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

ASSESMENT OF EMDIBIR TOWN WATRE SUPPLY SYSTEM IN CHEHA WOREDA, GURAGE ZONE, SNNPR, ETHIOPIA

Thesis on the Degree of Master of Science in Civil and Environmental Engineering

(Major in Water Supply and Environmental Engineering)

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In

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Approved By Board of Examiners

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ABSTRACT

Urban water supply and consumption challenges are the widespread problems in most of the developing countries such as Ethiopia. The thesis paper focused on the water supply system of Emdibir town, capital city of Cheha Woreda Guraghe zone of Southern Nation Nationality People Regional State of Ethiopia.

The main objective of this study was to assess the water supply systems of Emdibir town and to suggest some remedial measure. The water supply coverage has been evaluated by depending on the amount of water production and consumption rate.

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

The analysis result has confirmed that the current water supply coverage of the town is 63.3 % of maximum daily demand. The current average per capita water production is 24.71/c/day. From one year production and consumption data the average loss become 21.4%. There are aged pipes, oversized and undersized pipes, high pressures and low pressure, high gap between demand and supply, pump capacity problem in the system.

The study concluded that the total water demand and the current level of water supply service in the town are not adequate.

Therefore, taking these challenges into consideration, it was suggested that providing alternative water sources, active involvement of the communities and participation of different actors and other sustainable approaches would prove to be an effective and efficient adaptive measures.

Key words: - Water demand, Non-revenue water and Water GEMS model.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADD	Average day demand
DCI	Ductile Cast Iron
DI	Ductile iron
ETWSE	Emdibir Town Water Supply Enterprise
GI	Galvanized Iron
HDPE	High-Density Polyethylene
IWA	International Water Association
JMP	Joint Monitoring Programme for WASH
Km	Kilometer
L/c/d	Liter per capita per day
L/s	Litter Per second
LHD	Low Hour Demand
M/s	Meter per second
MDD	Maximum Day Demand
MDG	Millennium Development Goal
MOFED	Ministry of Finance and Economic Development
MWoR	Ministry of Water Resource
NRW	Non-Revenue Water
O&M	Operation and Maintenance
OWNP	One WASH National Program
PHD	Peak Hour Demand
PRV	Pressure Reduce Valve
PVC	Polyvinyl Chloride
PVC	Poly Vinyl Chloride
SDG	Sustainable Development Goal
UAP	Universal Access Program
UFW	Unaccounted For Water
UNDP	United Nations Development Program
UNICEF	United Nations Children’s Emergency Fund
WASH	Water Supply Sanitation and Hygiene..
WHO	World Health Organization

WSS	Water Supply and Sanitation
WSSP	Water Supply and Sanitation Program

Chapter One

1. Introduction

1.1. Background

Water is one of the most important basic needs to humanity all over the world. Many countries in both the developed and developing world faced significant problems in maintaining reliable water supplies. In fact, as like oxygen, water is a decisive factor for the existence of human life. Water is available in various forms such as rivers, lake, spring, streams etc. Potable and enough quantity of water are very essential for all living things. Getting enough demand of water may start from individual household up to the whole community. Access to and use of safe drinking water can make an immense contribution to health, productivity and social development.

At the beginning of the new millennium (2000), world leaders gathered vision to fight poverty in its many dimensions. That vision, which was translated into eight Millennium Development Goals (MDGs), has remained the overarching development framework for the world for the past 15 years. The MDGs put particular emphasis on the importance of improved coverage of water and sanitation supply and have a global target to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation by the year 2015. A good water supply system should fulfill two primary requirements; adequacy and reliability. Budget constraints, low revenues and shortfalls in operation and maintenance have resulted in insufficient expansion of the system and gradual degradation of the service; at the same time the water demands increased and scarcity worsened (Hickey, 2016).

According to WHO 2015, 75 L of drinking water per day is necessary to be able to prevent household disease and also 50 L a day for basic parent's sanitation (Abeje et al., 2015). Estimate reveals that about 52% of the population in Ethiopia traveled half an hour or more to collect water every day (Central Statistical Agency - CSA, 2014). This long travel distance to the nearest water source directly affects women and children who are mainly responsible for fetching water. Most girls and children find it too difficult to attend and succeed in school because a considerable amount of their time is used for domestic chores including fetching water. The challenges facing many countries in the world today in their struggle for economic and social development is increasingly related to water.

Ethiopia is one of the member countries that have adopted the Millennium Development Goals (MDG) declarations with its main objective towards poverty reduction (UNDP, 2008). As a part of the Universal Access Program (UAP), the water supply and sanitation program was ratified by the Ethiopian Parliament in 2005. These initiatives laid the framework for planning the Water Sanitation and Hygiene measures (WASH). The MDG target was to attain 70% of National Potable Water Access in 2015 whereas, the UAP national targets was to attain 98% of Rural Potable Water Access within 1.5Kms (15Liters/Capita/Day) and 100% of Urban Potable Water Access within 0.5Km (20Liters/Capita/Day) by the end of 2012 (MoWR, 2006).

Rapid urbanization in Ethiopia is leading to overcrowding, development of slums and informal settlements. They in turn inhibit the increase in the nature of challenges that affect effective urban water supply and consumption systems. Ethiopia is one of sub-Saharan countries with low water supply coverage. According to MoWR Annual report (2015), water supply coverage of country is 46.39% for rural population and 82.02% in urban area and overall water supply coverage of the country is 52.46% in 2014/15. Access to safe drinking water supplies and sanitation services in Ethiopia are among the lowest in Sub-Saharan Africa. According to Edward (2016), major problems of water supply in urban centers of Ethiopia include low production levels, inadequate distribution systems and leakages in many areas.

There are serious constraints in meeting the challenge to provide adequate water sustainably for all urban residents in Ethiopia. Moreover, due to insufficient structures coupled with rapid population growth and urbanization, the gap between demand and supply of water continues to widen. The situation in the study area is not different from such realities. Unreliability, non-functionality and non-sustainable nature makes the existing service level in different parts of Ethiopia is lesser than the required levels.

The Ethiopian government's efforts on implementing a water sector development program are based on the national resource management policy. At the regional level, the water resource bureau is engaged in planning, distributing, operating, maintenance, monitoring, and evaluating urban water supply and sanitation projects. Initially, there were scattered efforts in water supply and sanitation to improve the provision of clean and adequate water supply and sanitation facilities, yet their coverage remains low and inadequate (Emdibir Town Water Supply Enterprise).

Emdibir is the administrative center of Cheha woreda, and the city consists of governmental and non-governmental organization office, different institution, public and private health center and several commercial and institutional companies (Emdibir Town Administration - ETA, 2017). The water supply system of Emdibir town established first in 1986 when a borehole was drilled in the town and connected to elevated masonry tank. The system then went under expansion at different times mainly for the source development. However, due to different factors the water supply shortage becomes serious problem for the population of the town yet. Emdibir town water supply service enterprise (ETWSSE) showed that to solve the problem of Emdibir town water supply system, the regional government at the year 1985 implemented a project by developing “Bojebar” large spring which is located at 8km away from the town. The spring has a potential of 55 lit/sec. These project aims to supply water for Emdibir town and rural community living along the pipe line from the source to the town and that would satisfy the demand of the targeted beneficiaries and raise the water supply service level from 80% to 100% until the end of design period.

Even if the project planned to solve the problem permanently, after implementation, some technical and management problems came out. Sound knowledge about the Availability of sources, Treatment facilities, Supply systems, Distribution mechanisms, Demands and Consumption systems is very much important in studies pertaining(right) to water supply. This attempt identifies the root causes and the major challenges of water supply and consumption systems. The studies conducted at national level, indicated that the challenges of water supply varied from place to place based on residence and consumption. There were no previous studies done in Emdibir town in this regard. Therefore, the present study was intended to assess the magnitude of water supply and its consumption system. The challenges that are being faced by the community of the town and service providers will be addressed. The research would bridge the existing research gap and helps to plan or replicate the findings for sustainable development of urban water supply and consumption system in other parts of the country.

1.2. Statement of the problem

Ethiopia has untapped water resources, like major river basins, large lakes, and numerous wells and springs. Tapping the water resources is a challenge, due to constraints like financial and technical reasons. The rapid urban growth and spatial expansion of cities and towns in Ethiopia resulted undesirable consequences on the already slim WSS[1] infrastructure. The operation system and maintenance of their service levels complicated the problem even more. Water supply system in Emdibir town has not been able to provide and sustain adequate drinking water services to the people. The main problem is lack of sustainable access to improved water supply service for the people in an efficient manner. A large proportion of population does not have access to improved services and those with access are concerned with the quality of services such as water quality, adequacy, and reliability.

The people of Emdibir were fetching water from the nearby rivers, streams and traditional wells. The problem of water supply in Emdibir town is not only adequacy and quality but also it has the problem of distribution and reliability. As the entire town water network system are interconnected to each other without separating which system is serving which area and how much water is distributed to which area, this makes difficult the identification and the distribution of water losses at different spatial location. The current water supply system does not have sufficient capacity to cope with the demands. The communal standpipes in the area do not receive water for longer period. There is always a regular breakdown of electric engine that is used to pump water. One of the major challenges in this area is infrastructure failure and the municipality does not have staff capacity or financial resources to

[1] *WSS (water supply and sanitation).*

implement such systems quickly, hence the majority of residents do not have access to safe water and sanitation services. The failure by the municipality to extend water and sanitation services to villagers put people at risk. The villages are forced to use open sources water from rivers and hand dug wells which often has serious consequences to health and hygiene.

In the past, different organizations and individual researchers have illustrated only the coverage indicators of water supply in terms of population and its poor quality during the periods of their study. However, the outcomes of their research haven't indicated reasons for the inadequate production of the water, the less coverage, the limited consumption and fairness of the tariff structure set by Board. Moreover, they didn't investigate the prevalence of further demand and the possibility of willingness to pay; the challenging problems that encountered the community due to poor functioning of the water supply system.

1.3. Objective of the study

1. 3.1. General objective

- The main objective of the study is to assess the water supply system of Emdibir town.

1.3.2. Specific Objectives

The specific objectives of the study are:-

- To evaluate and compare the total demand and supply of exiting system.
- To identify water loss problem in the existing pipe system.
- To suggest the remedial solution for the problems.

1.4. Research Question

1. How much is the current status of water supply and demand of the town?
2. What is the level of water connection and per capita water production of the town?
3. How is the level of scheme management?
4. What are the solutions to satisfy the demand?

1.5. Significance of the Study

Studying the extent, coverage and dynamics of urban water supply service helps to identify the pressing problems in service delivery. This study is expected to increase the knowledge and up to date information on the city water supply size and its undesirable impacts on the urban community due to shortage of water supply. It is expected to increase the knowledge and up to date information on urban water supply systems and its adverse impacts on the urban population. It will also serve as a working document to policy makers in the water sector, the Non-Governmental Organizations (NGOs), the community and environmental advocates. The study will add literature to the existing knowledge.

1.6. Scope of the study

This research mainly focused on water supply problems level in Emdibir town. The town was selected due its fast growing nature and there were no adequate research so far conducted on water supply in the area. I have been personally observed many water and sanitation problems in the town. Furthermore, the study also emphasized on the administrative issues like accessibility, affordability, distribution problems, the cause and the consequence of inadequate water supply. It does not include the aspects of water supply which are outside of the researcher objective. Due to some major challenges associated with the collection of the data, the study was exposed for some limitations. The first limitation of the study was associated with availability of sufficient information regarding to the study area water supply distribution system network condition which has been designed for town. Secondly the study suffers from lack of sufficient secondary data related with urban water supply design due the inadequacy of works regarding the study area and the poor documentation of the water supply authority offices.

1.7. The thesis content

This research paper has totally five chapters. Chapter one is about background, statement of problems, research objective and research questions. And chapter two is discussed about literature review related to demand, supply and water supply systems. Also chapter three is discussed about the method the data collection and preparation. And also chapter four is discussed about water supply coverage, demand projection, water loss analysis and hydraulic model analysis and results. Finally chapter five is about conclusion and recommendation.

Chapter two

2. Literature review

2.1. Introduction

Water is crucial for human survival and economic development. The provision of adequate supply of potable water in urban areas in both developed and developing countries is essential for life. In relation to this, Alebel.K (2014), provision of adequate potable water in developing countries in addition to drinking, cleaning etc… improves health by reducing causes of water related illnesses such as diarrhea, cholera, and the like. This also helps to reduce both the mortality and morbidity rates and the number of working days lost. The developing cities have great difficulty in both technical and financial capacity to develop and expand water supply projects. One of the difficulties among the other is imbalance between demand and supply, losses of water by various ways in all level of the distribution system and poor management of the scheme. As a result the distribution of water among the available resource becomes unsatisfactory. Because of the poor management, the existing infrastructure asset increases the level of losses in the water supply and results demand gap. As this research deals with imbalance between demand and supply, bursting and leakage problem of pipe system and hydraulic modeling issues related will be reviewed in this chapter.

Evidence from empirical research (Vasquez et al., 2015) indicates that improved water supply schemes in many developing countries are not functioning properly. There have been similar studies carried out in some of Ethiopian towns. Generally, the studies revealed that the water demand is more than the supply. For instance, Tizazu (2013) at Yirgalem town showed that, water supply service could not meet water demands of the town with existing capacity. Challa (2014) and Reda (2014) reported that there is low water coverage and frequent interruption. To expand water supply to urban areas, implementing proper demand management strategies is required. Pertinent information on the residential water demand of households is necessary to properly assess the factors that affect residential water demand.

As stated by WHO & UNICEF (2008) the world's population is projected to expand to nine billion people by 2050. It was approximated that 90% of the additional 3 billion people will be living in various developing countries, which are already experiencing severe water scarcity. Approximations demonstrated that by 2030, 75 to 250 million people in Africa only would be experiencing water shortage. Millennium Development Goal-VII aims to raise access to secure water, in order to achieve this, water supplies should reach an included 1.5 billion people by 2015.Some notable achievement in the MDG were, the increase of population from 4.1 billion in 1990 to 5.3billion in 2004 with access to water from improved sources (International Journal of Creative Research Thoughts (IJCRT) www.ijcrt.org Volume 6, Issue 2 April 2018).

Mushir (2012) carried out studies on water supply and consumption relating to home functions, in Nekemate Town, Ethiopia. In this investigation, it was found that the economic backwardness and topographical features of the land determined the supply of water for consumption in the study area. The study revealed that amount of income; working conditions and education were indicators and influenced the water consumption in the town. Mekonnen and R.Uttama (2014) studied on the assessment of potable water supply in Awaday town, Ethiopia. The study indicated that, inadequate water supply, poor standards and absence of correct allocation were caused due to high interruptions in electric power supply and administration problems. In this study, it was felt that, the causes and effects of water interruptions were necessary for a better understanding.

Kebede (2015) studied on the urban water supply system in Hosanna town, Ethiopia. The objective of this study was to assess the household water supply problems by using descriptive survey research design. The results showed that the major factors attributed to lower supply of water were, shortage of water provision, high cost of piped water connection, rapid population growth, frequent interruption and lack of narrowing gap between communities. It was concluded that majority of the dwellers preferred to use alternative sources, which have seriously contributed to water supply problems. Yehuala Minwuye (2015) conducted studies on assessing the potable water supply and distribution problems in Rebugebeya town, Ethiopia

2.2. Water demand and coverage

2.2.1. General

According to UNICEF (2006), every person needs 20 to 50 liters of potable water a day for their basic needs: drinking, cooking and cleaning, but more than one in six does not have access to such amount of potable water. Africa has the lowest total water supply coverage of any region, with only 62 percent of the population having access to improved water supply. The situation is worst in rural areas, where coverage is only 47 percent. According to the JMP (2010), around 2.6 billion people do not have access to basic sanitation; and as a result of poor access to basic sanitation 1.5 million peoples die each year. Many of these people live in south East Asia and sub-Saharan Africa.

Sanitation coverage in Africa also is poor, only 60 percent of the total population in Africa has sanitation coverage, with coverage varying from 84 percent in urban areas to 45 percent in rural areas (JMP, 2010). More than 768 million people worldwide, most of them in developing countries are lacking access to any form of improved water supply sources within one kilometer of their home (WHO and UNICEF, 2013). Lack of access to safe and adequate water supplies contributes to ongoing poverty through the economic costs of poor health and time and energy expended in fetching water. The importance of adequate quantity of water for human health has been considerable. However, guidance on the minimum household water requirement to assure good health is lacking.

Therefore, it is important to keep in mind when ensuring that adequate quantities of domestic supply are available for these purposes and in interpreting and applying minimum values (WHO, 2003). WHO in its drinking water quality guideline defines domestic water as ‘water used for all usual domestic purposes including consumption, bathing and food preparation'(WHO, 2003). Therefore, the requirements with regard to the adequacy of water supply apply across all these uses and not only in relation to consumption of water. This definition provides an overall framework for domestic water usage in terms of quality requirement.

According to the millennium development goal, drinking water target; to halve the proportion of the population without sustainable access to safe drinking water (an increase in coverage from 76% to 88%) between 1990 and 2015. Between 1990 and 2012, 2.3 billion people gained access to an improved drinking water source, raising global coverage to 89% in 2012. In a further 35 countries, 26 of which are in sub Saharan Africa, coverage of improved drinking water supply was between 50% and 75%. Between 1990 and 2012, 2.3 billion people gained access to an improved drinking water source: 1.6 billion gained access to a piped supply on premises, and 700 million gained access to an improved supply, which could range from a public tap to a hand pump, protected dug well or protected spring.

Despite this progress, 748 million people still do not use improved sources of drinking water, 43% of whom live in Africa.” The problem of inadequate access to water and sanitation exists in both rural and urban areas, the problem is particularly pressing in cities. With internal migration and the “urbanization of poverty,” cities are where an increasing proportion of the poor live. In the last three decades, growth in urban populations in developing countries exceeded or more that of rural areas three times more, (UNICEF, 2014). The water, sanitation and hygiene infrastructure of many cities is therefore stressed beyond current capacity and infrastructure investments have not kept pace with rapid and unplanned urbanization. The solutions necessarily require clever innovations in design of contracts, pricing policies, and market development (Majer.B, 2015).

2.2.3. Water demand and supply

A municipal water supply system has the objective of providing an adequate and reliable water supply to meet the following demands: residential; commercial; industrial; municipal and educational building use; include parks and recreation, street cleaning, decorative water fountains, etc.

Types of water transmission or distribution system

Usually, treated water is conveyed to service reservoirs for distribution to consumers. In urban systems, a water transmission system may also be necessary to convey water from a treatment plant to a number of service reservoirs located at different convenient points in the city. In some cities, there may be a number of sources and water treatment plants supplying service reservoirs and water distribution systems. These distribution systems may be separate or linked. Both water transmission systems and water distribution systems are networks of pipes. However, water transmission systems have a tree-like configuration, whereas water distribution systems usually have loops. Sometimes, supply of water from the clear water tank at the treatment plant to various service reservoirs is by gravity. Often, treated water is either pumped directly to various reservoirs or pumped to a main balancing reservoir, which, in turn, supplies water to various service reservoirs by gravity. Such systems are termed complete gravity, direct pumping and combined gravity and pumping systems, respectively.

Components of water transmission or distribution systems

Water distribution systems contain several components. Each network is unique in source, layout, topography of the service area, pipe material, valves and meters, and consumer connections. The description of the system should be as detailed as possible and include at least the location of major transmission and distribution mains, storages, secondary treatment devices (e.g. booster disinfection), pumps, valves and other fittings. A small distribution system may have a single source node, such as an elevated service reservoir or pumping arrangement directly supplying water from the sump (underground storage) at the treatment plant to the network. A large network, however, may have several source nodes –service and balancing reservoirs and pumping stations.

The layout of a distribution network depends on the existing pattern of streets and highways, existing and planned subdivision of the service area, possible sites for ground and elevated service reservoirs, and location and density of demand centers. The topography of the service area may be flat or uneven. Booster pumps necessary for pumping water to high areas within the network. Similarly, it may be necessary to provide pressure-reducing valves for areas with lower elevation to reduce pressure. Check-valves may also be necessary to maintain flow in the selected direction and restrict flow from the opposite direction. Pipes in the distribution network may be of cast or ductile iron, mild steel, concrete, polyvinyl chloride (PVC) and high-density polyethylene.

Valves are provided in distribution systems to control flow, isolate pipelines during repairs and replacement, drain pipelines during cleaning, reduce pressure, maintain flow in selected directions, allow air to enter pipelines while emptying, and release air at higher points and during filling. Meters are provided to measure flows of water from the source, transfer of water between zones and the supply of water to consumers. Hydrants with single or multiple outlets are provided in the network to supply water for fire extinguishing purposes.

2.3. Water supply service

Water services focus on the delivery of water to people. It can be defined as the quantity of water of a given quality accessible by users and the system used to deliver water. In practice, the two (service and system) are often closely related. According to Moriarty et al (2011) there is critical difference between system and service. For example, a borehole and hand pump operated at the village level provides one type of service while a professionally managed network of household taps another. However, engineers and planners focus on systems and lose the objectives to be achieved by providing new water supply infrastructure. Coverage is often calculated by counting the number of systems implemented without considering whether they are in fact providing the planned level of service (Moriarty et al, 2011). `

2.4. Productive water uses and domestic water quantity

Generally adequate and safe water supply should be assured for basic consumption (drinking and cooking), hygiene and household productive uses in order to achieve health benefits that could be obtained from water supply. The quantity of water that households collect and use is primarily dependent on accessibility though cost and system reliability may also have significant influences. Health benefits gained from water supply are more dependent not on the quantities of water rather on the level of service which in turn inform the likely volume of water that can be collected and used. Maximum health benefits are ensured from proper water usage and good hygiene behaviors and simple provision of infrastructure alone is unlikely to maximize health gains (WHO, 2003).

2.5. The water supply and demand situation of the world

Recently thought the global use of improved water sources showed progress from time to time but still 605 million people don't have access to safe drinking water which clearly shows the pressure of the population growth (WHO, 2014). Besides the population pressure of the globe, the water supply and demand gap are worsted by various factors of inequitable distribution of water rights, economy and resource availabilities. The world's water security situation is basically influenced by two grand driving forces: pressure on the supply of water and pressure on the demand for water. Pressures on water supply include; impact of climate change, multinational use of water basins and aquifers, poor water supply infrastructure and intermittency are just only listing some of the major once. On the other hand pressured on the demand side includes; population growth and distribution, changes in diet and industry are the prime challenges for the spontaneous increment of water demand of the world today.

According to the WHO and UNICEF report, in 2012,89% of the world's population used drinking water from improved sources (54% from a piped connection in their dwelling(home), plot or yard, and 35% from other improved drinking water sources), leaving 780 million people lacking access to an improved source of water (WHO/UNICEF, 2012). The world meets the United Nations' Millennium Development Goal (MDG) drinking water target to halve the proportion of people without sustainable access to safe drinking water by 2015, 5 years ahead of schedule (WHO/UNICEF, 2012). More than 2 billion people gained access to improved water sources from 1990 to 2010. However if trends continue, 605 million people lives without an improved drinking water source in 2015 (WHO/UNICEF, 2012). Access to safe drinking water is measured by the percentage of the population having access to and using improved drinking water sources.

2.6. Status report on drinking water supply and sanitation

2.6.1. Global drinking water and sanitation situation report 2013

Universally, safe drinking water and sanitation have been recognized as essential bloodlines for human life, dignity and poverty eradication. Globally, MDG has set common ground to improve human development through the attainment of 88% and75% goal targets by 2015 for improved drinking water and sanitation respectively (Blok land, 2014). Since 1990, about 1.9 billion people relied on improved sanitation facility globally. Towards the end of 2011, however, about 2.5 billion people still patronize unimproved sanitation facilities whereas one (1) billions of this population practiced open defecation as depicted by Figure (WHO/UNICEF, 2013). From 1990-2011, massive MDG sanitation coverage for about 636million people was achieved in Eastern Asia compare to Sub-Sahara Africa where heavy reliance on open defecation is still on the increase(WHO/UNICEF, 2013). It became worrisome that, Sub-Sahara Africa has done little to pull the world from 2011 global off-track position of 64% sanitation coverage compare to 75% MDG sanitation target expected by 2015.

2.6.2. Water sources and sanitation classifications

Water for drinking purpose can be found from natural sources like surface water, ground water and rain water. Water from all these sources to use for household activities need treatment based up on their impurities. Though the treatment and the degree of cleanness of the water make the water safe or unsafe to drink, WHO and UNICEF classified water sources as improved and unimproved based on their purity to drink. Table below elaborates about the improved and unimproved water sources.

Table 1: Definition of Improved and Unimproved water and sanitation

Water supply		sanitation	
Improved	**Unimproved**	**Improved**	**Unimproved**
Piped household water connection	Unprotected well	Connection to a public sewer	Connection to a public latrine
Public standpipe	Unprotected dug well	Connection to a septic system	Public latrines
Borehole	Unprotected spring	Pour-flush latrine	Latrines with an open pit
Protected dug well	Surface water (river, dam, lake, pond, stream, canal, irrigation channel)	Simple pit latrine	-
Protected spring	Vendor-provided water (cart with small tank/drum, tanker truck)	Ventilated improved pit latrine	-
Rainwater collection	Bottled water*		-

Source: JMP, 2006. (* Bottled water is not considered improved due to limitations in the potential quantity not quality of the water)

Table 2: Improved and unimproved water supply sources coverage in Ethiopia

Water sources	**Urban (%)**	**Rural (%)**
Household connection	61.6	3.0
Public stand post/pipe	33.2	20.9
Protected spring or dud well	1.2	11
Collected rain water	0.0	0.3
Unprotected spring or dug well	1.5	31.7
Directly used from Pond water	2.0	28.6
Provided by tanker	0.0	0.0
Protected borehole or tube well	0.5	4.5
Total	**100**	**100**

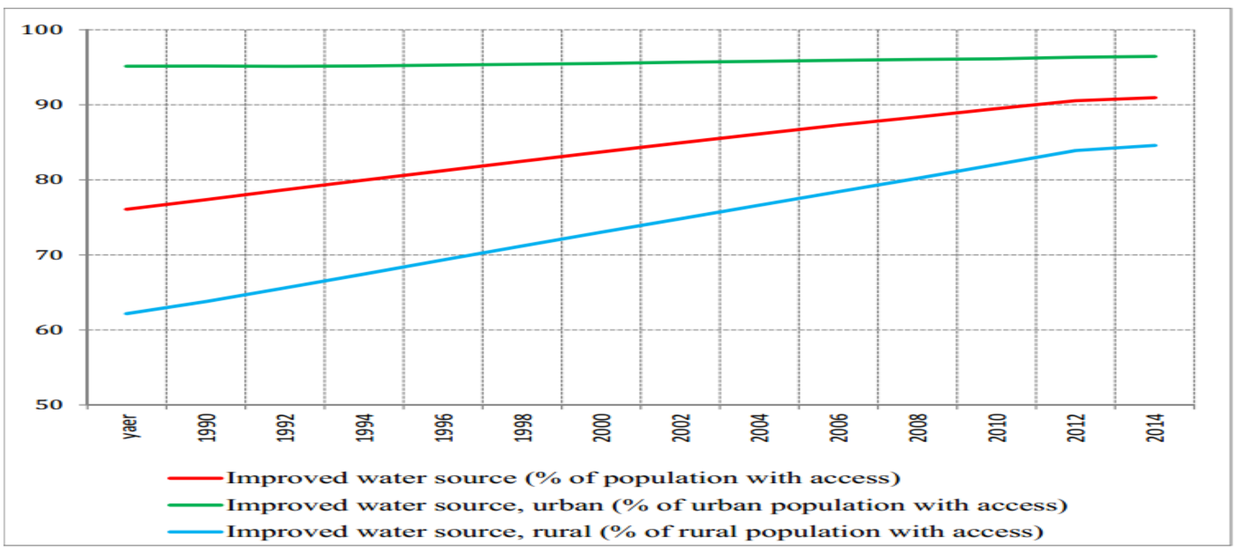
Source: WHO (2006), access to improved and unimproved sources

Potable water coverage

The WHO/UNICEF JMP report of 2015 indicated that the improved water coverage in Ethiopia was found to be 93% and 49% in urban and rural areas, respectively. The country coverage of improved water source usage reached 57%. On the other hand, 30% of the total Ethiopian citizens rely on unimproved drinking water sources. Even though improved[2] water sources are available, they are often far away from the beneficiary households and are located at inconvenient locations. The management system of stakeholders coupled with water quality problems and inaccessible water sources are some of the basic problems (Demeke, 2009; Bhandari and Grant, 2007).

The topography of Ethiopia is characterized by rugged landscapes on which women and children travel long distances by carrying large containers up and down steep slopes. In addition to that, the lack of safe water supply has other series negative consequences such as the Workload in fetching unsafe water from mostly distant unimproved[3]or traditional water points make them vulnerable to health problems. As a result, most of the children miss the opportunity of attending school, while women spend 10-50% of their daytime fetching water from polluted water points, losing time on productive activities (Ethiopian Water Resources Management Policy, 1999; Crow, 2001).WHO, basic access can be defined as the availability of drinking water at least 20 liters per day per person, a distance of not more than 1 km from the source to the house and a maximum time taken to collect round trip of 30 minutes. The UNDP (2008) says the minimum absolute daily water need per person per day is 50 liters).

Figure 1: percentage of world population without safe access water, 2015



(Source: Computed from WHO/UNICEF (JMP) for water supply and sanitation (wssinfo.org))

[2] An improved drinking water source is defined as a type of drinking water facility or water delivery point that by the nature of its design protects the drinking water source from external contamination, particularly or fecal origin and which can be piped into dwelling, plot or yard, public tape/stand pipe, tube well/borehole, protected dug well, rain water collection and protected springs (Van Norden 2007 as cited by Sutton, 2008).

[3] Unimproved sources include unprotected dug well, unprotected springs, tanker truck, surface water (river, dam, lake, pond, stream, and irrigation canal), and bottled water (Van Norden 200 7 by Sutton, 2008).

2.7. Benefits of improving access to water and sanitation

Increasing access to water and sanitation is an input of development and poverty reduction, as it has major health benefits as well as associated social, economic and environmental benefits. Public health will be guaranteed if there is access to potable water and basic sanitation since the highest causes of illness and death in developing country is related to poor access to potable water and basic sanitation (Potstone (2010). As a result of this, illness and deaths reduce the productivity of the economy of a nation; poor sanitation has an adverse effect on the environment which in turn may affect the source of the economy like agriculture and tourism. One of the major benefits of water and sanitation improvements is the time saving associated with better access. Time savings occur due to, for example, the relocation of a well or borehole to a site closer to user communities, the installation of piped water supply to households, closer access to latrines and shorter waiting times at public latrines. These time savings translate into either increased production, improved education levels or more leisure time (Hutton & Haller, 2004).

WHO figures asserted that improved water supply reduces diarrhea morbidity by 6 percent to 25 percent, and improved sanitation reduces morbidity by 32 percent (WHO, 2009). Thus, the improvement on water supply and sanitation has a direct and concrete impact on health. As Hutton, G., et al, (2007) explain the occurrence of diarrheal diseases caused by unsafe drinking water and improper sanitation would be reduced if improvements were made in water and sanitation. Since diarrheal diseases are highly associated with unsafe drinking water and sanitation and poor hygiene, the improvements in water and sanitation would have a significant outcome. It is common that people who are most vulnerable to water-borne diseases are those who use polluted drinking water sources. The report from UNICEF (2010), in the world 884 million people use unimproved drinking water sources in 2010, and in 2015 estimates about 672 million people will still using unimproved drinking water sources.

The improvements in water supplies and sanitation also have an impact on poverty and economy, as it is logical that only healthy people are strong enough to work and fulfill their needs. As Hutton, G., et al, (2007) stated the improvement to water and sanitation will have economic benefits of three types: direct economic benefits of avoiding diarrheal diseases, indirect economic benefits related to health improvements and non-health benefits related to improvements in water and sanitation. The direct economic benefits of avoiding diarrheal diseases include cost savings due to the reduced incidence of diarrheal disease, full health care costs, and non-health sector direct costs. The indirect economic benefits include productivity effects of improved health and the non-health benefits.

2.8. Impacts of water and sanitation inaccessibility

Although water and sanitation are the primary needs of human being, unimproved water and sanitation services have many negative impacts on people livelihood. Among which; health, socio-economic, environmental degradation and poor educational performance are the major.

2.8.1. Health impacts

The improvement of water and sanitation in developing countries is largely driven by the need to reduce the incidence and prevalence of infectious disease caused by pathogenic microorganisms. The majority of pathogens that affect humans are derived from faces and transmitted. Pathogen transmission may occur through a variety of routes including food, water, poor personal hygiene and flies (Ahmed H, 2001). According to USAID/E Statement of Work (SOW) for the Millennium Water Alliance (MWA) Water, Sanitation & Hygiene (WASH) program evaluation, "approximately 3.1% of deaths worldwide are attributed to unsafe water, sanitation and hygiene practices. Africa carries the heaviest burden, with 4 to 8% of all disease in Africa being related to poor water, sanitation and hygiene. In Ethiopia, water and sanitation related diarrhea accounts for approximately 20% of all deaths in children under the age of five, taking the lives of close to 100,000 children annually.

Thirty two percent of this diarrhea could be prevented by improving sanitation interventions such as pit latrines, septic tanks and composting toilets" USAID/E (2008). According to FDRE (2005) Demographic and Health survey, only 8% of Ethiopian households have water on their premises and only 38% have a toilet. In addition, poor water and sanitation is the source for many other health problems including parasites that attribute to high prevalence of diarrhea, cholera, malaria, trachoma.

2.8.2. Socio-economic impacts

According to Ethiopian Ministry of Health (2005), the negative infections of water and sanitation inaccessibility are known to have short-term health impacts and long term debilitating effects. In the long term, child development is impaired resulting in growth retardation and diminished learning abilities. It is estimated that 4 in 10 children will not realize their educational potential which ultimately inhibits socio-economic development. In addition there is a potential productive time lost to illness caring for the sick and attending clinics. There are also the financial costs of treatment for medicines and clinic attendance.

2.8.3. Poor educational performance

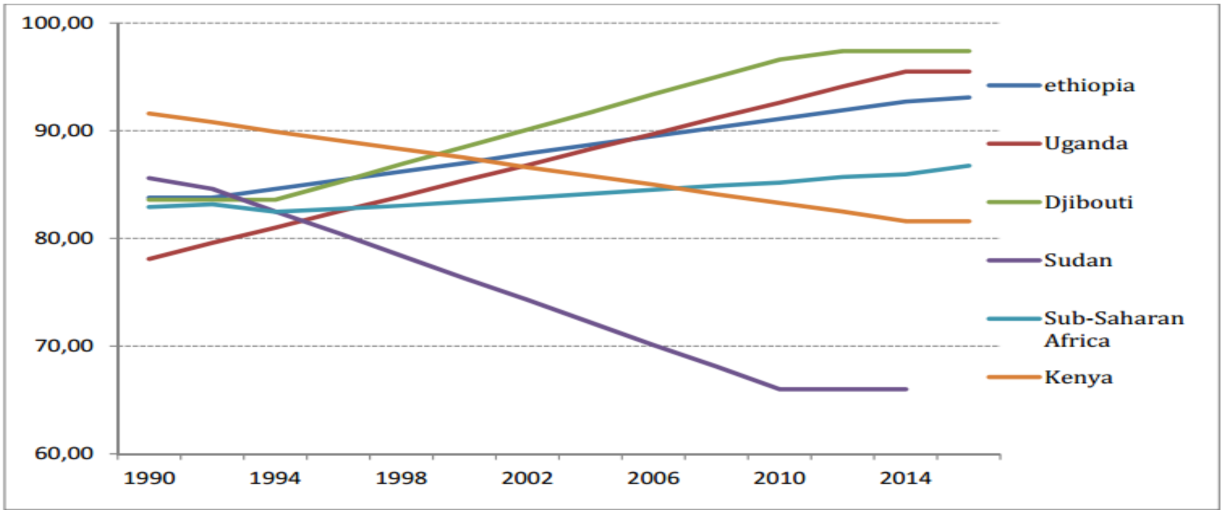
According to the Federal Democratic Republic of Ethiopia National Hygiene and Sanitation Strategy of (MoH,2005), Ministry of Health 2005 as well as the diminished learning abilities mentioned above, it is widely believed that a significant number of school days are lost due to diarrhea. This mainly affects girls who end up staying at home to care for siblings. Worm infestations, anemia and vitamin A loss have been shown to decrease learning abilities among 4 in 10 girls. Lack of separate, private, secure, hygienic latrines, particularly in adolescence (during menstruation) is associated with a high dropout rate of girls.

2.9. Urban water supply in Africa

In the year 2000 all most all African countries were adopted the millennium development goals and seeks to "halve by 2015 the proportion of people without access to safe drinking water and sanitation" (Todaro and Smith, 2014). However in Sub-Saharan Africa it is anticipated to rich the target to the year 2040, after 25 year from the expected target (Sutton, 2014).That is why still, around 276.5 million of the people living in sub Saharan Africa are left without access to safe water with a majority of them being women and children living in rural households (WHO/UNICEF for WSS, 2015). SSA has the lowest drinking water coverage and the lowest sanitation coverage in the world (WHO, 2012). With only 56 percent of the population enjoying access to safe water, Sub-Saharan Africa lags behind other regions in terms of access to improved water sources.

In Africa the sustainability of water projects still remains the major challenge for continued provision of water to the rural population. The Water Supply Network indicates an average rate of non-functionality for hand-pumps in sub-Saharan Africa is 36% which is shameful wastage in the sector. Due to this fact huge amount money which estimated to be hundreds of millions of dollars over the last 20 years are wasted. Having recognizing such trends community managed projects has been envisaged but still the problem remains intact due to lack real participation of the community. Based on present trends, it appears that the region is unlikely to meet the target of 75 percent access to improved water by 2015, as specified in the Millennium Development Goals (MDG). Looking in to the trends of urban improved water coverage, in East Africa for instance the progress is still remained undone. As shown in the Figure below only Djibouti reaches around 97.3% of urban improved water coverage, this percentage is even very high as compared to the urban provision of the other east African as well as sub Saharan African countries. Unfortunately among the East African countries, Ethiopia has the lowest improved water coverage estimation as compared to Uganda and Djibouti. Even though the prospects of urban water supply have shown some progress, still the trend fails to converge with the urban water supply.

Figure 2: Urban improved water coverage in Sub-Saharan Africa and East African



Source: Computed from WHO/UNICEF, 2015.

2.10. Ethiopia's surface water resources

Ethiopia has many surface and groundwater resources though the amount of groundwater resources not known with any certainly. However, the MoWR (2010) reported that it is estimated that the country has a potential of approximately 2.6 billion cubic meters of groundwater. Table below which is derived from the MoWR highlights the surface water resources of the country.

Table 3: Surface water resources of major river basins in Ethiopia

No.	River basin	Catchment area (km^2)	Annual runoff (Bm^3)	Specific discharge (* /s/Km^2)
1	Abbay	199, 812	52.6	7.8
2	Awash	112, 700	4.6	1.4
3	Baro- Akobo	74, 100	23.6	9.7
4	Genale-Dawa	171, 050	5.80	1.2
5	Mereb	5, 700	0.26	3.2
6	Omo-Gibe	78, 200	17.90	6.7
7	Refit - valley	52, 740	5.60	3.4
8	Tekeze	89, 000	7.63	3.2
9	Wabe- shebele	200, 214	3.15	0.5
10	Afar danakil	74, 000	0.86	-
11	Ogaden	77,100	0	-
12	Ayisha	2 200	0	-
Total		**1, 136, 816**	**122.00**	**37.1**

* /s/Km^2: Liters per second per square kilometers

Source: Ministry of Water Resource (MWR), 2010

2.11. Drinking water supply in Ethiopia

Ethiopia has been long characterized by limited access to safe drinking water services. Even though coverage of safe drinking water supply has gradually increased at the national level, the rate is still very low. Inadequate quality of drinking water also remains a major cause of health problems and poor sanitation in rural areas of Ethiopia. The unavailability of safe drinking water in most rural and urban locations is one of the main causes of diarrhea among children under the age of five (CSA 2014). Previous empirical studies elsewhere also show that access to improved water is an important contributor to improved child health and mortality reduction (Degnet Abebaw and et al, 2015). In this regard, Getachew.y (2014) stated that, water supply and sanitation situation in Ethiopia is very poor, as most of the population does not have access to safe and adequate water supply and sanitation facilities. Diarrheal diseases caused by improper management of water and sanitation are among the major causes of infant and child morbidity and mortality.

In addition to health improvement, WHO (2014) have shown that the provision of sufficient potable water for People within reasonably short distance from a reliable and acceptable source is a precondition for the people’s well-being and sustainable economic progress. Regarding to this, the Ethiopia Water and Sanitation program WSP, (2015) identified the nature of linkage between WSS and poverty reduction. Ethiopia has long been characterized by limited access to safe drinking water services. In 1990, for instance, only 19 percent of the country’s population had access to a safe drinking water supply (Degnet Abebaw and et al, 2011).

Even though coverage of safe drinking water supply has gradually increased at the national level, the rate is still very low (Degnet Abebaw and et al, 2011). In Ethiopia, the problem of drinking water supply is further compounded by physical distance. A recent estimate reveals that about 52 percent of the population traveled half an hour or more to collect water every day (CSA 2006). This long travel distance to the nearest water source directly affects women and children, who are mainly responsible for fetching water. This has an implication on the productivity of women. The long hours spent in fetching water taking a significant amount of time that could be employed in other income-generating activities. The human capital implication for young girls cannot be overlooked as well. Most girls in Ethiopia find it too difficult to attend and succeed in school because a significant amount of their time is used for domestic chores, including fetching water.

From recant literature in the Amhara region, although the region is well endowed with a substantial amount of water resources potential, the performance of potable water supply and distribution is found to be low. Based on 2009/10 data the regional water supply coverage is not exceeding 60 %. This indicates that 40 % of the people have no access to clean water (Amhara Region Health Bureau Report, June 2011). This coverage also less than the standard set by world health organization which is a daily requirement of 45 liters per person and Ethiopian water access of 15 L/C/D in the 1.5 km source distance. Thus, people who are not accessed are forced to use unsafe drinking water from unprotected wells, rivers, and ponds.

According to the report, drinking water supply coverage in the region has reached around 87% in the urban and 54% in the rural areas. Actually the region is rich in water source such as major lakes like Tana, Zengena, Tilba,Haik and there are more than 56 big rivers such as Blue Nile, Gilgel Abay, Belese, Angerb, Tekeza, etc. Even this is so in the region access to safe and adequate drinking water supply to the community is still have big gaps. The indicator for this is diarrhea is the major causes of morbidity in the region. In recognition of all these deep-rooted water problems in the country, especially in rural areas, the government has increased resource allocation to provide safe drinking water for its inhabitants. However, access still varies strongly across in the country, and the problem is more pronounced in rural than in urban areas. Moreover, as in many other countries in Sub-Saharan Africa, the water facilities may not be operating properly due to various technical problems, According to a recent survey (Degnet Abebaw and et al, 2011.)

The concept of sustainability and sustainable water supply

According to the United Nations development document written in 1987, entitled “Our Common Future”, definition; “Sustainable development is development that meets the needs of the present generations without compromising the ability of future generations to meet their own needs.” Sustainability of water supply projects has also been considered from a livelihoods perspective. In general a sustainable water supply system involves a number of issues that are internal and external to the community. According to Zelalem (2005), the following are key issues that are of a paramount importance to sustainable water supply systems:

- Community participation and involvement
- Community awareness raising and education
- Repair and maintenance service
- Water users management body and structure
- Conflict management
- Management capacity building/management procedures of water committees
- Technology
- Institutional Support. Observing the above factors separately as pre and post implementation factors, they of course form the building blocks for areas of investigation and measurement.

Demand projections are made according to past trends of water consumption and population growth. While these give quantitative estimates of the water supply required, other dimensions of demand remain neglected. Therefore, willingness to pay (WTP) and revealed preference studies for new or improved service has been found more useful in demand assessment, cited from in Assefa, 2006), demand management can be best achieved through three main mechanisms:

- The selection of a system coverage and service expansion plan to provide consumers with a high level of service.
- The setting of a tariff regime to control consumption, distribute social benefits.
- The education of consumers on water use practices to encourage greater efficiency and productivity in the use of water, and the minimizing of losses.

Safe, adequate and accessible supply of water together with proper sanitation is surely basic needs and essential components of primary health care. The four targets below include both interim and final targets and indicators and have received broad support among experts in the sector.

Target one: - By 2025, no one practices open defecation and inequalities in the practice of open defection have been progressively eliminated.

Target two: - By 2030 everyone uses a basic drinking water supply and hand washing facilities when at home, all users with basic drinking-water supply and adequate sanitation, hand washing facilities and menstrual hygiene facilities and inequalities in access to each of these service have been progressively eliminated.

Target three: - By 2040, everyone uses adequate sanitation when at home; the proportion of the population not using an intermediate drinking water supply service at home has been reduced by half, the excreta from at least half of schools, health centers and households with adequate sanitation are safely managed and inequalities in access to each of these of these services have been progressively reduced.

Target four: - All drinking –water supply, sanitation and hygiene service are delivered in progressively affordable accountable and financially and environmentally sustainable manner. **(**Source: Progress on sanitation and drinking-water - 2013 update, JMP, WHO/UNICEF, 2013). (Sources: -One WASH program document August 2013, New Era: post-2015 targets JMP.website,wash data.org). 159 million people still collected drinking water directly from surface water sources, 58% lived in sub-Saharan Africa.

Sustainable water and sanitation for all

Fresh water, in sufficient quantity and quality, is essential for all aspects of life and sustainable development. Water resources are embedded in all forms of development (e.g. food security, health pro-motion and poverty reduction), in sustaining economic growth in agriculture, industry and energy generation, and in maintaining healthy ecosystems.

Sustainable Development Goal 6

All 193 Member States of the United Nations General Assembly unanimously agreed to transform our world: the 2030 Agenda for Sustainable Development (the 2030 Agenda) in September 2015. The 2030 Agenda is a plan of action for people, the planet and prosperity. Member States resolved to "end poverty in all its forms", to take bold and transformative steps to "shift the world on to a sustainable path" and to ensure that "no one will be left behind".

Target 6.1: Achieve access to safe and affordable drinking water

Achieving universal access to safe and affordable drinking water by 2030 presents a huge challenge for all countries, not just those with low incomes. The proportion of the global population using at least a basic drinking water service increased from 81 per cent in 2000 to 89 per cent in 2015. Achieving target 6.1 means addressing the "unfinished business" of extending services to 844 million people who still lack even a basic water service, and progressively improving the quality of services to 2.1 billion people who lack water accessible on premises, available when needed and free from contamination (safely managed drinking water). It also implies going beyond households and providing access to services in schools, health-care facilities and other institutional settings.

Target 6.2: Achieve access to sanitation and hygiene and end open defecation

Achieving universal access to adequate and equitable sanitation and hygiene by 2030 is a major challenge in many parts of the world. Target 6.2 calls for countries to end open defecation, to ensure that everyone has access to a basic toilet and to put in place systems for safe management of excreta. The proportion of the global population using at least a basic sanitation service increased from 59 per cent in 2000 to 68 per cent between 2000 and 2015. However, 2.3 billion people still lacked basic services, 70 per cent were in rural areas. Furthermore, 4.5 billion people worldwide lacked a safely managed sanitation service in 2015.

Target 6.3: Improve water quality, wastewater treatment and safe reuse

Collecting, treating and reusing wastewater from households and industry, reducing diffuse pollution and improving water quality are major challenges for the water sector. Ambient freshwater quality is at risk globally. Freshwater pollution is prevalent and increasing in many regions worldwide. Preliminary estimates of household wastewater flows, from 79 mostly high- and high-middle-income countries, show that 59 per cent is safely treated. For these countries, it is further estimated that safe treatment levels of household wastewater flows with sewer connections and on-site facilities are 76 per cent and 18 per cent, respectively.

Target 6.4: Increase water-use efficiency and ensure freshwater supplies

Few countries have the natural and financial resources to continue increasing water supplies. The alternative is to make better use of available resources. This target addresses the issue of water scarcity and the importance of increasing water-use efficiency. More than 2 billion people live in countries experiencing high water stress. It affects every continent, hinders sustainability, and limits social and economic development.

Target 6.5: Implement integrated water resources management (IWRM)

The 2030 Agenda fully commits Member States to IWRM and transboundary cooperation over shared water resources. Putting this into practice will be the most comprehensive step that countries make towards achieving SDG 6. But, most countries will not meet the target by 2030 at current rates of implementation.

Target 6.6: Protect and restore water-related ecosystems

Historically, the drive for economic and social development has depended on exploiting natural resources, including water-related ecosystems. Today, as the demand for fresh water increases, awareness are focusing on ensuring that the limited capacity of the natural environment to sustain the multiple services that society has come to rely on is maintained.

2.12. Challenges of sustainable urban water supply

In the provision of adequate clean water to urban dwellers, the world faced many challenges, which are related to capacity of the nations, (i.e. technological or knowhow, institutional, inadequate finance, rapid urbanization and declining of global water resource).

Lack of capacity

Capacity can be described in terms of the human, technological, infrastructural, institutional and managerial resources required at all levels from the individual through to national governance. Not only does capacity have to be built within each of these levels, but it has to be institutionalized and local communities need to be empowered to use it effectively. Additionally, capacity building incorporates the followings:-The capacity to measure and understand aquatic systems through monitoring, applied research, technology development and forecasting, so that reliable data are used for analysis and decision making and the capacity to identify and provide appropriate and affordable water technologies, infrastructure services and products through sustained research, investment and management.

Technological capacity

Innovative technologies are essential to overcome barriers to water service provision. Technological capacity includes the development and application of new technologies, the technical skills needed to effectively construct, operate and manage a technical solution; the translation of information regarding technologies to promote informed decision-making when implementing a technical solution; the availability and accessibility of spare parts (cited from Challa 2014). However, technology providers need a better understanding of local conditions and policies.

Institutional capacity

There is a need for institutions that bring together many disciplines, such as the natural sciences, public health, engineering and the social sciences. Integration and interaction between institutions and different sectors of the population, at decision-making and participative levels is required to plan and execute actions in a coordinated way. This integration is the basis for multi spectral approaches to ensure that planned goals are achieved and actions converge to solve environmental, water and health problems (Wallace et al, 2015).

2.13. The challenges for urban water supply in Ethiopia

Ethiopia has plenty of water resources but the available water is not distributed evenly across the Country and the amount varies with seasons and years. The challenge in any situation is to maintain a supply that is adequate to meet people's needs. To ensure that supply meets demand the source of the water must be carefully chosen, taking into account present and future demand for water, and the costs. The cost of water supplies is heavily influenced by the distance of reliable water sources from towns. The challenge for many towns is finding nearby water sources. Planning for present and future demand has to consider population growth. The demand for water is increasing in cities and towns due to an ever-growing population and the migration of people from rural areas to towns in search of jobs and a better life. There are also increasing demands from industrial and commercial development. The quantity of water required for domestic use depends not only on the number of people but also on their habits and culture, and on how accessible the water is. On average, Ethiopians in urban areas use only about 15 litters of water a day for their needs (MoH, 2013; Ali and Terfa, 2014).

There is a difference between the WHO estimate and the daily water consumption per person in Ethiopian towns. The shortfall is perhaps due to the shortage of private water taps, which means that people have to collect water from public taps. If people have a piped water supply in their home they are likely to wash and bathe more frequently, and some may have water-using appliances like washing machines. As water supply systems improve and access increases, the consumption of water will increase also. It is therefore important for water supply planners to consider the expected changes in society and in living standards. Planning of water supply projects should also consider the water requirements of schools, hospitals and other health facilities, churches and mosques, hotels, public washrooms, and other community facilities. The government of Ethiopia has set targets of 100% coverage of safe water supply in urban areas and 98% coverage in rural areas. These targets originated from the Universal Access Plan of 2005 and the Growth and Transformation Plan of 2010, and have been adopted by the One WASH National Program (OWNP), which is being implemented with major funding from government and international donors (FDRE, 2013).

Chapter Three

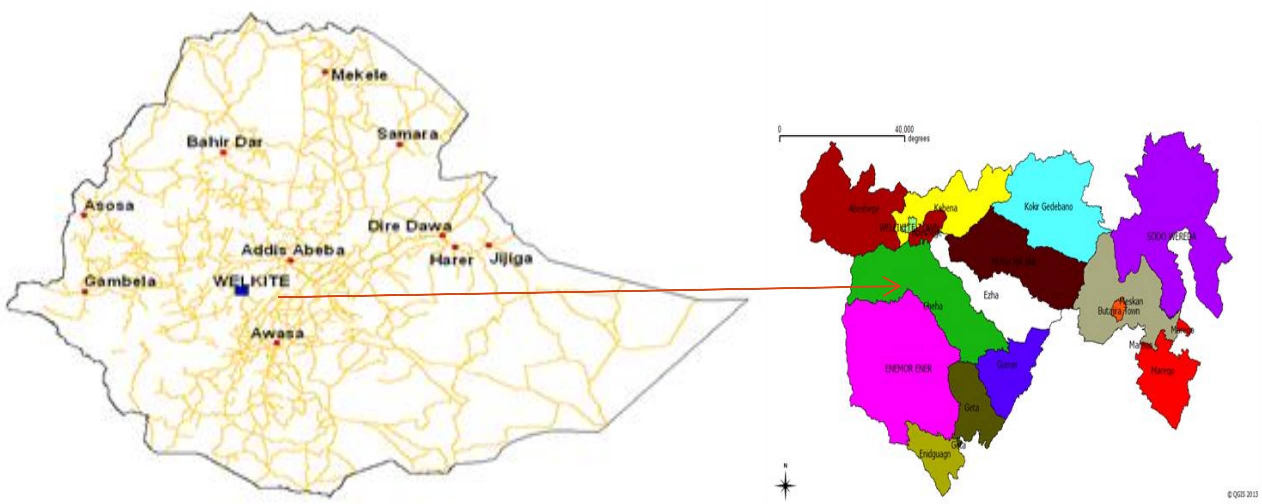
3. Research Methodology

3.1. Description of the study area

3.1.1. Location

Emdibir is a town in south-western Ethiopia, which is Located in the Guraghe zone of the southern nations, nationalities and peoples' region; it is the administrative center of Cheha woreda. The town is situated in the south-west plateau about 50km to the west of the main Ethiopia rift valley. According to the Gurage zone government, Emdibir is one of 12 towns with electrical power, one of 11 with telephone service and one of nine that have postal service. An all-weather road was built in 1963 by the Guraghe road association, which connected Emdibir to Addis Ababa. The town is located on at a distance of 180 km south-west Addis Ababa, and 300km from the capital of the region, Hawassa. The road and access route network in the town is fairly distributed. In addition to gravel roads there is about 5km asphalt road in the town. Based on the other GTP 2 national town categorization, Emdibir town is design for grouped under category 4 towns/cities (towns/cities with the projected population in the range of 20,000-50,000).

Figure 3: location of Emdibir town



Source: town administration office, 2017

3.1.2. Topography

The land form of Emdibir town comprises plains with river divides. These can be expressed by plain with an average of gentle slope of the land topography at geographical coordinate of UTM[4] between 379, 500 and 384, 000 east 895, 800 and 899, 600 north longitudes with average elevation of 2160m above sea level, the total area of the town is about 9.63km^2.

[4] UTM, universal transverse Mercator coordinate system

3.1.3. Climate

The study area is characterized by four types of typical climatic zone, namely, dega, weynadega, and kola climate with mean annual temperature ranging from 90°c-230°c. It is the hot to cold temperature condition, which has relatively shorter growing season. The mean annual rainfall is more than 50mm.

3.1.4. Population

According to the CSA report, the current population of Emdibir town is 20,773. It has to be used as a base population with average house hold size of 6.75, among whom 9, 532 are men .The town has two kebele, named as 01 and 02. Kebele 01 has 8 villages and total population of 8,503, while Kebele 02 has 9 villages with a total population of 12,270.

3.1.5. Major Socio-economic activity in the town

According to the findings of the detail socio-economic study means of income, trade is the major means of income in the town with the second being the government employees followed by agriculture. The socio-economic activities of the town are related to trade. The major undertaking in Emdibir town includes small scale trading and micro enterprises or hotels, cereal marketing.

3.2. Existing water supply and distribution systems of the town

The majority of the town dwellers are connected to the town's water supply system getting water mainly connected having yard service followed by users of water points available in the town. Despite to this connection most of the respondents have said as they are not satisfied with the quantity of water they get from the town's water supply system.

Table 4: Primary source of domestic water for Emdibir town

Primary source of domestic water	percentage
House connection from towns water supply	0.38%
Water points of the towns water supply system	20.99%
Nearby river	6.49%
Nearby simple protected springs	7.25%
From yard connection water supply system	64.89%
Grand total	100.00%

Source: town water authority office, 2017

The current functional source of Emdibir town is from spring called Bojebar found at UTM 376,718E, 901,102N with an average elevation of 1919m a.s.l. This is located at 8km away from the town and implemented to give service for the people of the town as well as the rural communities along the main pipe line and surrounding rural community of the town. The water from this spring source is pumped to the services reservoir constructed at the town. As measured by Emdibir town water office, using velocity and area method, the flow at the spring site is about 55 l/s. As a result the area along the course of the flow of the water from the main spring eye is full of mainly artisan type of springs. Masonry spring capping structure related to the site conditions having collection chamber for storage before pumping is designed to trap water from the selected source. The location of the spring box is at Easting 376,717.95, and Northing 901,101.57 having an average elevation of 1918.29m.a.s.l which is located below the spring source. Related to the demand, site conditions majorly related to the types of the spring, a masonry capping structure with having rectangular plan shape with total outer to outer sizes of 16m by 10.9m.

Figure 4: Existing water supply sources at Bojebar spring

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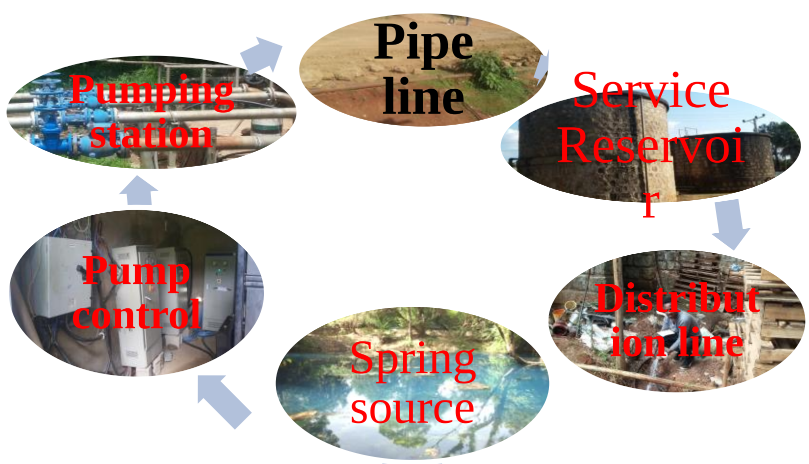


3.2.1. The water supply systems of Emdibir town schematically:-

3.2.2. Rising main form the spring source up to the elevated reservoir

The existing rising main from the Bojebar spring source to the service reservoir at the town is 3 inch GI pipe with a total of 8km. As described above, the water from the Bojebar spring is pumped to the reservoir using submersible pump installed in the wet well of the spring collection chamber. There are

25 m^3 ground rectangular concrete collection chambers for storage at this site and there are in the town for service reservoir: the one with 100m^3 concrete ground service reservoir built in 209.71m, located at 2128ma.s.l, and the other two 50m^3 and 75 m^3 each masonry reservoir constructed at different times.

Figure 5: Existing water supply system components in the town

Along the rising main there are two connections with 10m^3 elevated reservoirs and a water point for two villages between the spring and the elevated reservoir. Moreover, the water point for Sisie Debir and Emdibir high school is connected between rising main and the service reservoir. There is a total of 31 water points within supply system.

Figure 6: connection of existing rising main

In addition to the above spring source, there is also a borehole dug for the town with technical assistance by the zonal water and energy resource department at an elevation of 2095m.a.s.l. Even though the actual well information is not found from the zonal office, as per oral information from the TWU office its depth is about 200m with estimated yield of 1.8 l/sec. currently, the submersible pump is installed and has started to be functional using generator power source.

Figure 7: Existing pump station and newly drilled borehole

The current percentage of non-domestic demand

As we can see the tables below, the total current non-domestic water demand in Emdibir town is about 81.8m^3/d. This demand holds 15.7% of the current daily water production (2017). But the future, non-domestic demand shall be taken to be higher as the town has high potential for the expansion of non-domestic users. The future non-domestic demand shall be taken to be about 20% of the total adjusted domestic demand in order to assist many unexpected changes in the town and majority related to the design criteria.

3.2.3. Major limitations of the existing services

Even though, the limitations of the current water supply service are many, the major limitation of the existing water supply service in the town is the insufficiency of the water supply system to produce sufficient water from the source, even though the yield of the existing source is more than required to satisfy the current and future demands. The current capacity of the existing scheme is only about 6.3l/sec for not greater than 16 hours of pumping. Hence, the major problem of the water supply scheme of the town is production of insufficient water from the source. Moreover, the existing system in the town is old and does not cover the town in addition to the shortage of the water.

3.2.5. Existing water points

There are a total of 31 water points within supply system. All water points can be functional to the new water supply system with some maintenance for some water points. Some water points WP 25, WP 26, WP 27 and WP 28 are connected to the rising main after Gotam River. The total length of pipe for the existing system is about 21.726km.

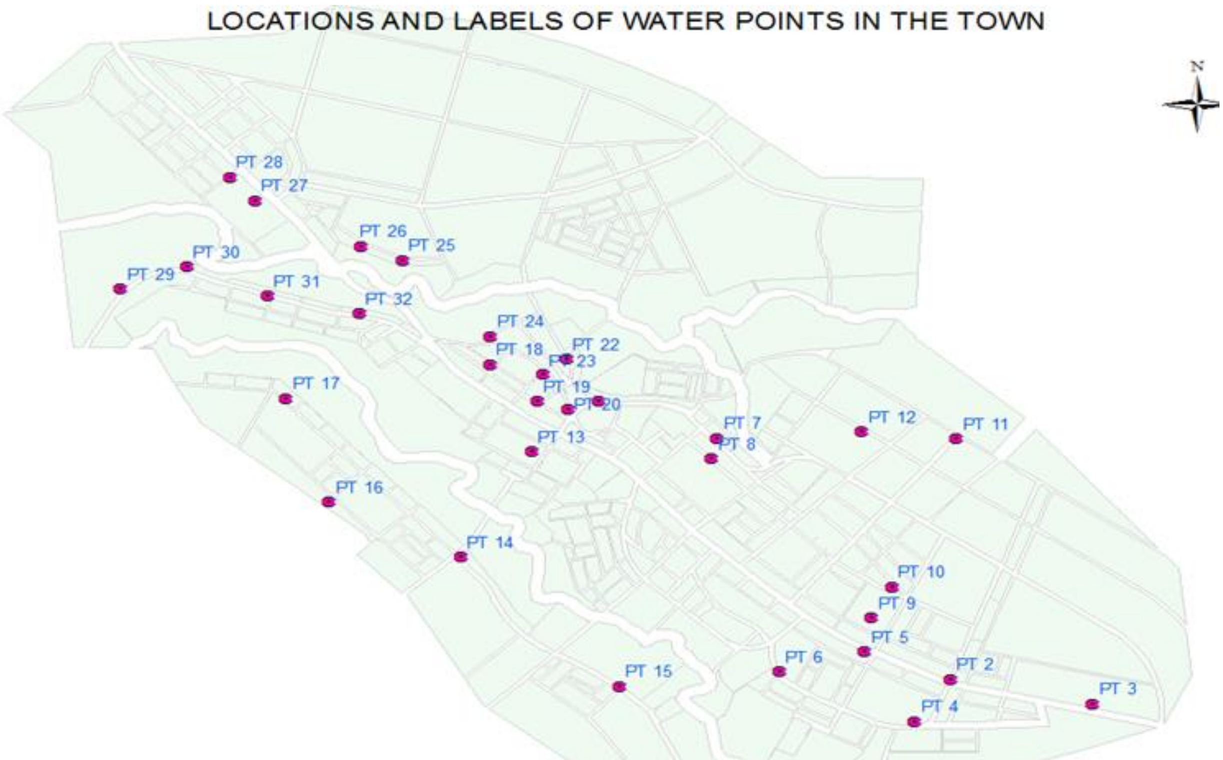


Table 4: Summary of Existing distribution system

Diameter	GI ,length (m)	HDPE, length (m)	Grand Total	Age category
1"	1054.61	12.19	1760.52	
1/2"	57.3		57.3	
1 1/2"	2984.9		2791.05	
2"	2398.45		2814.5	<=10 years
2 1/2"	841.56		576.99	
3"	1620.02		1680.68	
3/4"	141.12		141.12	10- 20 years
OD40		1435.91	1435.91	
OD50		6013.07	6013.07	
OD63		1112.83	1112.83	
OD75		689.46	689.46	
OD90		1507.54	1507.54	20- 32 years
Grand Total	**9,331.43**	**12,394.68**	**21,726.11**	

Figure 8: Photo of existing water point, junction and pipe line in the town

3.3. Existing town water supply service

3.3.1 Organizational structure and staffing

Emdibir town has a utility office established as per the regional proclamation number 40/1994. According to this proclamation, the utility is to be administered by local board assigned by the regional water bureau.

3.3.2. Office facilities for the town utility office

The town’s utility office does not have sufficient office facility required to carry out its service as per the required. It has two small room offices which does not have sufficient space for all services. Currently the utility office has only 15 staffs. The deployed staffs are not equivalent to the structure in terms of the quantity, and qualification.

3.3.3. Existing financial and store management of the TWU office

The existing financial management system is single entry system with procedural billing and financial recording forms and recording and approval procedures set in place. The billing process is manual.

Water demand adjustment factors

The domestic water demand seriously depends on two factors: socio-economic and climatic factors. Accordingly the per capita domestic water demands will be modified using these factors. Apparently the socio-economic factors will be fixed based on the personal judgment based on the socio-economic situation of the town. In case of climate, the mean annual temperature is the main variable. The following are applied as guidelines for the adjustment factors.

Table 5: Population vs. MDDF and PHDF

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

Source: MoWR (2006)

Adjustment due to socio-economic factors:-Socio-economic factors determine the degree of development of the towns.

Item	**Town category**	**Socio eco- factor**	**Descriptions**
1	A	1.1	towns enjoying high living standards and with very high potential for development
2	B	1.05	towns having a very high potential for development but now lower living standards
3	C	1.00	towns under normal Ethiopian conditions

Sources: MoWR (2006)

Climatic factors

Taking in to consideration the socio-economic situation of Emdibr town, it can be considered to be a typical Ethiopian town under high potential for development but it is in fact lower living standards at present. Thus, a socio-economic factor of 1.05 can be considered. Regarding the climatic conditions, the mean annual precipitation of Emdibr town is 850mm/year and grouped under group **B** of above groups. Therefore, a climatic factor of 1.0 can be applied. Based on the above finding, that means, the service levels, the estimated water demand for each service levels, and the climatic and socio-economic adjustment factors.

Town categories

Analysis of existing data has shown that certain characteristics of towns are strongly linked to their population size. In order to attribute certain characteristics to each town, the towns have been grouped into categories according to their population size. These categories have been used to determine present and future service levels (connection profiles), as well as present and future per capita consumption for each of the connection types. As shown the table below, Emdibir town can be categorized under category 5 depending on the number of population which is about more than twenty thousands (20,773).

3.5. Analysis of water demand coverage, service level and connection profile

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

3.6. Water supply coverage analysis

The water supply coverage of the town has been evaluated based on the average per capita consumption and level of connection per family. The average per capita consumption has been derived from the yearly consumption that was aggregated from the individual domestic water meters. Beside to the average per capita water consumption, the distribution of number of domestic connection per family has been also evaluated. Statistical analysis was used to evaluate the supply coverage for the entire town. The whole system water coverage has been evaluated by considering urban and rural domestic as well as Non-domestic user by using design guide line of MoWR (2006).

Urban domestic water supply coverage

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

Average daily per capita consumption

The volume of water consumed for domestic purpose has been distributed for all beneficiaries of the town to analyze the distribution of the water supply coverage. The average daily per capita consumption of the town was computed using this expression:-

$$\text{Per capita consumption (L/person/day)} = \frac{\text{Annual consumption } (m^3) * 1000 \text{ l}/m^3}{\text{Population number} * 365 \text{ day}}$$

The annual domestic demand amount in 2017 is (1,008.3m^3 *365)= 368,029.5m^3 (from the demand projection data) and the current total population of the town are estimated as 20,773 , therefore by using the above expression the average daily per capita consumption became 48.54/per capita/day.

Level of connection per family

Level of water connection per family is one mechanism to evaluate the level of water coverage. The total number of connection or water meter with in the town are about 1,100 and those are domestic water supply users, according to the census of the 2010 average family size of 6.7 is used for calculating the average number of connection per family using the following expression.

$$\text{Connection per family} = \frac{\text{Total number of connection}}{\text{No. population/ (average family size)}} = 1{,}100 / (20{,}773/6.7) = 0.355$$

The level of water connection as per the above expression became 0.355; this implies that the current connection coverage is only 35.5% and this clearly shows the level of water supply connection system in the town is very low.

3.7. Analysis of overall water demand coverage

The existing population and demand has to be forecasted until the end of design period. In addition water production and consumption data analysis to identify the loss. Generally in design the water supply scheme. For a town, it is necessary to determine the total quantity of water required for various proposes.

3.8. Hydraulic model analysis

To develop the hydraulic model for network analyze, adopted the following steps:

- Creating a pipe network from the water system GIS files using water GEMS.
- Allocating customer demands to pipe network nodes.
- Average demand for town=number of population *Per capita demand
- Maximum day demand= ADD *MDF
- Peak hour demand (PHD) =ADD * PHF
- Total storage capacity = minimum total reservoir storage capacity be in the range of 30% to 50% of the average daily demand
- NRW (%) = $\frac{\text{(production - metered use)}}{\text{(Production)}} \times 100\%$
- Base demand = population * per capita demand per day.

- The evaluation will made by calculating the squared relative difference between observed and simulated pressure for each test.
- The evaluation criteria will use statically method of correlation coefficient (R^2).

$$R^2 = \frac{\textbf{Sum}(\textbf{X}-\textbf{X mean})(\textbf{Y}-\textbf{Ymean})}{\sqrt{\sum(\textbf{X}-\textbf{Xmean})\textbf{2}*\sum(\textbf{Y}-\textbf{Ymean})\textbf{2}}}$$

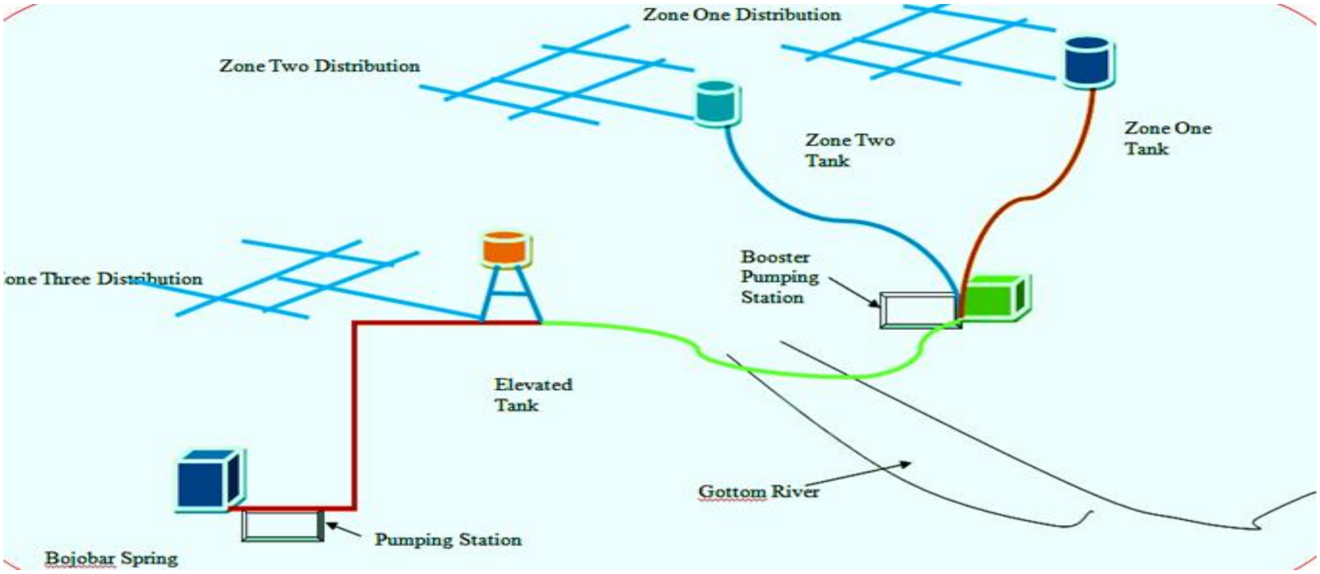
Where, R^2 is correlation coefficient, x and y are measured and simulated values, x, mean and y, mean are average value of measured and simulated data respectively. In general, based on the research objectives mentioned in this proposal, the methodology will adopt collection of primary and secondary data in office and also at the field level.

3.9. Model selection

Based on the availability, simplicity and powerfulness of the models, Water GEMS and Auto CAD is the selected model to analyze the water supply system. Using the selected model, we tried to design and analyze the main and the distribution line. All water supply system area is part of the study during evaluation of the water supply coverage. The required input data to analysis the selected model are:- junction elevation, reservoir elevation, spring elevation, pipe length, pipe size, pipe material type and the demand of each junction.

3.10. Data organization

The collected primary and secondary data organized on excel sheet depending on topography and technical point of view all the pipe network system divided in to three zones which have a total of 57 nodes. This is to create safe water supply distribution system in the town according to the population settlement and topographical locations of the villages. The tabulated data includes the elevation, pipe length, pipe size, pipe material type and the demand of each junction, elevation of the three reservoirs.
Zone-1 from 100m^3 balancing reservoir to the downstream part has 23 junctions. Zone-2, from 75m^3 ground reservoir to the downstream part of the reservoir and Zone-3, from the upstream of the spring source to some junctions. Zone one rests on the south eastern part of the town with elevation ranges from 2123.76m up to 2072.8m with maximum elevation difference of 51m. Zone two rests on central part of the town with elevation ranging from 2096.17m up to 2056.68m with maximum elevation difference of 40m. Zone three rests north western part of the town crossing Gottom River at the outlet road side having a range of elevation from 2032m up to 2,000m with maximum elevation difference of 32m which is found on the opposite side of zone two with different topographical nature. The schematically representation of the proposed water supply system for the town is as indicated in the figure here below.



3.11. General description of the proposed system

The proposed water supply system has three pressure zones. As pressure zones are required to have their own separate service reservoirs to optimize the pressure. This is also achieved for Emdibir having three service reservoirs. The locations of these service reservoirs have effect on the configurations of the system. In line with this the better economic system designed for the town is with the water from the above spring source initially to be pumped to zone three service reservoir which is required to be elevated to cover the nearby areas with gravity flow. This elevated reservoir has also sufficient elevation to drive water to the second station by gravity from where water can be separately pumped to the remaining two zones with different set of pumps having different duty points related to the design demands of each zone and the head to each zones. The locations and capacities of each reservoir for the three zones are as described in the sections here below. As a result of the analysis done related to the cost and O&M suitability, the pipe types selected for all the three zones are PN 10 HDPE pipe including for the rising and transmission mains.

3.12. Calibration and validation statistics

In fact after water distribution model has been developed; then it should be calibrated so that it accurately represents the actual working real life water distribution network under a variety of condition. This involves making minor adjustment to the input data then the model accurately simulated the pressure rate in the system. After the model analysis result has to be presented, pressures are measured throughout the water distribution system using pressure gage. The average pressure difference of ± 15.2 kpa (± 1.51 m) with a maximum difference of ± 50.3 kpa (± 5.03 m) represents a "Good" data and an average pressure difference of ± 29.6 kpa (± 2.96 m) with a maximum difference of ± 97.9 kpa (± 9.79 m) represents a "Poor".

The computed pressure and measured field pressure will not exactly match; Calibration of the pipe network system consists of determining the physical and operational characteristics of an existing system. There are many ways to judge on the performance of model calibration, the Validation statistics used in this study was by calculating the squared relative difference between observed and simulated pressure for each test. The results and the observation data were entered to an excel sheet and the value of squared error was calculated for every test then the mean square error and standard deviation calculated from excel sheet. Devices used for taking field measurements were the static pressure gauges and flow measurement device. The hydraulic model was calibrated by adjusting Hazen-Williams coefficients (C).

3.13. Selection of the study area

The selection of Emdibir as a study area from the major towns of the country is due to the researcher’s personal experience of severe water scarcity in the area for more than two decades and the prevailing serious problem in the town. There were several attempts done by the government and NGOs to resolve the problem of water scarcity through the expansion of water schemes. However, the problem is aggravating from time to time.

3.14. Research design and data collection

3.14.1. Study design

The survey utilized both quantitative and qualitative methods to explain concepts and measures to demonstrate implications of the issue under question. Primary data was collected from personal field observation. Data collection was undertaken by the researcher. Secondary data was collected from related literatures. Emdibir town water supply system have no organized data especially for old distribution network, hence all relevant primary data of main and distribution pipe line network has been collected.

3.14.2. Collected primary data

Using GPS instrument, the elevation of the main and distribution pipe line, reservoir, water point and by using pressure gauge the pressure in some junction has been collected. The discharge capacity of the spring along the flowing channel measured with the help of stop watch floating method. The type of pipe materials, fittings, diameter of the main and distribution pipe line and valves collected from the site in order to identify whether the system have quality problem or not.

3.14.3. Secondary data:-

Accordingly, official statistics and reports available in water projects implementing agencies' offices were the major sources of secondary data for this study. Moreover, different written documents both published and unpublished- books, CSA, government report documents, journals and research works in relation to the issue under consideration; government policy and strategy were reviewed to supplement the study as well as to review the overall water supply situation in the study area.

Chapter four

4. Result and Discussion

4.1. Water Demanded Coverage Analysis

4.1.1. Domestic Water Demand

Domestic water supply means the quantity of water required in the households for drinking, bathing, cooking, washing, watering animals, irrigating the garden etc. and mainly depends upon the life style, living standard, habits, social status, climatic conditions, and mode of service, price of water and affordability or providing of users. A domestic water supply can take different forms: a stream, a spring, a hand-dug well, and a borehole with hand pump, rainwater collection system, a piped water supply with tap stand or house connection.

Demand computation by mode of service

The following are most common service and are used in Emdibir.

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

4.1.3. Customers and expenditures of the TWU

According to the information available at the TWU office, the numbers of current customers of the service are 1,100.

Table 7: Connection by category and primary source of water in the town

No-	customer type	number
1	Regular yard connection	982
2	Governmental offices	28
3	Religious institutions	25
4	Commercial organization	60
5	Non-governmental	5
Total		**1,100**

House connection water supply	6.87%
Water points water supply system	20.99%
Nearby seasonal Springs	7.25%
Yard connection water supply system	64.89%
Grand total	**100%**

Source: town water utility service

Average demand by mode of service

According to standard of the country town, Emdibir have the third level towns and the average demand can be calculated as follow:-

Estimation of per capita water demand

Average demand for town=Number of population *per capita demand

Even if, there are many methods to estimate, the per capita demand for different service levels, we have chosen, to use the design manual, and also there will be growth as a result of economic and other related factors, we decide to divide the design period into two stages.

4.2. Non- domestic water demand

Non-domestic water demand is one of the most important water demands to be determined systematically.

Industrial water demand

As stated from the town water utility data's, the industrial demand for Emdibir town is taken to be 2-5% of the average domestic demand. According to standards and studies in similar town, the current industrial demand for Emdibir can be estimated fairly to be 2.5% of the total adjusted domestic demand.

Fire demand

Fire generally breaks out at commercial centers, stores etc. Big cities which have valuable properties require large quantity of water for firefighting. Fire demand is the quantity of water needed to extinguish fire which depends upon population, centers of buildings density of buildings and their resistance to fire. The quantity of water for fighting is small compared to the annual average consumption of water which will not be more than the amount of water distributed during the max day water demand. At any time, the municipal water supply system should be able to deliver needed fire flows to representative fire risks throughout the municipality from properly located fire hydrants. An adequate amount of water is essential to confining, controlling, and extinguishing hostile fires in structures.

1. For phase one, (end of 2028), $Q = 64 \sqrt{P} (1 - 0.01\sqrt{P})$ Where, Q = rate of flow of water in l/sec
   P = Population in thousand
   $Q = 64 \sqrt{31,215} (1\text{-}0.001\sqrt{31,215})$ = **9305.96 l/d =9.31 m^3/d.**

2. For phase two, (end of 2038), $Q = 64 \sqrt{P} (1 - 0.01\sqrt{P})$ Where, Q = rate of flow of water in l/sec
   P = Population in thousand
   $Q = 64 \sqrt{45,202} (1\text{-}0.001\sqrt{45,202})$ = **10,713.96 l/d =10.71 m^3/d.**

- Demands for public use: - Quantity of water required for public utility purposes such as washing Roads, cleaning of sewer, gardens, public fountains, watering of public parks etc.

Unaccounted for water (UFW)

Water losses in the water supply distribution system, illegal connections, overflow from reservoirs and improper metering etc..., are referred to as unaccounted for water. For Emdibir town, based on the past information on UFW record from the town WSU[5] office and the national design criteria related to the UFW. The estimated UFW of the town at the end of design period are as taken as 30% of the maximum day demand.

4.3. Design current and future water demand

Now that the total current non-domestic (its percentage) is known, we can determine the maximum and peak hourly demand for Emdibir town using design criteria.

- **Annual average day demand:** This is the average of the total amount of water used each day during a 1-year period.
- **Maximum day demand:** This is the amount of water required during the day of maximum consumption in a year.
- **Peak hour demand**: This represents the amount of water required during the maximum consumption hour in a given day.

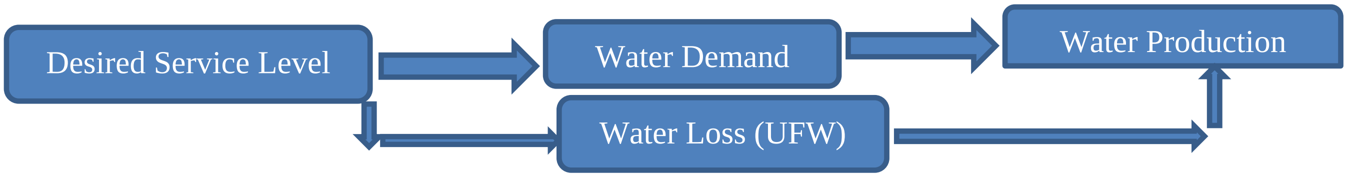
Typical procedures to estimate future water demand are:

- Forecast the future population of the service area for the initial and design years.
- Determine the average per capita daily water demand.
- Determine annual average per capita water demands.
- Determine maximum day demand for current and projected years.
- Determine the projected average day, maximum day, and peak hour demands.

Future domestic water demand

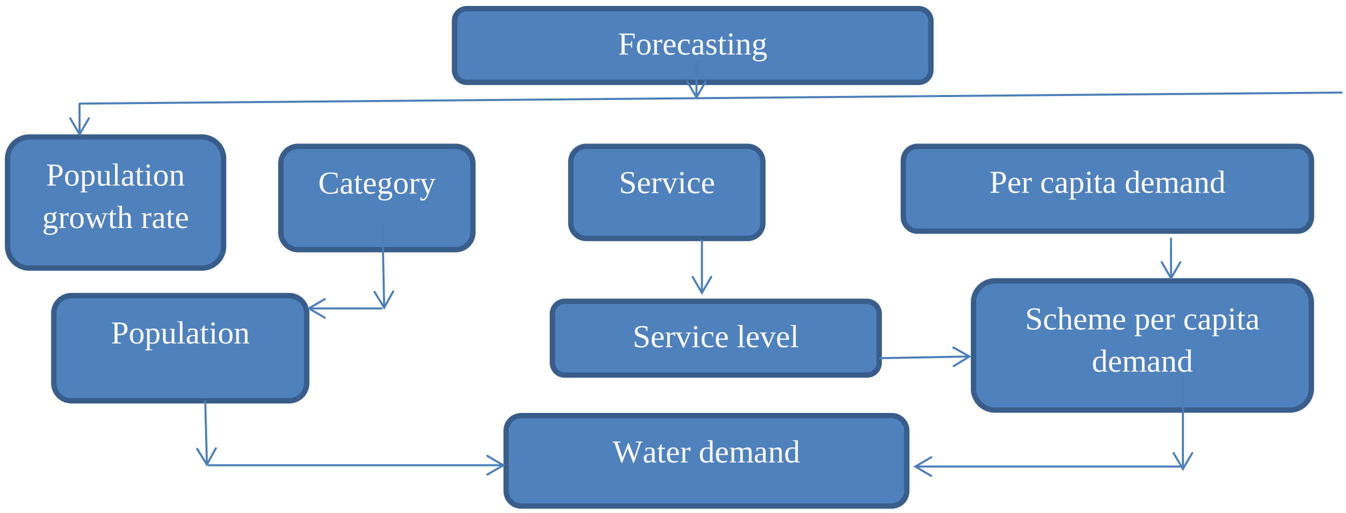
Forecast of future connection profile, considering household income growth and income the water demand forecast is basically determined by two parameters: the per-capita water consumption and the connection profile. Water consumption is also related to the income of household through an income-elasticity. When considering a certain desired service level as starting point, the resulting water demand is calculated by multiplying the per capita water demand with the population number. The subsequent water production capacity is the sum of the water consumed and the water losses (UFW) during production and transportation / distribution as illustrated diagrammatically here under.

[5] *WSU, water supply utility*



UFW is a component of the water demand, which usually is difficult to establish unless certain facilities are in place and it has been monitored constantly. The water demand forecasts follow the procedure in the chart shown in figure below:

Figure 9: water demand forecasting procedure



4.4. Demand projection

The detail design of the Bozebar spring system has been made first in year 2001 by Tropic Consultant and the conditions regarding the development of the town. Business plan for the town water supply is also prepared in year 2017 and design review for some of the proposed water supply components has been made. The review made during the business plan preparation in 2017, however, has not gone in to detail engineering issues therefore, the revise detail designs made for the water supply components based on the Bozebar spring by Abebaw Dagne water work consultant (July 2017).

4.4.1. Present water demand

It is clear that, for the purpose of this study, the only demand to be taken in to consideration is for the utility’s water supply system. If people have their own hand dug wells, or some institutions and commercial centers are having their own water supply system and are satisfied with the water they draw in cost, quality and other related matters, then they have no piped demand from the WSSE system. In cases where people utilize both the piped system and natural sources it becomes difficult to estimate the actual water demand as the reasons for utilizing other sources is not clear. In the case of Emdibr even though there is no any other private connection, hence, the current water demand is that quantity which can be supplied by the piped system from safe sources.

4.4.2. Population forecasting

Method by Country Statistic Authority (CSA): The main advantage of this method is conceptually simple and easily understood, and can be applied at almost any level of geography Thus, population estimation at some year in the future using CSA method can be expressed as

$$P_o * e^{K*n},$$ where P_n = population of n decades or years

P_o = base population

K = growth rate in percent

n = decade or year

Population projection

CSA has made population projection for both rural and urban settings up to the year 2030 in three variants, high, medium and low for each regional state in the country. The medium growth rate for all the regions in the country is as indicted in the table here below.

Table 8: Summary of population growth rate for different regions

Summary of regional population growth rate (%)							
region	settlement type	2000 - 05	2005 - 10	2010 - 15	2015 - 20	2020 - 25	2025 - 30
SNNPR	urban	4.80	4.60	4.30	4.10	3.90	3.70
	rural	2.80	2.50	2.30	2.10	1.80	1.50

Source: CSA 1994E.C: Population and housing census analytical report, Vol. II, 1999 E.C or (2001) G.C, Addis Ababa, Ethiopia)

Applying the above growth rates in the exponential model, the population of Emdibr town is projected up to year 2028 G.C as a first phase and moreover up to 2038 G.C for prediction during the second phase with a total of 20 years. Applying the above growth rates in the exponential model, the population of Emdibr town is projected up to year 2028 G.C as a first phase and moreover up to 2038 G.C for prediction during the second phase with a total of 20 years. The population projection growth rate for Emdibir town is shown below:

Table 9: The projected population of Emdibir town from 2018-2038)

Year in GC	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Population	21,643	22,549	23,494	24,282	25,249	26,254	27,298	28,385	28,987	30080	31,215

Year in GC	2029	2030	2031	2032	2033	2034	2035	2036	2,037	2,038
Population	32,393	33,615	34,882	36,198	37,563	38,980	40,450	41,976	43,559	45,202

4.4.3. Town category

Hence, according to GTP-2 categorization of towns Emdibir is grouped under category 5 for average consumption of 50 l/c/day for towns/cities (towns/cities with a population in the range of 20,000-50,000) with a maximum distance of 250m from the delivery point. Hence, despite the estimation of the service level, the average demand for all service level shall be 50 l/c/day. This will also reduce the error in estimating the demands for each service levels. The water demand forecast is basically determined by two parameters: the per-capita water consumption and the connection profile. Water consumption is also related to the income of household.

When considering a certain desired service level as starting point, the resulting water demand is calculated by multiplying the per capita water demand with the population number. The water production capacity is the sum of the water consumed and the water losses (UFW) during production and transportation / distribution. UFW is a component of the water demand, which usually is difficult to establish unless certain facilities are in place and it has been monitored constantly. Based on the above points, the current situations of the service levels, the current income level, and the national water supply master plan study for similar towns of category, the current study, and the design criteria set in the feasibility study, the future service levels are set to be as shown in percentage in the table here below:

Table 10: Total projected domestic and Non-domestic water demand

Year in G.C	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Population	21643	22549	23494	24282	25249	26254	27298	28385	28987	30080	31215
Connection											
HC (%)	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
YC (%)	68.5	69	69.5	70	70.5	71	71.5	72	72.5	73	73.5
PT (%)	29	28	27	26	25	24	23	22	21	20	19
Population											
HC	541	677	822	971	1136	1313	1501	1703	1884	2106	2341
YC	14826	15559	16328	16997	17801	1864	19518	20437	21016	21958	22943
PT	6277	6314		6313	6312	6301	6279	6245	6087	6016	5931
Ava (l/c/d)											
HC	92	93	94	95	97	98	99	100	102	103	104
YC	23	23.5	24	24.5	25	25	25	26	26	26	26
PT	12	12	12	12	12	12	12	12	13	13	13
Demand,M^3/d											
HC	49.8	62.9	77.3	92.3	110.2	128.6	148.6	170.3	192.2	216.9	244
YC	340.9	365.6	391.9	416.4	445	466.	487.9	531.4	546.4	570.9	597
PT	75.3	75.8	76.1	75.8	75.7	75.6	75.3	74.9	79.1	78.2	77.1
TDD,M^3/d	466.1	504.3	545.3	584.5	630.9	670.3	711.9	776.6	817.7	866	917
Climate	1	1	1	1	1	1	1	1	1	1	1
Socio-eco	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Adj-DD											
M^3/d	489.4	529.5	572.6	613.7	662.5	703.8	747.5	815.4	858.6	909.3	963
L/S	5.7	6.1	6.6	7.1	7.7	8.1	8.7	9.4	9.9	10.5	11.1
Current Total NDD = 62 m^3/d											
NDD (%)	0.4	0.39	0.38	0.37	0.36	0.35	0.34	0.33	0.32	0.31	0.3
NDD(m^3/d)	86.8	110.9	134.5	157.5	179.8	201.5	222.6	2439	262.9	282.1	301
DD+NDD,M^3/d	576.2	640.5	707.1	771.2	842.3	905.3	970.1	1058.5	1121.5	1191.4	1264
Loss, (%)	40	39	38	37	36	35	34	33	32	31	30
Loss, m^3/d	230.5	249.8	268.7	285.3	303.2	316.8	329.8	349.3	358.9	369.3	379.1
TAV Day D											
(M^3/d)	806.7	890.3	975.8	1056.5	1145.6	1222.1	1299.9	1407.8	1480.4	1560.7	1643
(L/S)	9.3	10.3	11.3	12.2	13.3	14.1	15	16.3	17.1	18.1	19
MDF	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
PHF	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
MDD											
M^3/d	1008.3	1112.9	1219.7	1320.6	1431.9	1527.7	1624.9	1759.7	1850.5	1950.9	2053
L/S	11.7	12.9	14.1	15.3	16.6	17.7	18.8	20.4	21.4	22.6	23.8
PHD											
M^3/d	1532.7	1691.6	1854	2007.4	2176.6	2322	2469.9	2674.8	2812.7	2965.4	3121
L/S	17.7	19.6	21.5	23.2	25.2	26.9	28.6	30.9	32.6	34.36	36.1

Year	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**
Population	32393	33615	34882	36198	37563	38980	40450	41976	43559	45202
Connection										
HC (%)	0.08	0.09	0.09	0.10	0.1	0.11	0.11	0.12	0.12	0.12
YC (%)	0.74	0.745	0.75	0.76	0.76	0.765	0.77	0.775	0.78	0.79
PT (%)	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.1	0.09
Population										
HC	2591.4	2857.3	3139.4	3438.8	3756.3	4092.9	4449.5	4827.2	5227	5424
YC	23970.8	25043	26161.5	27329.5	28547.9	29819.7	31146.5	32531.4	33976	35709
PT	5831	5714	5581	5430	5259	5067	4854	4617	4356	4068
Aval/c/d										
HC	105	106	107	109	110	110	110	110	110	110
YC	26.5	27	27.5	28	28	28	28	28	28	28
PT	14	14	14	14	14	14	14	14	14	14
Demand,M^3/d										
HC	272.1	302.9	335.9	374.8	413.2	450.2	489.4	530.9	574.9	596.7
YC	635.2	676.2	719.4	765.2	799.3	834.9	872.2	910.9	951.4	1000
PT	81.6	79.9	78.1	76.02	73.6	70.9	67.9	64.6	60.9	57
TDD,M^3/d	988.9	1059	1133.5	1216.1	1286.2	1356.1	1429.5	1506.5	1587	1654
Climatic	1	1	1	1	1	1	1	1	1	1
Socio-eco	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Adjusted DD										
M^3/d	1038.4	1112	1190.2	1276.9	1350.5	1423.9	1500.9	1581.8	1667	1736
L/S	12	12.9	13.8	14.8	15.7	16.5	17.4	18.3	19.3	20.1
NDD = 300.7 m^3/d,										
NDD (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
NDD(m^3/d)	311.5	333.6	357	383.1	405.1	427.2	450.3	474.6	499.9	521
DD+NDD,M^3/d	1349.9	1445.6	1547.2	1659.9	1755.6	1851.1	1951.3	2056.4	2167	2257
Loss, (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Loss, (m^3/d)	404.9	433.7	464.2	497.9	526.7	555.3	585.4	616.9	649.9	677
TAV Day D										
(M^3/d)	1754.9	1879.3	2011.4	2157.9	2282.3	2406.4	2536.7	2673.3	2817	2934
(L/S)	20.3	21.8	23.3	24.9	26.4	27.8	29.4	30.9	32.6	33.9
MDF	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
PHF	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
MDD										
M^3/d	2193.6	2349.1	2514.2	2697.4	2852.9	3008	3170.8	3341.6	3521	3667
L/S	25.4	27.2	29.1	31.27	337	34.87	36.7	38.7	40.8	42.4
PHD										
M^3/d	3334.3	3570.6	3821.6	4100	4336.4	4572.2	4819.6	5079.3	5352	5575
L/S	38.6	41.3	44.2	47.5	50.2	52.9	55.8	58.8	61.9	64.5

Summary of total water demand forecasting

s/n	Item	Demand (m^3/day)
1.	Domestic demand (end of design period)	⇨ (1,736.2) m^3/d
2.	Non-domestic demand(end of design period)	⇨ (520.8) m^3/d
3.	Domestic+ Non-domestic demand (2038)	⇨ (1,736+ 520.8) =2256.8 m^3/d
4.	30% loss for scheme having 20 year service)	⇨ (2,256.8*0.3) = 677.04 m^3/d
5.	Total daily demand at the end of design period(2038)	⇨ (6,967.87) m^3/d, (with factors)

Sample calculation

Calculation MDD and PHD at the end of design period is:-

Average day demand, (ADD) in 2030 = 2,934.1 m^3/day

Maximum day demand= ADD *MDF = 2,934.1*1.25 = 3,667.6m^3/day =42.4 l/sec

Peak hour demand (PHD) =ADD * PHF =2,934.1*1.9 =5,574.8m^3/day= 64.5 l/sec

Summary of population projection and water demand projection described as follows:

- Design year 2018 up to year 2038.
- Design population is taken as 19,593 for Emdibir town and 1,180 for the rural areas a total of 20,773 in 2018 and 45,202 at the end of design period in 2038.
- The current total maximum monthly production is 15,636m^3/month
- The daily pumping time is 16 hours and the discharge of the spring is about 6.3l/s.
- The current NRW is 21.4 % of the day water production.
- The current average per capita water production is 24.71/c/day.

4.5. Water demand by geographical distribution

As discussed earlier, the socio-economic as well as the water demand distribution is planned to be done on town’s plan basis at villages’ level having current settlements. In order to prepare cost effective and Sustainable water supply scheme, the current and projected demand shall be distributed in these villages related to the future development trend. According to the town administration the development trend of the town is majorly along the southern western in Yesemie_Ena_Fuka village, northern part of the town that is in gedam sefer and yegoche, in addition to the southern part of the town that is in yegonze-zigbie and yerezeb villages.

Distribution of the demand

Once the total demand is known on village level, then distribution of the lump sum demand among demand nodes is critical to design sustainable and efficient water supply system. The modern method of allocating demand among demand nodes using latest software, Water GEMS which runs in integration with GIS.

Household size and composition

According to the study conducted in the town with the town administration, the current total population of the town in 2017 is about 20,773. Of them 41% of the town's population is female while 59% percent is male.

4.6. Water loss analysis

4.6.1. Water loss and leakage

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

4.6.2. Design and operation of piped networks

Pressure can be lost by the action of friction at the pipe wall. The pressure loss is also dependent on the water demand, pipe length, gradient and diameter. When designing a piped system, the aim is to ensure that there is sufficient pressure at the point of supply to provide an adequate flow to the consumer. Pressure at any point in the system should be maintained within a range whereby the maximum pressure avoids pipe bursts and the minimum ensures that water is supplied at adequate flow rates for all expected demands. Hydraulic models are used to identify where, when and how negative and high pressures may occur and help to identify preventative measures such as system controlling methods and for selection of pipe materials according to the pressure.

4.6.3. Non-revenue water

Non-revenue water: - is water that is not billed and no payment is received. It is the difference between the volumes of water put into a water distribution system and the volume that is billed to customers. NRW comprises three components: physical (or real) losses, commercial (or apparent) losses, and unbilled authorized consumption.

Physical losses (real) losses: - comprise leakage from all parts of the system and overflows at the utility's storage tanks. They are caused by poor operations and maintenance, the lack of active leakage control, and poor quality of underground assets, joints, and fittings; leakage from reservoirs and tanks; reservoir overflows;

Commercial (apparent) losses: - are water that is not physically lost but does not generate revenue because of inaccuracies related to customer meter under registration, data-handling errors, and theft of water in various forms, Poor installation and workmanship, Poor materials mishandling of materials prior to installation, Incorrect backfill, Excess pressure, corrosion, vibration and traffic loading.

Unbilled authorized consumption: - includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer.

Water constitutes about two-thirds of the whole earth surface yet it is tragically limited in its availability as a freshwater to man. According to World Bank, (2014) report, freshwater constitutes only about 2.76 percent of the total water available on earth. And even with this, it is only less than one per cent which is readily available to be accessed and used by man. From this fresh water some of them are lost by different reason such as, loss (real or apparent water loss). Water loss which is a major component of Non-Revenue Water (NRW) is water that is not billed and no payment is received.

Table 11: IWA practice standard water balance

<table>
<tr><td rowspan="6">System
Input volume
=187,153.676m^3
=100 %</td><td rowspan="4">Authorized
Consumption
= 147,102.78 m^3
= 78.6%</td><td rowspan="2">Billed Authorised
consumption
= 147,812m^3/y
= 78.97%</td><td>Billed metered consumption
= 147,774.47 m^3/y
= 78.96%</td><td rowspan="2">Revenue water
=147,812 m^3/y
= 78.97%</td></tr>
<tr><td>Billed unmetered consumption
= 37.53 m^3/y
= 0.02%</td></tr>
<tr><td rowspan="2">Unbilled Authorized
Consumption
=12,426.85m^3/y
= 6.64%</td><td>Unbilled metered consumption
= 131.3 m^3/y
= 0.07%</td><td rowspan="4">Non- Revenue
Water
= 40,042 m^3/y
= 21.4%</td></tr>
<tr><td>Unbilled unmetered
consumption
= 12,295. 55m^3/y
= 6.57%</td></tr>
<tr><td rowspan="2">Water Losses
= 40,042 m^3/y
= 21.4%</td><td rowspan="2">Apparent Losses
= 27,615.15 m^3/y
= 14.8%</td><td>Unauthorized use
= 10,728.1m^3
= 5.7%</td></tr>
<tr><td>Metering inaccuracies
= 16,887.06 m^3/y
= 9.02%</td></tr>
</table>

Source: Emdibir town water utility

4.6.4. Components of NRW

Non-revenue water (NRW) is equal to the total amount of water flowing into the water supply network from a water treatment plant (the 'System Input Volume') minus the total amount of water that industrial and domestic consumers are billed authorized to use ('Billed Authorized Consumption'). The IWA defines NRW as follows:

NRW = System Input Volume − Billed authorized consumption

System Input Volume: - Is the annual volume of water input in to the supplying system.
Billed authorized consumption:-is the annual volume of metered and non-metered water taken by registered customers, the water supplier and others. The volume of real losses occurring in developing countries alone is sufficient to supply approximately 200 million people. World Bank, (2014) report

4.6.5. Causes of NRW

Leakage from transmission and distribution mains: - Leakages occurring from transmission and distribution mains are usually large events, causing damage to highway infrastructure and vehicles.

Leakage and overflows from the utility's reservoirs and storage tanks: - Leakage and overflows from reservoirs and storage tanks are easily quantified. Utility managers should observe overflows then estimate the average duration and flow rate of the events.

Meter bypassing: - Some customers try to reduce their water bills by using a meter bypass, which is an additional pipe installed around the meter.

Illegal use of fire hydrants: - Although the only legal use of fire hydrants is for firefighting, some use them illegally to fill tankers (normally at night) or to provide water supply to construction sites.

Data handling and accounting errors: - The typical method of data handling and billing requires a meter reader to visit each property and read the customer meter.

Production meter accuracy: - The accuracy of production flow meters is critical to calculate system NRW.

Occurrence of Leaks due to:-

Water main leaks: -Typically leaks due to corrosion of water mains usually start through small holes but can grow to very large leaks. Mostly causes on excessive pressure, poor workmanship, settlement of trenches overloading, and improper materials, and temperature stresses are the major ones.

Service Line leaks: -Typically the causes for service line leaks are the same as for the mains and it causes is during maintenance.

Customer Meter Box leaks (near or within meter boxes of customers):- Leaks may be caused by loose on the meter, broken or damaged couplings and broken meters.

Customer Connection Line leaks (customer side of the line): - Holes or breaks in customer connection lines and shutoff valves may cause these leaks.

Valves and Appurtenance leaks: - In distribution system typically loose connection and broken valves are common causes for this type of leak. (Water Aid Ethiopia, 2013)

7. Management of Non -revenue water

The need to prevent Non-revenue water losses and protect precious water resources has become increasingly important. Next to fixing materials quality, the second step for managing non-revenue water is pressure management, speed and quality of repair. A small reduction in pressure can mean a significant reduction in real losses through leaks.

4.7. Water supplying analysis

From town water utility office, data's recorded at the outlet of the water meter at the spring source and the pumping station shown below indicates the average monthly water production duration form 1, September 2017 up to 30, August. 2017 for one year data's are:-

Table 12: Recorded monthly water production in meter cube

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Total
m^3/m	14,987	14,875	15,954	15,821	14,964	15,889	15,982	16,975	16,649	15,724	14,839	14,975	187,634

The average monthly water consumption as recorded from the monthly bills is as shown in the table here below for the duration form 1, Sept. 2017 up to 30, Aug. 2017.

Table 13: Billed monthly water consumption in meter cube

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Total
m^3/m	12,400	11,907	13,400	12,900	10,304	13,078	11,654	13,012	12,765	11,905	12,812	11,675	147,812

Total Water loss expressed as: -One year production and consumption data of the study area used to compute the total loss as shown in table above by using this expression.

$$\textbf{NRW (\%)} = \sum\left(\frac{\text{Production} - \text{metered use}}{\text{Production}}\right) * 100\%$$

$$= \sum\left(\frac{187{,}364 - 147{,}322}{187{,}364}\right) * 100\%$$

= 21.4 %

Water loss expressed as per number of connection

The total number of connection in the study area is 1,100. The water loss per connection computed by using this expression

Water loss = Annual total loss *1000/ (number of connection*365). From the one year computed total water loss for the previous last year value is

$\sum 187{,}634 - \sum 147{,}632$ = 40,042 m^3/year.

= 40,042 *1000/ (1100*365)

= 99.73 Litter/connection/day

Current average per capita production: - is can be calculated by average daily water production divided by the current number of populations. The current average per capita water production is 24.71/c/day this means (187,364/365 =513.3m^3/d) or (513.2/20,773)*1,000 =24.71 l/c/d.

Water loss expressed as per length of pipes:-Expressing water loss as per kilometre of main pipe is one way to indicate the loss. The total length of pipes of size 50mm to 110mm is 21.7km and these total pipe length used to express the water loss.

Source: town water utility office.

- **Water loss** = Annual loss/ (length in km *365)
  = 40,042 / (21.7km *365)
  = 5.05m^3/km/day

Real and Apparent Loss Analysis: - Non-revenue loss is the sum of real loss and apparent loss. The expression is good indicator of loss and this study focus on two different areas which have relatively high and low average pressure. The IWA Water losses task force developed equation and its parameters are A, B, C based on statistical analysis of international data.

Unavoidable Average Real Losses (UARL): - It is recommended that the calculation of the UARL in letters/service connection/day is based on the following form of equation. This recognizes separate influences of real losses from:-

- Length of mains (Lm in km),
- Number of service connections (Nc),
- Total length of service connections from the edge of the street to customer meters (Lp in km),
- Average pressure (P in meters) when the system is pressurized.

$$\mathbf{UARL} = \left(\mathbf{A} * \frac{\mathbf{Lm}}{\mathbf{Nc}} + \mathbf{B} + \mathbf{C} * \frac{\mathbf{Lp}}{\mathbf{Nc}}\right) * \mathbf{P}(\mathbf{Litters/service\ connection/day})$$

Source: IWA practice standard water balance

Where, The appropriate values for A (18), B (0.80) and C (25) the equation and its parameters A, B, C are based on statistical analysis of international data,

Location 1, from 100m^3 balancing reservoir to 75m^3 service reservoir

For, Length of mains (Lm in km) = 8 km, from existing data.
Number of service connections (N c) = 254, from existing data.
Total length of service connections from the edge of the street to customer meters average 10m for individual
(L_p in km), =10m*254=2540m=2.54km.
Average pressure (P in meters) =38.8m, from model pressure result of these pipe line.

$$\mathrm{UARL} = \left(\mathrm{A} * \frac{\mathrm{Lm}}{\mathrm{Nc}} + \mathrm{B} + \mathrm{C} * \frac{\mathrm{Lp}}{\mathrm{Nc}}\right) * \mathrm{P}(\mathrm{Litters/service\ connection/day}).$$

= (18 *8/254 +0.8 + 25 * 2.54/254)*38.8
= 62.85 Lit / service connection / day

Annual Volume UARL is

= 62.85 lit *365
= 22,940.25 lit/ connection/year

Total annual UARL in all Connection is

= 22,940.25 lit/connection/year*254 connection

= 5,826.82 m^3/ connection /year.

Location 2, from 100m^3 balancing reservoir to 50m^3 service reservoir

There for, Length of mains (Lm in km) = 8km

Number of service connections (Nc) = 846

Total length of service connections from the edge of the street to customer meters average is 10m.

- (L_p in km), =10m*846=8460m=8.46km.
- Average pressure (P in meters =25.3m), from model result for distribution system.

$$\text{UARL} = \left(A * \frac{Lm}{Nc} + B + C * \frac{Lp}{Nc}\right) * P(\text{Litters/service connection/day})$$

= (18 *8/8460 +0.8 + 25 * 8.46/8460)*25.3

= 21.303 lit / service connection /day

- **Annual volume UARL is**

  = 21.303*365

  = 7,775.45 L/service connection/year

- Total Annual UARL in all Connection is

  = 7,775.45 Lit/connection /year*846 connection

  = 6,578.01 m^3/ year

- **Total sum from location 1 and 2 is**

  = 5,826.82 m^3/ year + 6,578.01 m^3/ year.

  = 12,404.85 m^3/ year.

From the one year computed total water loss for the previous last year (2017) value is 40,042 m^3/ year.

$$\sum \text{APPARET LOSS} = (\text{NRW} - \text{Real loss})$$

= 40,042 m^3/ year -12,404.85m^3/year

= 27,615.15 m^3/ year.

4.8: Summary and findings of the analysis

Water loss analysis and leakage of the system need a detail data due to its complex nature. In fact, in developing countries like Ethiopia, the data scarcity is usually the main problem. Based on the result of the analysis the following conclusions and findings are drawn;

- Higher water loss and unavoidable real loss is found on gravity flow in distribution network system. This line has long pipe length and many connections compared to the main pressure system.
- More than 50% of the total pipe age categories are aged between 20 to 32 years. This indicates clearly that most of the current functional pipes are relatively old. Hence, due to high pressure, non-physical water loss is bursting pipes.

- Ethiopian government has planned to reduce NRW from 39% to 20% until 2020. But, in the case of Emdibir town water supply analysis, the result of NRW shows 21.4%. This indicates either the water management system is very good or need further research to identify appropriate value of water loss by collecting all necessary data including some other missing data.

4.9. Hydraulic Model Analysis

4.9.1. Model results by using existing data's

By using surveyed data of pipe line elevation, size of pipe, material type and other relevant parameters, the water supplies network developed and the analysis is done by using Water CAD software. Elevation, demand, length, pipe size and type of materials are the input of the model, whereas velocity at pipe and pressure at every junction was the output. The total water demand is analyzed based on the number of customer of domestic, public and industrial user of each junction. According to Emdibir town water supply office, the peak hour demand of the town occurs in between 8:00 AM to 10 AM and 5:00pm to 8:00pm. To compute the demand at different loading condition needs respective demand factors. According to design manual of MOWR (2014) below, the maximum day factor and peak hour's factor set as per the number of population. Hence, the MDF and PHF of Emdibir town is 1.25 and 1.9 respectively. Moreover, Emdibir town has very high potential for development. Therefore, by using 1.00 adjustment factors the peak hour factor became 1.9.

Demand distribution in each junction

Sample demand distribution calculation in each junction

Base demand vs. Sample calculation made at J-77, it is located near to balancing reservoir which supplies water for 540 communities, Base demand = Population * Per capita demand per day (24.7) l/day), = 540 * 24.7 l/day =13,554 l/day = 0.16 l/sec

MDD = 0.16 l/s *1.25 = 0.2 l/s

PHD = 0.16 l/s * 1.9 = 0.3 l/s

LHD = 0.16 l/s * 0.2 = 0.03 l/s

Table 14: Existing distribution in each junction

Label	Elevation(m)	Zone	Demand (L/s)
J-1	2,007.58	Zone - 2	0.25
J-21	1,948.22	Zone - 1	0.22
J-25	1,957.48	Zone - 1	0.39
J-26	1,949.09	Zone - 1	0.54
J-28	1,944.60	Zone - 1	0.87
J-29	1,950.05	Zone - 1	0.31
J-31	2,034.06	Zone - 2	0.59
J-32	2,032.95	Zone - 2	0.58
J-34	2,038.03	Zone - 2	0.79
J-45	1,935.46	Zone - 2	0.13
J-47	1,924.68	Zone - 2	0.21
J-48	1,925.89	Zone - 2	0.23
J-49	1,934.75	Zone - 2	0.39
J-50	1,939.12	Zone - 2	1.25
J-51	1,940.94	Zone - 2	0.29
J-9	1,965.17	Zone - 1	0.11
J-1	2,007.58	Zone - 2	0.25
J-11	1,960.49	Zone - 1	0.92
J-14	1,961.48	Zone - 1	0.11
J-15	1,958.11	Zone - 1	0.26
J-16	1,958.65	Zone - 1	0.18
J-17	1,948.05	Zone - 1	0.21
J-19	1,945.59	Zone - 1	0.42
J-20	1,948.43	Zone - 1	0.38
J-53	1,954.63	Zone - 1	0.17
J-54	1,958.49	Zone - 1	0.19
J-56	1,951.56	Zone - 1	0.05
J-65	1,915.60	Zone - 2	0.23
J-66	1,923.56	Zone - 2	0.14
J-67	1,937.12	Zone - 2	0.13
J-68	1,916.90	Zone - 2	0.18
J-70	2,032.54	Zone - 2	0.15
J-71	1,954.00	Zone - 1	0.28
J-72	1,953.18	Zone - 1	0.27
J-73	1,954.54	Zone - 1	0.34
J-74	1,959.58	Zone - 1	0.21
J-77	2,103.22	Zone - 1	0.16
J-80	1,942.88	Zone - 1	0.29
J-83	1,953.11	Zone - 1	0.42

Label	Elevation(m)	Zone	Demand (L/s)
J-86	2,014.00	Zone - 2	0.08
J-89	2,009.00	Zone - 2	0.37
J-90	2,006.00	Zone - 2	0.53
J-92	1,958.34	Zone - 1	0.11
J-93	1,994.00	Zone - 2	0.21
J-94	2,017.20	Zone - 2	0.13
J-95	2,046.17	Zone - 2	0.46
J-132	2,031.58	Zone - 2	0.22
J-137	2,018.83	Zone - 2	0.13
J-138	2,008.81	Zone - 2	0.2
J-139	1,996.37	Zone - 2	0.32
J-140	1,982.96	Zone - 2	0.32
J-141	2,012.12	Zone - 2	0.35
J-142	1,982.81	Zone - 2	0.18
J-143	1,972.99	Zone - 2	0.15
J-154	2,003.08	Zone - 2	0.53
J-155	1,922.42	Zone - 2	0.33
J-156	1,938.36	Zone - 2	0.45
J-158	1,938.50	Zone - 2	0.15
J-160	1,937.80	Zone - 2	0.19
J-161	1,922.18	Zone - 2	0.25
J-108	2,031.81	Zone - 2	0.12
J-116	2,029.49	Zone - 2	0.13
J-117	2,025.23	Zone - 2	0.1
J-118	2,048.64	Zone - 2	0.05
J-120	2,032.05	Zone - 2	0.09
J-121	2,030.51	Zone - 2	0.06
J-123	2,026.83	Zone - 2	0.11
J-125	2,024.29	Zone - 2	0.14
J-126	2,052.61	Zone - 2	0.09
J-170	1,956.49	Zone - 1	0.3
J-24	2,101.54	<None>	9
J-25	2,085.67	<None>	9
J-26	2,086.31	<None>	9
J-27	2,092.50	<None>	9
J-28	2,087.83	<None>	9
J-29	2,107.05	<None>	9
J-30	2,102.67	<None>	9
J-31	2,082.14	<None>	9

Table15: Existing pump model report data

Label	Elevation (m)	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (m)	Hydraulic Grade(m)	Flow (L/s)	Pump head (m)
PMP-1	1918	Pump Definition - 1	On	1918.73	2124.54	6.3	205.81

Table 16: Existing reservoir model report

Label	Elevation (m)	Zone	Flow (Out net) (L/s)	Hydraulic grade (m)
R-5	2098.17	Zone - 2	12.2	2098.17
R-6	2124.99	Zone - 1	17.5	2124.99
R-7	1918.75	<None>	22.5	1918.75

Table17: Hourly demand factor for Emdibir town

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

At Average Day Demand Condition (ADD)

Maximum Pressure = 42m, at J-31, zone-2
Minimum Pressure = 13, at J-141, zone-2
Maximum Velocity =3.05/se at p-94, with pipe diameter 32mm
Minimum Velocity = 0.01m/s, at P-26, with pipe diameter 32mm

According to MoWR[6], (2014) report, for safe hydraulic system of water distribution the recommended value of pressure and velocity is at distribution system the pressure must be not less than 15m and not more than 60 m head, the minimum velocity not less than 0.5m/s and the maximum velocity should be less than 3m/s.

[6] *MoWR= ministry of water resource*

4.10.2. Reservoir

Operational reservoirs should be provided to command a distribution system, located at elevations providing the required pressure for water flow within the system. They should have sufficient storage to cover the difference between hourly peak demand and actual supply from the source, firefighting demands.

4.10.3. Types of reservoirs

The two main types of reservoir are the ground level type (GLR) and elevated water tank type (EWT). Whenever, the local topographical conditions permit, ground level reservoirs are preferable. Ground level reservoirs will be usually be of solid block masonry or reinforced concrete, cylindrical or rectangular. Elevated water tanks will be cylindrical or conical in reinforced concrete (M0WR 2014).The study area has one ground and two elevated functional circular reinforced concrete reservoirs.

Reservoir location

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

Reservoir equipment's

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

4.11.4. Total storage requirement

In order to provide for security of supplies above the need for balancing purposes it is recommended that the minimum total reservoir storage capacity be in the range of 30% to 50% of the average daily demand (M0WR 2012). The study area has one 100m^3 reservoir, one 75m^3 reservoir and one 50m^3 elevated reservoirs which have a total of 225m^3 reservoir. To check this capacity enough or not the total average day demand as per computed above is equal to 2934.1m^3/day and the level of existing storage computed as:

$$= 0.3*2934.1 \quad \text{to} \quad 0.5*2934.1$$

$$= 880.23\ m^3/\ day \text{ to } 980.43\ m^3/\ day.$$

So, the storage capacity of existing reservoir has been not on the recommended renege and the scheme is not safe regarding to storage capacity. Therefore, there is need of additional reservoir construction.

4.11. Model Calibration and Validation

Calibration is an iterative procedure of parameter evaluation and adjustment by comparing simulated and observed values**.** The Water Gems Model was calibrated by adjusting sensitive parameter such as Hazen-Williams Coefficient. As the model gives automatically C value of ductile iron (GI) Pipe 130 and for PVC pipe 150 since, the system is old and should have roughness coefficient of pipe less than the model value. There for, this standard value of Hazen-Williams (C-value) used to adjust the model Value until closed to the measured value. When the value of C becomes adjusted it changes the roughness**,** friction and flow velocity effects of the pipe line. This means the age of pipe line have significant role in the water pipe line.

Table 18: C value for pipe materials

S/N	Type of material	C, value for new pipe	C, value for existing pipe
1	PVC	130	100-110
2	Steel	110	90-110
3	GI	120	100-110

Source: design criteria manual of MOWR (2010)

Head loss, according to Hazen William is expressed as:-

$$Hf = 10.675 * Q^{1.852} * C^{-1.852} * D^{-4.87} * L$$

Where, H_f = Head loss due to friction (m)

Q = Discharge of submersible pump (m3/sec)

C = Hazen William friction coefficient (120)

D = Economic diameter of pipe (m)

L = Delivery pipe length

After water distribution model has been developed, it must be calibrated so that it accurately represents the actual working real life water distribution network under a variety of condition. This involves making minor adjustment to the input data then the model accurately simulated the pressure rate in the system. Pressures are measured throughout the water distribution system using pressure gage instrument for model calibration. The computed pressure and measured field pressure will not exactly match. Devices used for taking field measurements were the static pressure gauges and flow measurement device by Steady state measurements. By taking the above condition in to consideration, pipe line between balancing reservoirs to services reservoir and on selected point of distribution system the level of pressure and discharge measurement has been made at ten selected points by using pressure gage and water mater instrument. Ten observed pressure data were collected at main and distributing networks as shown in the table below for calibration and validation. Model validation is used to assure that the calibrated model property assesses all the variables and conditions. The hydraulic model calibration parameters that are typically set and adjusted pipe roughness factors. The result shows that when the Hazen-Williams roughness coefficient increases the value of the pressure increases and head losses decreases.

4.12. Model performance evaluation

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

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

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

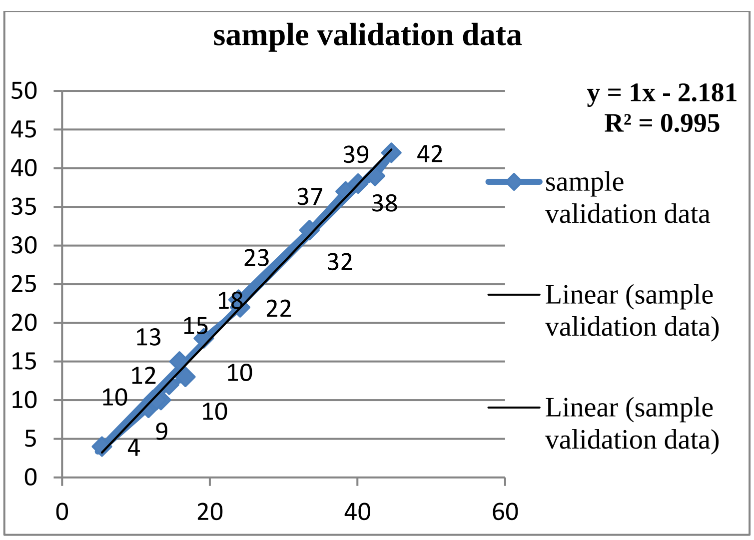
Figure 12: Sample measured junction pressure data validation and time series with distribution network

Table 19: Sample validation data

No.	Sample Location	Measured pressure(m)	Computed pressure	Difference	Measured Time(am)	Sample Location		
						X(m)	Y(m)	Elevation(m)
1	J-29	19.2	18	+1.92	7:05	382,184.78	897,125.27	2101.54
2	J-30	24.1	22	+2.1	8:35	381,384.33	897,650.94	2085.67
3	J-24	23.9	23	+0.9	9:55	381,557.34	897,533.04	2086.31
4	J-27	33.5	32	+1.5	10:25	381,683.95	897,452.50	2092.50
5	J-28	38.4	37	+1.4	10:55	381,874.22	897,328.83	2087.83
6	J-26	40.1	38	+2.1	11:22	382,027.18	897,226.68	2107.05
7	J-25	42.4	39	+2.4	11:53	382,104.64	897,175.34	2102.67
8	J-31	44.6	42	+2.6	12:15	381,342.07	897,677.98	2082.14
9	J-54	5.4	4	+1.4	10:30	382,360.96	382,360.96	1973.64
10	J-53	11.7	9	+2.7	11:22	382,302.18	897,389.95	1961.48
11	J-56	12.3	10	+2.3	08:23	382,254.60	897,438.92	1,958.00
12	J-9	13.4	10	+3.4	09:15	382,220.68	897,412.12	1,958.65
13	J-16	12.8	10	+2.8	10:45	382,186.98	897,377.90	1948.05
14	J-15	14.5	12	+2.5	11:21	382,154.37	897,337.72	1965.17
15	J-14	16.7	13	+3.7	08:28	382,175.63	897,517.02	1948.22
16	J-11	15.9	15	+0.9	10:55	382,144.99	897,483.31	1954.63

The statistical correlation plot of observed versus computed pressure during validation process. The result shows that R^2=0.995 or (99.5) %. This implies that the computed pressure is within the acceptable limit.

Figure 13: Sample validation value of observed and computed



Measured pressure(m)	Computed pressure
19.2	18
24.1	22
23.9	23
33.5	32
38.4	37
40.1	38
42.4	39
44.6	42
5.4	4
11.7	9
12.3	10
13.4	10
12.8	10
14.5	12
16.7	13

4.14. Finding and Conclusion about Existing System

From model analysis results of existing water supply system of Emdibir town, numbers of problems are indicated. These problems are in fact indicated in comparison with the minimum and maximum requirement of water supply system designing, which is set by (M0WR 2014). Based on the result of the analysis the following findings and recommendation are drawn;

- High velocity occurred for smaller pipe size and low velocity occurred for largest pipe size with low demand. Existing distribution system is installed not corresponding with the water supply and demand distribution flowing.
- Most of the distribution and main pipe line diameters are under out of the recommended size according to the system.
- Most of the pipe age is too old and it leads for occurrence of corrosion and leakage. Bursting of the gravity pipe line was happened not only in the high pressure zone but also happened in normal pressure zone of pipe due to operational problem.
- Due to the diameter of the main pipe line (pressure line) is not under the required size, the pump cannot deliver sufficient water for the customer service.
- In main pipe line, there is no check vale to control back flow at the time occurrence of pipe explosion.

4.15. Model results after new adjustments of the existing systems.

4.15.1 Pressure zone

Classify the study area in to pressure zones is also important to design and implement cost effective system related to the design criteria majorly to limit the average pressure within the acceptable limits. The pressure zones shall be described under this section. The elevation of the distribution system ranges from elevation of 2103.76masl (J-77) at the highest service reservoir up to 2061.56masl (J-121), at the lowest point. Thus the range of the elevation difference is 42m. Accordingly, the town’s distribution system is divided in to three pressure zones as per the topographical nature of the ground and due to low pressure in the system with in the supply area.

Selected source

The feasible source selected for water supply system as per the overall analysis done at the feasibility stage of this study is from existing spring source called Bojobar having sufficient yield equivalent to the demand in two phases. As a result the area along the course of the flow of the water from the main spring eye is full of mainly artisan type of springs. The design discharges estimated to Emdibir town are as estimated in two phases are as indicated in the table here below:-

Table 20: Estimated demand for the town in two phase

No-	Description of the design demands	Value for Phase One	Value for phase two	Required to design
1	maximum daily demand(l/sec)	23.8	42.4	Uses to determine the source capacity, reservoir capacity, rising mains (pipe diameter), and some more components.
2	peak hourly daily demand(l/sec)	36.1	64.5	distribution system (maximum daily demand)

Table 21: Distribution of maximum daily demand among node in two phases

No-	Description	Value in l/sec	Share of each zone in (l/sec)			Total of zonal demands in l/sec
			Zone one	zone two	zone three	
1	maximum day demand during phase one	23.8	11.67	8.58	3.55	**Σ =42.4**
2	maximum day demand during phase Two	36.1	18.76	10.72	6.62	Σ =**64.5**

Zone one and two distribution system

As a result of the hydraulic analysis following the selection of pipe type, the distribution system for the town is designed using HDPE pipe all to PN10. This part of the system will cross the main asphaltic road once with the second line connected to the other side of the main asphaltic road passes through the culvert. This zone is connected to zone two system with two pipes which will be closed permanently unless to be opened during emergency cases. Hence, the result of pipe line analysis selected for zone is as indicated in the table here below:-

Table 22: size, type and length of zone one, two and three distribution system

No	HDPE pipe with outer diameter(PN10, PE100)	sum of length (m)
1	OD12	2865
2	OD25	2289
3	OD50	1472
4	OD63	617
5	OD90	610
6	OD120	385
7	OD300	239
	Grand total	**Σ= 8,477**

No	HDPE pipe with outer diameter(PN10, PE100)	sum of length (m)
1	OD12	4733
2	OD25	3028
3	OD50	1415
4	OD63	2430
5	OD90	366
6	OD120	67
7	OD300	512
	Grand total	**Σ =12,551**

Zone three distribution system

The type of pipes for this zone are also the same as that of the previous zones pipes with their detail as indicated in the table here below:

No-	HDPE pipe with Outer Diameter (PN10, PE100)	Sum of Length (m)
1	OD90	122
2	OD120	609
3	OD300	187
		Σ= 918

Locations of the reservoirs

All the service reservoirs for the three zones are required at highest elevation place within the pressure zone. These points are determined by conducting topographic surveying in the town. As a result the peak elevation points for reservoir sites are as indicated in the tables here below:-

Table 23: newly model pipe report after adjustment of existing systems

Label	Start Node	End Node	Diameter (mm)	Material	Hazen-Williams	Check Valve	Flow (l/s)	Velocity (m/s)
P-43	J-138	J-1	110.0	HDPE	150.0	False	4.78	0.50
P-44	J-1	J-140	32.0	HDPE	150.0	False	1.1	1.37
P-57	J-11	J-10	50.0	HDPE	150.0	False	-1.52	0.77
P-63	J-92	J-88	12.0	HDPE	150.0	False	0.181	1.60
P-66	J-78	J-77	300.0	HDPE	150.0	False	44.3	0.63
P-75	J-73	J-74	120.0	HDPE	150.0	False	-9.8	0.87
P-82	J-137	J-93	50.0	HDPE	150.0	False	-2.1	1.07
P-83	J-93	J-138	50.0	HDPE	150.0	False	-2.31	1.17
P-86	J-1	J-89	50.0	HDPE	150.0	False	3.43	1.75
P-87	J-89	J-139	32.0	HDPE	150.0	False	2.31	2.87
P-90	J-141	J-89	25.0	HDPE	150.0	False	-0.746	1.52
P-91	J-140	J-141	25.0	HDPE	150.0	False	0.779	1.59
P-92	J-141	J-142	25.0	HDPE	150.0	False	1.18	2.40
P-96	J-142	J-139	25.0	HDPE	150.0	False	-0.694	1.41
P-100	J-67	J-68	25.0	HDPE	150.0	False	-1.07	2.17
P-105	J-26	J-19	50.0	HDPE	150.0	False	-1.14	0.58
P-106	J-170	J-29	50.0	HDPE	150.0	False	-2.67	1.36
P-108	J-170	J-26	32.0	HDPE	150.0	False	-0.593	0.74
P-112	J-80	J-20	50.0	HDPE	150.0	False	-2.08	1.06
P-114	J-20	J-29	120.0	HDPE	150.0	False	-16.7	1.48

P-115	J-29	J-19	32.0	HDPE	150.0	False	1.08	1.34
P-124	J-73	J-56	110.0	HDPE	150.0	False	7.83	0.82
P-129	J-72	J-73	63.0	HDPE	150.0	False	-4.75	1.53
P-149	J-107	J-106	12.0	HDPE	150.0	False	-0.157	1.39
P-189	J-34	J-95	25.0	HDPE	150.0	False	-1.39	2.83
P-203	J-71	J-72	63.0	HDPE	150.0	False	-2.38	0.76
P-206	J-116	J-117	50.0	HDPE	150.0	False	-1.99	1.01
P-218	J-101	J-100	50.0	HDPE	150.0	False	-3.25	1.66
P-220	J-76	J-77	200.0	HDPE	150.0	False	-38.1	1.21
P-17	R-6	J-78	300.0	GI	130.0	False	44.5	0.63
P-18	J-10	J-77	90.0	GI	130.0	False	-4.13	0.65
P-19	J-88	J-76	12.0	GI	130.0	True	-0.144	1.27
P-28	J-80	J-170	12.0	GI	130.0	False	0.0449	0.40
P-30	J-68	J-70	25.0	GI	130.0	False	-0.379	0.77
P-39	J-95	R-5	50.0	GI	130.0	False	1.46	0.74
P-48	J-117	J-121	25.0	GI	130.0	False	-0.385	0.79
P-49	J-121	J-126	150.0	GI	130.0	False	11.2	0.63
P-50	J-126	J-138	120.0	GI	130.0	False	7.29	0.64
P-51	J-56	J-21	12.0	GI	130.0	False	0.0665	0.59
P-53	J-100	J-58	120.0	GI	130.0	False	-6.78	0.60
P-54	J-100	J-73	90.0	GI	130.0	False	3.13	0.49
P-55	J-21	J-11	32.0	GI	130.0	False	-0.63	0.78
P-56	J-92	J-56	150.0	GI	130.0	False	15.1	0.85
P-57	J-92	J-74	150.0	GI	130.0	False	-15.4	0.87
P-58	J-92	J-11	12.0	GI	130.0	False	0.0297	0.26
P-59	J-29	J-56	150.0	GI	130.0	False	-20.8	1.18
P-69	J-2	J-45	32.0	GI	130.0	False	-0.864	1.07
P-77	J-37	J-34	25.0	GI	130.0	False	-0.539	1.10
P-78	J-68	J-34	25.0	GI	130.0	False	0.948	1.93
P-79	J-95	J-70	25.0	GI	130.0	False	0.529	1.08
P-80	J-74	J-76	150.0	GI	130.0	False	-25.4	1.44
P-81	J-76	J-58	120.0	GI	130.0	False	8.35	0.74
P-82	J-19	J-21	32.0	GI	130.0	False	-0.475	0.59
P-83	J-72	J-101	150.0	GI	130.0	False	16.4	0.93
P-87	J-63	J-2	25.0	GI	130.0	False	0.316	0.64
P-88	J-67	J-37	32.0	GI	130.0	False	0.978	1.22
P-89	J-24	J-45	12.0	GI	130.0	False	0.0146	0.13

P-91	J-80	J-71	50.0	GI	130.0	False	-2.1	1.07
P-92	J-20	J-72	150.0	GI	130.0	False	14.3	0.81
P-93	J-116	J-107	12.0	GI	130.0	False	0.0841	0.74
P-94	J-117	J-106	63.0	GI	130.0	False	-2.71	0.87
P-99	J-137	J-68	32.0	GI	130.0	False	1.82	2.26
P-100	J-139	J-137	12.0	GI	130.0	True	-0.154	1.37
P-103	J-139	J-67	32.0	GI	130.0	False	1.45	1.80
P-104	J-24	J-67	32.0	GI	130.0	False	-1.41	1.75
P-105	J-24	J-142	32.0	GI	130.0	False	-1.69	2.10
P-106	J-45	J-37	32.0	GI	130.0	False	-0.982	1.22
P-107	J-126	J-71	12.0	GI	130.0	False	-0.0104	0.9
P-108	J-105	J-101	12.0	GI	130.0	False	-0.209	1.85
P-109	J-106	J-25	63.0	GI	130.0	False	-2.99	0.96
P-110	J-126	J-26	32.0	GI	130.0	False	1.8	2.24
P-111	J-26	J-116	32.0	GI	130.0	False	-1.78	2.21
P-112	J-121	J-25	150.0	GI	130.0	False	-14.6	0.83
P-113	J-25	J-101	150.0	GI	130.0	False	-19.3	1.09
P-117	R-7	PMP-1	300.0	GI	130.0	False	113	1.60
P-119	PMP-1	J-31	300.0	GI	130.0	False	113	1.60
P-121	J-31	J-32	300.0	GI	130.0	True	87.8	1.24
P-123	J-32	J-33	300.0	GI	130.0	False	62.8	0.65
P-125	J-33	J-34	300.0	GI	130.0	False	37.8	0.53
P-127	J-34	J-35	150.0	GI	130.0	False	12.8	0.72
P-129	J-35	J-36	150.0	GI	130.0	False	-12.2	0.69
P-130	J-36	R-6	250.0	GI	130.0	False	-37.2	0.76
P-136	J-63	J-24	32.0	GI	130.0	False	-0.526	0.65

Table 24: new junction model report after adjustments

Label	Elevation (m)	zone	Demand(L/s)	Hydraulic grade(m)	Pressure (H_2o)
J-2	2,038.64	Zone - 2	1.18	2,054.41	16
J-1	2,079.58	Zone - 2	0.249	2,111.63	32
J-21	2,081.22	Zone - 1	0.222	2,113.35	32
J-26	2,089.09	Zone - 1	0.543	2,108.85	20
J-29	2,080.05	Zone - 1	0.31	2,118.06	38
J-34	2,054.03	Zone - 2	1.8	2,071.13	17
J-37	2,053.66	Zone - 2	0.535	2,063.74	10
J-45	2,030.46	Zone - 2	0.133	2,057.96	27

J-10	2,111.57	Zone - 1	2.61	2,122.97	11
J-11	2,091.49	Zone - 1	0.915	2,119.20	28
J-19	2,077.59	Zone - 1	0.419	2,111.18	34
J-20	2,083.43	Zone - 1	0.383	2,116.49	33
J-56	2,091.56	Zone - 1	2.05	2,119.32	28
J-58	2,086.99	Zone - 1	1.57	2,122.68	36
J-63	2,035.16	Zone - 2	0.21	2,056.82	22
J-67	2,055.12	Zone - 2	0.125	2,069.45	14
J-68	2,071.90	Zone - 2	0.184	2,090.15	18
J-70	2,072.54	Zone - 2	0.151	2,093.39	21
J-71	2,084.00	Zone - 1	0.275	2,113.05	29
J-72	2,093.18	Zone - 1	0.268	2,115.96	23
J-73	2,094.54	Zone - 1	0.343	2,120.47	26
J-74	2,099.58	Zone - 1	0.207	2,121.59	22
J-76	2,110.00	Zone - 1	4.18	2,123.90	14
J-77	2,110.22	Zone - 1	2.12	2,124.71	14
J-78	2,101.54	Zone - 1	0.16	2,124.86	23
J-80	2,077.88	Zone - 1	0.29	2,109.58	32
J-88	2,056.00	Zone - 1	0.325	2,079.91	24
J-89	2,073.00	Zone - 2	0.374	2,107.23	34
J-92	2,092.00	Zone - 1	0.107	2,120.45	28
J-93	2,074.00	Zone - 2	0.206	2,109.32	35
J-95	2,060.17	Zone - 2	0.464	2,099.92	40
J-100	2,091.36	Zone - 1	0.391	2,121.35	30
J-137	2,067.83	Zone - 2	0.126	2,107.24	39
J-138	2,078.81	Zone - 2	0.203	2,111.85	33
J-139	2,066.37	Zone - 2	0.323	2,080.89	14
J-140	2,062.96	Zone - 2	0.321	2,105.82	43
J-141	2,068.12	Zone - 2	0.349	2,097.75	30
J-142	2,052.81	Zone - 2	0.179	2,073.30	20
J-101	2,090.56	Zone - 1	0.117	2,114.40	24
J-105	2,067.11	Zone - 2	0.209	2,084.89	18
J-106	2,081.88	Zone - 2	0.131	2,112.46	31
J-107	2,069.71	Zone - 2	0.241	2,101.55	32
J-116	2,079.49	Zone - 2	0.13	2,109.85	30
J-117	2,085.23	Zone - 2	1.1	2,110.87	26
J-121	2,080.51	Zone - 2	3.06	2,112.90	32

J-126	2,085.61	Zone - 2	2.1	2,112.64	27
J-170	2,082.49	Zone - 1	3.31	2,106.81	24
J-24	2,031.78	Zone - 2	2.56	2,058.25	26
J-25	2,090.35	Zone - 2	1.69	2,113.46	23
J-26	2,057.45	Zone - 2	3.58	2,093.89	36
J-31	2,101.26	Zone - 3	25	2,125.97	25
J-32	2,083.42	Zone - 3	25	2,125.25	42
J-33	2,103.61	Zone - 3	25	2,124.90	21
J-34	2,103.31	Zone - 3	25	2,124.57	21
J-35	2,109.01	Zone - 3	25	2,123.19	14
J-36	2,100.29	Zone - 3	25	2,124.49	24

Table 25: new model pump report after adjustment

Label	Elevation (m)	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (m)	Hydraulic Grade (m)	Flow (L/s)	Pump Head (m)
PMP-1	1,918.00	Pump Definition - 1	On	1,918.64	2,126.65	41	209.02

Table 26: new model reservoir report after adjustment

Label	Elevation(m)	zone	Flow(l/s)	Hydraulic grade(m)
R-5	2,098.17	Zone - 2	16	2,098.17
R-6	2,124.99	Zone - 1	11.7	2,124.99
R-7	1,918.29	<None>	42.5	1,918.29

Chapter Five

5. Conclusion and Recommendation

5.1. Conclusion

Adequate quantity and acceptable quality of water supply is one of the basic needs of human beings, but the provision of potable water for Emdibir Town is inefficient. The situation becomes worst and more complicated due to the population growth, spatial expansion of the town and number of technical and management problem which outstripped its ability to supply sufficient water for its inhabitants. Based on the results, some conclusions are reached. These conclusions are intended not only to ease the problem temporarily but to look for other solutions and alternatives in the long term. The current water production of the town is not satisfying the demand. Moreover, the existing system in the town is old and does not cover the town in addition to the shortage of the water.

The average per capita consumption of the town is lower while compared with the minimum requirement of domestic demand which is (50-70) l/c/day. It’s set by (M0WR 2014). The existing pump has not capacity to deliver maximum day demand. The state of water supply in the town in terms of coverage for customers, reliability, accessibility, and sustainability is not at the required level. The rate of water distribution system is inefficient. The major constraints of distribution systems identified are low pipeline networks, inadequate pressure in the pipe. Moreover, a lot of unplanned connection along the gravity main line, poor water management and under estimation of the demand during the construction of the water system has contributed enormously for the shortage of potable water in the town.

5.2. Recommendation

- To have enough water access for the town, the water governing board should put in place different alternatives. Based on the availability of enough spring water, it is imperative to increase production. For this, additional pump should be installed.

- It is necessary to build separate reservoir & pipe line for rural community. This separate service system, without minimizing the quantity of water to rural community will help to deliver more amount of water to the town service reservoir.

- Moreover, to increase the water production for the town, the existing non-functional two boreholes which have sum of 2 l/s should be improved and make them functional.

- The old distribution system doesn’t follow the technical procedure. For example, along the 14km gravity line a lot of connection made for different institution like agricultural site and small institutional park during the peak period. This affects the amount of water delivered by service reservoir. Therefore, the office should immediately install gate valves for junctions and water meter in different critical area to help them for safe operation and to bill the institution per the amount of water that they consumed.

- As for distribution network, it is important to control the water flow by gate valve for location of high pressure and fixing air release valve for low pressure zone. Moreover, to increase the capacity of the distribution network by considering from economical point of view, it is better to use parallel pipe line installation which has a capacity to cover the demand gap.

- For the main line (pressure main) there is need of check valve at least in two places. This helps to control back flows when there is occurrence of pipe explosions.

- To prevent the main pipe line and gravity line from bursting, we recommend two important measures: the first one is using quality joint materials or fittings, avoiding leakage, applying activities like suitable anchoring to prevent pressure line vibrations during pumping water**.** The second one is entomb the pipe line underground, changing the GI pipe line into HDPE, fixing air release valves and changing the illegal pipe line installation by proper master plan rout or layout.

- Management of Emdibir town water supply totally needs improvement to maximize the overall performance of the utility. Timely upgrading and acquaintance of staffs with innovative ideas, new technologies with clear purpose and change is a tool for improvement. Visiting such institutions by other same proper functional utility would be helpful to improve the performance of the board, management and staffs.
- Consequently, in order to satisfy the water demand of the town the following measures should be taken.
    - Expansion activities with rehabilitation of the existing structures at the source, as the yield of the source is sufficient enough to satisfy the current and future demands.
    - All the water points which are not functional should be repair to increase the water supply coverage.
    - Some of the distribution pipe lines should be match with the sizes and types of the required materials to deliver sufficient water for the customers effectively.
    - The concerned stakeholders (Guraghe zone water and mining office, electric and power authority, Emdibir branch) should be provides their own responsibility accordingly.
    - Additional study should be conduct to find out other possible causes for water shortage.

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Appendix

Appendix 1: - Surveyed junction data for existing system.

Label	X(m)	Y(m)	Elev (m)	zone
J-78	382,749.65	896,803.82	2101.51	zone-1
J-77	382,644.77	896,889.23	2110.22	zone-1
J-36	382,581.06	896,831.74	2100.29	zone-3
J-10	382,856.74	897,075.31	2111.57	zone-1
J-58	382,383.90	896,824.09	2086.99	zone-1
J-76	382,539.18	896,975.26	2110.23	zone-1
J-88	382,683.82	897,105.87	2056.89	zone-1
J-11	382,642.61	897,270.25	2091.49	zone-1
J-92	382,564.67	897,202.54	2092.45	zone-1
J-74	382,420.07	897,075.20	2099.58	zone-1
J-35	382,312.42	897,039.27	2109.11	zone-3
J-100	382,100.24	897,026.72	2091.36	zone-1
J-73	382,268.79	897,194.89	2094.54	zone-1
J-56	382,410.95	897,410.95	2091.56	zone-1
J-21	382,493.88	897,403.24	2081.22	zone-1
J-18	382,401.72	897,488.19	2077.59	zone-1
J-29	382,318.73	897,411.90	2080.05	zone-1
J-20	382,247.75	897,345.00	2083.43	zone-1
J-72	382,167.21	897,274.25	2093.18	zone-1
J-101	382,999.63	897,109.36	2090.56	zone-1
J-105	382,952.79	897,063.55	2067.11	zone-2
J-34	382,052.94	897,242.77	2103.31	zone-3
J-107	381,843.59	897,098.92	2069.71	zone-2
J-106	381,879.82	897,134.40	2081.88	zone-2
J-25	381,916.01	897,174.80	2090.35	zone-2
J-116	381,769.71	897,165.22	2079.49	zone-2
J-117	381,802.18	897,199.73	2055.23	zone-2
J-121	381,834.33	897,240.09	2080.51	zone-2
J-26	381,710.93	897,219.38	2057.45	zone-2
J-116	381,769.71	897,165.22	2079.49	zone-2

J-26	382,166.51	897,682.54	2089.09	zone-1
J-95	381,941.41	897,604.47	2060.17	zone-2
J-70	381,877.78	897,537.42	2072.54	zone-2
R-5	382,020.45	897,682.40	2098.17	zone-2
J-33	381,803.40	897,434.71	2103.61	zone-3
J-138	381,634.75	897,406.12	2078.81	zone-2
J-93	381,696.36	897,470.95	2064.11	zone-2
J-137	381,755.68	897,535,58	2067.83	zone-2
J-68	381,813.58	897,593.42	2071.91	zone-2
J-34	381,873.65	897,662.00	2054.03	zone-2
J-37	381,795.99	897,727.29	2053.66	zone-2
J-139	381,679.35	897,603.62	2066.37	zone-2
J-67	381,736.89	897,664.41	2055.12	zone-2
J-89	381,612.46	897,521.83	2063.67	zone-2
J-1	381,562.39	897,466.47	2079.58	zone-2
J-140	381,493.01	897,527.00	2062.96	zone-2
J-141	381,541.54	897,581.33	2068.12	zone-2
J-32	381,595.09	897,604.64	2083.42	zone-3
J-142	381,612.46	897,655.90	2052.81	zone-2
J-24	381,668.54	897,716.51	2031.78	zone-2
J-45	381,729.29	897,782.53	2030.46	zone-2
J-2	381,676.08	897,823.93	2038.64	zone-2
J-63	381,615.19	897,759.50	2035.16	zone-2
J-31	381,482.27	897,692.15	2101.26	zone-3
R-7	381,351.15	897,795.24	1918.29	none
R-6	381,741.68	897,711.56	2124.99	zone-1
J-126	381,777.16	897,287.06	2085.61	zone-2
J-71	381,935.18	897,461.52	2084.22	zone-1
J-80	382,018.22	897,537,28	2077.88	zone-1
J-170	382,092.47	897,613.19	2082.49	zone-1
J-126	381,777.16	897,287.06	2085.61	zone-2

Appendix 2: - Pipe information for existing distribution

Label	Length (m)	Start node	Stop node	Material	Diameter
P-1	20.12	$100m^3R$	d36	GI	3"
P-10	196.29	PT5	d43	GI	1 1/2"
P-100	397.15	d17	d-16	HDPE	OD50
P-101	260.3	d-16	d-15	HDPE	OD50
P-102	89.61	d-16	PT18	HDPE	OD50
P-103	54.25	d17	d18	HDPE	OD50
P-104	141.43	d18	d19	HDPE	OD50
P-105	7.92	d19	PT19	HDPE	OD50
P-107	84.43	Tank 2	C2	HDPE	OD50
P-108	97.84	C2	C4	GI	1 1/2"
P-109	64.92	C4	PT21	GI	1 1/2"
P-11	243.23	d43	PT6	GI	1 1/2"
P-110	170.99	PT21	C5	GI	2 1/2"
P-111	59.44	C5	C6	HDPE	OD75
P-112	99.67	C6	C7	HDPE	OD75
P-113	19.51	C7	PT22	GI	1 1/2"
P-114	103.94	PT22	C8	GI	1 1/2"
P-115	7.92	C8	PT23	GI	1 1/2"
P-116	78.64	C8	C9	HDPE	OD50
P-117	149.05	C9	C10	HDPE	OD50
P-118	14.94	C10	C11	HDPE	OD50
P-119	17.37	C11	C12	HDPE	OD50
P-12	64.31	d36	d37	HDPE	OD50
P-120	43.28	C12	PT24	GI	3"
P-121	117.96	C2	C3	HDPE	OD63
P-122	126.19	C3	PT20	HDPE	OD63
P-123	84.43	d4	d6	HDPE	OD40
P-124	49.38	d6	d7	HDPE	OD40
P-125	284.68	d7	d26	HDPE	OD40
P-126	286.82	d26	d27	GI	1 1/2"
P-127	160.93	d27	d28	GI	1 1/2"
P-128	119.48	d28	d29	GI	1 1/2"
P-129	560.53	d34	d44	GI	1 1/2"
P-13	56.39	d37	d38	GI	3"
P-130	56.08	d44	d45	PVC	2"
P-131	172.82	d45	d46	GI	2"
P-132	164.9	A1	Tank 2	GI	1"
P-133	28.35	A1	A2	GI	1"
P-134	12.8	A2	A3	GI	1"
P-135	302.06	A3	A14	GI	3"
P-136	193.85	A14	A17	GI	3"
P-137	63.09	A17	A-1	GI	3"
P-138	174.65	A-1	A23	GI	3"
P-139	53.34	A23	A24	GI	1"
P-14	260.6	d38	d35	GI	1"
P-140	60.66	B8	B7	PVC	3"

P-143	124.97	A-1	A-2	GI	1"
P-144	173.74	A-2	A-3	GI	1"
P-145	46.94	A17	A18	GI	2"
P-146	108.81	A18	A19	GI	1 1/2"
P-147	120.4	A18	A20	GI	1 1/2"
P-148	71.32	A20	A21	GI	1 1/2"
P-149	103.02	A14	A15	GI	1 1/2"
P-15	35.36	d35	d34	GI	1"
P-150	60.96	A3	A4	GI	2"
P-151	53.64	A4	A5	GI	1"
P-152	62.18	A5	A6	HDPE	OD40
P-153	70.71	A6	A7	HDPE	OD40
P-154	204.22	A7	A13	HDPE	OD40
P-155	120.4	A6	A16	HDPE	OD50
P-156	197.82	A4	A8	HDPE	OD50
P-157	129.84	A8	PT8	GI	OD50
P-158	103.63	PT8	A12	GI	OD50
P-159	60.96	A8	A9	GI	3/4"
P-16	173.43	d34	d31	HDPE	OD40
P-160	79.86	A9	A10	GI	11/2"
P-161	21.34	A10	PT7	HDPE	OD40
P-162	244.14	A10	A11	HDPE	OD40
P-17	70.1	d31	d30	HDPE	OD40
P-18	128.93	d37	A-4	HDPE	OD40
P-19	6.71	A-4	PT9	HDPE	OD40
P-2	274.62	d36	PT2	GI	2"
P-20	80.16	A-4	A-5	GI	3/4"
P-21	14.94	A-5	A-6	PVC	11/2"
P-22	87.78	A-6	J-162	GI	3"
P-23	4.57	J-162	PT10	PVC	1"
P-24	17.07	J-162	A-7	PVC	1"
P-25	244.75	A-7	A-8	PVC	11/2"
P-26	231.95	A-8	A-9	PVC	1"
P-27	359.97	A-9	A-10	PVC	2"
P-28	30.78	A-10	PT11	PVC	1"
P-29	311.2	A-10	A-11	PVC	1"
P-3	98.15	PT2	d39	PVC	1"
P-30	102.72	A-11	PT12	PVC	11/2"
P-31	82.6	d35	d47	PVC	11/2"
P-32	60.35	d47	A24	GI	2 1/2"
P-33	57.3	A24	B8	GI	1/2"
P-34	138.68	B8	B4	GI	2"
P-35	58.22	B4	B5	HDPE	OD50
P-36	292.91	B4	B2	HDPE	OD50
P-37	123.75	B2	B3	HDPE	OD50
P-38	480.36	B2	B1	HDPE	OD50
P-39	326.14	d47	d48	HDPE	OD90

Appendix 3:- existing water point surveyed data.

No.	Label	Elevation(m)	Northing(m)	Easting, X, m
1	PT 9	2,117	896,834	382,823
2	PT 8	2,087	897,570	382,199
3	PT 7	2,084	897,664	382,223
4	PT 6	2,102	896,584	382,463
5	PT 5	2,118	896,677	382,796
6	PT 4	2,122	896,356	382,989
7	PT 32	2,055	898,240	380,829
8	PT 31	2,039	898,320	380,472
9	PT 30	2,023	898,457	380,160
10	PT 3	2,134	896,435	383,681
11	PT 29	2,02	898,354	379,902
12	PT 28	2,034	898,870	380,327
13	PT 27	2,037	898,762	380,425
14	PT 26	2,036	898,551	380,836
16	PT 24	2,056	898,135	381,341
17	PT 23	2,078	897,961	381,546
18	PT 22	2,077	898,030	381,634
19	PT 21	2,083	897,834	381,762
20	PT 20	2,091	897,800	381,640
21	PT 2	2,128	896,549	383,129
22	PT 19	2,077	897,835	381,523
23	PT 18	2,056	898,004	381,338
24	PT 17	2,049	897,848	380,546
25	PT 16	2,057	897,369	380,714
26	PT 15	2,085	896,516	381,841
27	PT 14	2,077	897,115	381,223
28	PT 13	2,083	897,601	381,500
29	PT 12	2,108	897,693	382,785
30	PT 11	2,098	897,662	383,151
31	PT 10	2,107	896,977.62	382,903.38

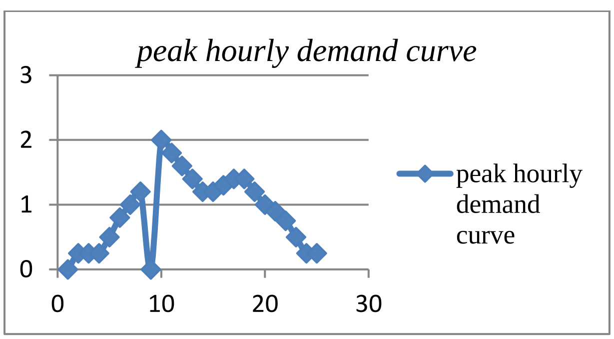
Appendix 4: - Surveyed reservoir data.

Label	X(m)	Y(m)	Elevation	zone	Flow(l/s)
R-5	382,020.45	897,682.40	2098.17	zone-2	12
R-6	381,741.68	897,711.56	2124.99	zone-1	17.5
R-7	381,351.15	897,795.24	1918.29	none	22.5

Appendix 5: - Surveyed reservoir data.

Label	X(m)	Y(m)	Elevation	zone
pump	381,415.86	897,745.71	1981.00	none

Appendix6:- Hourly demand factor for Emdibir town



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

Source: SNNPR water and mining resource office, (2014).

Appendix 7:- Peak hourly demand in each junction

Label	Elevation (m)	Zone	Pressure (m H2O)	Base demand (D), (l/s)	Maximum day demand(D*1.2)	Peak hourly demand(D*2)	Low demand(D*0.25)
J-1	2,007.58	Zone - 2	8	0.25	0.30	0.50	0.06
J-21	1,948.22	Zone - 1	15	0.22	0.27	0.44	0.06
J-25	1,957.48	Zone - 1	4	0.39	0.47	0.78	0.10
J-26	1,949.09	Zone - 1	12	0.54	0.65	1.09	0.14
J-28	1,944.60	Zone - 1	16	0.87	1.05	1.75	0.22
J-29	1,950.05	Zone - 1	11	0.31	0.37	0.62	0.08
J-31	2,034.06	Zone - 2	17	0.59	0.71	1.18	0.15
J-32	2,032.95	Zone - 2	19	0.58	0.70	1.17	0.15
J-34	2,038.03	Zone - 2	16	0.80	0.96	1.60	0.20
J-45	1,935.46	Zone - 2	5	0.13	0.16	0.27	0.03
J-47	1,924.68	Zone - 2	6	0.21	0.25	0.42	0.05
J-48	1,925.89	Zone - 2	5	0.23	0.28	0.47	0.06
J-49	1,934.75	Zone - 2	5	0.39	0.47	0.79	0.10
J-50	1,939.12	Zone - 2	9	1.25	1.05	1.50	0.31
J-51	1,940.94	Zone - 2	10	0.29	0.34	0.57	0.07
J-9	1,965.17	Zone - 1	10	0.11	0.13	0.21	0.03
J-11	1,960.49	Zone - 1	15	0.92	1.10	1.83	0.23
J-14	1,961.48	Zone - 1	13	0.11	0.13	0.22	0.03
J-15	1,958.11	Zone - 1	12	0.26	0.31	0.51	0.06
J-16	1,958.65	Zone - 1	10	0.18	0.22	0.36	0.05
J-17	1,948.05	Zone - 1	18	0.21	0.26	0.43	0.05
J-19	1,945.59	Zone - 1	16	0.42	0.50	0.84	0.10
J-20	1,948.43	Zone - 1	13	0.38	0.46	0.77	0.10
J-53	1,954.63	Zone - 1	9	0.17	0.21	0.34	0.04
J-54	1,958.49	Zone - 1	4	0.19	0.22	0.37	0.05
J-56	1,951.56	Zone - 1	10	0.05	0.06	0.10	0.01
J-65	1,915.60	Zone - 2	19	0.23	0.27	0.45	0.06
J-66	1,923.56	Zone - 2	15	0.14	0.16	0.27	0.03
J-67	1,937.12	Zone - 2	6	0.13	0.15	0.25	0.03
J-68	1,916.90	Zone - 2	14	0.18	0.22	0.37	0.05
J-70	2,032.54	Zone - 2	11	0.15	0.18	0.30	0.04
J-71	1,954.00	Zone - 1	7	0.28	0.33	0.55	0.07
J-72	1,953.18	Zone - 1	8	0.27	0.32	0.54	0.07
J-73	1,954.54	Zone - 1	7	0.34	0.41	0.69	0.09
J-74	1,959.58	Zone - 1	16	0.21	0.25	0.41	0.05
J-77	2,103.22	Zone - 1	13	0.12	0.14	0.24	0.03
J-80	1,942.88	Zone - 1	18	0.29	0.34	0.57	0.07
J-83	1,953.11	Zone - 1	8	0.42	0.50	0.83	0.10
J-84	1,943.63	Zone - 1	18	0.40	0.48	0.79	0.10
J-86	2,014.00	Zone - 2	12	0.08	0.10	0.17	0.02
J-87	2,002.50	Zone - 2	14	0.22	0.26	0.43	0.05
J-89	2,009.00	Zone - 2	6	0.37	0.45	0.75	0.09
J-90	2,006.00	Zone - 2	6	0.53	0.63	1.06	0.13
J-92	1,958.34	Zone - 1	16	0.11	0.13	0.21	0.03
J-93	1,994.00	Zone - 2	11	0.21	0.25	0.41	0.05
J-94	2,017.20	Zone - 2	5	0.13	0.16	0.26	0.03

J-95	2,046.17	Zone - 2	15	0.46	0.56	0.93	0.12
J-132	2,031.58	Zone - 2	11	0.22	0.26	0.44	0.05
J-137	2,018.83	Zone - 2	5	0.13	0.15	0.25	0.03
J-138	2,008.81	Zone - 2	8	0.20	0.24	0.41	0.05
J-139	1,996.37	Zone - 2	12	0.32	0.39	0.65	0.08
J-140	1,982.96	Zone - 2	16	0.32	0.39	0.64	0.08
J-141	2,012.12	Zone - 2	13	0.35	0.42	0.70	0.09
J-142	1,982.81	Zone - 2	15	0.18	0.21	0.36	0.04
J-143	1,972.99	Zone - 2	11	0.15	0.18	0.29	0.04
J-154	2,003.08	Zone - 2	3	0.53	0.63	1.05	0.13
J-155	1,922.42	Zone - 2	10	0.33	0.39	0.65	0.08
J-156	1,938.36	Zone - 2	8	0.45	0.54	0.90	0.11
J-158	1,938.50	Zone - 2	8	0.15	0.18	0.31	0.04
J-160	1,937.80	Zone - 2	7	0.19	0.23	0.38	0.05
J-161	1,922.18	Zone - 2	10	0.25	0.30	0.51	0.06
J-108	2,031.81	Zone - 2	10	0.12	0.15	0.25	0.03
J-116	2,029.49	Zone - 2	13	0.13	0.15	0.25	0.03
J-117	2,025.23	Zone - 2	17	0.10	0.12	0.20	0.03
J-118	2,048.64	Zone - 2	6	0.05	0.06	0.09	0.01
J-120	2,032.05	Zone - 2	10	0.08	0.10	0.17	0.02
J-121	2,030.51	Zone - 2	12	0.06	0.07	0.11	0.01
J-123	2,026.83	Zone - 2	16	0.11	0.14	0.23	0.03
J-125	2,024.29	Zone - 2	18	0.14	0.16	0.27	0.03
J-126	2,061.61	Zone - 2	10	0.10	0.11	0.19	0.02
J-170	1,956.49	Zone - 1	5	0.30	0.36	0.60	0.08
J-24	2,101.54	<None>	23	9	10.80	18.00	2.25
J-25	2,085.67	<None>	39	9	10.80	18.00	2.25
J-26	2,086.31	<None>	38	9	10.80	18.00	2.25
J-27	2,092.50	<None>	32	9	10.80	18.00	2.25
J-28	2,087.83	<None>	37	9	10.80	18.00	2.25
J-29	2,107.05	<None>	18	9	10.80	18.00	2.25
J-30	2,102.67	<None>	22	9	10.80	18.00	2.25
J-31	2,082.14	<None>	42	9	10.80	18.00	2.25

Appendix 8:- model output of pressure junction at night flow demand

Label	Start Node	End Node	Diameter (mm)	Material	Flow (l/s)	Night flow factor	Night low*flow factor (l/s)
P-43	J-138	J-1	110.0	HDPE	4.78	2.00	9.56
P-44	J-1	J-140	32.0	HDPE	1.1	2.00	2.2
P-57	J-11	J-10	50.0	HDPE	-1.52	2.00	-3.04
P-63	J-92	J-88	12.0	HDPE	0.181	2.00	0.36
P-66	J-78	J-77	300.0	HDPE	44.3	2.00	88.6
P-75	J-73	J-74	120.0	HDPE	-9.8	2.00	-19.6
P-82	J-137	J-93	50.0	HDPE	-2.1	2.00	-4.2
P-83	J-93	J-138	50.0	HDPE	-2.31	2.00	-4.62
P-86	J-1	J-89	50.0	HDPE	3.43	2.00	6.86
P-87	J-89	J-139	32.0	HDPE	2.31	2.00	4.62
P-90	J-141	J-89	25.0	HDPE	-0.746	2.00	-1.49

P-91	J-140	J-141	25.0	HDPE	0.779	2.00	1.55
P-92	J-141	J-142	25.0	HDPE	1.18	2.00	2.36
P-96	J-142	J-139	25.0	HDPE	-0.694	2.00	-1.39
P-100	J-67	J-68	25.0	HDPE	-1.07	2.00	-2.14
P-105	J-26	J-19	50.0	HDPE	-1.14	2.00	-2.28
P-106	J-170	J-29	50.0	HDPE	-2.67	2.00	-5.34
P-108	J-170	J-26	32.0	HDPE	-0.593	2.00	-1.19
P-112	J-80	J-20	50.0	HDPE	-2.08	2.00	-4.16
P-114	J-20	J-29	120.0	HDPE	-16.7	2.00	-33.4
P-115	J-29	J-19	32.0	HDPE	1.08	2.00	2.16
P-124	J-73	J-56	110.0	HDPE	7.83	2.00	15.66
P-129	J-72	J-73	63.0	HDPE	-4.75	2.00	-9.5
P-149	J-107	J-106	12.0	HDPE	-0.157	2.00	-0.31
P-189	J-34	J-95	25.0	HDPE	-1.39	2.00	-2.78
P-203	J-71	J-72	63.0	HDPE	-2.38	2.00	-4.76
P-206	J-116	J-117	50.0	HDPE	-1.99	2.00	-3.98
P-218	J-101	J-100	50.0	HDPE	-3.25	2.00	-6.5
P-220	J-76	J-77	200.0	HDPE	-38.1	2.00	-76.2
P-17	R-6	J-78	300.0	Ductile Iron	44.5	2.00	89
P-18	J-10	J-77	90.0	Ductile Iron	-4.13	2.00	-8.26
P-19	J-88	J-76	12.0	Ductile Iron	-0.144	2.00	-0.29
P-28	J-80	J-170	12.0	Ductile Iron	0.0449	2.00	0.09
P-30	J-68	J-70	25.0	Ductile Iron	-0.379	2.00	-0.76
P-39	J-95	R-5	50.0	Ductile Iron	1.46	2.00	2.92
P-48	J-117	J-121	25.0	Ductile Iron	-0.385	2.00	-0.77
P-49	J-121	J-126	150.0	Ductile Iron	11.2	2.00	22.4
P-50	J-126	J-138	120.0	Ductile Iron	7.29	2.00	14.58
P-51	J-56	J-21	12.0	Ductile Iron	0.0665	2.00	0.133
P-53	J-100	J-58	120.0	Ductile Iron	-6.78	2.00	-13.56
P-54	J-100	J-73	90.0	Ductile Iron	3.13	2.00	6.26
P-55	J-21	J-11	32.0	Ductile Iron	-0.63	2.00	-1.26
P-56	J-92	J-56	150.0	Ductile Iron	15.1	2.00	30.2
P-57	J-92	J-74	150.0	Ductile Iron	-15.4	2.00	-30.8
P-58	J-92	J-11	12.0	Ductile Iron	0.0297	2.00	0.06
P-59	J-29	J-56	150.0	Ductile Iron	-20.8	2.00	-41.6
P-69	J-2	J-45	32.0	Ductile Iron	-0.864	2.00	-1.73
P-77	J-37	J-34	25.0	Ductile Iron	-0.539	2.00	-1.08
P-78	J-68	J-34	25.0	Ductile Iron	0.948	2.00	1.89
P-79	J-95	J-70	25.0	Ductile Iron	0.529	2.00	1.06
P-80	J-74	J-76	150.0	Ductile Iron	-25.4	2.00	-50.8
P-81	J-76	J-58	120.0	Ductile Iron	8.35	2.00	16.7
P-82	J-19	J-21	32.0	Ductile Iron	-0.475	2.00	-0.95
P-83	J-72	J-101	150.0	Ductile Iron	16.4	2.00	32.8
P-87	J-63	J-2	25.0	Ductile Iron	0.316	2.00	0.64

P-88	J-67	J-37	32.0	Ductile Iron	0.978	2.00	1.96
P-89	J-24	J-45	12.0	Ductile Iron	0.0146	2.00	0.03
P-91	J-80	J-71	50.0	Ductile Iron	-2.1	2.00	-4.2
P-92	J-20	J-72	150.0	Ductile Iron	14.3	2.00	28.6
P-93	J-116	J-107	12.0	Ductile Iron	0.0841	2.00	0.17
P-94	J-117	J-106	63.0	Ductile Iron	-2.71	2.00	-5.42
P-99	J-137	J-68	32.0	Ductile Iron	1.82	2.00	3.64
P-100	J-139	J-137	12.0	Ductile Iron	-0.154	2.00	-0.31
P-103	J-139	J-67	32.0	Ductile Iron	1.45	2.00	2.9
P-104	J-24	J-67	32.0	Ductile Iron	-1.41	2.00	-2.82
P-105	J-24	J-142	32.0	Ductile Iron	-1.69	2.00	-3.38
P-106	J-45	J-37	32.0	Ductile Iron	-0.982	2.00	-1.96
P-107	J-126	J-71	12.0	Ductile Iron	-0.0104	2.00	-0.02
P-108	J-105	J-101	12.0	Ductile Iron	-0.209	2.00	-0.42
P-109	J-106	J-25	63.0	Ductile Iron	-2.99	2.00	-5.98
P-110	J-126	J-26	32.0	Ductile Iron	1.8	2.00	3.6
P-111	J-26	J-116	32.0	Ductile Iron	-1.78	2.00	-3.56
P-112	J-121	J-25	150.0	Ductile Iron	-14.6	2.00	-29.2
P-113	J-25	J-101	150.0	Ductile Iron	-19.3	2.00	-38.6
P-117	R-7	PMP-1	300.0	Ductile Iron	13	2.00	26
P-119	PMP-1	J-31	300.0	Ductile Iron	11	2.00	22
P-121	J-31	J-32	300.0	Ductile Iron	7.8	2.00	15.6
P-123	J-32	J-33	300.0	Ductile Iron	62.8	0.65	40.82
P-125	J-33	J-34	300.0	Ductile Iron	37.8	0.53	20.034
P-127	J-34	J-35	150.0	Ductile Iron	12.8	0.72	9.216
P-129	J-35	J-36	150.0	Ductile Iron	-12.2	0.69	-8.418
P-130	J-36	R-6	250.0	Ductile Iron	-37.2	0.76	-28.272
P-136	J-63	J-24	32.0	Ductile Iron	-0.526	0.65	-0.3419

Source: Emdibir town water utility office, (2015)

Appendix 10: - Model analysis results for pipe length and diameters.

No.	HDPE pipe with outer diameter (PN10, PE100)	Sum of length (m)
1	OD12	7598
2	OD25	5317
3	OD50	2887
4	OD63	3047
5	OD90	976
6	OD120	452
7	OD300	751
Grand total		**Σ=21,028**

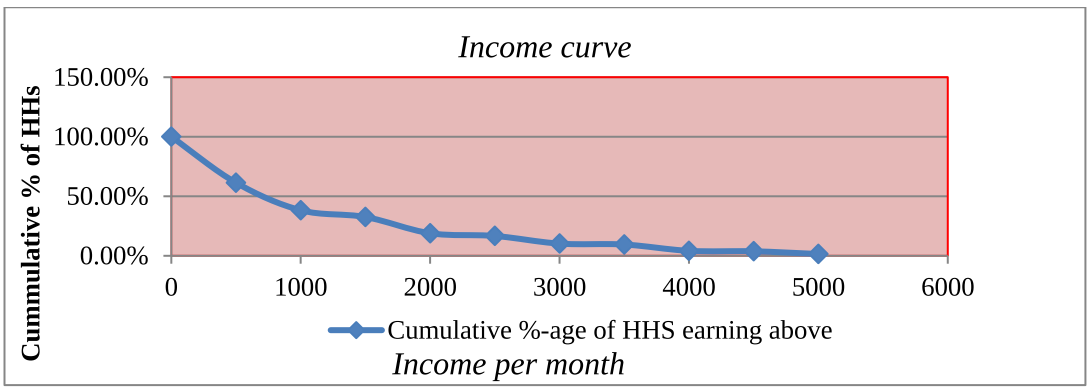
Appendix 11:- The list of villages, blocks with the number of HHs and populations

Appendix 13: - List of Hotels in the town.

No.	Kebele	Name of Hotel	Village Name	No. of Bed
1	02	Damo Welde Hotel	Damo Wolde Sefer	48
2	01	Cheha Menich Hotel	Lukwanda	7
3	02	Daniel Hotel	Selam Safer	18
4	02	Temam Hotel	Selam Safer	26
5	02	Chereka Hotel	Kangare sefer	15
6	02	Murar Hotel	Histanat Tesfa Sefer	27

Source: Emdibir town administration

Appendix 18: - Income curve of households in Emdibir Town



Source: Socio-economic study by ADE

Appendix 20:- population forecasting data

Population Projection for Emdibir town from (2029 G.C.) up to (2038 G.C)

Where, p– Projected population, with

p_o – Current population, 20,773 in 2017

po – Current population

e – The base of the natural logarithm (2.72)

t – Difference in years for projection

k– Population growth rate in decimal form.

Year in GC	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Population	21,643	22,549	23,494	24,282	25,249	26,254	27,298	28,385	28,987	30080.8

Year in GC	2029	2030	2031	2032	2033	2034	2035	2036	2,037	2,038
Population	32,393	33,615	34,882	36,198	37,563	38,980	40,450	41,976	43,559	45,202

Appendix 21:-. Pipe report for existing system

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams(c)	Flow(L/s)	Velocity (m/s)
P-11	58	J-28	J-83	50	HDPE	150	-0.29	0.15
P-20	45	J-48	J-47	32	HDPE	150	0.50	0.63
P-21	39	J-47	J-45	32	HDPE	150	0.34	0.42
P-34	147	J-120	J-132	32	HDPE	150	-0.23	0.29
P-38	92	J-86	J-87	50	HDPE	150	4.62	2.36
P-39	96	J-87	J-143	32	HDPE	150	2.72	3.38
P-43	143	J-138	J-1	32	HDPE	150	0.25	0.32
P-44	92	J-1	J-140	32	HDPE	150	0.43	0.53
P-46	143	J-93	J-89	32	HDPE	150	0.56	0.69
P-47	45	J-137	J-94	32	HDPE	150	-1.98	2.46
P-48	95	J-94	J-139	32	HDPE	150	1.69	2.1
P-53	63	J-121	J-118	32	HDPE	150	0.05	0.06
P-54	57	J-118	J-117	32	HDPE	150	0.11	0.13
P-67	80	J-11	J-14	63	HDPE	150	2.77	0.89
P-68	133	J-14	J-92	50	HDPE	150	-0.83	0.42
P-69	49	J-74	J-9	63	HDPE	150	2.38	0.76
P-70	71	J-9	J-92	50	HDPE	150	0.94	0.48
P-75	101	J-73	J-74	32	HDPE	150	-1.65	2.05
P-81	145	J-90	J-154	32	HDPE	150	-0.11	0.14
P-82	48	J-137	J-93	32	HDPE	150	1.86	2.31
P-83	78	J-93	J-138	32	HDPE	150	1.09	1.36
P-84	43	J-138	J-154	32	HDPE	150	0.63	0.79
P-85	48	J-90	J-1	32	HDPE	150	-0.42	0.52
P-86	75	J-1	J-89	32	HDPE	150	-0.84	1.04
P-87	49	J-89	J-139	32	HDPE	150	-1.54	1.91
P-88	54	J-139	J-87	32	HDPE	150	-1.69	2.1
P-89	54	J-94	J-86	50	HDPE	150	-3.80	1.94
P-90	93	J-141	J-89	32	HDPE	150	-0.88	1.1
P-91	70	J-140	J-141	32	HDPE	150	0.10	0.13
P-92	49	J-141	J-142	32	HDPE	150	0.64	0.79
P-94	52	J-143	J-66	32	HDPE	150	4.55	2.65
P-96	94	J-142	J-139	32	HDPE	150	-1.52	1.88
P-97	66	J-66	J-67	32	HDPE	150	1.53	1.9
P-98	68	J-51	J-155	32	HDPE	150	-0.63	0.78
P-99	38	J-155	J-48	32	HDPE	150	0.74	0.92
P-100	98	J-67	J-68	50	HDPE	150	0.85	0.43
P-103	150	J-70	J-71	63	HDPE	150	0.24	0.54

P-105	86	J-26	J-19	50	HDPE	150	-0.50	0.25
P-106	85	J-170	J-29	50	HDPE	150	-0.54	0.28
P-108	45	J-170	J-26	50	HDPE	150	0.05	0.02
P-112	82	J-80	J-20	50	HDPE	150	-0.58	0.29
P-113	58	J-25	J-20	50	HDPE	150	0.95	0.48
P-114	50	J-20	J-29	50	HDPE	150	0.51	0.26
P-115	46	J-29	J-19	50	HDPE	150	0.27	0.13
P-116	87	J-84	J-25	50	HDPE	150	-0.55	0.28
P-124	51	J-73	J-56	50	HDPE	150	-0.26	0.13
P-125	49	J-56	J-54	32	HDPE	150	-0.49	0.61
P-126	51	J-54	J-53	32	HDPE	150	-0.41	0.51
P-127	46	J-53	J-21	32	HDPE	150	-0.19	0.23
P-129	63	J-72	J-73	63	HDPE	150	-1.57	0.5
P-130	50	J-72	J-25	50	HDPE	150	0.38	0.16
P-131	111	J-21	J-15	32	HDPE	150	-1.06	1.32
P-132	68	J-15	J-14	50	HDPE	150	-3.50	1.78
P-134	48	J-17	J-16	32	HDPE	150	-0.99	1.24
P-135	43	J-16	J-15	50	HDPE	150	-2.18	1.11
P-136	107	J-54	J-17	32	HDPE	150	-0.78	0.97
P-137	104	J-53	J-16	32	HDPE	150	-1.01	1.25
P-159	45	J-65	J-161	32	HDPE	150	0.93	1.16
P-160	41	J-161	J-160	32	HDPE	150	0.71	0.89
P-161	42	J-160	J-158	32	HDPE	150	0.52	0.65
P-165	43	J-66	J-155	32	HDPE	150	1.72	2.14
P-166	59	J-65	J-66	32	HDPE	150	-1.16	1.44
P-167	57	J-161	J-155	32	HDPE	150	-0.32	0.04
P-168	56	J-160	J-48	32	HDPE	150	-0.12	0.3
P-169	57	J-158	J-47	32	HDPE	150	0.04	0.05
P-180	44	J-67	J-51	50	HDPE	150	0.55	0.28
P-181	126	J-51	J-49	50	HDPE	150	0.90	0.46
P-182	92	J-49	J-50	50	HDPE	150	0.59	0.3
P-183	170	J-50	J-68	50	HDPE	150	-0.66	0.34
P-184	69	J-32	J-34	32	HDPE	150	-0.85	1.05
P-186	70	J-95	J-31	63	HDPE	150	10.10	3.24
P-187	61	J-31	J-70	63	HDPE	150	9.76	3.13
P-188	51	J-32	J-31	32	HDPE	150	0.26	0.32
P-189	53	J-34	J-95	32	HDPE	150	-1.64	2.04
P-190	78	J-95	J-83	50	HDPE	150	0.12	0.3
P-194	56	J-120	J-123	50	HDPE	150	0.15	0.07
P-198	146	J-125	J-123	32	HDPE	150	0.18	0.22
P-199	76	J-125	J-126	32	HDPE	150	0.34	0.43
P-200	81	J-126	J-118	32	HDPE	150	0.10	0.13
P-203	90	J-71	J-72	63	HDPE	150	-0.93	0.3
P-206	81	J-116	J-117	32	HDPE	150	0.02	0.02
P-15	56	J-71	J-84	63	HDPE	150	0.65	0.21
P-17	57	J-143	J-142	32	Ductile Iron	130	-1.97	2.45
P-18	59	J-132	J-125	50	Ductile Iron	130	0.65	0.33
P-19	41	J-156	J-158	32	Ductile Iron	130	-0.33	0.41
P-20	58	J-156	J-45	32	Ductile Iron	130	-0.12	0.15
P-21	80	J-28	J-170	63	Ductile Iron	130	-0.58	0.19
P-22	82	J-83	J-80	63	Ductile Iron	130	-0.71	0.23

P-23	51	J-170	J-80	50	Ductile Iron	130	-0.39	0.2
P-24	62	J-80	J-84	50	Ductile Iron	130	-0.80	0.41
P-25	111	J-56	J-9	32	Ductile Iron	130	-1.33	1.66
P-27	62	J-25	J-56	63	Ductile Iron	130	-1.51	0.48
P-28	141	R-5	J-95	63	Ductile Iron	130	12.20	2.91
P-30	58	J-121	J-108	32	Ductile Iron	130	0.10	0.13
P-31	61	J-108	J-117	32	Ductile Iron	130	-0.20	0.02
P-32	80	J-123	J-121	32	Ductile Iron	130	0.21	0.26
P-33	57	J-126	J-116	32	Ductile Iron	130	0.14	0.18
P-34	133	J-86	J-70	63	Ductile Iron	130	-8.51	2.73
P-35	39	J-70	J-132	50	Ductile Iron	130	1.10	0.56
P-38	106	J-24	R-6	90	Ductile Iron	130	-9.50	0.7
P-39	72	J-77	R-6	63	Ductile Iron	130	-8.04	2.58
P-42	209	J-25	J-26	90	Ductile Iron	130	7.51	2.6
P-44	150	J-26	J-27	90	Ductile Iron	130	-4.49	2.6
P-46	227	J-27	J-28	90	Ductile Iron	130	-7.50	2.6
P-48	184	J-28	J-29	90	Ductile Iron	130	-6.90	2.6
P-50	93	J-29	J-30	90	Ductile Iron	130	-11.50	2.6
P-51	94	J-30	J-24	90	Ductile Iron	130	-10.50	2.6
P-52	62	PMP-1	J-31	90	Ductile Iron	130	12.50	2.6
P-53	50	J-31	J-25	90	Ductile Iron	130	13.50	2.6
P-54	40	R-7	PMP-1	90	Ductile Iron	130	8.50	2.6
P-55	67	J-45	J-49	32	Ductile Iron	130	0.08	0.1
P-56	71	J-29	J-53	32	Ductile Iron	130	-0.61	0.76
P-57	67	J-19	J-21	32	Ductile Iron	130	-0.65	0.81
P-58	66	J-20	J-54	32	Ductile Iron	130	-0.52	0.64
P-59	183	J-11	J-77	32	Ductile Iron	130	-3.69	2.59
P-60	141	J-74	J-77	32	Ductile Iron	130	-4.24	2.27

- Sample calculation made at J-77, it is located near to balancing reservoir which supplies water for 540 rural communities,

  Base demand = Population * Per capita demand per day (25.1 l/day)
  = 540 * 25.1 l/day
  =13,554 l/day
  = 0.16 l/sec

  MDD = 0.16 l/s *1.25 = 0.2 l/s
  PHD = 0.16 l/s * 1.9 = 0.3 l/s
  LHD = 0.16 l/s * 0.2 = 0.03 l/s

Appendix:-22:- Existing pump model report data

Label	Elevation (m)	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (m)	Hydraulic Grade(m)	Flow (L/s)	Pump head (m)
PMP-1	1,918	Pump Definition - 1	On	1,918.73	2,124.54	9	205.81

Appendix:-23:-Existing reservoir model report data

Label	Elevation (m)	Zone	Flow (Out net) (L/s)	Hydraulic grade (m)
R-5	2,098.17	Zone - 2	12.2	2,098.17
R-6	2,124.99	Zone - 1	17.5	2,124.99
R-7	1,918.75	<None>	22.5	1,918.75

Appendix:-24:- Existing node demand analysis

Label	Elevation (m)	Zone	Demand (L/s)	Hydraulic grade (m)	Pressure (m H_2O)
J-1	2,007.58	Zone - 2	0.25	2,000.00	8
J-21	1,948.22	Zone - 1	0.22	1,963.27	15
J-25	1,957.48	Zone - 1	0.39	1,961.61	4
J-26	1,949.09	Zone - 1	0.54	1,961.04	12
J-28	1,944.60	Zone - 1	0.87	1,960.97	16
J-29	1,950.05	Zone - 1	0.31	1,961.21	11
J-31	2,034.06	Zone - 2	0.59	2,051.54	17
J-32	2,032.95	Zone - 2	0.58	2,051.76	19
J-34	2,038.03	Zone - 2	0.79	2,054.43	16
J-45	1,935.46	Zone - 2	0.13	1,930.26	5
J-47	1,924.68	Zone - 2	0.21	1,930.53	6
J-48	1,925.89	Zone - 2	0.23	1,931.21	5
J-49	1,934.75	Zone - 2	0.39	1,930.22	5
J-50	1,939.12	Zone - 2	1.25	1,930.01	9
J-51	1,940.94	Zone - 2	0.29	1,930.84	10
J-9	1,965.17	Zone - 1	0.11	1,974.96	10
J-11	1,960.49	Zone - 1	0.92	1,975.03	15
J-14	1,961.48	Zone - 1	0.11	1,974.01	13
J-15	1,958.11	Zone - 1	0.26	1,969.83	12
J-16	1,958.65	Zone - 1	0.18	1,968.73	10
J-17	1,948.05	Zone - 1	0.21	1,966.22	18
J-19	1,945.59	Zone - 1	0.42	1,961.18	16
J-20	1,948.43	Zone - 1	0.38	1,961.29	13
J-53	1,954.63	Zone - 1	0.17	1,963.16	9
J-54	1,958.49	Zone - 1	0.19	1,962.64	4
J-56	1,951.56	Zone - 1	0.05	1,961.95	10
J-65	1,915.60	Zone - 2	0.23	1,934.44	19
J-66	1,923.56	Zone - 2	0.14	1,938.57	15
J-67	1,937.12	Zone - 2	0.13	1,930.93	6
J-68	1,916.90	Zone - 2	0.18	1,930.49	14
J-70	2,032.54	Zone - 2	0.15	2,043.38	11
J-71	1,954.00	Zone - 1	0.28	1,961.49	7
J-72	1,953.18	Zone - 1	0.27	1,961.64	8
J-73	1,954.54	Zone - 1	0.34	1,961.92	7
J-74	1,959.58	Zone - 1	0.21	1,975.44	16
J-77	2,103.22	Zone - 1	0.16	2,116.28	13
J-80	1,942.88	Zone - 1	0.29	1,961.11	18
J-83	1,953.11	Zone - 1	0.42	1,961.00	8
J-84	1,943.63	Zone - 1	0.39	1,961.44	18
J-86	2,014.00	Zone - 2	0.08	2,025.62	12
J-87	2,002.50	Zone - 2	0.22	2,016.15	14
J-89	2,009.00	Zone - 2	0.37	2,002.85	6

Label	Elevation (m)	Zone	D.D (L/s)	Hydraulic grade (m)	Pressure (m H_2O)
J-90	2,006.00	Zone - 2	0.53	1,999.49	6
J-92	1,958.34	Zone - 1	0.11	1,974.58	16
J-93	1,994.00	Zone - 2	0.21	2,005.42	11
J-94	2,017.20	Zone - 2	0.13	2,021.80	5
J-95	2,046.17	Zone - 2	0.46	2,061.41	15
J-132	2,031.58	Zone - 2	0.22	2,043.02	11
J-137	2,018.83	Zone - 2	0.13	2,013.32	5
J-138	2,008.81	Zone - 2	0.20	2,000.59	8
J-139	1,996.37	Zone - 2	0.32	2,008.59	12
J-140	1,982.96	Zone - 2	0.32	1,999.00	16
J-141	2,012.12	Zone - 2	0.35	1,998.94	13
J-142	1,982.81	Zone - 2	0.18	1,997.81	15
J-143	1,972.99	Zone - 2	0.15	1,983.95	11
J-154	2,003.08	Zone - 2	0.53	1,999.62	3
J-155	1,922.42	Zone - 2	0.33	1,932.36	10
J-156	1,938.36	Zone - 2	0.45	1,930.18	8
J-158	1,938.50	Zone - 2	0.15	1,930.54	8
J-160	1,937.80	Zone - 2	0.19	1,931.21	7
J-161	1,922.18	Zone - 2	0.25	1,932.35	10
J-108	2,031.81	Zone - 2	0.12	2,042.14	10
J-116	2,029.49	Zone - 2	0.13	2,042.15	13
J-117	2,025.23	Zone - 2	0.10	2,042.14	17
J-118	2,048.64	Zone - 2	0.05	2,042.19	6
J-120	2,032.05	Zone - 2	0.09	2,042.51	10
J-121	2,030.51	Zone - 2	0.06	2,042.20	12
J-123	2,026.83	Zone - 2	0.11	2,042.50	16
J-125	2,024.29	Zone - 2	0.14	2,042.81	18
J-126	2,052.61	Zone - 2	0.09	2,042.25	10
J-170	1,956.49	Zone - 1	0.30	1,961.04	5
J-24	2,101.54	<None>	9	2,124.80	23
J-25	2,085.67	<None>	9	2,124.51	39
J-26	2,086.31	<None>	9	2,124.51	38
J-27	2,092.50	<None>	9	2,124.51	32
J-28	2,087.83	<None>	9	2,124.55	37
J-29	2,107.05	<None>	9	2,124.62	18
J-30	2,102.67	<None>	9	2,124.69	22
J-31	2,082.14	<None>	9	2,124.52	42
J-90	2,006.00	Zone - 2	0.53	1,999.49	6