>14014</b>	<b>17759</b>	<b>7441</b>	<b>14051</b>	<b>12285</b>	<b>10916</b>	<b>11726</b>	<b>8815</b>	<b>12557</b>	144063
7.W/Minch	Private	6996	9066	9005	8962	10690	10888	10521	10986	11135	10160	9999	10566	118974
	commerci	2620	4356	4318	4926	5418	4165	3556	3625	3668	3480	3653	4165	47948
	Institutional	3827	5745	5800	5728	8919	6388	5219	8517	7622	6057	6108	6394	76323
	governme	334	256	298	327	485	340	408	499	395	397	433	472	4644
	<b>Total</b>	<b>13778</b>	<b>19423</b>	<b>19420</b>	<b>19944</b>	<b>25511</b>	<b>21780</b>	<b>19704</b>	<b>23626</b>	<b>22820</b>	<b>20092</b>	<b>20193</b>	<b>21598</b>	247889
8.Berea	Private	2511	3339	3323	3048	3685	4269	3530	4047	3548	3143	2873	4369	41685
	commerci	1472	1797	1767	1816	1870	1863	1362	1696	1443	1327	1894	2506	20813
	Institutional	35	50	53	49	53	100	68	68	93	63	53	120	805
	governme	129	150	145	134	146	196	119	111	94	78	111	256	1670
	<b>Total</b>	<b>4148</b>	<b>5337</b>	<b>5288</b>	<b>5047</b>	<b>5754</b>	<b>6428</b>	<b>5079</b>	<b>5922</b>	<b>5178</b>	<b>4611</b>	<b>4930</b>	<b>7251</b>	64974
9.Chamo	Private	4869	5518	5585	5772	7474	7723	6550	6645	6514	6462	5070	5778	73960
	commerci	2234	2223	2262	2429	2589	2569	1804	1901	1818	1801	1469	2429	25528
	Institutional	836	953	1170	1419	2103	2432	1516	1406	820	756	1270	1425	16106
	governme	125	111	73	80	165	229	137	105	83	105	123	133	1469
	<b>Total</b>	<b>8063</b>	<b>8806</b>	<b>9090</b>	<b>9701</b>	<b>12330</b>	<b>12953</b>	<b>10008</b>	<b>10056</b>	<b>9235</b>	<b>9124</b>	<b>7931</b>	<b>9766</b>	117063
10.Doeysa	Private	4493	4300	3857	3715	5263	4928	5319	5126	4982	3733	3812	3788	53316
	commerci	1545	1537	1698	1437	1960	1788	1626	1804	1595	1291	1543	1479	19304
	Institutional	273	300	249	597	345	371	275	256	252	169	191	146	3424
	Industry	6	2	3	3	4	1	0	8	4	3	0	2	36
	governme	209	235	149	3620	7202	3957	6535	2200	4199	3107	3928	3799	39141
<b>Total</b>	<b>6526</b>	<b>6374</b>	<b>5956</b>	<b>9372</b>	<b>14775</b>	<b>11045</b>	<b>13755</b>	<b>9395</b>	<b>11032</b>	<b>8303</b>	<b>9474</b>	<b>9214</b>	115222	
11.Difana	Private	3584	3770	3024	3495	3717	3807	4168	3229	3384	3404	2747	3661	41989
	commerci	1239	1257	1242	1282	1787	1137	1684	1860	2024	1578	1659	2120	18868
	Institutional	66	68	199	766	992	750	834	761	946	132	403	637	6555
	Industry	12	17	6	1	3	4	8	6	5	6	9	12	90
	governme	800	735	849	717	792	507	1018	813	1028	800	825	1080	9964
<b>Total</b>	<b>5701</b>	<b>5847</b>	<b>5319</b>	<b>6262</b>	<b>7291</b>	<b>6205</b>	<b>7712</b>	<b>6669</b>	<b>7387</b>	<b>5921</b>	<b>5643</b>	<b>7509</b>	77466	
<b>TOTAL</b>		<b>68922</b>	<b>75164</b>	<b>72020</b>	<b>85075</b>	<b>102044</b>	<b>89385</b>	<b>91231</b>	<b>90170</b>	<b>87056</b>	<b>79754</b>	<b>75935</b>	<b>87420</b>	<b>1004174</b>

## 2. Year 2012

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Tot
1.Kulifo	Private	4469	4788	3958	5066	4345	6231	5831	5230	5350	4932	4985	5079	60263
	commerci	1234	1152	1437	1056	804	937	928	824	953	974	939	1016	12254
	Institutional	64	51	43	63	57	136	78	68	93	61	115	117	946
	governme	126	96	132	83	71	147	14	44	46	60	72	68	958
	<b>Total</b>	<b>5894</b>	<b>6087</b>	<b>5570</b>	<b>6268</b>	<b>5276</b>	<b>7451</b>	<b>6851</b>	<b>6165</b>	<b>6441</b>	<b>6027</b>	<b>6110</b>	<b>6280</b>	<b>74421</b>
2.Gurba	Private	2407	2492	2775	2914	2603	3692	2833	3686	2511	2950	2400	3136	34397
	commerci	0	0	0	0	0	1	9	0	7	5	2	6	30
	Institutional	1243	1053	1192	1252	639	1177	606	1186	853	1284	849	1312	12647
	governme	175	280	412	291	482	320	266	60	62	384	315	390	3438
	<b>Total</b>	<b>3825</b>	<b>3825</b>	<b>4379</b>	<b>4457</b>	<b>3723</b>	<b>5191</b>	<b>3714</b>	<b>4932</b>	<b>3433</b>	<b>4623</b>	<b>3566</b>	<b>4844</b>	<b>50513</b>
3.Menharia	Private	1517	2133	2081	2620	2221	3375	2635	2565	2880	2565	2313	2565	29470
	commerci	1541	2120	2236	2551	1725	2949	1954	2170	2367	1842	2110	2197	25762
	Institutional	27	1	4	228	298	276	134	325	222	211	146	180	2052
	governme	30	42	46	21	46	42	62	67	55	71	75	75	632
	<b>Total</b>	<b>3115</b>	<b>4295</b>	<b>4367</b>	<b>5421</b>	<b>4290</b>	<b>6642</b>	<b>4785</b>	<b>5127</b>	<b>5524</b>	<b>4688</b>	<b>4645</b>	<b>5016</b>	<b>57916</b>
4.Woze	Private	1957	1137	1345	1969	3216	2316	2912	3279	2805	3112	2337	1952	28338
	commerci	0	50	16	19	24	8	1	25	31	46	49	39	307
	Institutional	153	73	439	691	334	191	511	899	753	766	1302	691	6802
	governme	0	0	0	0	2	2	1	2		1	0	1	9
	<b>Total</b>	<b>2110</b>	<b>1261</b>	<b>1800</b>	<b>2680</b>	<b>3576</b>	<b>2517</b>	<b>3424</b>	<b>4206</b>	<b>3590</b>	<b>3924</b>	<b>3688</b>	<b>2683</b>	<b>35457</b>
5.Edgether	Private	5026	4967	4419	5502	4958	5942	5678	5706	5103	4402	4548	4464	60715
	commerci	416	355	412	386	254	486	535	536	430	311	320	251	4693
	Institutional	667	705	683	618	678	523	576	474	511	431	272	316	6453
	governme	3	4	7	6	3	4	3	2	3	5	6	6	53
	<b>Total</b>	<b>6113</b>	<b>6031</b>	<b>5521</b>	<b>6513</b>	<b>5893</b>	<b>6955</b>	<b>6791</b>	<b>6718</b>	<b>6047</b>	<b>5149</b>	<b>5147</b>	<b>5037</b>	<b>71914</b>
6.M/ketema	Private	3781	3555	3154	3761	5385	3342	4807	4210	4208	4781	3193	4156	48333
	commerci	5714	5835	5301	6168	7522	4045	6542	6001	6752	6872	4610	6874	72237
	Institutional	2022	1622	1393	1823	2697	1254	3019	1914	1404	1412	753	1412	20727
	governme	4948	3386	1444	5374	6097	452	2801	2888	975	1264	2215	2903	34746
	<b>Total</b>	<b>16465</b>	<b>14399</b>	<b>11292</b>	<b>17126</b>	<b>21701</b>	<b>9093</b>	<b>17170</b>	<b>15013</b>	<b>13339</b>	<b>14329</b>	<b>10772</b>	<b>15345</b>	<b>176043</b>
7.W/Minch	Private	8549	11079	11004	10951	13063	13305	12857	13424	13606	12415	12218	12912	145385
	commerci	3202	5323	5276	6020	6620	5089	4345	4429	4482	4252	4464	5089	58592
	Institutional	4677	7021	7088	7000	10899	7806	6377	10407	9314	7401	7464	7813	93266
	governme	408	313	364	400	592	416	498	610	483	485	529	577	5674
	<b>Total</b>	<b>16836</b>	<b>23735</b>	<b>23732</b>	<b>24371</b>	<b>31174</b>	<b>26615</b>	<b>24078</b>	<b>28870</b>	<b>27885</b>	<b>24552</b>	<b>24676</b>	<b>26392</b>	<b>302917</b>
8.Berea	Private	3069	4081	4061	3724	4503	5217	4314	4946	4336	3840	3510	5339	50939
	commerci	1799	2196	2159	2219	2285	2277	1664	2072	1763	1621	2314	3063	25434
	Institutional	43	61	65	60	65	122	83	83	113	77	65	146	984
	governme	158	184	177	164	178	240	145	136	115	96	135	313	2041
	<b>Total</b>	<b>5069</b>	<b>6522</b>	<b>6462</b>	<b>6167</b>	<b>7031</b>	<b>7855</b>	<b>6207</b>	<b>7237</b>	<b>6328</b>	<b>5634</b>	<b>6025</b>	<b>3860</b>	<b>79398</b>
9.Chamo	Private	5950	6744	6824	7054	9133	9437	8004	8120	7959	7897	6195	7061	90378
	commerci	2730	2717	2764	2968	3164	3140	2205	2323	2221	2200	1795	2968	31195
	Institutional	1021	1165	1430	1734	2569	2972	1853	1718	1002	924	1551	1741	19681
	governme	152	136	90	98	201	280	167	128	101	129	150	163	1795
	<b>Total</b>	<b>9853</b>	<b>10761</b>	<b>11108</b>	<b>11854</b>	<b>15068</b>	<b>15829</b>	<b>12229</b>	<b>12288</b>	<b>11285</b>	<b>11149</b>	<b>9692</b>	<b>11933</b>	<b>143049</b>
10.Doeysa	Private	5490	5254	4713	4540	6432	6022	6500	6264	6088	4561	4658	4629	65152
	commerci	1888	1878	2075	1756	2395	2184	1987	2205	1950	1578	1886	1807	23589
	Institutional	333	367	304	730	422	453	336	313	308	207	233	178	4184
	Industry	8	2	3	3	5	2	0	10	5	3	0	2	44
	governme	255	287	182	4424	8801	4836	7986	2688	5132	3797	4799	4642	47830
<b>Total</b>	<b>7974</b>	<b>7789</b>	<b>7278</b>	<b>11453</b>	<b>18055</b>	<b>13497</b>	<b>16809</b>	<b>11481</b>	<b>13482</b>	<b>10146</b>	<b>11577</b>	<b>11259</b>	<b>140800</b>	
11.Dilfana	Private	4380	4607	3696	4271	4542	4652	5093	3946	4136	4159	3356	4473	51311
	commerci	1514	1536	1518	1567	2184	1390	2057	2272	2473	1928	2027	2591	23056
	Institutional	80	83	243	936	1213	917	1020	930	1155	162	493	778	8010
	Industry	15	21	7	2	3	5	9	8	6	8	11	14	110
	governme	978	898	1037	877	968	619	1244	994	1257	978	1008	1320	12176
<b>Total</b>	<b>6967</b>	<b>7145</b>	<b>6500</b>	<b>7652</b>	<b>8909</b>	<b>7582</b>	<b>9424</b>	<b>8150</b>	<b>9027</b>	<b>7235</b>	<b>6895</b>	<b>9176</b>	<b>94662</b>	
<b>TOTAL</b>		<b>84222</b>	<b>91850</b>	<b>88008</b>	<b>103961</b>	<b>124696</b>	<b>109227</b>	<b>111483</b>	<b>110186</b>	<b>106381</b>	<b>97458</b>	<b>92791</b>	<b>106827</b>	<b>1227090</b>

### 3. Year 2013

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Tot
1.Kulfo	Private	4026	4314	3566	4564	3914	5614	5253	4712	4820	4444	4491	4576	54296
	commerci	1112	1038	1294	951	724	844	837	742	858	878	846	916	11041
	institutiona	58	46	39	57	52	122	70	61	84	55	103	105	852
	governme	114	86	119	75	64	132	13	40	41	54	65	61	863
	<b>Total</b>	<b>5310</b>	<b>5484</b>	<b>5019</b>	<b>5647</b>	<b>4754</b>	<b>6714</b>	<b>6173</b>	<b>5555</b>	<b>5803</b>	<b>5430</b>	<b>5505</b>	<b>5658</b>	<b>67053</b>
2.Gurba	Private	2168	2245	2500	2626	2345	3326	2552	3321	2263	2658	2162	2825	30992
	commerci	0	0	0	0	0	1	8	0	6	4	2	6	27
	institutiona	1120	949	1074	1128	575	1061	546	1069	769	1157	765	1182	11395
	governme	158	252	372	262	434	289	240	54	56	346	284	352	3098
	<b>Total</b>	<b>3447</b>	<b>3446</b>	<b>3946</b>	<b>4016</b>	<b>3355</b>	<b>4677</b>	<b>3346</b>	<b>4444</b>	<b>3093</b>	<b>4165</b>	<b>3213</b>	<b>4365</b>	<b>45511</b>
3.Menarhia	Private	1367	1921	1875	2361	2001	3041	2374	2311	2595	2311	2084	2311	26553
	commerci	1389	1910	2014	2299	1554	2657	1761	1955	2132	1660	1901	1980	23211
	institutiona	25	1	4	205	268	249	120	293	200	190	132	162	1849
	governme	27	38	42	19	42	38	56	60	50	64	68	67	569
	<b>total</b>	<b>2807</b>	<b>3870</b>	<b>3934</b>	<b>4884</b>	<b>3866</b>	<b>5985</b>	<b>4311</b>	<b>4619</b>	<b>4977</b>	<b>4224</b>	<b>4185</b>	<b>4520</b>	<b>52182</b>
4.Woze	private	1763	1025	1212	1774	2897	2087	2624	2955	2527	2804	2106	1759	25532
	commerci	0	45	14	17	22	7	0	23	28	41	44	35	277
	institutiona	138	66	396	623	301	172	460	810	679	690	1173	623	6129
	governme	0	0	0	0	1	1	1	2	1	1	1	1	8
	<b>total</b>	<b>1901</b>	<b>1136</b>	<b>1621</b>	<b>2414</b>	<b>3222</b>	<b>2268</b>	<b>3085</b>	<b>3789</b>	<b>3234</b>	<b>3536</b>	<b>3323</b>	<b>2418</b>	<b>31946</b>
5.E/Ber	private	4529	4475	3982	4958	4467	5353	5115	5141	4597	3966	4098	4022	54703
	commerci	375	320	372	348	229	438	482	483	388	280	289	226	4229
	institutiona	601	636	615	557	611	471	519	427	460	389	245	285	5814
	governme	3	4	6	6	3	4	3	2	3	4	6	6	48
	<b>total</b>	<b>5508</b>	<b>5434</b>	<b>4975</b>	<b>5869</b>	<b>5309</b>	<b>6266</b>	<b>6119</b>	<b>6053</b>	<b>5448</b>	<b>4639</b>	<b>4637</b>	<b>4538</b>	<b>64794</b>
6.M/Ketema	private	3407	3203	2842	3389	4851	3011	4331	3793	3791	4307	2877	3745	43547
	commerci	5148	5258	4776	5557	6777	3644	5895	5407	6084	6192	4154	6193	65085
	institutiona	1822	1461	1255	1643	2430	1130	2721	1725	1265	1273	679	1272	18675
	governme	4458	3051	1301	4842	5493	407	2524	2602	878	1139	1996	2616	31306
	<b>total</b>	<b>14835</b>	<b>12973</b>	<b>10174</b>	<b>15430</b>	<b>19552</b>	<b>8193</b>	<b>15470</b>	<b>13526</b>	<b>12019</b>	<b>12910</b>	<b>9705</b>	<b>13826</b>	<b>158613</b>
7.W/Minch	private	7703	9982	9915	9867	11770	11988	11584	12095	12259	11186	11009	11634	130990
	commerci	2885	4796	4754	5424	5965	4585	3915	3991	4038	3831	4022	4585	52791
	institutiona	4214	6326	6386	6307	9820	7033	5746	9377	8392	6668	6725	7040	84032
	governme	368	282	328	360	534	374	449	549	435	437	477	520	5113
	<b>total</b>	<b>15170</b>	<b>21385</b>	<b>21382</b>	<b>21958</b>	<b>28088</b>	<b>23980</b>	<b>21694</b>	<b>26012</b>	<b>25124</b>	<b>22122</b>	<b>22233</b>	<b>23779</b>	<b>272926</b>
8.Berea	private	2765	3677	3659	3355	4057	4700	3887	4456	3907	3460	3163	4810	45896
	commerci	1621	1979	1946	1999	2059	2052	1500	1867	1589	1461	2085	2759	22916
	institutiona	39	55	59	54	59	110	75	75	102	69	59	132	887
	governme	142	166	159	148	161	216	131	122	104	86	122	282	1839
	<b>total</b>	<b>4567</b>	<b>5876</b>	<b>5823</b>	<b>5556</b>	<b>6335</b>	<b>7077</b>	<b>5592</b>	<b>6520</b>	<b>5701</b>	<b>5077</b>	<b>5428</b>	<b>7983</b>	<b>71537</b>
9.Chamo	private	5361	6076	6149	6355	8229	8503	7212	7316	7171	7115	5582	6362	81430
	commerci	2459	2448	2491	2675	2851	2829	1987	2093	2001	1982	1617	2675	28107
	institutiona	920	1050	1288	1562	2315	2678	1670	1548	903	832	1398	1569	17732
	governme	137	122	81	88	181	252	151	115	91	116	135	147	1617
	<b>total</b>	<b>8878</b>	<b>9696</b>	<b>10008</b>	<b>10680</b>	<b>13576</b>	<b>14261</b>	<b>11019</b>	<b>11072</b>	<b>10167</b>	<b>10046</b>	<b>8732</b>	<b>10752</b>	<b>128886</b>
10.Doeysa	private	4946	4734	4246	4091	5795	5426	5856	5644	5485	4110	4197	4171	58701
	commerci	1701	1692	1870	1582	2158	1968	1790	1987	1757	1422	1699	1628	21254
	institutiona	300	331	274	657	380	408	303	282	277	186	210	161	3770
	industry	7	2	3	3	5	1	0	9	4	3	0	2	40
	governme	230	259	164	3986	7929	4357	7196	2422	4624	3421	4324	4183	43094
<b>total</b>	<b>7185</b>	<b>7018</b>	<b>6557</b>	<b>10319</b>	<b>16267</b>	<b>12161</b>	<b>15145</b>	<b>10344</b>	<b>12147</b>	<b>9142</b>	<b>10431</b>	<b>10145</b>	<b>126859</b>	
11.Difana	private	3946	4151	3330	3848	4092	4191	4589	3555	3726	3747	3024	4031	46230
	commerci	1364	1384	1367	1412	1967	1252	1854	2047	2228	1737	1827	2334	20773
	institutiona	72	75	219	844	1093	826	919	838	1041	146	444	701	7217
	industry	13	19	6	1	3	5	8	7	6	7	10	13	99
	governme	881	809	934	790	872	558	1121	895	1132	881	908	1189	10971
<b>total</b>	<b>6277</b>	<b>6438</b>	<b>5856</b>	<b>6895</b>	<b>8027</b>	<b>6832</b>	<b>8491</b>	<b>7343</b>	<b>8133</b>	<b>6519</b>	<b>6212</b>	<b>8268</b>	<b>85290</b>	
<b>TOTAL</b>		<b>75883</b>	<b>82756</b>	<b>79294</b>	<b>93668</b>	<b>112350</b>	<b>98413</b>	<b>100445</b>	<b>99277</b>	<b>95849</b>	<b>87809</b>	<b>83604</b>	<b>96250</b>	<b>1105598</b>

#### 4. Year 2014

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Tot
1.Kulfo	Private	3980	4264	3526	4512	3870	5550	5193	4658	4765	4393	4440	4524	53676
	commerci	1099	1026	1280	940	716	835	827	734	849	868	836	905	10915
	Institutional	57	45	38	56	51	121	69	60	83	55	102	104	842
	governme	113	85	118	74	63	131	13	39	41	53	64	60	854
	<b>Total</b>	<b>5249</b>	<b>5422</b>	<b>4961</b>	<b>5582</b>	<b>4700</b>	<b>6637</b>	<b>6102</b>	<b>5492</b>	<b>5737</b>	<b>5368</b>	<b>5443</b>	<b>5594</b>	<b>66287</b>
2.Gurba	Private	2144	2219	2472	2596	2319	3288	2523	3283	2237	2627	2137	2793	30638
	commerci	0	0	0	0	0	1	8	0	6	4	2	6	27
	Institutional	1108	938	1061	1115	569	1049	540	1056	760	1144	756	1168	11265
	governme	156	249	367	259	429	285	237	54	55	342	281	348	3062
	<b>Total</b>	<b>3407</b>	<b>3407</b>	<b>3901</b>	<b>3970</b>	<b>3316</b>	<b>4623</b>	<b>3308</b>	<b>4393</b>	<b>3058</b>	<b>4117</b>	<b>3176</b>	<b>4315</b>	<b>44992</b>
3.Menharia	Private	1351	1900	1853	2334	1979	3006	2347	2284	2566	2284	2060	2284	26249
	commerci	1373	1888	1991	2272	1536	2626	1741	1933	2108	1641	1879	1957	22946
	Institutional	24	1	3	203	265	246	119	290	198	188	130	160	1827
	governme	27	37	41	19	41	37	55	59	49	63	67	66	563
	<b>Total</b>	<b>2775</b>	<b>3826</b>	<b>3889</b>	<b>4828</b>	<b>3821</b>	<b>5916</b>	<b>4262</b>	<b>4567</b>	<b>4921</b>	<b>4176</b>	<b>4137</b>	<b>4468</b>	<b>51586</b>
4.Woze	Private	1743	1013	1198	1754	2864	2063	2594	2921	2498	2772	2081	1739	25241
	commerci	0	45	14	17	22	7	0	22	27	41	43	35	274
	Institutional	136	65	391	616	297	170	455	800	671	682	1159	616	6059
	governme	0	0	0	0	1	1	1	2	1	1	1	1	8
	<b>Total</b>	<b>1879</b>	<b>1123</b>	<b>1603</b>	<b>2387</b>	<b>3185</b>	<b>2242</b>	<b>3050</b>	<b>3746</b>	<b>3197</b>	<b>3495</b>	<b>3285</b>	<b>2390</b>	<b>31581</b>
5.Edgetber	Private	4477	4424	3936	4901	4416	5292	5057	5082	4545	3921	4051	3976	54079
	commerci	371	316	367	344	226	433	476	477	383	277	285	223	4180
	Institutional	594	628	608	551	604	466	513	422	455	384	242	281	5748
	governme	3	3	6	6	3	3	3	2	3	4	6	6	48
	<b>Total</b>	<b>5445</b>	<b>5372</b>	<b>4918</b>	<b>5801</b>	<b>5249</b>	<b>6195</b>	<b>6049</b>	<b>5983</b>	<b>5386</b>	<b>4586</b>	<b>4584</b>	<b>4486</b>	<b>64054</b>
6.M/ketema	Private	3368	3167	2809	3350	4796	2977	4282	3749	3748	4258	2844	3702	43050
	commerci	5089	5198	4722	5494	6700	3602	5827	5345	6014	6121	4106	6123	64342
	Institutional	1801	1445	1240	1624	2403	1117	2689	1705	1251	1258	671	1257	18462
	governme	4407	3016	1286	4786	5431	402	2495	2572	868	1126	1973	2586	30948
	<b>Total</b>	<b>14665</b>	<b>12825</b>	<b>10057</b>	<b>15254</b>	<b>19329</b>	<b>8099</b>	<b>15294</b>	<b>13372</b>	<b>11881</b>	<b>12763</b>	<b>9594</b>	<b>13668</b>	<b>156802</b>
7.W/Minch	Private	7615	9868	9801	9755	11635	11851	11452	11957	12119	11058	10883	11501	129495
	commerci	2852	4741	4700	5362	5897	4533	3870	3945	3992	3787	3976	4533	52188
	Institutional	4166	6253	6313	6235	9708	6952	5680	9270	8296	6592	6648	6959	83072
	governme	364	278	324	356	528	370	444	543	430	432	472	514	5054
	<b>Total</b>	<b>14996</b>	<b>21141</b>	<b>21138</b>	<b>21707</b>	<b>27767</b>	<b>23706</b>	<b>21446</b>	<b>25715</b>	<b>24838</b>	<b>21869</b>	<b>21979</b>	<b>23508</b>	<b>269809</b>
8.Berea	Private	2734	3635	3617	3317	4010	4646	3842	4405	3862	3421	3127	4756	45372
	commerci	1602	1956	1923	1977	2035	2028	1483	1846	1571	1444	2061	2728	22654
	Institutional	38	55	58	53	58	108	74	74	101	69	58	130	877
	governme	141	164	157	146	159	213	129	121	103	85	120	278	1818
	<b>Total</b>	<b>4515</b>	<b>5809</b>	<b>5756</b>	<b>5493</b>	<b>6263</b>	<b>6996</b>	<b>5529</b>	<b>6446</b>	<b>5636</b>	<b>5019</b>	<b>5366</b>	<b>7892</b>	<b>70720</b>
9.Chamo	Private	5300	6006	6079	6283	8135	8406	7129	7232	7090	7034	5518	6289	80500
	commerci	2431	2420	2462	2644	2818	2796	1964	2069	1979	1960	1599	2644	27786
	Institutional	910	1038	1273	1544	2289	2647	1650	1530	893	823	1382	1551	17530
	governme	136	121	80	87	179	249	149	114	90	115	134	145	1599
	<b>Total</b>	<b>8776</b>	<b>9585</b>	<b>9894</b>	<b>10558</b>	<b>13421</b>	<b>14099</b>	<b>10893</b>	<b>10945</b>	<b>10051</b>	<b>9931</b>	<b>8632</b>	<b>10629</b>	<b>127414</b>
10.Doeysa	Private	4890	4680	4198	4044	5729	5364	5790	5580	5422	4063	4149	4123	58031
	commerci	1682	1673	1848	1564	2133	1946	1769	1964	1737	1406	1680	1610	21011
	Institutional	297	327	271	650	376	404	299	279	274	184	208	159	3727
	Industry	7	2	3	3	5	1	0	9	4	3	0	2	39
	governme	227	256	162	3940	7839	4307	7113	2394	4571	3382	4275	4135	42602
<b>Total</b>	<b>7103</b>	<b>6938</b>	<b>6482</b>	<b>10201</b>	<b>16081</b>	<b>12022</b>	<b>14972</b>	<b>10226</b>	<b>12008</b>	<b>9037</b>	<b>10311</b>	<b>10029</b>	<b>125411</b>	
11.Difana	Private	3901	4103	3292	3804	4045	4143	4537	3514	3684	3705	2990	3985	45702
	commerci	1348	1368	1352	1396	1945	1238	1832	2024	2202	1718	1806	2307	20536
	Institutional	71	74	216	834	1080	816	908	828	1029	144	439	693	7134
	Industry	13	19	6	1	3	5	8	7	6	7	10	13	98
	governme	871	800	924	781	862	551	1108	885	1119	871	898	1175	10845
<b>Total</b>	<b>6205</b>	<b>6364</b>	<b>5790</b>	<b>6816</b>	<b>7935</b>	<b>6754</b>	<b>8394</b>	<b>7259</b>	<b>8040</b>	<b>6444</b>	<b>6142</b>	<b>8173</b>	<b>84316</b>	
<b>TOTAL</b>		<b>75016</b>	<b>81811</b>	<b>78389</b>	<b>92598</b>	<b>111067</b>	<b>97289</b>	<b>99298</b>	<b>98143</b>	<b>94754</b>	<b>86806</b>	<b>82650</b>	<b>95151</b>	<b>1092972</b>

## 5. Year 2015

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Tot
1. Kulfo	private	5266	5642	4665	5970	5120	7343	6871	6163	6305	5812	5874	5985	71017
	commerci	1454	1358	1693	1244	947	1104	1094	971	1123	1148	1106	1198	14441
	institutiona	76	60	51	74	68	160	92	80	109	72	135	138	1115
	governme	149	113	156	98	83	173	17	52	54	70	85	80	1129
	<b>total</b>	<b>6945</b>	<b>7173</b>	<b>6564</b>	<b>7386</b>	<b>6218</b>	<b>8781</b>	<b>8074</b>	<b>7266</b>	<b>7591</b>	<b>7103</b>	<b>7201</b>	<b>7401</b>	87702
2. Gurba	private	2836	2936	3270	3434	3068	4351	3338	4343	2959	3476	2828	3695	40536
	commerci	0	0	0	0	0	1	10	0	8	6	3	7	35
	institutiona	1465	1241	1404	1476	753	1388	715	1398	1005	1513	1001	1546	14904
	governme	206	330	486	343	567	378	314	71	73	453	371	460	4052
	<b>total</b>	<b>4508</b>	<b>4507</b>	<b>5161</b>	<b>5252</b>	<b>4388</b>	<b>6117</b>	<b>4377</b>	<b>5812</b>	<b>4046</b>	<b>5448</b>	<b>4203</b>	<b>5709</b>	59527
3. Menariya	private	1787	2513	2452	3088	2618	3978	3106	3022	3394	3022	2726	3022	34730
	commerci	1816	2498	2634	3007	2033	3475	2303	2558	2789	2171	2486	2589	30360
	institutiona	32	1	5	268	351	326	157	383	262	248	172	212	2418
	governme	35	49	55	25	55	49	73	79	65	83	89	88	744
	<b>total</b>	<b>3671</b>	<b>5062</b>	<b>5146</b>	<b>6388</b>	<b>5056</b>	<b>7828</b>	<b>5639</b>	<b>6042</b>	<b>6510</b>	<b>5524</b>	<b>5474</b>	<b>5911</b>	68251
4. Woze	private	2306	1340	1585	2321	3790	2730	3431	3865	3306	3668	2754	2300	33395
	commerci	0	59	19	23	29	9	1	30	36	54	57	46	362
	institutiona	181	86	517	815	393	225	602	1059	888	903	1534	815	8016
	governme	0	0	0	0	2	2	1	3	1	1	1	1	11
	<b>total</b>	<b>2486</b>	<b>1486</b>	<b>2121</b>	<b>3158</b>	<b>4214</b>	<b>2966</b>	<b>4035</b>	<b>4956</b>	<b>4230</b>	<b>4625</b>	<b>4346</b>	<b>3162</b>	41784
5. E/Ber	private	5923	5853	5208	6484	5843	7002	6691	6724	6013	5188	5360	5261	71550
	commerci	491	418	486	455	299	573	630	631	507	367	378	295	5531
	institutiona	786	831	804	729	799	617	679	558	602	508	320	372	7604
	governme	4	5	8	7	4	5	4	3	4	6	7	7	63
	<b>total</b>	<b>7204</b>	<b>7107</b>	<b>6507</b>	<b>7676</b>	<b>6944</b>	<b>8196</b>	<b>8003</b>	<b>7916</b>	<b>7126</b>	<b>6068</b>	<b>6065</b>	<b>5935</b>	84748
6. M/Ketema	private	4456	4190	3717	4432	6346	3939	5665	4961	4959	5634	3763	4898	56958
	commerci	6733	6877	6247	7268	8864	4766	7710	7072	7957	8099	5433	8101	85128
	institutiona	2383	1912	1641	2149	3179	1478	3558	2256	1655	1664	888	1663	24426
	governme	5831	3991	1701	6333	7185	532	3301	3403	1149	1489	2610	3421	40947
	<b>total</b>	<b>19403</b>	<b>16969</b>	<b>13307</b>	<b>20182</b>	<b>25574</b>	<b>10716</b>	<b>20234</b>	<b>17692</b>	<b>15720</b>	<b>16886</b>	<b>12694</b>	<b>18083</b>	207459
7. W/M/finch	private	10075	13056	12968	12906	15394	15679	15152	15820	16035	14630	14399	15216	171330
	commerci	3773	6272	6218	7094	7802	5997	5121	5220	5282	5011	5261	5997	69048
	institutiona	5512	8274	8352	8249	12844	9198	7516	12264	10976	8722	8796	9208	109910
	governme	481	368	429	471	698	490	587	718	569	571	624	680	6687
	<b>total</b>	<b>19841</b>	<b>27970</b>	<b>27967</b>	<b>28720</b>	<b>36737</b>	<b>31365</b>	<b>28375</b>	<b>34022</b>	<b>32862</b>	<b>28934</b>	<b>29079</b>	<b>31102</b>	356975
8. Berea	private	3617	4809	4786	4389	5306	6147	5084	5828	5110	4526	4137	6292	60029
	commerci	2120	2588	2545	2615	2693	2684	1962	2442	2078	1911	2727	3609	29973
	institutiona	51	72	77	70	77	143	98	98	133	91	77	172	1160
	governme	186	217	208	193	210	282	171	160	136	113	159	368	2405
	<b>total</b>	<b>5973</b>	<b>7686</b>	<b>7616</b>	<b>7268</b>	<b>8286</b>	<b>9257</b>	<b>7315</b>	<b>8528</b>	<b>7457</b>	<b>6640</b>	<b>7100</b>	<b>10442</b>	93567
9. Chamo	private	7012	7947	8042	8313	10763	11121	9433	9569	9380	9306	7301	8321	106507
	commerci	3217	3202	3257	3498	3729	3700	2598	2737	2618	2593	2115	3498	36762
	institutiona	1203	1373	1685	2043	3028	3503	2184	2024	1181	1089	1828	2052	23193
	governme	180	160	106	116	237	330	197	151	119	152	177	192	2115
	<b>total</b>	<b>11612</b>	<b>12682</b>	<b>13090</b>	<b>13969</b>	<b>17756</b>	<b>18653</b>	<b>14412</b>	<b>14481</b>	<b>13298</b>	<b>13139</b>	<b>11421</b>	<b>14063</b>	168578
10. Doeysa	private	6470	6192	5554	5350	7579	7097	7660	7382	7174	5375	5489	5455	76779
	commerci	2225	2213	2446	2069	2822	2574	2341	2598	2298	1860	2223	2130	27799
	institutiona	392	432	358	860	497	534	396	369	363	243	275	210	4931
	industry	9	3	4	4	6	2	0	12	6	4	0	3	52
	governme	301	339	215	5213	10371	5698	9411	3168	6047	4475	5656	5471	56366
<b>total</b>	<b>9398</b>	<b>9179</b>	<b>8576</b>	<b>13496</b>	<b>21277</b>	<b>15906</b>	<b>19809</b>	<b>13530</b>	<b>15887</b>	<b>11957</b>	<b>13643</b>	<b>13269</b>	165926	
11. Difaana	private	5162	5429	4355	5033	5352	5482	6002	4650	4874	4901	3955	5272	60467
	commerci	1784	1810	1788	1847	2573	1638	2424	2678	2914	2273	2389	3053	27171
	institutiona	94	98	286	1103	1429	1080	1202	1096	1362	191	580	917	9439
	industry	18	25	8	2	4	6	11	9	7	9	13	17	130
	governme	1152	1058	1222	1033	1140	729	1466	1171	1481	1152	1188	1555	14349
<b>total</b>	<b>8210</b>	<b>8420</b>	<b>7660</b>	<b>9018</b>	<b>10499</b>	<b>8936</b>	<b>11105</b>	<b>9604</b>	<b>10638</b>	<b>8526</b>	<b>8126</b>	<b>10814</b>	111556	
<b>TOTAL</b>		<b>99251</b>	<b>108241</b>	<b>103713</b>	<b>122513</b>	<b>146949</b>	<b>128720</b>	<b>131378</b>	<b>129850</b>	<b>125366</b>	<b>114850</b>	<b>109351</b>	<b>125891</b>	<b>1446072</b>

## 6. Year 2016

kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Tot
1.Kulfo	private	4887	5236	4329	5540	4751	6815	6377	5719	5851	5394	5451	5554	65904
	commerci	1350	1260	1571	1155	879	1025	1015	901	1042	1065	1027	1112	13401
	institutiona	70	56	47	69	63	149	85	74	101	67	125	128	1034
	governme	138	105	144	91	77	161	15	48	50	65	79	74	1048
	<b>total</b>	<b>6445</b>	<b>6657</b>	<b>6091</b>	<b>6854</b>	<b>5770</b>	<b>8149</b>	<b>7492</b>	<b>6743</b>	<b>7044</b>	<b>6591</b>	<b>6682</b>	<b>6868</b>	<b>81387</b>
2.Gurba	private	2632	2725	3035	3187	2847	4037	3098	4031	2746	3226	2624	3429	37617
	commerci	0	0	0	0	0	1	9	0	8	5	3	7	33
	institutiona	1360	1152	1303	1369	698	1288	663	1297	933	1405	929	1435	13831
	governme	192	306	451	318	527	350	291	66	68	420	344	427	3760
	<b>total</b>	<b>4183</b>	<b>4183</b>	<b>4789</b>	<b>4874</b>	<b>4072</b>	<b>5676</b>	<b>4061</b>	<b>5394</b>	<b>3755</b>	<b>5055</b>	<b>3900</b>	<b>5298</b>	<b>55241</b>
3.Menariya	private	1659	2332	2276	2866	2429	3691	2882	2805	3150	2805	2530	2805	32229
	commerci	1685	2319	2445	2790	1886	3225	2137	2373	2588	2014	2307	2403	28174
	institutiona	30	1	4	249	326	302	146	356	243	230	160	197	2244
	governme	33	46	51	23	51	46	68	73	60	77	82	82	691
	<b>total</b>	<b>3407</b>	<b>4697</b>	<b>4775</b>	<b>5928</b>	<b>4692</b>	<b>7264</b>	<b>5233</b>	<b>5607</b>	<b>6042</b>	<b>5127</b>	<b>5079</b>	<b>5486</b>	<b>63337</b>
4.Woze	private	2140	1244	1471	2154	3517	2533	3184	3586	3068	3403	2556	2135	30990
	commerci	0	55	17	21	27	9	1	27	34	50	53	43	336
	institutiona	168	80	480	756	365	209	558	983	824	838	1423	756	7439
	governme	0	0	0	0	2	2	1	3	1	1	1	1	10
	<b>total</b>	<b>2307</b>	<b>1379</b>	<b>1968</b>	<b>2930</b>	<b>3910</b>	<b>2752</b>	<b>3744</b>	<b>4599</b>	<b>3926</b>	<b>4292</b>	<b>4033</b>	<b>2934</b>	<b>38776</b>
5.E/Ber	private	5497	5432	4833	6017	5422	6498	6209	6240	5580	4814	4974	4882	66398
	commerci	455	388	451	423	277	532	585	586	471	340	350	274	5133
	institutiona	729	771	746	676	741	572	630	518	558	472	297	345	7057
	governme	3	4	8	7	3	4	3	3	3	5	7	7	58
	<b>total</b>	<b>6685</b>	<b>6596</b>	<b>6038</b>	<b>7123</b>	<b>6444</b>	<b>7606</b>	<b>7427</b>	<b>7346</b>	<b>6613</b>	<b>5631</b>	<b>5628</b>	<b>5508</b>	<b>78646</b>
6.M/Ketama	private	4135	3888	3449	4113	5889	3655	5257	4604	4602	5228	3492	4545	52857
	commerci	6249	6382	5798	6745	8226	4423	7155	6563	7384	7516	5042	7517	78999
	institutiona	2211	1774	1523	1994	2950	1372	3302	2093	1536	1545	824	1544	22667
	governme	5411	3703	1579	5877	6668	494	3063	3158	1066	1382	2422	3175	37998
	<b>total</b>	<b>18006</b>	<b>15747</b>	<b>12349</b>	<b>18729</b>	<b>23732</b>	<b>9944</b>	<b>18777</b>	<b>16418</b>	<b>14588</b>	<b>15670</b>	<b>11780</b>	<b>16781</b>	<b>192521</b>
7.W/Minch	private	9350	12116	12034	11977	14286	14550	14061	14681	14880	13577	13362	14121	158993
	commerci	3501	5821	5770	6584	7240	5566	4752	4844	4902	4650	4882	5566	64077
	institutiona	5115	7678	7751	7655	11919	8536	6974	11381	10185	8094	8162	8545	101996
	governme	447	342	398	437	648	454	545	667	528	530	579	631	6206
	<b>total</b>	<b>18412</b>	<b>25956</b>	<b>25953</b>	<b>26652</b>	<b>34092</b>	<b>29106</b>	<b>26332</b>	<b>31573</b>	<b>30495</b>	<b>26851</b>	<b>26985</b>	<b>28862</b>	<b>331271</b>
8.Berea	private	3356	4463	4441	4073	4924	5705	4718	5408	4742	4200	3839	5839	55707
	commerci	1967	2402	2361	2427	2499	2490	1820	2266	1929	1773	2531	3349	27814
	institutiona	47	67	71	65	71	133	91	91	124	84	71	160	1076
	governme	173	201	193	180	195	262	159	149	126	105	148	342	2232
	<b>total</b>	<b>5543</b>	<b>7133</b>	<b>7067</b>	<b>6744</b>	<b>7689</b>	<b>8590</b>	<b>6788</b>	<b>7914</b>	<b>6920</b>	<b>6162</b>	<b>6589</b>	<b>9690</b>	<b>86830</b>
9.Chamo	private	6507	7375	7463	7714	9988	10320	8753	8880	8705	8636	6775	7722	98838
	commerci	2985	2971	3023	3246	3460	3434	2411	2540	2429	2406	1963	3246	34115
	institutiona	1117	1274	1563	1896	2810	3251	2026	1879	1096	1010	1697	1904	21523
	governme	167	149	98	107	220	306	183	140	111	141	164	178	1963
	<b>total</b>	<b>10776</b>	<b>11769</b>	<b>12148</b>	<b>12964</b>	<b>16478</b>	<b>17310</b>	<b>13374</b>	<b>13439</b>	<b>12341</b>	<b>12193</b>	<b>10599</b>	<b>13050</b>	<b>156439</b>
10.Doeysa	private	6004	5746	5154	4965	7034	6586	7108	6851	6657	4988	5094	5062	71250
	commerci	2065	2054	2270	1920	2619	2389	2172	2411	2132	1726	2063	1977	25797
	institutiona	364	401	332	798	461	496	368	343	337	226	255	195	4576
	industry	9	3	3	3	6	2	0	11	5	3	0	3	48
	governme	279	314	199	4838	9625	5288	8734	2940	5612	4153	5249	5077	52307
	<b>total</b>	<b>8721</b>	<b>8518</b>	<b>7959</b>	<b>12525</b>	<b>19745</b>	<b>14761</b>	<b>18382</b>	<b>12556</b>	<b>14743</b>	<b>11096</b>	<b>12660</b>	<b>12313</b>	<b>153979</b>
11.Difana	private	4790	5038	4042	4671	4967	5087	5570	4315	4523	4549	3671	4892	56113
	commerci	1655	1679	1660	1714	2388	1520	2250	2485	2704	2109	2217	2833	25214
	institutiona	88	91	265	1024	1326	1002	1115	1017	1264	177	539	851	8759
	industry	16	23	8	2	3	6	10	9	7	9	12	15	120
	governme	1069	982	1134	959	1058	677	1361	1087	1374	1069	1102	1443	13316
	<b>total</b>	<b>7619</b>	<b>7814</b>	<b>7108</b>	<b>8369</b>	<b>9743</b>	<b>8292</b>	<b>10306</b>	<b>8912</b>	<b>9872</b>	<b>7912</b>	<b>7541</b>	<b>10035</b>	<b>103523</b>
<b>TOTAL</b>		<b>92105</b>	<b>100447</b>	<b>96245</b>	<b>113692</b>	<b>136368</b>	<b>119451</b>	<b>121918</b>	<b>120500</b>	<b>116339</b>	<b>106580</b>	<b>101477</b>	<b>116826</b>	<b>1341948</b>

## 7. Year 2017

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	tot
1. Kullo	private	5949	6374	5270	6744	5784	8296	7763	6963	7123	6566	6636	6762	80229
	commerci	1643	1534	1913	1405	1070	1248	1236	1097	1268	1297	1250	1353	16314
	institutiona	86	68	58	84	76	181	104	90	123	82	153	156	1259
	governme	168	128	176	111	94	196	19	59	61	79	96	90	1276
	<b>Total</b>	<b>7846</b>	<b>8103</b>	<b>7415</b>	<b>8344</b>	<b>7024</b>	<b>9920</b>	<b>9121</b>	<b>8208</b>	<b>8575</b>	<b>8024</b>	<b>8135</b>	<b>8361</b>	<b>99077</b>
2. Gurba	private	3204	3317	3695	3880	3466	4915	3771	4907	3343	3927	3195	4175	45793
	commerci	0	0	0	0	0	1	12	0	9	6	3	8	40
	institutiona	1655	1402	1586	1667	850	1568	807	1579	1136	1710	1130	1746	16838
	governme	233	372	549	387	641	427	355	81	83	511	419	520	4577
	<b>Total</b>	<b>5093</b>	<b>5092</b>	<b>5830</b>	<b>5934</b>	<b>4957</b>	<b>6910</b>	<b>4944</b>	<b>6566</b>	<b>4571</b>	<b>6154</b>	<b>4748</b>	<b>6449</b>	<b>67248</b>
3. Menharia	private	2019	2839	2770	3489	2957	4494	3508	3414	3835	3414	3080	3414	39234
	commerci	2052	2822	2976	3397	2296	3926	2602	2889	3151	2452	2809	2925	34297
	institutiona	37	1	5	303	396	368	178	433	296	280	195	239	2731
	governme	40	55	62	28	62	55	83	89	73	94	100	99	841
	<b>Total</b>	<b>4147</b>	<b>5718</b>	<b>5813</b>	<b>7217</b>	<b>5712</b>	<b>8843</b>	<b>6371</b>	<b>6826</b>	<b>7355</b>	<b>6241</b>	<b>6183</b>	<b>6678</b>	<b>77104</b>
4. Woze	private	2605	1514	1790	2622	4281	3084	3877	4366	3734	4143	3111	2599	37726
	commerci	0	67	21	25	32	10	1	33	41	61	65	52	409
	institutiona	204	97	585	920	444	254	680	1196	1003	1020	1733	920	9056
	governme	0	0	0	0	2	2	1	3	1	1	1	1	13
	<b>Total</b>	<b>2809</b>	<b>1678</b>	<b>2396</b>	<b>3567</b>	<b>4760</b>	<b>3351</b>	<b>4558</b>	<b>5599</b>	<b>4779</b>	<b>5225</b>	<b>4910</b>	<b>3572</b>	<b>47204</b>
5. E/Ber	private	6692	6612	5883	7325	6601	7910	7559	7596	6793	5860	6055	5943	80830
	commerci	554	473	549	515	338	647	712	713	573	414	427	334	6248
	institutiona	888	939	909	823	902	696	767	631	680	574	362	420	8591
	governme	4	5	9	8	4	5	4	3	4	6	8	8	71
	<b>total</b>	<b>8138</b>	<b>8029</b>	<b>7351</b>	<b>8671</b>	<b>7845</b>	<b>9259</b>	<b>9042</b>	<b>8943</b>	<b>8050</b>	<b>6855</b>	<b>6852</b>	<b>6705</b>	<b>95740</b>
6. M/Ketema	private	5034	4733	4199	5007	7169	4450	6400	5604	5602	6364	4251	5533	64346
	commerci	7607	7769	7058	8211	10014	5385	8710	7989	8989	9149	6137	9151	96170
	institutiona	2692	2159	1854	2427	3591	1670	4020	2548	1870	1880	1003	1879	27594
	governme	6587	4508	1922	7154	8117	601	3729	3844	1298	1683	2949	3865	46258
	<b>total</b>	<b>21920</b>	<b>19170</b>	<b>15033</b>	<b>22799</b>	<b>28891</b>	<b>12106</b>	<b>22859</b>	<b>19986</b>	<b>17759</b>	<b>19076</b>	<b>14340</b>	<b>20429</b>	<b>234367</b>
7. W/Minch	private	11382	14749	14650	14580	17391	17713	17117	17872	18114	16528	16267	17190	193552
	commerci	4262	7086	7024	8015	8814	6775	5785	5897	5967	5661	5943	6775	78004
	institutiona	6226	9347	9436	9319	14510	10392	8490	13855	12399	9853	9937	10402	124166
	governme	544	416	484	532	788	553	663	811	643	645	705	769	7554
	<b>total</b>	<b>22415</b>	<b>31598</b>	<b>31594</b>	<b>32445</b>	<b>41503</b>	<b>35433</b>	<b>32055</b>	<b>38435</b>	<b>37124</b>	<b>32687</b>	<b>32851</b>	<b>35136</b>	<b>403276</b>
8. Berea	private	4086	5433	5407	4958	5994	6945	5743	6584	5773	5113	4673	7108	67816
	commerci	2395	2924	2875	2954	3042	3032	2216	2759	2348	2158	3081	4077	33860
	institutiona	58	82	87	79	87	162	111	111	151	102	87	195	1310
	governme	210	245	235	219	237	319	193	181	154	128	180	416	2717
	<b>total</b>	<b>6748</b>	<b>8683</b>	<b>8603</b>	<b>8210</b>	<b>9360</b>	<b>10457</b>	<b>8263</b>	<b>9634</b>	<b>8425</b>	<b>7501</b>	<b>8021</b>	<b>11796</b>	<b>105703</b>
9. Chamo	private	7922	8978	9085	9391	12159	12564	10656	10810	10597	10513	8248	9400	120321
	commerci	3634	3617	3680	3952	4212	4180	2935	3092	2957	2929	2390	3952	41531
	institutiona	1359	1551	1903	2308	3421	3957	2467	2287	1334	1230	2065	2318	26201
	governme	203	181	119	131	268	372	223	170	135	172	200	216	2390
	<b>total</b>	<b>13118</b>	<b>14327</b>	<b>14788</b>	<b>15781</b>	<b>20059</b>	<b>21073</b>	<b>16281</b>	<b>16360</b>	<b>15023</b>	<b>14843</b>	<b>12902</b>	<b>15887</b>	<b>190443</b>
10. Doeysa	private	7309	6995	6274	6044	8563	8018	8654	8340	8105	6073	6201	6163	86737
	commerci	2514	2500	2763	2337	3188	2908	2645	2935	2596	2101	2511	2406	31405
	institutiona	443	488	405	971	562	603	448	417	410	275	311	237	5571
	industry	10	3	4	4	7	2	0	14	6	4	0	3	59
	governme	340	383	243	5890	11717	6438	10632	3579	6832	5055	6390	6180	63677
	<b>total</b>	<b>10616</b>	<b>10370</b>	<b>9689</b>	<b>15247</b>	<b>24036</b>	<b>17969</b>	<b>22378</b>	<b>15285</b>	<b>17948</b>	<b>13508</b>	<b>15412</b>	<b>14990</b>	<b>187448</b>
11. Difaana	private	5831	6133	4920	5686	6047	6193	6781	5253	5506	5537	4468	5956	68310
	commerci	2015	2044	2020	2086	2907	1850	2739	3025	3292	2567	2699	3449	30695
	institutiona	107	111	323	1247	1615	1220	1357	1238	1538	215	656	1036	10663
	industry	20	28	9	2	4	7	13	10	8	10	15	19	146
	governme	1302	1195	1380	1167	1288	824	1656	1323	1673	1302	1342	1757	16210
	total	9275	9512	8654	10188	11861	10095	12546	10850	12018	9632	9180	12216	126025
	<b>TOTAL</b>		<b>112125</b>	<b>122280</b>	<b>117165</b>	<b>138404</b>	<b>166009</b>	<b>145415</b>	<b>148418</b>	<b>146692</b>	<b>141626</b>	<b>129747</b>	<b>123534</b>	<b>142219</b>

## 8. Year 2018

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	tot
1. Kullo	private	5689	6095	5039	6449	5531	7933	7423	6658	6811	6279	6346	6466	76719
	commerci	1571	1467	1829	1344	1023	1193	1182	1049	1213	1240	1195	1294	15600
	institutiona	82	65	55	80	73	173	99	86	118	78	146	149	1204
	governme	161	122	168	106	90	187	18	56	58	76	92	86	1220
	<b>total</b>	<b>7503</b>	<b>7749</b>	<b>7091</b>	<b>7979</b>	<b>6717</b>	<b>9486</b>	<b>8722</b>	<b>7849</b>	<b>8200</b>	<b>7673</b>	<b>7779</b>	<b>7995</b>	<b>94743</b>
2. Gurba	private	3064	3172	3533	3710	3314	4700	3606	4692	3197	3755	3055	3992	43790
	Commercial					0	1	11	0	9	6	3	8	38
	institutiona	1583	1341	1517	1594	813	1499	772	1510	1086	1635	1081	1670	16101
	governme	223	356	525	370	613	408	339	77	79	489	401	497	4377
	<b>total</b>	<b>4870</b>	<b>4869</b>	<b>5575</b>	<b>5674</b>	<b>4740</b>	<b>6608</b>	<b>4728</b>	<b>6279</b>	<b>4371</b>	<b>5885</b>	<b>4540</b>	<b>6167</b>	<b>64306</b>
3. Menharia	private	1931	2715	2649	3336	2828	4297	3355	3265	3667	3265	2945	3265	37518
	commerci	1962	2699	2846	3248	2196	3754	2488	2763	3013	2345	2686	2797	32797
	institutiona	35	1	5	290	379	352	170	414	283	268	186	229	2612
	governme	38	53	59	27	59	53	79	85	70	90	96	95	804
	<b>total</b>	<b>3966</b>	<b>5468</b>	<b>5559</b>	<b>6901</b>	<b>5462</b>	<b>8456</b>	<b>6092</b>	<b>6527</b>	<b>7033</b>	<b>5968</b>	<b>5913</b>	<b>6386</b>	<b>73731</b>
4. Woze	private	2491	1448	1712	2507	4094	2949	3707	4175	3571	3962	2975	2485	36076
	commerci	0	64	20	10	31	10	15	32	39	58	62	50	391
	institutiona	195	93	559	880	425	243	650	1144	959	975	1657	880	8660
	governme	0	0	0	0	2	2	1	3	1	1	1	1	12
	<b>total</b>	<b>2686</b>	<b>1605</b>	<b>2291</b>	<b>3397</b>	<b>4552</b>	<b>3204</b>	<b>4373</b>	<b>5354</b>	<b>4570</b>	<b>4996</b>	<b>4695</b>	<b>3416</b>	<b>45139</b>
5. E/Ber	private	6399	6323	5626	7005	6312	7564	7228	7264	6496	5604	5790	5683	77294
	commerci	530	452	525	492	323	619	681	682	548	396	408	319	5975
	institutiona	849	898	869	787	863	666	733	603	650	549	346	402	8215
	governme	4	5	9	8	4	5	4	3	4	6	8	8	68
	<b>total</b>	<b>7782</b>	<b>7678</b>	<b>7029</b>	<b>8292</b>	<b>7502</b>	<b>8854</b>	<b>8646</b>	<b>8552</b>	<b>7698</b>	<b>6555</b>	<b>6552</b>	<b>6412</b>	<b>91552</b>
6. M/Ketema	private	4814	4526	4015	4788	6855	4255	6120	5359	5357	6086	4065	5291	61531
	commerci	7274	7429	6749	7852	9576	5149	8329	7640	8596	8749	5869	8751	91963
	institutiona	2574	2065	1773	2321	3434	1597	3844	2437	1788	1798	959	1797	26387
	governme	6299	4311	1838	6841	7762	575	3566	3676	1241	1609	2820	3696	44234
	<b>total</b>	<b>20961</b>	<b>18331</b>	<b>14375</b>	<b>21802</b>	<b>27627</b>	<b>11576</b>	<b>21859</b>	<b>19112</b>	<b>16982</b>	<b>18242</b>	<b>13713</b>	<b>19535</b>	<b>224115</b>
7. W/Minch	private	10884	14104	14009	13942	16630	16938	16368	17090	17322	15805	15555	16438	185085
	commerci	4076	6776	6717	7664	8428	6479	5532	5639	5706	5413	5683	6479	74592
	institutiona	5954	8938	9023	8911	13875	9937	8119	13249	11857	9422	9502	9947	118734
	governme	520	398	463	509	754	529	634	776	615	617	674	735	7224
	<b>total</b>	<b>21434</b>	<b>30216</b>	<b>30212</b>	<b>31026</b>	<b>39687</b>	<b>33883</b>	<b>30653</b>	<b>36754</b>	<b>35500</b>	<b>31257</b>	<b>31414</b>	<b>33599</b>	<b>385635</b>
8. Berea	private	3907	5195	5170	4741	5732	6641	5492	6296	5520	4889	4469	6797	64849
	commerci	2290	2796	2749	2825	2909	2899	2119	2638	2245	2064	2946	3899	32379
	institutiona	55	78	83	76	83	155	106	106	144	98	83	186	1253
	governme	201	234	225	209	227	305	185	173	147	122	172	398	2598
	<b>total</b>	<b>6453</b>	<b>8303</b>	<b>8227</b>	<b>7851</b>	<b>8951</b>	<b>10000</b>	<b>7902</b>	<b>9213</b>	<b>8056</b>	<b>7173</b>	<b>7670</b>	<b>11280</b>	<b>101079</b>
9. Chamo	private	7575	8585	8688	8980	11627	12014	10190	10337	10133	10053	7887	8989	115058
	commerci	3475	3459	3519	3779	4028	3997	2807	2957	2828	2801	2285	3779	39714
	institutiona	1300	1483	1820	2207	3271	3784	2359	2187	1276	1176	1975	2217	25055
	governme	194	173	114	125	256	356	213	163	129	164	191	207	2285
	<b>total</b>	<b>12544</b>	<b>13700</b>	<b>14141</b>	<b>15091</b>	<b>19182</b>	<b>20151</b>	<b>15569</b>	<b>15644</b>	<b>14366</b>	<b>14194</b>	<b>12338</b>	<b>15192</b>	<b>182112</b>
10. Doeysa	private	6989	6689	6000	5780	8188	7667	8275	7975	7750	5807	5930	5893	82943
	commerci	2404	2391	2642	2235	3049	2781	2529	2807	2482	2009	2401	2301	30031
	institutiona	424	467	387	929	537	577	428	399	392	263	297	227	5327
	industry	10	3	4	4	7	2	0	13	6	4	0	3	56
	governme	325	366	232	5632	11204	6156	10167	3422	6533	4834	6110	5910	60891
	<b>total</b>	<b>10152</b>	<b>9916</b>	<b>9265</b>	<b>14580</b>	<b>22985</b>	<b>17183</b>	<b>21399</b>	<b>14616</b>	<b>17163</b>	<b>12917</b>	<b>14738</b>	<b>14334</b>	<b>179248</b>
11. Dillana	private	5576	5865	4705	5437	5782	5922	6484	5023	5265	5295	4273	5695	65322
	commerci	1927	1955	1932	1995	2780	1769	2619	2893	3148	2455	2581	3298	29352
	institutiona	102	106	309	1192	1544	1167	1298	1184	1471	206	627	991	10197
	industry	19	27	9	2	4	7	12	10	8	10	14	18	140
	governme	1245	1143	1320	1116	1232	788	1584	1265	1600	1245	1283	1680	15501
	<b>total</b>	<b>8869</b>	<b>9096</b>	<b>8275</b>	<b>9742</b>	<b>11342</b>	<b>9653</b>	<b>11997</b>	<b>10375</b>	<b>11492</b>	<b>9211</b>	<b>8778</b>	<b>11682</b>	<b>120512</b>
<b>TOTAL</b>		<b>107220</b>	<b>116931</b>	<b>112040</b>	<b>132335</b>	<b>158747</b>	<b>139054</b>	<b>141940</b>	<b>140275</b>	<b>135431</b>	<b>124071</b>	<b>118130</b>	<b>135998</b>	<b>1562172</b>

## 9. Year 2019

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Tot
1. Kullo	private	5741	6120	5091	6501	5583	7985	7466	6710	6863	6331	6398	6518	77334
	commerci	1590	1486	1848	1363	1042	1212	1201	1068	1232	1259	1214	1313	15828
	institutiona	87	70	60	85	78	178	104	91	123	83	151	154	1264
	governme	170	131	177	115	99	196	27	65	67	85	101	95	1328
	<b>total</b>	<b>7588</b>	<b>7807</b>	<b>7176</b>	<b>8064</b>	<b>6802</b>	<b>9571</b>	<b>8798</b>	<b>7934</b>	<b>8285</b>	<b>7731</b>	<b>7864</b>	<b>8080</b>	<b>95754</b>
2. Gurba	private	3140	3247	3609	3785	3390	4771	3672	4767	3265	3884	3126	4000	44656
	Commerci					0	5	21	0	17	27	8	18	96
	institutiona	1590	1348	1524	1594	820	1507	780	1518	1096	1646	1092	1682	16197
	governme	234	367	536	370	624	418	349	87	87	496	408	503	4479
	<b>total</b>	<b>4964</b>	<b>4962</b>	<b>5669</b>	<b>5749</b>	<b>4834</b>	<b>6701</b>	<b>4822</b>	<b>6372</b>	<b>4465</b>	<b>6053</b>	<b>4634</b>	<b>6203</b>	<b>65428</b>
3. Menharia	private	2004	2788	2722	3409	2901	4370	3428	3338	3731	3338	3018	3338	38385
	commerci	2030	2767	2914	3316	2264	3822	2556	2831	3081	2413	2754	2865	33613
	institutiona	66	15	20	321	410	383	201	445	314	299	217	260	2951
	governme	52	84	89	41	73	67	93	99	84	104	110	109	1005
	<b>total</b>	<b>4152</b>	<b>5654</b>	<b>5745</b>	<b>7087</b>	<b>5648</b>	<b>8642</b>	<b>6278</b>	<b>6713</b>	<b>7210</b>	<b>6154</b>	<b>6099</b>	<b>6572</b>	<b>75954</b>
4. Woze	private	2540	1496	1760	2554	4142	2997	3754	4223	3619	4010	3023	2533	36651
	commerci	9	74	30	21	40	20	26	42	49	68	73	59	511
	institutiona	223	122	587	910	453	271	676	1172	987	1003	1684	908	8996
	governme	6	5	6	4	8	9	7	9	8	6	7	8	82
	<b>total</b>	<b>2778</b>	<b>1697</b>	<b>2383</b>	<b>3489</b>	<b>4643</b>	<b>3297</b>	<b>4371</b>	<b>5446</b>	<b>4663</b>	<b>5087</b>	<b>4787</b>	<b>3508</b>	<b>46240</b>
5. E/Ber	private	6459	6383	5686	7065	6371	7624	7288	7324	6556	5664	5850	5743	78013
	commerci	542	464	537	504	335	631	693	694	560	408	420	331	6119
	institutiona	865	914	885	803	879	682	747	619	664	564	361	418	8401
	governme	10	11	15	14	11	11	12	9	10	13	15	14	145
	<b>total</b>	<b>7876</b>	<b>7772</b>	<b>7123</b>	<b>8386</b>	<b>7596</b>	<b>8948</b>	<b>8740</b>	<b>8646</b>	<b>7780</b>	<b>6555</b>	<b>6552</b>	<b>6412</b>	<b>92678</b>
6. M/Ketema	private	5064	4776	4265	5038	7105	4505	6375	5609	5607	6336	4315	5541	64535
	commerci	7674	7829	7149	8252	9976	5549	8729	8040	8996	9149	6269	9151	96763
	institutiona	2676	2167	1875	2423	3536	1699	3946	2539	1890	1900	1061	1899	27611
	governme	6474	4486	2013	7016	7937	750	3741	3851	1416	1784	2995	3871	46334
	<b>total</b>	<b>21888</b>	<b>19258</b>	<b>15302</b>	<b>22729</b>	<b>28554</b>	<b>12503</b>	<b>22791</b>	<b>20039</b>	<b>17909</b>	<b>19169</b>	<b>14640</b>	<b>20462</b>	<b>235243</b>
7. W/Minch	private	11369	14589	14494	14427	17115	17423	16852	17575	17807	16290	16040	16915	190896
	commerci	4278	6978	6919	7866	8630	6681	5734	5841	5908	5615	5885	6681	77016
	institutiona	6257	9241	9326	9214	14177	10240	8422	13552	12160	9725	9805	10250	122369
	governme	540	418	483	529	775	549	654	796	635	637	694	755	7465
	<b>total</b>	<b>22444</b>	<b>31226</b>	<b>31222</b>	<b>32036</b>	<b>40697</b>	<b>34893</b>	<b>31662</b>	<b>37764</b>	<b>36510</b>	<b>32267</b>	<b>32424</b>	<b>34617</b>	<b>397762</b>
8. Berea	private	4853	6141	6116	5687	6678	7587	6438	7246	6466	5835	5415	7743	76206
	commerci	2763	3269	3222	3298	3382	3372	2592	3111	2718	2537	3419	4372	38055
	institutiona	76	99	104	97	105	176	127	126	165	119	104	207	1505
	governme	240	273	264	248	265	344	224	213	186	161	211	437	3066
	<b>total</b>	<b>7932</b>	<b>9782</b>	<b>9706</b>	<b>9330</b>	<b>10430</b>	<b>11479</b>	<b>9381</b>	<b>10696</b>	<b>9535</b>	<b>8652</b>	<b>9149</b>	<b>12759</b>	<b>118832</b>
9. Chamo	private	8159	9169	9272	9564	12211	12598	10774	10921	10717	10634	8471	9573	122063
	commerci	3679	3663	3723	3983	4232	4201	3011	3161	3032	3005	2489	3983	42162
	institutiona	1427	1610	1947	2334	3398	3911	2486	2314	1403	1303	2102	2344	26579
	governme	206	195	126	137	268	368	225	175	141	176	203	219	2439
	<b>total</b>	<b>13471</b>	<b>14637</b>	<b>15068</b>	<b>16018</b>	<b>20109</b>	<b>21078</b>	<b>16496</b>	<b>16571</b>	<b>15293</b>	<b>15118</b>	<b>13265</b>	<b>16119</b>	<b>193243</b>
10. Doeysa	private	7376	7076	6387	6167	8575	8054	8662	8362	8137	6194	6318	6280	87588
	commerci	2545	2532	2783	2376	3190	2922	2670	2948	2623	2150	2542	2442	31723
	institutiona	449	492	412	954	562	602	453	424	417	288	322	252	5627
	industry	14	8	8	9	11	6	4	18	10	9	3	7	116
	governme	611	651	518	5901	11490	6442	10453	3707	6819	5120	6396	6196	64304
	<b>total</b>	<b>10995</b>	<b>10759</b>	<b>10108</b>	<b>15408</b>	<b>23828</b>	<b>18026</b>	<b>22242</b>	<b>15459</b>	<b>18006</b>	<b>13761</b>	<b>15581</b>	<b>15177</b>	<b>189358</b>
11. Dillana	private	6481	6770	5609	6341	6682	6822	7384	5923	6165	6195	5173	6595	76140
	commerci	2327	2355	2332	2395	3180	2169	3019	3293	3548	2855	2981	3698	34152
	institutiona	242	246	449	1332	1684	1307	1438	1324	1611	346	767	1131	11877
	industry	24	32	14	10	12	15	20	18	16	18	22	26	227
	governme	1461	1359	1536	1335	1451	1007	1803	1484	1819	1464	1502	1899	18120
	<b>total</b>	<b>10535</b>	<b>10762</b>	<b>9932</b>	<b>11405</b>	<b>13009</b>	<b>11320</b>	<b>13664</b>	<b>12042</b>	<b>13159</b>	<b>10878</b>	<b>10445</b>	<b>13349</b>	<b>140516</b>
<b>TOTAL</b>		<b>114623</b>	<b>124316</b>	<b>119434</b>	<b>139701</b>	<b>166150</b>	<b>146458</b>	<b>149245</b>	<b>147682</b>	<b>142815</b>	<b>131425</b>	<b>125440</b>	<b>143258</b>	<b>1651008</b>

## 10. Year 2020

Kebele		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	tot
1. Kullo	private	5647	6026	4997	6407	5489	7891	7372	6641	6769	6237	6304	6424	76204
	commerci	1569	1466	1827	1343	1022	1193	1181	1048	1212	1238	1194	1293	15586
	institutiona	83	65	56	80	73	174	99	86	118	77	146	150	1207
	governme	167	128	174	111	96	194	24	61	63	82	98	91	1289
	<b>total</b>	<b>7466</b>	<b>7685</b>	<b>7054</b>	<b>7941</b>	<b>6680</b>	<b>9452</b>	<b>8676</b>	<b>7836</b>	<b>8162</b>	<b>7634</b>	<b>7742</b>	<b>7958</b>	<b>94286</b>
2. Gurba	private	2939	3048	3410	3585	3190	4568	3470	4560	3066	3685	2927	3801	42249
	Commerci	4	3	4	5	6	7	15	7	13	26	5	13	108
	institutiona	1472	1278	1454	1523	750	1431	711	1449	1026	1575	1020	1612	15301
	governme	214	348	516	351	604	397	327	65	68	476	389	482	4237
	<b>total</b>	<b>4329</b>	<b>4677</b>	<b>5384</b>	<b>5464</b>	<b>4550</b>	<b>6403</b>	<b>4523</b>	<b>6081</b>	<b>4173</b>	<b>5762</b>	<b>4341</b>	<b>5908</b>	<b>61895</b>
3. Menharia	private	1899	2683	2617	3304	2796	4265	3323	3233	3626	3233	2913	3234	37126
	commerci	1937	2674	2821	3223	2171	3721	2463	2738	2988	2320	2661	2771	32488
	institutiona	57	7	12	312	400	374	192	436	306	290	208	251	2845
	governme	48	80	84	37	70	64	89	95	79	100	106	105	957
	<b>total</b>	<b>3941</b>	<b>5444</b>	<b>5534</b>	<b>6876</b>	<b>5437</b>	<b>8424</b>	<b>6067</b>	<b>6502</b>	<b>6999</b>	<b>5943</b>	<b>5888</b>	<b>6361</b>	<b>73416</b>
4. Woze	private	2407	1362	1628	2421	4009	2864	3621	4090	3486	3877	2890	2400	35055
	commerci	5	70	25	17	36	16	22	38	45	64	69	55	462
	institutiona	191	90	555	872	421	239	644	1140	955	971	1652	876	8606
	governme	4	4	4	2	6	7	5	7	6	4	5	6	60
	<b>total</b>	<b>2607</b>	<b>1526</b>	<b>2212</b>	<b>3312</b>	<b>4472</b>	<b>3126</b>	<b>4292</b>	<b>5275</b>	<b>4492</b>	<b>4916</b>	<b>4616</b>	<b>3337</b>	<b>44183</b>
5. E/Ber	private	6313	6245	5548	6927	6233	7486	7150	7186	6418	5526	5712	5605	76349
	commerci	531	453	526	493	324	620	682	683	549	397	409	320	5987
	institutiona	850	899	870	788	864	667	732	604	649	549	346	403	8221
	governme	7	8	12	11	7	8	9	6	7	10	12	11	108
	<b>total</b>	<b>7701</b>	<b>7605</b>	<b>1461</b>	<b>8219</b>	<b>7428</b>	<b>8781</b>	<b>8573</b>	<b>8479</b>	<b>7623</b>	<b>6482</b>	<b>6479</b>	<b>6339</b>	<b>90665</b>
6. M/Ketema	private	4286	3998	3483	4260	6327	3727	5597	4831	4829	5558	3537	4763	55196
	commerci	6506	6661	5981	7084	8808	4381	7561	6872	7828	7981	5101	7983	82747
	institutiona	2344	1835	1543	2091	3204	1367	3614	2207	1558	1568	729	1567	23627
	governme	5916	3928	1455	6458	7379	192	3183	3293	858	1226	2437	3313	39638
	<b>total</b>	<b>19052</b>	<b>16422</b>	<b>12462</b>	<b>19893</b>	<b>25718</b>	<b>9667</b>	<b>19955</b>	<b>17203</b>	<b>15073</b>	<b>16333</b>	<b>11804</b>	<b>17626</b>	<b>201208</b>
7. W/Minch	private	9961	13181	13086	13019	15707	16027	15444	16167	16399	14882	14632	15507	174012
	commerci	3709	6409	6350	7297	8061	6112	5165	5272	5339	5046	5316	6112	70188
	institutiona	5355	8339	8424	8312	13275	9338	7520	12650	11258	8823	8903	9348	111545
	governme	486	364	429	475	721	495	600	742	581	583	640	701	6817
	<b>total</b>	<b>19511</b>	<b>28293</b>	<b>28289</b>	<b>29103</b>	<b>37764</b>	<b>31972</b>	<b>28729</b>	<b>34831</b>	<b>33577</b>	<b>29334</b>	<b>29491</b>	<b>31668</b>	<b>362562</b>
8. Berea	private	3677	4965	4940	4511	5502	6411	5262	6070	5293	4659	4239	6567	62096
	commerci	2177	2683	2636	2712	2796	2786	2006	2525	2132	1951	2833	3786	31023
	institutiona	54	77	82	75	83	154	105	104	143	97	82	185	1241
	governme	192	225	216	200	217	296	176	165	138	113	163	389	2490
	<b>total</b>	<b>6100</b>	<b>7950</b>	<b>7874</b>	<b>7498</b>	<b>8598</b>	<b>9647</b>	<b>7549</b>	<b>8864</b>	<b>7706</b>	<b>6820</b>	<b>7317</b>	<b>10927</b>	<b>96850</b>
9. Chamo	private	7112	8122	8225	8517	11164	11551	9727	9874	9670	9587	7424	8526	109499
	commerci	3318	3302	3362	3622	3871	3840	2650	2800	2671	2644	2121	3622	37823
	institutiona	1200	1383	1720	2107	3171	3684	2259	2087	1176	1076	1875	2117	23855
	governme	185	174	105	116	247	347	204	154	120	155	182	198	2187
	<b>total</b>	<b>11815</b>	<b>12981</b>	<b>13412</b>	<b>14362</b>	<b>18453</b>	<b>19422</b>	<b>14840</b>	<b>14915</b>	<b>13637</b>	<b>13462</b>	<b>11602</b>	<b>14463</b>	<b>173364</b>
10. Doeysa	private	6240	5940	5251	5031	7439	6918	7526	7226	7001	5058	5182	5144	73956
	commerci	2132	2119	2370	1963	2777	2509	2257	2535	2210	1737	2129	2029	26767
	institutiona	374	417	337	879	487	527	378	349	342	213	247	177	4727
	industry	12	6	5	7	9	4	2	15	8	7	2	5	82
	governme	403	412	354	5062	10270	5222	9233	2868	5599	4281	5276	5266	54246
	<b>total</b>	<b>9161</b>	<b>8894</b>	<b>8317</b>	<b>12942</b>	<b>20982</b>	<b>15180</b>	<b>19396</b>	<b>12993</b>	<b>15160</b>	<b>11296</b>	<b>12836</b>	<b>12621</b>	<b>159778</b>
11. Dillana	private	5399	5688	4527	5259	5600	5740	6302	4841	5083	5113	4091	5513	63156
	commerci	1841	1867	1844	1907	2692	1681	2531	2805	3060	2367	2493	3210	28298
	institutiona	73	77	280	1163	1515	1138	1260	1155	1442	177	598	962	9840
	industry	19	29	11	7	9	12	17	15	13	15	19	23	189
	governme	1201	1099	1276	1075	1191	747	1543	1224	1559	1204	1242	1639	15000
	<b>total</b>	<b>8506</b>	<b>8760</b>	<b>7938</b>	<b>9411</b>	<b>11007</b>	<b>9318</b>	<b>11653</b>	<b>10040</b>	<b>11157</b>	<b>8876</b>	<b>8443</b>	<b>11347</b>	<b>116483</b>
<b>TOTAL</b>		<b>100189</b>	<b>110237</b>	<b>99937</b>	<b>125021</b>	<b>151089</b>	<b>131392</b>	<b>134253</b>	<b>133019</b>	<b>127759</b>	<b>116858</b>	<b>110559</b>	<b>128555</b>	<b>1474690</b>

### Appendix C: Water usage category data

No.	Category	Woze	Kulfo	Dilfana	Menhar ia	Gurba	Edget ber	M/kete ma	W/Min c	Bere	Doysa	Chamo
1	Commercial	56394.05	16397.73	56889.23	22194.5		18888.79	127327	320623	94143	155516	153431
2	Administrative	3200.66	6812.67	2842.15	3846.01	37145	2208.79	36646.99	0	0	0	0
3	Industry	12820.16	18508.11	438754.56	0	168614.4	1251.68	24734.03	19753.48	0	0	0
4	Service	2726214	39209	482810.00		153156	165160	538917	772873	66431	95351	43552
5	Road&tran st.											
6	Green	10683.78	56247.63	1177.29	0	8353.29	4361.07	0	49115.66	0	0	7436.17
7	Forest	126144.5	140281.56	0.00	0	319542.7	135973.8	0	0	0	0	43929
8	Specialfunc .	22619										
9	Agriculture		227287.2	310655.52		2021910						
10	Residence	365758	471723	175159.00	194438	231036	570044	239985	791593	380686	493270	566354
	Total(m2)	3323834.15	976466.9	1468287.75	220478.51	2939757	897888.1	967610	1953958	541260	744137	814702.2

### Appendix D: Water production data

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Water production (m <sup>3</sup> /year)	1394686	1636120	1625879	1681495	1954151	1890068	2237856	2264017	2425762	2494537