ADDIS ABABA UNIVERISTY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

DEPARTEMENT OF CIVIL ENGINEERING

Assessment on The Performance of AAWSA Controlled Sewerage System - The Case of Arada Sub city

By

Rekik Tsegaye

Advisor: Dr. Habtamu Hailu

A thesis submitted to School of Graduate Studies, Addis Ababa University in partial fulfillment for the Degree of Masters of Science in Civil Engineering (Water Supply and Environmental Engineering)

Addis Ababa University

School of Post Graduate Studies

Assessment on The Performance of AAWSA controlled Sewerage system (The case of Arada Sub city)

A thesis submitted to School of Graduate Studies, Addis Ababa University in partial fulfillment for the Degree of Masters of Science in Civil Engineering (Water Supply and Environmental Engineering)

By: Rekik Tsegaye

Advisor: Dr Habtamu Hailu

November, 2011

Assessment on The Performance of AAWSA controlled Sewerage system (The case of Arada Sub city)

A thesis submitted to School of Graduate Studies, Addis Ababa University in partial fulfillment for the Degree of Masters of Science in Civil Engineering (Water Supply and Environmental Engineering)

Date of Defense ----------

Approval by board of Examiners

1. ---------- ---------- ----------
   Chairman Signature Date

2. ---------- ---------- ----------
   Adviser Signature Date

3. ---------- ---------- ----------
   Internal examiner Signature Date

4. ---------- ---------- ----------
   External examiner Signature Date

CERTIFICATION

The undersigned certify that they have read the thesis entitled: Assessment on The Performance of AAWSA controlled Sewerage system (The case of Arada Sub city) and here by recommended for the acceptance by the Addis Ababa University in partial fulfillment for the Degree of Masters of Science in Civil Engineering (Water Supply and Environmental Engineering)

_____

Dr. Habtamu

(Advisor)

Date _____

DECLARATION AND COPY RIGHT

I, Rekik Tsegaye, declare that this thesis is my own work and that it has been presented and will not be presented by me to any other University for similar or any other degree award.

_____

Signature _____

Date _____

Acknowledgement

First of all, my glory goes to the ALMIGHTY GOD; through him all things are possible.

Secondly, I would like to express my sincere and deepest gratitude to my Advisor Dr. Habtamu Hailu, Assistant Professor, Department of Civil Engineering, AAiT for all his guidance, material support, and encouragement and excited support that led to the completion of this work.

I would also like to express my heart–felt thanks to AAWSA (Arada Sub city) workers especially, Ato yedenkachw, Ato Dabi, Ato Gebeyw Ato Terssa Worken, Ato Zelalem and w/ro Ababa for all their material support and valuable comments and suggestion to this research work. Furthermore, I would like to thank for Arada Sub city for providing me land use information.

Finally, my appreciation and thanks go to all my family especially my mother and two sisters and all my friends who helped me in financial, suggestion and generally in any form of support for completion of this work

Abstract

Wastes originating from domestic, commercial, and industrial sources (often mixed with storm water) are collected, treated, and discharged back into the environment. The purpose of sanitary service is to prevent ground water pollution and minimize water borne diseases. The city of Addis Ababa provides sewerage service to its inhabitants by connecting their internal sewer lines to the sewerage network; however the level of service is still regarded as very low. This paper is therefore meant to assess the performance of the existing sewerage system both in technical and economic efficiency terms specifically in the Arada sub city, Addis Ababa. To achieve this, different evaluation methods were used. The methods comprise field visits (accompanied by capturing some pictures of the problem areas), cost analysis and comparison of the two common waste disposal techniques used in the city, Viz. vacuum truck and sewer line, gathering questionnaire from customers in order to identify the satisfaction level and finally evaluation of the sewerage network using sewer CAD version 4.3 to check and compare the existing hydraulic capacity and the future expectations. From the field visits different problems are identified which include manhole rising, manhole overflow, manhole loss and infrastructure problems. From cost analysis and questionnaire, it was identified that there is lack of awareness and interest by the customers to connect their waste disposal point to the sewerage line. However, it was found out that sewer line is efficient than vacuum truck service considering cost and service efficiency. Finally the sewer cad analysis indicated that the existing sewer network can serve under capacity if the upstream area loads are excluded. However, the inclusion of the upstream area (Merkato site) to the Lideta existing sewerage system resulted in a complete system failure. The identified problems associated with sewerage system can therefore be overcome through having efficient operation and maintenance services in cooperation with other infrastructure agencies and through awareness creation.

Table Contents

List of Figures

List of tables

List of Abbreviation and Acronyms

ASCE	=	American Society Civil Engineers
AAWS	=	Addis Ababa Water and Sewerage Authority
CSO	=	Combined Sewage Overflow
STEP	=	Septic Tank Effluent Pump
WWM	=	Waste Water Management
NWSC	=	Nepal Water Supply Corporation
I/I	=	Inflow and infiltration
NH and SS	=	National Hygiene and Sanitation Strategy
PWSS	=	Protected Water Supply Schemes
ADWF	=	Average Dry Weather Flow
GWI	=	Ground Water Infiltration
PWWF	=	Peak Wet Weather Flow
CPHEEO	=	Clay Pipe Engineering Manual
HDPE	=	High Density Polyethylene
PVC	=	Polyvinyl Chloride
ABS	=	Acrilonitrile Butadiene Styrene
FRP	=	Fiber Reinforced Plastic
GIS	=	Geographical information system
PCCP	=	Pre-stressed Concrete Cylinder Pipe
CCTV	=	Closed Circuit Television
ECT	=	Eddy Current Testing
RFEC	=	Remote Field Eddy Current
MFL	=	Magnetic Flux Leakage
SASW	=	Spectral Analysis of Surface Waves
UTM	=	Universal Trans Mercato

Chapter One

1.0 Introduction

1.1 Background

Growth in world population and urbanization presents a host of challenges to the engineers and planners who design, maintain, and operate wastewater management systems. Wastewater is defined as "the spent or used water of a community or industry which contains dissolved and suspended matter."(ASCE,1982). Wastes originating from domestic, commercial, and industrial sources (often mixed with storm water) are collected, treated, and discharged back into the environment. In developing regions, unprecedented growth and the accompanying increase in wastewater production mean that the environment is progressively less able to absorb pollution loads.

A sewer system is the "life-line" for a municipality and is generally the most cost intensive of all Infrastructure systems. However, in many places this system is getting deteriorated due to a number of factors including excessive usage, aging, change of the surrounding soil, and mismanagement which leaves communities vulnerable to unexpected catastrophic failures that disrupt not only sewer service but above-ground activities as well. Defective sewer systems are regarded as 'time bombs'. Leaking underground sanitary sewer systems can cause exfiltration of raw wastewater and industrial discharge through leaking pipes, polluting soi1 and groundwater. In other cases, infiltration of groundwater through leaky joints and cracks in the pipe system can lead to excess cost at the treatment plant or contribute to pipe collapse (ASCE, 1994). Furthermore, due to their low visibility, rehabilitation of sewer systems is frequently neglected until a major fai1ure occurs, often resulting in difficult and costly rehabilitation requirements.

There are two main avenues to improving sewer rehabilitation planning. The first is the collection and storage of adequate inspection information regarding the current condition of the sewer system; the second is the ability to predict sewer deficiency prior to failure to facilitate sewer inspection and repair prior to collapse. Sewer network systems are considered an essential part of the urban water infrastructure, which have to be carefully operated and Maintained in a rational, sustainable and scientifically based manner (Ertl and Haberl, 2006). But now, developing countries face additional challenges related to maintaining or improving

the level of service in the face of aging wastewater infrastructure, new customers in need of sewer service, and increasingly strict environmental regulations.

Sewers are defined as conduits that collect and transport wastewater or drainage water from an area to a discharge location. There are three main types of sewer systems that fall under the jurisdiction of most municipalities. These sewer collection systems consist of sanitary, storm, and combined conduits. A sanitary sewer system carries waterborne wastes containing minor quantities of inadvertent storm, surface, and groundwater from residences, commercial buildings, industrial plants, and institutions. Water related diseases are a human tragedy, killing millions of people each year (account for 80% of all deaths in developing countries). Type of water related disease and water born are cholera, typhoid, giardiasis, amoebiasis, diarrhea, dracunuliasis, schistosomiasis and malaria. improved water supply and sanitation leads to reduced incidence of morbidity and mortality. Whereas, storm sewer system carries storm runoff, along with street waste and wash wastewater or drainage. It excludes domestic and industrial wastewater. However, a combined sewer system is typically found in older parts of cities and represents collection systems that carry a mixture of domestic and industrial wastewater along with storm runoff.

In Ethiopia, sanitary services are still at a very low level of development (AAWSA, 1999) Addis Ababa is the only town in the country with a sewer network. Even in the capital city only a little greater than four percent of the urban populations are connected to this sewer network. Addis Ababa Water and Sewerage Authority (AAWSA) have controlled eight branches. The existing sewerage system in the city is totally a separate system and employs a decentralized septic tank system approach. The waste water inflow to the treatment plant is under its design capacity in the dry weather and it overflows in the rainy season though the number of customers connected to the system is far lower than the design capacity. These sewers over flows are observed in the many parts of the city at manholes and complete diversion of sewer to the rivers are practiced due to blockage of downstream sewer sections as a result of illegal construction works on the sewer routes and additional inflow.

Arada Branch, one of the branches whose sewerage system controlled by AAWSA is also facing the same problem especial around municipal area, Zemen bank, Gola Michael Park and Babis area. The number of population living in this part of a city is around 297, 942 within a total area of around 9.54 sq.km. The number of customers connected to water service is around 42,214 and the sewer line length laid in the existing Arada branch sewerage system

have a total length of approximately 3 km of main trunk line and 15 km of secondary and laterals sewers. The maximum size of the main trunk line diameter is 500mm size made of Asbestos cement and the minimum size of 150mm PVC type is utilized in the house connection purpose. The minimum and maximum gradient is generally 0.05 m/m to 0.1m/m and the minimum and maximum velocity is about 0.6--3m/s. The number of customers connected to the existing sewer system in Arada Branch has reached 90 (BCEOM and GKW Consult, 1993).This paper is, therefore, proposed to investigate the performance of the present sewerage system at Arada Branch in terms of technical efficiency and economy.

1.2. Objective

The main objective of this research is to assess the performance of the existing sewerage system in Arada Sub city, Addis Ababa in terms of technical efficiency and economy.

The specific objectives are:

- To identify major problem areas for performance of sewerage system in Arada Sub city.
- To check the design standard of the existing sewer system.
- To determine the design capacity of the distribution system by using SEWER CAD and compare with the existing condition in Arada Sub city of AAWSA
- To evaluate the economical efficiency of the sewerage system in Arada Sub city.

1.3. Statement of the problem

The waste water inflow to the treatment plant reaches its design capacity in the dry season and it is over in the rainy season even though the number of customers connected to the system is far lower than the design capacity. Sewers over flows are observed in the different parts of the city at manholes and complete diversion of sewer to the rivers are practiced due to blockage of downstream sewer sections as a result of illegal construction works on the sewer routes and additional inflow.

Realizing a new sewerage system requires a huge financial resource as well as a longer realization period which can hamper the existing development trend. To coup up with this huge demand trend it is wise to utilize the existing separate sewer system efficiently along realization of the new projects. Currently the Addis Ababa City government is implementing huge condominium housing project which requires efficient service of the modern sewerage system. The condominium development work is becoming the major customer to demand the sewerage system services. This development trend cannot be handled easily by the existing decentralized septic tank system approach as it has been practiced before. Therefore the historical slower rate of sewer connection trend will not continue as it is in the near future. This study can be taken as a part of this resource maximization effort by studying the performance of the existing distribution system in Arada Sub city.

1.4. Research question

1. Is the existing sewerage system at Arada branch technically efficient in providing the required service?
2. Which type of disposal system economical in Arada Sub city?
3. Which part of the area(s) in the Arada Sub city is (are) facing service delivery problem more?

1.5. Structure of the thesis

This thesis report consists of five chapters. A general over view on the need of performance of assessment of AAWSA controlled sewerage system in general and the case of Arada Sub city in particular and as well objectives of this study and statement of the problem are given in the first chapter. The second chapter is the Literature Review which contains a collection of previous studies related to this study. Materials and Methods used in this study are discussed in the third chapter. It reports about data collection and analysis, sewer layout and design, and system evaluation criteria. Results and discussion is the fourth chapter, in which the results obtained in data analysis is presented and discussed. The fifth chapter presents the conclusions drawn in reference to the objectives of the study and forwards some recommendations.

Chapter Two

2.0. Literature Review

2.1. Types of sewerage system

Sewer networks are considered as complex large-scale systems since they are geographically distributed and interconnected with a hierarchical structure. Each subsystem is composed of a large number of elements with time-varying behavior exhibiting numerous operating modes and subject to dynamic changes because of external conditions (weather and operational constraints). Most cities around the world have sewage systems that combine sanitary and storm water flows within the same network.

This is why these networks are known as combined sewage systems (CSS). This discharge to the environment, known as combined sewage overflow (CSO), contains biological and chemical contaminants creating a major environmental and public health hazard (SAC group, 2009). According to Mays, 2001, the earliest drainage systems date back to as early as the third century B.C. with the Indus civilization followed by the Mesopotamians. The systems from this period were developed primarily for storm water drainage, but frequently conveyed sanitary waste too. During the second century B.C., the Minoan civilization developed extensive drainage systems on the island of Crete. These included the first documented separate sewer system in Knossos (Mays, 2001). Between 1100 and 700 B.C., the Greeks began constructing the first sewers under streets.

Most sewer systems in the early twentieth century were constructed as combined sewer systems, sized primarily to convey storm water flow and carrying sanitary sewage as an afterthought. Because treatment facilities could not handle large wet weather flows, these systems had diversions, or overflows, installed to discharge combined sewage directly to the receiving water during high-flow events (Metcalf and Eddy, 1914). Generally in the world, as putted by Choi (2001), there are three main types of sewer systems that fall under the jurisdiction of most municipalities. These are:

- Storm sewer system caring storm runoff along with street waste and wash wastewater or drainage. It excludes domestic and industrial wastewater.
- A combined sewer collection system conveying wastewater generated by residential, commercial, and industrial users plus storm water generated from surface runoff.

- A separate sanitary sewer systems are designed to convey wastewater and storm water in separate pipes. However, sanitary sewers may also collect wet weather flow using illegal connections from roof leaders, house drains, sump pumps, or storm sewers, as well as through defects in the pipes and manholes. Separate sewers are used to collect wastewater from residential, commercial, institutional, and industrial sources. Where there are large influxes of storm water, a separate sewer system would be best suited.

There are four options for wastewater collection systems. These are: 1) gravity sewers 2) vacuum sewers 3) pressure sewer 4) Small diameter gravity sewer (Choi, 2003). The first two methods are currently implemented in Arada Sub city.

a) Conventional gravity sewers

Conventional gravity sewers transport wastewater by gravity flow from high to low points. They are designed so that the slope and size of the pipe is adequate to maintain flow towards the discharge point without surcharging manholes or pressurizing the pipe. Conventional gravity sewers remain the most common technology used to collect and transport domestic wastewater. Properly designed systems can handle grit and solids in sanitary sewage as well as maintain a minimum velocity which reduces the production of hydrogen sulfide and methane. The need for a self cleansing slope can require deep excavations and/or additions of pumping or lift stations. Several different types of wastewater collection systems have been developed as alternatives to conventional sewers. The network of piping for an alternative collection system can be laid in much shallower and narrower trenches. They also do not need to be laid in a straight line nor with a uniform gradient. This means they can be laid in such a manner as to easily avoid obstacles.

b) Vacuum sewers

Vacuum sewer systems take wastewater from a holding tank. When the wastewater reaches a certain level, sensors within the holding tank open a vacuum valve that allows the contents of the tank to be sucked into the network of collection piping. The vacuum within the system is created by a vacuum station at a central location. Vacuum stations are small buildings that house a large storage tank and a system of vacuum pumps.

c) Pressure sewers

Pressure sewers use the pressure force supplied by pumps to deliver wastewater to a central location from each property. A pressure system is a small diameter pipeline (typically

100mm), shallowly buried, and following the contour of the land. The systems eliminate the need for lift stations of a conventional system and also infiltration is eliminated because manholes are not required, thus piping materials are not exposed to groundwater fluctuations. There are two types of pressure systems distinguished by the type of pump used. A septic tank effluent pump (STEP) uses septic tanks to capture the solids, grit, grease and stringy material that allows for smaller diameter piping. The effluent pump then provides the necessary pressure to move the wastewater through the system.

d) Small diameter gravity sewers

Small diameter gravity sewers provide primary treatment at each connection and convey only the effluent. This system is similar to the STEP system in that it would require homeowners to maintain their existing septic tank. Grit, grease and other troublesome solids which might cause obstructions in the collector mains are separated from the flow and retained in the septic tanks. Effluent from each tank is discharged to the collector sewer via gravity. There is a lower required velocity in the sewers because solids are not transported through the system. Therefore the pipes do not have to be as large or as sloped.

2.2. Urban and rural sewerage system

Rapid urbanization, change in consumption habit and negligence towards preservation of environmental condition brought new scenario of urban and rural areas with disposal of wastewater and industrial effluent into the river systems or into ground water through septic tanks. However, Badan (2006) reported that the rapid urbanization has created severe demand on Wastewater Management (WWM) but less priority was given to the issue of WWM.

As stated in WWCS (2009), the specific requirements of the sanitary sewage system will depend on whether the development is defined as a rural or urban development. Regardless, the intent of the sanitary system design is to properly convey sewage generated from the development to an appropriate treatment system. The conveyance and treatment systems are to be approved by the county and must meet current design standards. The developer is responsible to confirm adequate capacity in any existing downstream collection or treatment system, if such information is not readily available from the system owner. Generally, rural systems will involve individual disposal fields on each lot, or a collection system and communal treatment/disposal component. The requirements for urban Sanitary Sewerage Systems will be dependent upon the existing and proposed population numbers, the site suitability, the establishment of contributing sanitary basins or benefiting sanitary areas,

existing system capacities and flows, and future growth areas. If this specification does not cover an area of sanitary sewerage system concern, the onus will be upon the developer to make recommendations and present alternative corrective measures based on sound economic, engineering, environmental, and operational and maintenance criteria for approval by the County.

2.3. Problems of urban sewerage system

As Badan (2006) has found out the sanitary sewerage system in some countries has practically failed with inviting huge environmental hazard and damage to human health. The management issues of ownership, institutional capacity, operation and maintenance, and timely expansion of these systems have become major problems because of following reasons:

- Lack of adequate capacity of the responsible authorities to deal with (financial resources, agreed programs of operation and maintenance, acceptable quality of construction),
- Lack of ability to address the issues in a timely manner,
- Overlapping responsibility between Water Supply Corporation and municipalities,
- The combined sewers as brick channels are the property of the local governments but are used for sewage disposal. The responsibility for operation and maintenance is confused and overlapping,
- The expansion of sewerage network is carried out by the municipalities together with the local communities based on their demand created by unplanned urban growth
- Similarly, the roadside drainage is frequently used for sewerage disposal and interferes with the authority of the Department of Roads. Actually, the ownership of roadside drainage within the urban areas is also confusing,
- Lack of coordination and clear jurisdiction of authorities between the local governments and authorities are major management issues,
- There is also confusion on the use of revenue for operation and maintenance.

In addition to the management aspect of sewerage problems the following common technical problems are listed in Regional Drainage Policies, Volume 4, 2005:

Inflow and infiltration (I/I) in sewer systems

The term "infiltration" is used for water entering the sewer system from groundwater or from below ground level and "inflow" is used for water entering the sewer system directly. Infiltration enters the sewer system through openings such as: displaced or open pipe joints; cracks, fractures and breaks in the fabric of the main sewer and lateral connections, and manhole chambers.

The term "Inflow" implies flows that enter the sewer system via sources such as faulty manhole covers, cross connections from surface water sewers/domestic drains and land drainage connections. Inflow and infiltration (I/I) in sewer systems can cause many problems.

- Increased operational and capital costs in the sewer network and at treatment plants,
- Reduced sewer and treatment capacity leading to increased operation of combined sewer overflows, flooding and pollution,
- Reduced sewer and treatment capacity restricting future development,
- Lowering of groundwater levels leading to detrimental effects on local water resources,
- Loss of soil into sewers causing operational problems and structural damage,
- These problems all ultimately result in increased costs,

Overflows and Diversions

Overflows: wastewater can leave a collection system through a diversion facility specially constructed to regulate the overflow, or simply by flowing out through an open manhole cover. When the water level in the sewer reaches an opening, whether it is a weir, valve, manhole lid, or catch basin, water will leave the sewer. One of the difficulties in handling any overflows is deciding on the fate of the water that leaves the collection system. It can be

- Lost to a receiving water body,
- Ponded and then flowed back into the sewer when water levels in the sewer drop below the pond surface,
- Moved overland to the next catch basin or other inflow point,
- Some combination of the above,

Diversion: chambers constructed to handle overflows, the overflows usually are directed to a receiving stream. However, when a manhole overflows, the fate of the water depends on the topography at the overflow. Since many overflows occur at depressions, the water may be Ponded and then return after the flow peak passes.

- Lack of adequate capacity of the responsible authorities to deal with (financial resources, agreed programs of operation and maintenance, acceptable quality of construction
- Lack of ability to address the issues in a timely manner
- Similarly, the roadside drainage is frequently used for sewerage disposal and interferes with the jurisdiction of the Department of Roads. Actually, the ownership of roadside drainage within the urban areas is also confusing,
- Lack of coordination and clear jurisdiction of authorities between the local governments and authorities are major management issues,

2.4. Urban sewerage system in Ethiopia

The majority of the population in Ethiopia, urban and rural alike does not have access to safe and adequate sanitation facilities. A study carried out by PPP (GTZ, 1999) indicates that three-fourth of the health problems of children in Ethiopia are communicable diseases attributed to unsafe and inadequate provision of water and unhygienic waste management, particularly sewage. Other studies revealed that only 11.5 % of the population has access to sanitation facilities while 88.5 % are without proper sanitation facilities. The existing capacity of the wastewater sector in Ethiopia is currently relatively low, in particular in regard to alternative concepts and technologies aiming at more decentralized and environmentally friendly, energy and resource saving solutions. Decentralized wastewater systems recycling the water (grey water) and dry sanitation have to be introduced in order to demonstrate cost-efficient and environmentally friendly sanitation moreover reducing the wastage of precious and scarce drinking water.

According to the website of the Ministry of Water Resources, "about half of the total population of the country does not have clean water access, and the sanitation situation is extremely low." A World Bank Report entitled "Ethiopia Managing Water Resources to Maximize Sustainable Growth" noted that "Water supply and sanitation in both urban and rural communities are characterized by low levels of service and lack of sustainability. User fees are often so low that they do not even provide for adequate maintenance of existing facilities. Urban piped water supply systems often operate well below capacity due to maintenance problems. Rationing and service interruptions are frequent. Water utilities tend to be understaffed and staffs are underpaid, inadequately trained and lacking in the resources to do their job. Budget resources combined with donor and bilateral assistance have been

insufficient to significantly improve coverage. With the exception of Addis Ababa, which has a sewage system, households are expected to finance, install, and maintain their own sanitation facilities – latrines and septic tank. Most towns do not have adequate means of septic removal and many do not have designated areas for water disposal or do not adequately enforce regulations. This situation contributes to environmental degradation of the cities, and, in some cases to contamination of the water supply (Ethiopia Community Profile, 2006)

2.5. Types of existing system in Ethiopia

2.5.1. Types of existing sewerage system in Addis Ababa

There was a few study conducted to quantify the infiltration, inflow and design problems on the separate sewerage system to notify the problem at the early stage in Addis Ababa. Even though the sewer expansion work is costly, the AAWSA is striving to expand the sewer line system to reach more customers without considering the efficient use of the existing sewer lines. In developing countries, lack of sanitation coverage and continuously growing populations are increasing the pressures on receiving waters. Coming to its historical background we can classify the city sewerage system development trend in to four generations of drains and sewers starting from the beginning of the twentieth century. The first three of these networks were combined sewers intended to collect storm water and wastewater flows.

As AAWSA's 1984-2009 documentation shows the oldest drainage system dates from the reign of Emperor Menelik and is located in the old centre of the city at Arada. The total length is limited to less than 5 km and the main purpose was the collection of storm water. The second generation of sewers was completed concurrently with new roads before World War II. They mainly serve the central market (Mercato), Piazza area and what used to be the southern centre of the town around the railway station. The network was designed as a combined system, draining wastewater and storm water from the built up areas.

The third generation of sewers followed a period of accelerated growth in the city after World War II. They were installed during the construction of new roads and the improvement of existing ones. Main streets were provided with two lines of drains discharging to watercourses. This was the case of in the existing main roads in the city core (Churchill road, Menelik and Entoto Avenue, Belay Zeleke and Weatheral street north of the city hall and Fitawrari Habte Giorgis street up to little Akaki) and to the east along Haile Gebre Selasse

road. These drainage lines are still used as combined sewers for collection and disposal of storm water and discharge untreated wastewater directly into the nearby watercourses. The Fourth generation of sewer is a Separate Sewerage System which was carried out in the early seventies. It was designed for the collection and conveyance of wastewater to the Kality treatment plant. This service area is the residential areas of Ledeta in the west and east Bole, as well as the business and commercial districts of the city centre.

The 1993 master plan divides the city into three main catchments namely, Akaki catchments, Kality catchments and eastern catchments. Each catchments system are planned to have its own central treatment units and waste water collection system (BCEOM and GKW Consult, 1993).

Currently only Kality catchment is connected to separate sewer line system partially. The rest two are totally relying on on-site sanitation system like dry pit latrines and septic tank. The sewer line length laid in the existing Kality sewerage system have a total length of approximately 30 km main trunk line (500-800mm) and 140 km of secondary(300-400mm) and laterals sewers(150-200mm). The number of customers connected to the existing sewer system has reached 4006 by the mid year 2009. The Kality sewerage system was designed on the basis of an average water consumption of 150 litres per capita per day to serve an equivalent population of 55,000. The maximum size of the main trunk line diameter is 800mm size made of Asbestos cement and the minimum size of 150mm PVC type is utilized in the house connection purpose. The minimum gradient is generally 0.05 m/m to 0.03 m/m and the maximum velocity is about 4 m/s.

2.5.2. Status of the sewerage systems in Ethiopia

Ethiopia, according to the recent census conducted in 2007, has a projected population of 77.6 million people in 2009. It is the second most populated country in sub Saharan Africa. The national water supply and sanitation coverage according to the Health and Human Rights Info (HHRI) and Ministry of Health (MoH) 2007/08 is 59.5% and 37% respectively. The National Hygiene and Sanitation Strategy calls for all households to have access to and use a sanitary latrine. Institutions are also asked to ensure the installation of appropriate latrines with urinals and hand washing facilities at schools, health posts, markets and public places. Ethiopia has no separate sanitation policy but a National Hygiene and Sanitation Strategy (NH and SS) and protocol that emanated from the Health Policy. The NH and SS was developed to enable 100% adoption of improved sanitation and hygiene practice particularly

in the rural settings of Ethiopia. Both the NH and SS and the Protocol stress a zero subsidy approach for household sanitation facilities but with some allowance for supporting the vulnerable, while regarding urban sanitation there is no single strategy that has been well embraced by all actors (S.S.S and G.A, 2009). The Water Resource Management and the Environmental policies and strategies also call attention to hygiene promotion and hygiene education, excreta disposal, collection, treatment and sanitary disposal of separate, wastewater treatment and collection, treatment and sanitary disposal of solid waste.Access for water in Ethiopia in case of rural is defined 15 l/c/d within a 1.5 km radius from protected water supply schemes (PWSS) while urban is defined 20 l/c/d within water coverage is defined as total number of protected water users covered, expressed as percentage of total population. This is occasionally estimated as follows: a) urban - production of water from existing sources adjusted for hours of service, water loss and system reliability less non-domestic water demand divided by total per capita daily demand and b) rural - estimated as percentage of people that can be supplied with water calculated by multiplying the number of existing functional schemes by average number of users per scheme.

Access to latrines/toilet facilities is defined as number of households with latrine divided by total number of households. The coverage trends over time, across regions, and between rural and urban areas for both water and sanitation are as shown in Table 2.1.

Table 2.1 Water and Sanitation coverage Reference (S.S.S & G.A, 2009)

Regions	Access to Safe Water				National Access to Latrines/Toilet Facilities	
	National		Urban	Rural	Urban	Rural
Addis Ababa (%)	99.00	95.00	95.00		91.25	
Afar (%)	48.60	55.40	77.40	53.10	21.16	3.00
Amhara (%)	28.00	53.70	87.80	49.00	12.44	29.00
Benshangul Gumuz (%)	27.20	49.30	93.10	44.30	33.91	16.00
Dire Dawa (%)	90.80	73.00	72.00	75.80	68.11	34.00
Gambela (%)	54.70	98.60	43.90	28.33	3.00	0.00
Harari (%)	73.30	32.50	27.50	41.00	55.98	30.00
Oromia (%)	32.00	58.30	97.90	52.00	24.93	35.00
SNNPR (%)	34.30	63.60	72.10	63.00	57.27	55.00
Somali (%)	39.00	37.90	61.60	32.90	26.04	10.00
Tigray (%)	54.00	59.10	72.00	56.00	18.95	40.00
National (%)	35.90	59.50	86.20	53.90	30.63	37.00

2.6. Design of sewerage system

2.6.1 Design considerations

The design of cost-effective and efficient sewage collection system is accomplished by proper layout and sizing of sewers. The design period for all sewers in the system is 30 years, while pumping machinery is designed for 15 years. The criteria adopted for design of sewerage system and sewage treatment as presented in Uttar Pradesh (2010):

Dry Weather Flow: 80% of water supply (i.e. 135 lpcd)

Peak Factor: As per CPHEEO Manual

Design Equation: Manning Formula, with n=0.011

Sewer Material: RCC NP2 / NP3 pipe for laterals, collector, sub-trunk and trunk sewers

Velocity: Min. Velocity ≥ 0.6m/s (0.45 m/sin initial reaches)

Max. Velocity ≤ 3m/s

Depth of Flow: All sewers flowing ≤ 0.8 full (CPHEEO)

Infiltration: 5000 lit/Km/day

Minimum Diameter: 150 mm.

Maximum Depth of Invert: The maximum depth of invert shall be 6-7m. In exceptional cases, like crossings, drop manholes and at pumping station locations larger depths up to 8m is considered (Case specific basis).

Minimum Cover: Without protection 0.75 m (up to top of pipe)

Bedding: Granular compact bedding 150 mm (minimum) or as per design.

Backfill: All Backfills shall be mechanically compacted and compaction density measured up to acceptable levels or as specified based on soil analysis.

Design Loading: Structural design of buried pipes (As per CPHEEO)

Manholes: Location (a) At change of slopes in Pipeline
(b) At change of direction
(c) At junctions
(d) At change of pipe diameter
(e) At termination sewer
(f) At any designed special location

Spacing: Up to 900 mm dia -30m c/c and 900 to 1400 mm dia -100m c/c

Sanitary sewers are designed primarily to carry to a satisfactory point of treatment and ultimate disposal of the spent water supply of a community, industrial wastes and

unavoidable amounts of ground water infiltration. All waters not containing impurities which are actually or potentially objectionable should be excluded as far as possible from the sanitary sewer system. The flow rates of sewage for which sewer capacity should be provided must be determined from careful considerations of the present and probable future quantities of domestic sewage and commercial and industrial wastes. According to O'Brien and Gere (2004) the following guides are intended to be used by design engineers for development projects.

- **Design flows:** municipal or sanitary sewers are normally designed to carry the peak residential, commercial and industrial flow, including the infiltration, where such condition exists. The computation of design flow is governed by rate of water supply in the project area:

a) **Sewer Loads for Dry Weather Conditions:** Sewage flow resulting from sanitary wastewater

(Combined input of domestic, commercial and industrial flows) and infiltration and inflows from sewer joints and service connections, during periods with an absence of rainfall or snowmelt.

- Average Dry Weather Flow (ADWF) = Sanitary Base Flow + Groundwater Infiltration (GWI) Average Dry Weather Flow (ADWF) is the average flow that occurs in sanitary sewers on a daily basis with no evident reaction to rainfall.
- Groundwater infiltration (GWI) is an allowance that is added to the sanitary base flow (derived from sewage flow factors) to obtain the dry weather flow.

b) **Sewer Loads for Wet Weather Conditions:-** Sewage flow resulting from sanitary wastewater (combined input of domestic commercial and industrial flows) infiltration and inflows from sewer joints and service connections, during periods of rainfall or snowmelt; or storm water generated by either rainfall or snowmelt that enters the sanitary sewer system

- Peak Wet Weather Flow (PWWF) = Average Dry Weather Flow (ADWF) + Rainfall-Dependent I/I (RDI/I) Where: Peak Wet Weather Flow (PWWF) equals the peak hourly flow during wet weather conditions.

- Rainfall-Dependent I/I consists of rainfall that enters the collection system through direct connections (roof leaders, manholes, etc.) and causes an almost immediate increase in wastewater flows.
- Peak Wet Weather Flow (PWWF) = Average Dry Weather Flow (ADWF) x Peak Factor .The peak factor is equal to the PWWF/ADWF.

❖ **Sizing:** Since the quantity of domestic sewage is a function of the population and of water consumption, lateral and sub main sewers should be designed for the saturation density of population expected in the areas served. The sewer system should be designed for tributary areas, land use and population estimated based on the Master Plan of Sanitary Sewers. Minimum sewer size recommended in CPHEEO (CLAY PIPE ENGINEERING MANUAL) manual is 150 mm. The criterion governing the minimum size of gravity sewer is to reduce the possibility of clogging. For this project, the minimum sewer pipe size is 150mm, which is in line with recommendation by CPHEEO. A minimum pipe size of 150mm shall be used for all public sewers and private sewers within street**.**

❖ **Friction Loss type and methods**: Wall roughness may change over time because of pipe-wall corrosion or scale deposition. In sewage pipelines, the problem is mainly one of corrosion and/or slime coating. This problem may be mitigated through the use of corrosion-resistant pipe materials or pipe coatings, with associated pipe velocities high enough to minimize slime buildup. Most hydraulic models allow the modeler to select from the Darcy-Weisbach, Hazen- Williams, or Manning head loss formulas, depending on the nature of the problem and the modeler's preferences. The Darcy-Weisbach formula is more physically-based than the others. It is derived from the balance of forces acting on flow in pipes (although f is still found empirically). With appropriate fluid viscosities and densities, Darcy-Weisbach can be used to find the head loss in a pipe for any Newtonian fluid in any flow regime. The Hazen-Williams and Manning formulas, however, are empirically based and generally only apply to water in turbulent flow. The Hazen-Williams formula is the predominant equation used in the United States for pressure pipes, while the Darcy-Weisbach formula predominates in Europe. The Manning formula is not generally used for pressure flow except with inverted siphons and surcharged sewers. Roughness coefficient (n) for P.V.C is 0.01 and for other material 0.01.

- **Pipes:** Gravity sewer pipes are available in a variety of materials, including cast and ductile iron, PVC (polyvinyl chloride, concrete, asbestos cement, HDPE (high density polyethylene), ABS (acrilonitrile butadiene styrene), FRP (fiber reinforced plastic), brick, and vitrified clay. Most pipe has solid walls, although there are some truss or profile wall pipes available. Most new sewer pipe has a circular cross section; however, many older sewers, especially those made from brick, have different.

- **Manholes**: its structures designed to provide access to a sewer. Access is required for visual inspection of sewers, placement and maintenance of flow or water quality monitoring instruments, and cleaning and repair of the sewer. The use of lined, coated manholes or plastic manholes is increasing for economic reasons and to provide corrosion resistance and reduce infiltration through the manhole walls.

According to ASCE (1982), a manhole design must pass four major tests:

- Provide convenient access to sewers for observation and maintenance operations
- Cause a minimum of interference with the hydraulics of the sewer
- Be durable and generally watertight
- Be strong enough to support applied loads cross-sectional shapes.

Manholes shall be located on the sewer main at the following points:

a. At intervals not to exceed 400 feet.
b. At changes of pipe size, slope or direction.
c. At six (6) inch and larger service lateral connections to the main.
d. At service lateral connection to a 15 inch Trunk Sewer or larger.
e. At the end of the sewer main.
f. At transitions between PVC and other pipe material

- **Shape and Dimensions of manhole:** Most manholes are round and 1.2–1.8 m in diameter, with larger sizes for larger sewers. In small sewers, the manhole is generally centered over the pipe. For large-diameter sewers, the manhole entrance is often offset, with a work platform to the side of the sewer. The rungs or ladders used for entering manholes should be corrosion resistant to provide the long-term durability and strength needed to prevent failure**.**

The following are some additional considerations related to manhole location:

- Street intersections are common locations for manholes (American Society Civil Engineers, 1982),
- A terminal manhole should be located at the upper end of a sanitary sewer to provide access for maintenance,
- Manholes should not be placed in a location that allows surface water to enter,
- Inserts may be used to limit infiltration through pick holes,
- Manholes in cross-country settings usually have chimneys raised above the ground to prevent surface water intrusion.

❖ **Flow and Velocity**:-Most sewer design is based on providing enough slopes to achieve a minimum velocity of 0.6 m/s at full flow. However, in the upper reaches of most sewer systems, flows are very low and are frequently zero (intermittent flow). With such low flows, the minimum velocity necessary for the pipes to be self cleansing is rarely achieved. With one or two houses at the end of a sewer branch, it is unlikely that flows will exceed 0.3 l/s yet most sewers in these situations perform adequately. This is possible because velocity does not decrease proportionally with flow.

The question remains of what flow an engineer should use when determining whether the velocity will be high enough to prevent solids deposition. Standard references (ASCE, 1982) provide a curve for the ratio between minimum and average flows, with the minimum flow being checked for minimum velocity. However, the lowest value on that curve, 0.2, corresponds to a population of 1000, whereas there are many sewers serving much smaller populations. While such a value is probably not correct, the true minimum velocity in small sewers is zero, and there is a statistical distribution of flow such that 0.2 times the average flow would be extremely small. In small sewers, it may be best to think of self-cleaning as an event that occurs only once or twice a day, especially during the early years of a pipe's life. The concept of a minimum-to-average flow ratio is meaningless in small sewers with intermittent flow, so basing slopes on minimum velocity may be impractical. The engineer is then faced with adopting minimum slopes from the standards without explicitly basing the design on velocity.

- **Velocity and slope:** For incompressible flow, volumetric flow rate (also called discharge) is usually use in conservation of mass expressions, so flow rate and velocity are related by the conservation of mass equations.

  Maximum Velocities: Impact, pipe erosion, and manhole nuisance and safety issues have resulted in maximum sewage velocities commonly being limited to about 4.6 m/s unless special requirements are met, such as the use of ductile-iron pipes and/or special energy-dissipation features at the downstream manhole. At simple, straight-through manholes, higher velocities are acceptable, perhaps as high as 6.1 m/s. Conversely, at multiple-inlet and/or direction-change manholes lower maximum velocities on the order of 2.4 m/s or lower may be appropriate.

Minimum Velocities: Sanitary flows carry a wide variety of inert and putrefactive particles. To avoid long-term deposition and accumulation of these materials, the wastewater must carry these particles to the treatment facility. The traditional approach has proven adequate to avoid serious sediment buildup in most sewer lines, but it does not address self-cleansing as accurately as does the tractive force method .Minimum slopes to achieve a velocity of 0.61 m/s for Manning's n = 0.013. Due to the difficulty in precise invert placement and the very small invert elevation gain from flatter slopes, a minimum slope of 0.050 is recommended for large pipes. The velocities resulting from this minimum slope are shown in Table 2.2 for pipe sizes 915 mm and larger approach to self-cleansing is to require a full-pipe velocity of at least 0.61 m/s.

Table 2.2 Minimum slopes for various pipe sizes.

Pipe Diameter(mm)	Slope(m/100 m)
152	0.49
203	0.34
254	0.25
305	0.20
381	0.15
357	0.12
533	0.093
610	0.077
686	0.066
762	0.057
838	0.050

2.6.2 System design tools

At present, there are several sewer asset management decision-support tools available. These tools are varied in their scope and focus. As it has been reported by Ana *et al.* (2000), the main concepts of each tool are described in the succeeding text. The asset management decision-support tools under this category refer to those tools that deal mainly with performance modeling.

a) **Bengassem and Bennis model (Canada):** This model is a systematic methodology to evaluate the structural and hydraulic conditions of a sewer system, using fuzzy inference system as an aid in the development of a rehabilitation program (Bengassem and Bennis, 2000). The method encompasses structural inspection and hydraulic simulation to evaluate the condition of the components of the sewer network. Fuzzy theory is then applied at the pipe sections level to integrate all the evaluation factors, to come up with a performance assessment of the sewer network. Three aspects are considered in the evaluation of the structural performance: 1) intrinsic (i.e. pipe defects), 2) extrinsic (i.e. pipe characteristics and environment characteristics affecting pipe degradation, e.g. geotechnical factors, hydro-geological factors and various factors including seismic or tectonic activity), and 3) site vulnerability (i.e. nature of site, soil density).
b) **Baik model (US)**: The Baik model estimates the transition probabilities of different condition states in Markov chain-based deterioration models for wastewater systems, using an ordered probit model (Baik *et al.*, 2006). The idea is to predict the future condition of the sewers so that managers can prepare inspections, rehabilitation and replacement activities in a timely and cost-effective fashion. To estimate transition probabilities, the model requires data from the condition assessments of the existing system: for structural assessment, internal inspection is required and for hydraulic assessment, models are used. Infiltration and inflow are also investigated.
c) **Heisted method (Sewer Cad):** the above two methods used to analyze sewer network based on given data but Sewer CAD is preferred because of two reason: first most of the time AAWSA used to design the sewerage system by sewer cad and the data collected also fit to sewer cad. Second, it is known that Sewer CAD is easily accessible software. Data analysis is done using Sewer CAD, which is an extremely powerful program for the design and analysis of gravity flow and pressure flow through pipe networks and pumping stations. The program can be run in AutoCAD mode, giving you all the power of AutoCAD's capabilities, or in Stand-Alone mode utilizing our own graphical interface.

Sewer CAD allows you to construct a graphical representation of a pipe network containing information such as pipe data, pump data, loading, and infiltration. You have a choice of conveyance elements including circular pipes, arches and boxes.

2.7 Performance Analysis Tools

2.7.1 Performance analysis of sewerage systems

As Christopher (2009) reported, in conducting condition assessment, it is important to understand the dynamics of pipe failure including the level, type, and severity of a failure mechanism. Failure can be a sudden, catastrophic collapse of a pipe, restricted hydraulic capacity, or a variety of other performance conditions that result in the inability of the pipe to perform as necessary for the minimum acceptable level of operation of the system. The purpose of condition assessment is to detect pipe defects which indicate the likelihood of pipe failure, as well as to assess the collection system's performance. This section discusses the mechanisms of pipe failure, the various types of pipe defects, and the relationship between the condition of a pipe and its performance. It is important to understand that the mechanisms and impacts of pipe failure are highly dependent upon the pipe material and type of sewer (i.e. force main, gravity line).

2.7.2 Technical performance Technologies

There are a variety of technologies available for assessment of collection systems.

a) **Closed Circuit Television (CCTV)** is a well-established and common industry method used for inspecting pipes. It provides visual data on leaks, location of service laterals, and sediment and debris accumulation. The primary disadvantages to CCTV technology are that it only provides a view of the pipe surface above the waterline; it does not provide any structural data on the pipe wall integrity; and it does not provide a view of the soil envelope supporting the pipe. For inspections of gravity lines, basic CCTV systems are not able to measure slope. There are needs for higher resolution cameras with better lighting; and improvements in crawler technology to better negotiate obstructions, grease, and off-set joints. The quality of defect identification and pipe condition assessment using CCTV is highly dependent on many factors including operator interpretation, picture quality, and flow level. Innovative camera technologies include zoom cameras, digital inspection, push cameras, and advances in crawler technology.

b) **Fogging** is a simple possibility false connection. A fog machine is used to blow smoke into the domestic sewer system. This then escapes at all pen drainage point connected to this network. This method is used in particular to determine false connection to the waste water network such as roof drainage or ground drainage. It is not suitable for more detailed recording of the network structure or recognized leaks.

c) **Acoustic technologies** use measuring devices to detect vibrations and/or sound waves. In pipeline assessment, acoustic sensors are used to detect signals emitted by defects. Three types of acoustic technologies are used for pipeline assessment: leak detectors, which are used to detect the acoustic signals emitted by pipeline leaks; acoustic monitoring systems, which are used to evaluate the condition of pre-stressed concrete cylinder pipe (PCCP) by detecting the signals emitted by breaking pre-stressed wires; and sonar, or ultrasonic systems, which emit high frequency sound waves and measure their reflection in order to detect a variety of pipe defects.

d) **Electrical/Electromagnetic** currents are the basis of several sewer evaluation techniques. The electrical leak location method is used to detect leaks in surcharged non-ferrous pipes. Eddy Current Testing (ECT) and Remote Field Eddy Current (RFEC) technology identify defects in ferrous pipes. Magnetic Flux Leakage (MFL) inspection is widely used in the oil and gas industry to measure metal loss and detect cracks in ferrous pipelines.

e) **Laser profiling** uses a laser to create a line of light around the pipe wall, highlighting the shape of the sewer. This technique allows for the detection of changes to the pipe's shape, which may be caused by deformation, corrosion, or siltation. Laser inspection can only be used to inspect the portions of a pipe wall that are above the water line. To assess the entire internal surface of a pipeline requires the pipe to be taken out of service. Lasers are often used in combination with other inspection methods, most commonly CCTV and/or sonar.

f) **Innovative methods** based on a variety of technologies are currently being developed for the evaluation of sewer collection systems. Gamma-gamma logging is a technique used primarily to evaluate cast-in-place concrete pilings and can provide information on the average bulk density of the concrete and the location of voids. Ground Penetrating Radar can detect underground voids, and is potentially useful for examination of pipe bedding and to locate leaks. Infrared Thermograph involves the use of an infrared camera to measure the temperature differential across an object and is a potential method of detecting sewer defects such as leaks and voids. Micro-

Deflection is a nondestructive technology used to evaluate general conditions and joint integrity of brick, concrete, and clay structures using a load to create a slight deformation or micro-deflection in the test material. Impact Echo and Spectral Analysis of Surface Waves (SASW) are acoustic wave techniques for locating and measuring cracks, delimitations, voids, and honeycombing in concrete and masonry.

2.7.3 Economic evaluation of sewerage system

Cost is always a main factor in any project decision. Before starting the cost comparison of the two methods the advantage and disadvantage of each method is presented based on Arada Sub city current situation.

- **Advantage of using sewer line**
  - Long design period
  - Low exposure of disease
  - Economically (with design period)
  - Low time take to get the service
  - After getting the service no more thinking about disposal
  - Durable
  - Generally better way of disposal system
- **Disadvantage of using sewer line**
  - Not accessible every where
  - For low income difficult to use
  - Topography limitation
  - Initial cost may challenge (it need flash toilet)
- **Advantage of using vacuum truck line**
  - For low income easy to use interims of cost
  - No need of modern toilet
- **Disadvantage of using vacuum truck line**
  - To get the service take long time(even two month)
  - Topography limitation
  - Exposure of disease during the service
  - Road accessibility problem
  - More challenge face during repetition of the service.

The capital costs for any of the options available involves a number of factors such as house connections, sewer mains and pumping stations. Based on Choi (2003), the primary cost trade-offs to develop a plan are presented in table 2.3 and are discussed thoroughly below.

Table 2.3 A summary of the cost comparisons

	House Connections ($/household)	Sewer Mains ($/meter)	Operation and Maintenance ($)
Gravity Sewer	2,500	230-330	200,000
Vacuum Sewer	5,000	130-200	400,000
Pressure Sewer	7,000	115-165	None

a) House Connections

Gravity sewers have the simplest and lowest typical cost of about $2,500 for a house connection. Vacuum sewers require a vacuum valve station at each property with typical costs starting at $5000 per household. Pressure sewers are the most expensive option with pump costs approaching $7,000 per household. Small diameter gravity sewers have a house connection cost of installing and maintaining the interceptor tanks. Similar to pressure sewers, the cost of installing interceptor tanks is a significant cost. Usually existing septic tanks cannot be used as interceptor tanks because they are not watertight and cannot be inspected and repaired cost effectively. Pressure and small diameter gravity sewers are both well suited for communities with houses that are far apart. Arada branch, where the houses are close together, is therefore not conducive for pressure and small diameter gravity systems.

b) Sewer Mains

The conventional gravity system has slope requirements to maintain gravity flow. This demands deep excavations and/or additions of pumping or lift stations which drive up construction costs. Pressure sewers are the most cost effective sewer mains to implement. They do not require deep excavation and typical cost per meter range from $115-165. Small diameter gravity sewers have a small diameter (~150mm) and can be also busied at a relatively shallow depth. Vacuum sewers are typically 15- 25% higher in cost than pressure sewers and gravity sewers are generally more than 100% higher in cost than the lower cost pressure sewers. Where the required length of sewer between service connections is comparatively short, the cost of providing conventional sewers is usually affordable unless some other obstacle is present. Due to lack of awareness, economically, to discharge there waste uses other illegal method.

c) Operation and Maintenance

The operation and maintenance cost for pressure systems tend to be high because of the pumps. In areas where electric supply is not reliable, these systems could be more trouble than help in that constant monitoring or the addition of backup power is needed at each household. There is less risk with a vacuum system since the vacuum station has a central location, so just one back up power system is required. There is also a cost of cleaning and maintaining each tank at each home. In higher density areas, this could prove to be more costly than the savings from pipe network installations fees for pressure sewers.

Chapter Three

3. Materials and Methods

3.1. Description of the study area

3.1.1. General

The objective of this study is to assess the performance of the existing sewerage system in terms of technical and economic efficiency. The branch division of Addis Ababa city is categorized in two, i.e. AAWSA division (eight Sub city) and Municipal division (ten Sub city). This study focuses on the AAWSA division specifically the Arada Sub city (Figure 3.1).

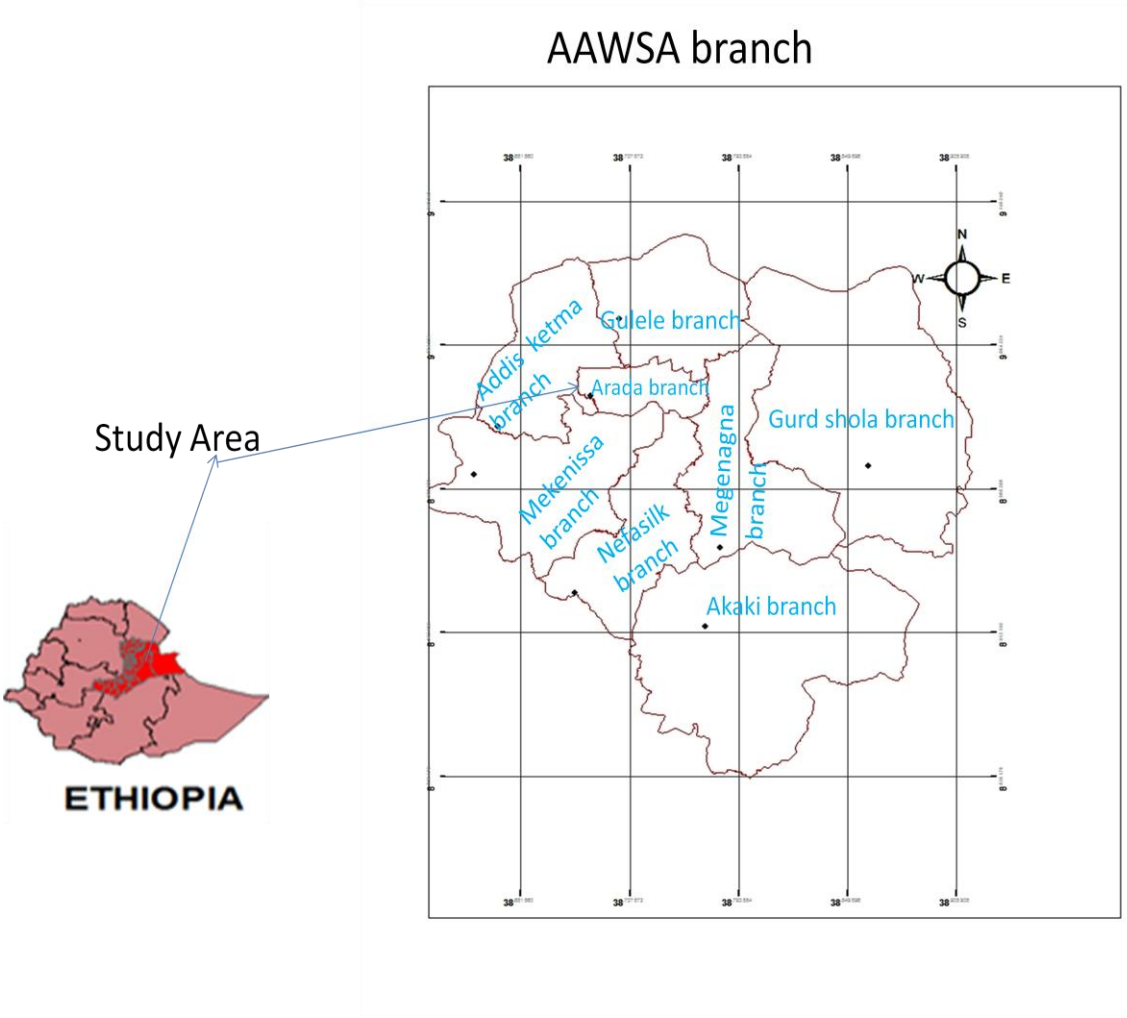

Figure 3.1 Description of the study area

3.1.2 Location

Arada branch is located in the North West of Addis Ababa. Arada Sub city is the smallest of the eight branches of Addis Ababa. Arada Sub city has a population of 297,942. Based on UTM projection, Arada branch extends from east (475757.5945, 997249.8541) to west (469042.6126, 997662.7915) and from the south (471587.2056, 995862.069) to north (472960.5372, 998892.6743). The average elevation of the area approximately ranges from 2300m to 2500m asl (meter above mean sea level).

3.1.3 Land use and land Cover

The dominant land cover units in the study area is divided into residential, commercial, institutional, forest cover, water bodies and condominium area. Currently most of the old residential areas are abandoned due to the planning and construction of new buildings and condominium. For example if we consider for the case Casanches area, Ledta site and some part of Arat Kilo almost new constructions are built in the area. Arada has high population density (Table 3.1).

Table 3.1 Land use information related to Arada branch

Item	**Value**
Total area	9.54 sq.km
No of private house	25000
No of commercial house	3811
No of worda (kebele)	10
No of private Hospital	2
No of government Hospital	2
No of condominium Site	19
No of condominium household	2011

3.2 Sewerage Network in Arada Sub city

Arada branch wastewater collection system consists of approximately 3km main trunk line, more than 15km secondary line and laterals of gravity sewer pipes, 520 manholes, and no pumping stations. Pipe sizes in the collection system ranges from 150 to 500 mm in diameter. In more recent constructions PVC pipes are used extensively but previously they were concrete pipes..

System customers are categorized to domestic groups and non domestic groups. For domestic customer connections an average of 6 people per connection is taken (CSA, 2007). For the non domestic connections, 300 population equivalent is considered for each connection based on the 1993 waste water master plan study report. For both group 80 l/c/d water consumption rate utilized by considering the existing city level total water supply volume to total population.

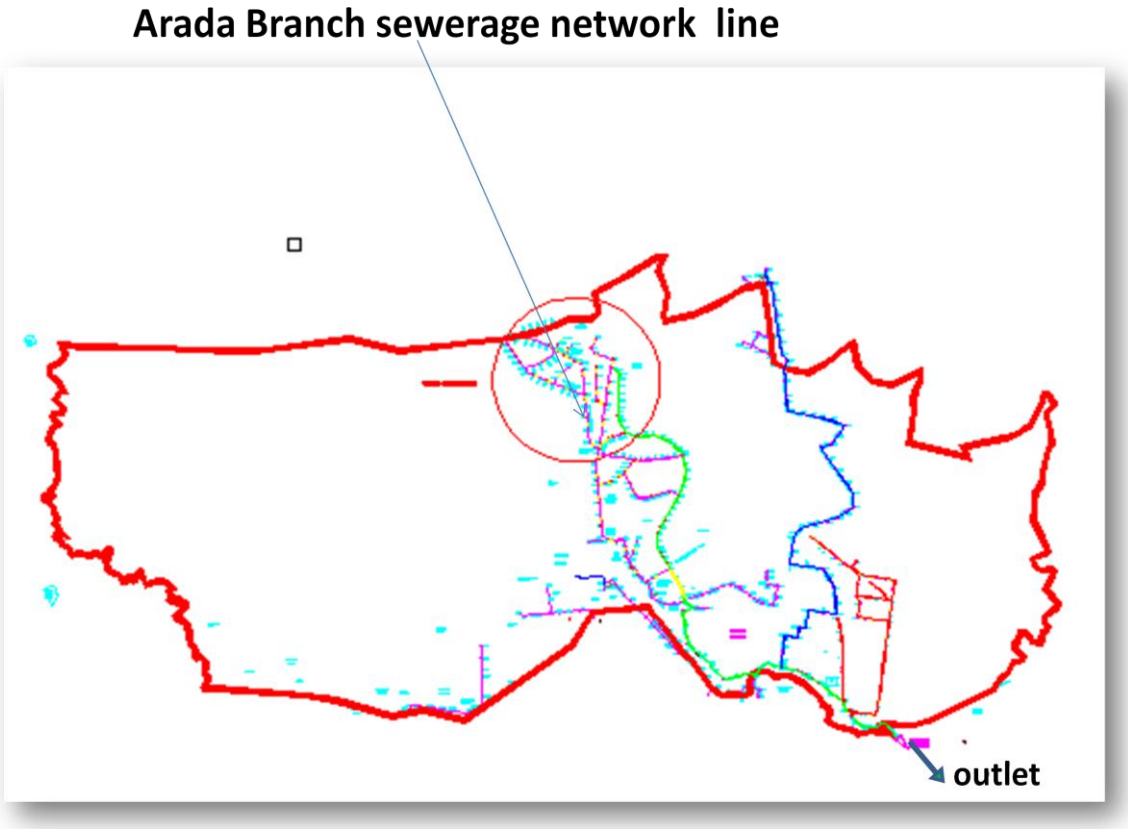

Figure 3.3 Arada Sub city sewerage network line

Arada Sub city has a population growing from time to time. The 2010 population of Arada is 297,942 according to CSA. The annual population flux causes large variations in water and sanitation loads. The untreated sewage is discharged by four means: using rivers, sewer line, and storm line as well as using vacuum trucks. Water is collected from a surface source as well as ground source in the surrounding areas and distributed in buried pipe lines with treatment and without any treatment other than chlorination. Due to lack of organized network and inefficient water supply source, consumers are not served accordingly. The present sewerage disposal methods include septic tanks, sewer lines, illegally connected storm lines and discharges to the river. Arada Sub city serves the northern portion of the

service area and is located along municipality area .the map of Arada Sub city with road network and sewer line newt can shown in the fig 3.4

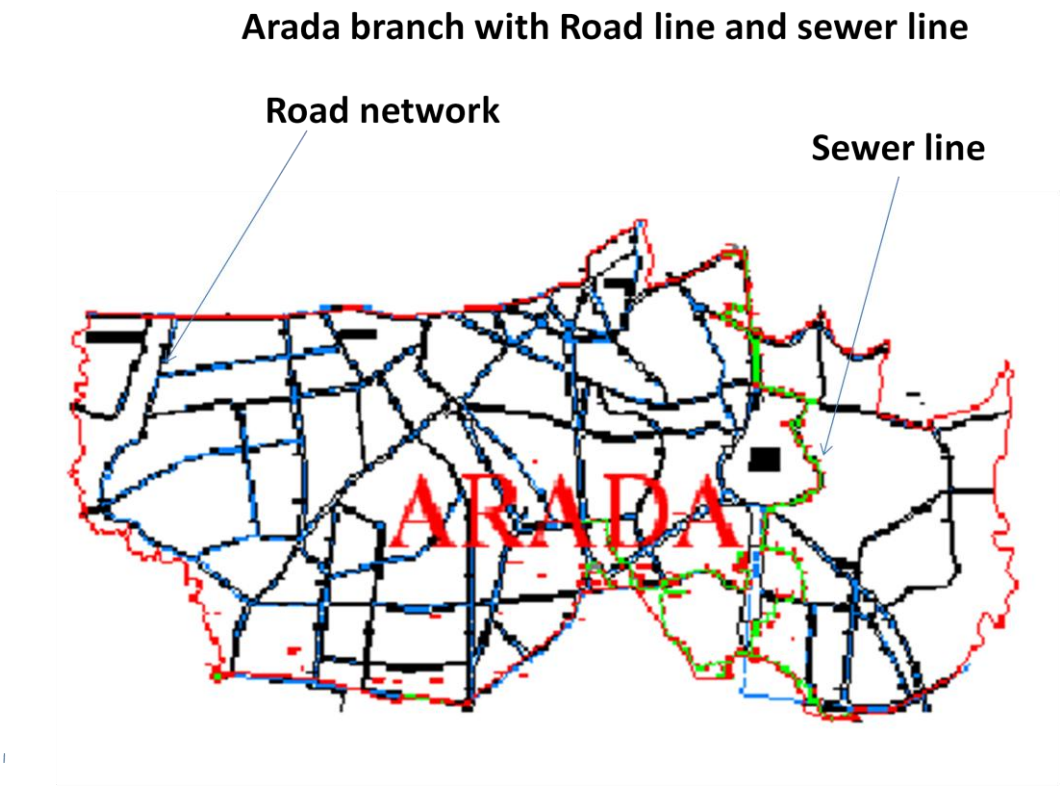

Figure 3.4: Net work map with Road line and sewer line

Arada branch is mostly occupied by old buildings. Many of the buildings are used for shops, hotels, institutions and residence. There are two methods of sanitary collection systems in Arada branch separaty sewer line and vacuum truck collection. But there is widespread serious problem of connecting residential wastewater to storm water collection network. The sewage is directly taken into channels that end up in Kalit treatment plant. All of the wastewater goes untreated until it reaches to Kalit treatment plant. Currently wastewater collection and conveyance system is served by one wastewater treatment plant (kality treatment plant) and a dry bed treatment (Koteb dry bed) but in the near future it is proposed to have two additional treatment plants (eastern catchment and Akaki treatment plant). Arada Sub city serves the North West portion of the city and it is located along the municipality area.

3.3. Data Collection

3.3.1 Field visit

A field visit to the study area was conducted on different days. The field visit was conducted mainly for two reasons: primarily to identify and evaluate the existing situation, as well as to compare the theoretical background with the real situation. Secondly, to have some pictures related to the problems so as to present the problem more clearly.

3.3.2. Sewer cad analysis

The types of data collected for sewer analysis are:

- Sewer line layout and Coverage area,
- Number of Customers connected to the sewer system,
- Physical observation on the sewer sections to identify overflowing manholes and damaged sewer sections to get primary data,
- X and Y coordinate, manhole name, manhole depth, pipe diameter, ground and invert elevation of manhole, structural diameter of manhole, minimum and maximum velocity and slope of the pipe are the most important data for sewer cad analysis,
- Locations of streets and required rights of way,
- Details of existing and proposed sanitary sewers.

3.3.3 Cost analysis

The types of data collected for cost analysis are:

- Types of customer (residential or commercial),
- Types of building,
- Diameter of the pipe to be connected to the service line,
- Diameter of the service line,
- Depth of manhole
- Length of sewer pipe
- Manhole internal diameter (Id)
- Pipe material type
- Date of connections
- Wereda, kebele and house number of the connecter,
- Number of customer served by both vacuum truck line and sewer line.

3.3.4 Existing situation of Arada Sub city sewage network line

Table 3.2 Data collection for existing situation of Arada branch

Item	Value	
Population	297,942	
Water Connections	43,914	
Sewage Connections	71	
Sewage Network (km)	15km secondary line	
	3km main trunk line	
Water Coverage (%)	73	
Sewage Coverage (%)	4	
Water Produced (1,000 m^3)	301,000	
Unaccounted-for Water (%)	37	
Water Average Tariff (birr/m^3)	0-7 m^3	1.75 birr
	8-20 m^3	3.80 birr
	21-40 m^3	4.75 birr
	41-100 m^3	5.95 birr
Wastewater inflow	7500m3/day	
Sewage Average Tariff (birr/m^3)	500-600	
Employees	186	
Distribution	By Gravity	
Method of distribution	Separate	

The hydraulic model of Arada Sub city wastewater collection and conveyance system includes gravity flow pipe and manholes. The key design parameter for the pipes and manholes in the model include:

Pipes

- **Pipe name**: the names of pipes are designate as P.V.C, RCP, ASP, CP, DIP, etc. But most of the sewers in Arada branch are P.V.C type. PVC pipes are favorable for the following reasons:

  Corrosion resistance,

  Not easily breakable,

  Flexible to transportation,

Long design period and
Economical

- **Length**: it is the distance interval between manholes to manhole. In Arada branch the maximum interval is 90-100m but the minimum interval depend on the condition of the topography of the land.
- **Pipe diameter**: the diameter of the pipe which is set in mm. In Arada branch the pipe diameter lies in between 150 and 500mm; and 150-200mm is used for customer connection especial for condominium 200mm diameter but for the case of secondary and lateral line 250-500mm pipes are used.

- **Manholes (nodes)**
  - **Manhole name**: unique name by which an element will be referred in reports, error messages, and tables. But in Arada Sub city the name of manholes is given alphabetically
  - **Ground surface elevation**: elevation of the ground surface at the node. This can be evaluated by using different methods such as global map, GPS and network map. Most of the time Arada branch adapt to use network map and GPS data.
  - **Manhole invert elevation:** the manhole elevation below ground surface.
  - **Structural diameter**: it is the diameter of the manhole, in Arada branch the diameter of manhole is 1 meter.

3.4. Data Analysis

3.4.1 Analysis of sewer system design factors

In the hydraulic design of sewers, the basic design variables are flow rate, maximum and minimum velocity for self-cleansing, pipe slope, depth of flow, and head losses. Various equations have been developed to relate these variables. Gravity flow sanitary systems design involves reviewing design considerations and selecting basic design data and criteria. Once these factors were set, the system was designed, which included preparation of a preliminary sewer system design and design of the individual sewers.

❖ **Average Daily Flow**.

The wastewater flow in Arada Sub city consists of wastewater from residential, commercial and institutional sources and infiltration. Determining the rate of flow is crucial in the design of a collection system. A common indicator and quantifier of wastewater flow is drinking water consumption and use. According to the Arada Sub city, the average potable water consumption is 110 liters/person/day (AASWSA, 2004). The base population of the Arada branch was assumed to be 297,942. The total base flow was calculated as the product of the base population and the average water consumption per person which is around 32,773,620 liters per day.

❖ **Loading**.

The average wastewater flows were putted into the network as loads at different manholes. Each catchment area contributed a load to a predetermined manhole. An average flow per hectare is used under the assumption that all the different types of property are evenly distributed throughout the Arada Sub city. The average flow per hectare is 3,435,390 L/sq.km /day which is determined from the total base flow 32,773,620 liters per day divided by the total area of the Arada Sub city 9.54 sq.km. The load to each manhole was then calculated by finding the load contribution from the corresponding catchment area. An APPENDIX C displays the wastewater loads to each manhole that has a catchment area associated with it.

- Sanitary base flow - applied at manholes in the model of the sewer system.
- Groundwater infiltration (GWI) – applied to each segment of pipe in the sewer model.
- Rainfall-dependent inflow infiltration - applied at manholes in the model of the sewer system

❖ **Infiltration**.

In the design, allowance was made for unavoidable infiltration as well as for the expected wastewater. According to Arada branch design report the infiltration rate of 10 l/day/km is considered. This is based on pipe diameter-length. In Arada Sub city most of the time infiltration rate is assumed as a variable which does not significantly change the total flow.

❖ **Sewer pipe material and sizes**.

The proposed pipe material is Polyvinyl chloride (PVC). PVC is favored because it is light-weight but strong. It is also smoother than other materials (Manning's roughness, n of 0.01)

and highly resistant to corrosion. Other types of pipes such as concrete pipes (n=0.013), are susceptible to corrosion due to acid and hydrogen sulfide attack. Sewer pipes must have a minimum diameter to account for large objects that may enter the sewers. The pipe size used in Arada branch ranges from 150 to 500 mm in diameter.

❖ **Depth of cover.**

The depth of a sewer depends upon the depth of existing underground structures, specifically water lines, drainage line, telephone line, EELPA line and basements. In Arada Sub city basement structures are not considered for the reason that some customers may get the chance to connect both drainage line and ground water illegally to sewer line. Due to the above problem, the depth of pipe is limited .Therefore the minimum pipe depth of sewers for this design is 1-1.5 meter below ground surface within the Arada Sub city. In Arada Sub city the typical standards for minimum cover is 1m.

❖ **Depth of Excavation**.

A maximum excavation depth was set because it is expensive and impractical to excavate deeper than a certain level. The maximum excavation depth was set at 6 meter below ground surface.

❖ **Velocity**.

The flow within the sewers must retain a sufficient velocity in order to flush out any solids that deposit during low flow. The typical minimum and maximum velocity for gravity pipes in Arada branch as well as in the Addis Ababa water and sewerage authority used default constraint, these are 0.6m/s & 3m/s. Recommendation for PVC pipe slopes at corresponding pipe sizes. It is based on a minimum velocity, when flowing 75% full, of 0.6 m/s.

3.4.2 Sewer system layout and design

Before sewer networks can be drawn, the location for a potential sewer area must be determined. Three locations of pipes networks were identified for design purpose. These are (See Figure 3.6). Design 1 which found around ledita new construction site and Design 2 these site was chosen because it currently potential serves for connection area and which extend from palace area to Casanches menhara and the last one found around starting from Felewha area up to serategna sefer which helps to identify the problem of line without connection and helps to show the existing situation. But ledita site helps to demonstrate for the future case. figure 3.6 up to 3.9 shows the location of each selected area.

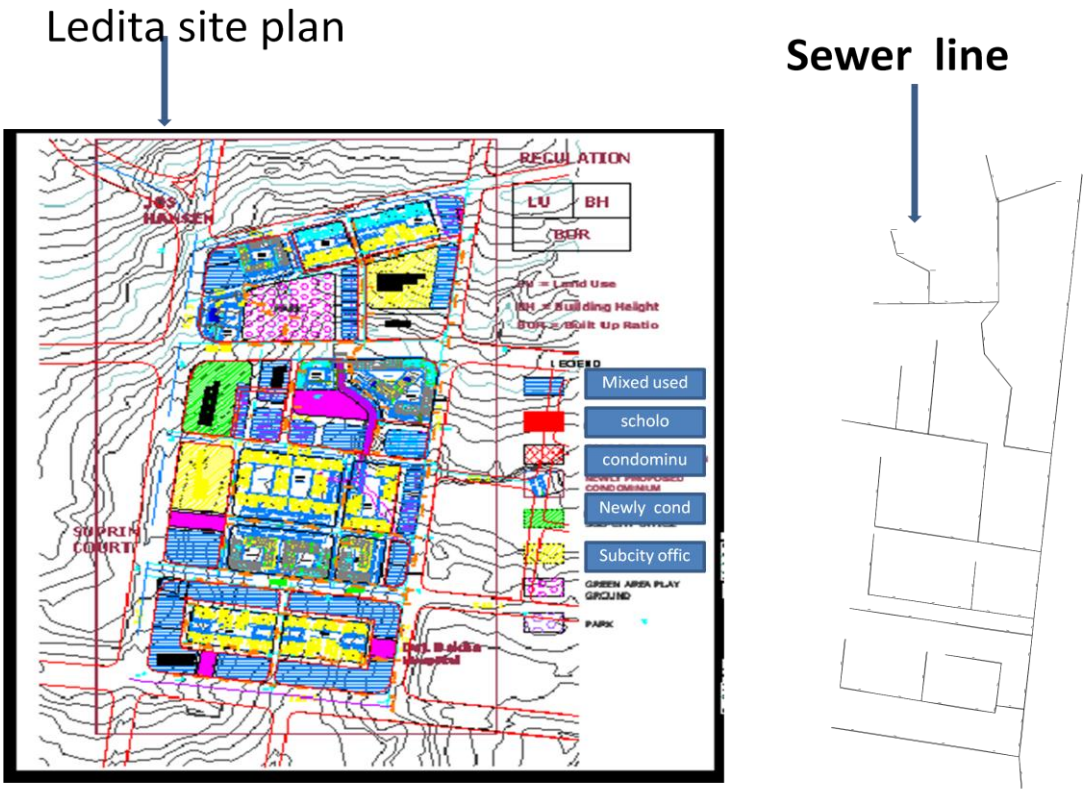

Figure 3.6 Ledita site plan and sewer line layout

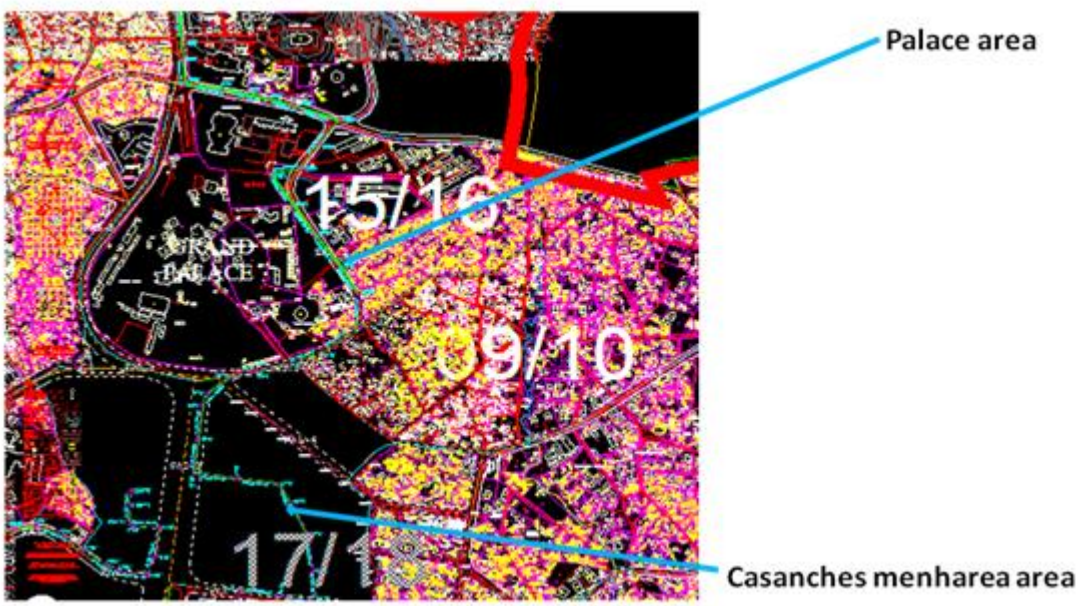

Figure 3.7 Network map around palace area and Casanches menharea area

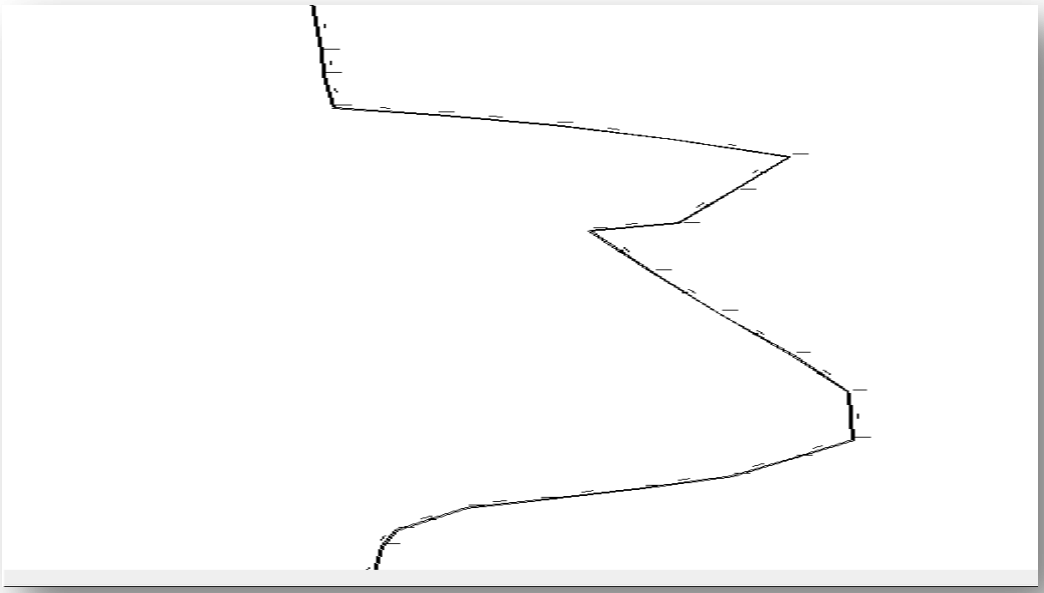

Figure 3.9 Sewer line around palace area and Casanches menharea area

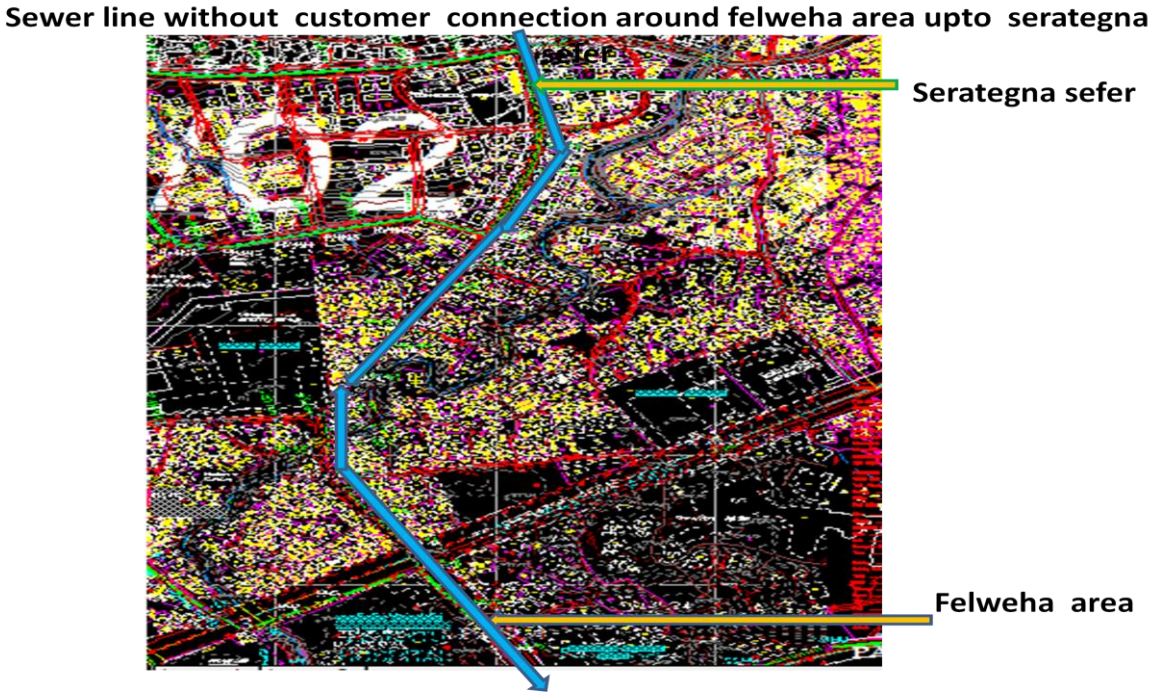

Figure 3.9 Network map around felweha area up to seretegna sefer

3.4.3. Sewer cad analysis

After all the design factors and constraints were set, a more detailed profile and model of the sewer network was created. A spreadsheet was prepared in Microsoft Excel to record the data and steps in the computations for each section of sewer between manholes. Data analysis was done using Sewer CAD, which is an extremely powerful program for the design and analysis of gravity flow and pressure flow through pipe networks and pumping stations. The program

can be run in AutoCAD mode, giving all the power of AutoCAD's capabilities, or in Stand-Alone mode utilizing own graphical interface. Sewer CAD allows one to construct a graphical representation of a pipe network containing information such as pipe data, pump data, loading, and infiltration. There are choice of conveyance elements including circular pipes, arches, boxes and more. Sewer CAD is so flexible one can use it for all phases of his/her project from the feasibility report to the final design.

3.4.4 System performance evaluation criteria

3.4.4.1 Technical performance evaluation Criteria

In order to evaluate the performance of the system, it is proposed to apply two methods. First, interviews were conducted with Arada Sub city workers and some pictures were taken from site. This helps to identify both the construction and working method problems. Second, using Sewer CAD software the problems were identified. These can be done using the following procedure. First the minimum and maximum values of the design parameters are set as a constraint in accordance with Arada Sub city requirements. These values are taken in conjunction with Haestad Method. The sewer invert elevations, pipe diameters, pipe slopes and velocities were determined by trial and error to find the best fit values given the design factors and constraints**.** For the system to perform best, it should have to fulfill the following criteria.

Table 3.3 Slope –pipe diameter constraint range

Pipe Diameter(mm)	**Minimum Slope (m/ m)**	**Maximum Slope (m/m)**
150	0.49	For any pipe size the maximum slope is not greater than or equal to 10(m/m)
200	0.40	
250	0.28	
300	0.22	
350	0.45	
400	0.15	
450	0.14	
500	0.10	

Table 3.4 Minimum and maximum velocity range for any pipe size in Arada Sub city.

Velocity	Magnitiude
Minimum velocity	0.6m/s
Maximum velocity	3m/s

Table 3.5 Depth covers constraint range for any pipe size in Arada Sub city.

Depth	Magnitudes
Minimum cover	0.9m
Maximum cover	5m

3.4.4.2 Economic evaluation criteria

In Arada Sub city the untreated sewage is discharged by four means by using rivers, sewer line, storm line as well as using vacuum truck. But here for the economical evaluation both sewer line and vacuum truck are considered since both are legally accepted methods. The evaluation method is based on two ways:

1. Overall cost of sewer line connection and vacuum truck for design period of 30 years (to get the service for customer).
2. In terms of satisfaction level (these may include duration to get service, awareness, operation and maintenance cost, quality of the service ...etc this can be done by using questionnaire.

Chapter Four

4. Results and Discussion

4.1 Field visit

4.1.1 Problems on manhole

As it is presented in the pictures below the Arada Sub city sewer line existing situation can be categorized into four problem areas.

4.1.1.1 Manhole rising and right way problem

a) Causes of the problem

- Currently in Addis Ababa most of the roads are reconstructed as well as new road construction are underway, because of these some of the manholes have the chance to cover with road material, these may happen due to shortage of communication with road authority and AAWSA itself.
- As the workers indicated, there was good maintenance worker division group before the new working method was implemented. But currently that group is distributed to each branch of AAWSA due to these the maintenance is carried in deficiencies.
- All the sewer line, drainage line, EELPA line, tele line and water lines must be constructed based on right way principle, but most of the lines are constructed without the respect of the right way principle and also they don't have good information about right way. As the pictures point out the place of manhole is almost at the center of the asphalt but the manhole should be placed by the side of the asphalt. From the total manhole that are exposed to rising problem are around 4.21%.

b) Consequences of the problem

- Manhole rising problem may cause inflow and infiltration problems since the cover of the manhole is below the cover of the asphalt this leaves a chance to the water to easily penetrate to the manhole
- Due to the unlevel surface of the asphalt, vehicles may encounter a problem during driving.
- Due to right way problem, construction of sewer line is difficult and it may cause shortage of connections to customers. Some of the Manhole which have rising and right way problem from figure 4.1 up to figure 4.5.

a) Manhole rising problem

Figure 4.1: Sewer manhole around grand palace (Photo taken on June, 2011)

b) Manhole rising problem

Figure 4.2 A sewer manhole around Berhanna Selam printing (Photo taken on June, 2011)

c) Manhole rising problem

Figure 4.3 A sewer manhole around Berhanna Selam press (Photo taken on June, 2011)

a) Right way problem

Figure 4.4 : Sewer Manhole around grand palace (Photo taken on june,2011)

b) Right way problem

Figure 4.5: Sewer manhole around grand palace (Photo taken on June, 2011)

4.1.1.2 Manhole overflow and cover constraint problem

a) Causes of the problem

- most of the time manhole overflow problem occurred due to additional flows (inflow and infiltration) and construction defects, these can be expressed in terms of shortage of cover constraint (below the standard) or due to 90 degree bend (these problem are identified during the field observation of the four problematic manhole areas) the direction change of each manhole is 90 degree bend. From this it is conclude that these might be an additional problem. the total manhole that are exposed to overflow problem are around 1.36%.
- It is known that the existing system is gravity, topography is one of the constraint to have efficient connection and pipe network, without the appropriate consideration of topographic slopes constructing sewer lines may cause both overflow and clogging problems

b) Consequences of the problem

- During rainy season there is unexpected and unwanted flow over the surface, that makes the surrounding dirty and reek problem
- Both vehicle and pedestrian movements get stranded. Some of the Manhole which has overflow and cover constraint problem. i.e. Figure 4.6 and 4.7.

a) Over flow problem

Figure 4.6 A sewer manhole around Zemen Bank (Photo taken on June, 2011)

b) Cover constraint problem

Figure 4.7 Sewer manhole around Zemen bank (Photo taken on june,2011)

4.1.1. 3 Cover and lost manhole problem

a) Cause of the problem

- Manhole is lost when it is completely covered by asphalt (earthy material) and construction problem (due to minimum cover). These problems happen when there is new construction of road and during rainy time (land and unnecessary material may cover the manhole). Manhole also lost when building built on it. In Arada branch almost around 20 manholes have such problems these are:

Table 4.1 Lost of Manhole in Arada branch

Number of manhole	Name of manhole	X Coordinate	Y Coordinate	Z Coordinate(elevation)
1	89GY			
2	19GY	15165.3271	956.2654	
3	20GY	15209.4547	1048.34	
4	21GY	15193.0702	1022.8520	
5	28GY	15488.13	702.7094	
6	35GY	1534.9270	276.5727	
7	27GY	15511.8344	783.1690	
8	42GY05	14759.7606	249.1420	2435
9	HV4Q	14354.7015	577.9919	2376.76
10	FW14B	13857.1747	753.3648	2383.48
11	FW14C	13864.4946	703.6200	2383.20
12	ECA1	15696.6378	2334.0119	
13	ECA2	15592.7836	2346.1937	
14	ECA17B	15721.3779	1489.0931	
15	ECA17	15771.5184	1547.3547	
16	JK7			
17	JK10			
18	22HD	13203.6095	1655.0672	2276.60

b) Consequences of the problem

- Difficult to maintain when problem occurs, in order to identify the problem it is better to consider one related problem around Bambis area. before one year the problem of breakage line ocuur in bambis area and the nearest manhole is searching by different method even by using censor but no one couldnit get the manhole . due to lost these manhole unable to resolve the problem easily, for these case the manhole is needed for diversion case. .
    - It also difficult to have good database management and sewer line network. Some of the Manhole which has lost and cover problem. i.e. from Figure 4.10 up to 4.13.

a) Cover problem

Figure 4.8: Sewer manhole around Casanches menharea area (Photo taken on june,2011)

b) Cover problem

Figure 4.9: Sewer manhole around felweha area (Photo taken on June, 2011)

c) Lost manhole problem

Figure 4.10: Sewer manhole around felweha area (Photo taken on June,2011)

d) Lost manhole problem

Figure 4.11 Sewer manholes around tourist hotel (Photo taken on June, 2011)

4.1.1.4 Infrastructure problem

a) Cause of the problem

- Lack of communication between other infrastructure before construction (Road Authority ,TELE Communication, ELEPA, AAWSA itself)
- Not proper location and enough right way.
- Topography and design problem
- Not good network in all stakeholder
- Lack of adequate capacity of the responsible authorities to deal with (financial resources, agreed programs of operation and maintenance, acceptable quality of construction),
- Lack of ability to address the issues in a timely manner,
- Overlapping responsibility between Water Supply Corporation and municipalities,
- The responsibility for operation and maintenance is confused and overlapping,
- The expansion of sewerage network is carried out by the municipalities together with the local communities based on their demand created by unplanned urban growth

- Similarly, the roadside drainage is frequently used for sewerage disposal and interferes with the authority of the Department of Roads. Actually, the ownership of roadside drainage within the urban areas is also confusing,
- Lack of coordination and clear jurisdiction of authorities between the local governments and authorities are major management issues,
- There is also confusion on the use of revenue for operation and maintenance.

b) Consequences of the problem

- Unable to construct manhole as well as lay to pipe
- Difficult to connect for customer.
- Obstruction for vehicle. Some of the Manhole which has infrastructure problem. i.e. Figure 4.8 and 4.9.
- Increased operational and capital costs in the sewer network and at treatment plants,
- Reduced sewer and treatment capacity leading to increased operation of \ sewer overflows, flooding and pollution,
- Reduced sewer and treatment capacity restricting future development,
- Lowering of groundwater levels leading to detrimental effects on local water resources,
- Loss of soil into sewers causing operational problems and structural damage,
- These problems all ultimately result in increased costs

a) Water line problem (unable to install manhole)

Figure 4.12: Sewer manhole around beside berhann selam printing (Photo taken on June, 2011

b) Road authority problem (shortage of maintenance)

Figure 4.13: Sewer manhole around casanches (Photo taken on June, 2011)

4.2. Sewer line and Vacuum truck

The questionnaire data is collected in Arada Subcity from both office and field surveys.The n umber of questionnaire data collected from both residential and commercial customers based on random selection method for both case ,the resion why we select method of random selec tion becouse of the following resion . since unbalanced customer exist between the two custo mer ,especial we couldnit get the owner of the service user, almost all lack of awerenes about the use of seweragеservice. including the operators of the vacuum truck line is 50. With reg ard to sewer line the number of data collected reached 25 for both residential and commercial customers. During collection more challenges occurred in the case of sewer line customers. The challenges faced are to get the actual customers and to convince them the purpose of the data to be collected. From the collected data and customer feelings, during the collection, it is observed that most of the customers for vacuum truck line are not familiar with sewer line. A nd they are not satisfied with the vacuum truck service for the reason that the service will not start on time after registration (it took longer time up to two months). As the office workers r eported these problems occur because of shortage of vacuum truck (six vacuum trucks for the entire Arada Subcity) and shortage of maintenance during operation failures. The number of customers increases from time to timeThe very reason most of the customers need to get the service is when their septic tank is ful

The result of the questionnaire is based on the following ranking values.

4.2.1 Sewer line network service

Table 4.2 The ranking criteria

Ranking value	Point
Low take	0<X<=2
Medium	2<x<3.5
High	3.5<x<5

a) **From authority worker**

Table 4.3 Sewer line network service questionnaire result for authority

NO	Sewer line for case of residential	Result (10) customer			
		Low	Medium	high	Remark
1	Duration to get service	✓			Within two weeks
2	Awareness of the service	✓			
3	Quality of the service		✓		
4	Problem of the service related with operation and maintenance		✓		
5	Occurrence of the problem related to healthy	✓			
6	Satisfaction		✓		
7	Demand of the service			✓	
8	Cost of the service		✓		

b) From customer

Table 4.4 Sewer line network service questionnaire result for customer

NO	Sewer line for case of commercial	Result (20) customer			
		Low	Medium	high	Remark
1	Duration to get service in time			✓	
2	Awareness of the service	✓			
3	Quality of the service		✓		
4	Problem of the service related with operation and maintenance		✓		
6	Occurrence of the problem(overflow, noise, infiltration and inflow)	✓			
7	Satisfaction		✓		
8	Cost of the service		✓		

4.2.2. Vacuum truck line sewerage service

a) From Authority worker

Table 4.5. Vacuum truck line sewerage service questionnaire result for authority

No	For vacuum truck line for residential	Result (20) customer			
		Low	Medium	high	Remark
1	Duration to give the service	✓			Take two month
2	Awareness of the service	✓			
3	Quality of the service		✓		
4	Problem of the service with respect to vacuum truck operation and maintenance problem			✓	
6	Occurrence of the problem related to healthy		✓		
7	Satisfaction considering time, quality and cost.	✓			
8	Demand of the service			✓	
9	Cost of the service	✓			

b) From customer

Table 4.6. Vacuum truck line sewerage service questioner result for customer.

No	For vacuum truck line for commercial	Result (20) customer			
		Low	Medium	high	Remark
1	Duration to get service	✓			Take two month
2	Awareness of the service			✓	
3	Quality of the service	✓			With respect time
4	Problem of the service		✓		
6	Occurrence of the problem(noise, overflow and inflow to septic tank)		✓		
7	Satisfaction	✓			
8	Demand of the service			✓	
9	Cost of the service	✓			

4.3. Cost analysis

Arada Sub city uses two methods of waste disposal mechanisms. These are vacuum tuck line and sewerage line. The cost data for this study were collected from Arada branch's current use. Costs were estimated based on design period of thirty years for both vacuum truck line and sewer line. The data used for cost analysis can be referenced in Appendix F and G for both cases. The cost is calculated considering the current situation of Arada Sub city and computed based on cost of average length of sewer line. Comparing the two costs the residential case is slightly expensive than the vacuum truck line having a difference of around 700 birr.

Coming to the commercial case the cost of vacuum truck line is more expensive than sewer line and the difference is 1106 birr. Although the sewer line is slightly more expensive than vacuum sewers as the length increases, it is more preferred than the vacuum truck line. Currently the customer of truck line without service in Arada branch reached more than 1000 and especial in rainy seasons the number of customers increases much far from this figure. It is more challenging to deliver the service; it takes more than two month. This is due to the shortage of vacuum truck and the high demand of the customer to get the service. But looking at the number of sewer line users it is around 90 customers. As it is observed the numbers of customers connected to sewer line is too small. This can be quantified to the following reasons: shortage of awareness (even they don't know the service accessibility and purpose of the service), economical problem (due to expensive initial costs) but the government provides different methods of costing. One of the methods is paying for long duration. By considering all the above reasons using sewer line is better than vacuum truck especial related with its cost and reliable service. The cost calculation is presented in table 4.6.

Table 4.7.Cost estimation for vacuum truck line

for design period of 30 year	Birr/30 year
Average vacuum truck line cost for Residential for design period of 30 year	2070 birr per 30 years
Average vacuum truck line cost for commercial	7840 birr per 30 years

The calculation based on this value is 69 birr for residential one trip. For 30 trip per 30 years, it will be 2070 birr. Similarly, it is 196 birr for commercial one trip and for 40 trips per 30 years, it will be 7840 birr.

Table 4.8 Cost estimation for sewer line

For design period of 30 year	Birr/30 year
Average Sewer line connection cost for Residential	2771.81 birr per five meter
Average Sewer line connection cost for commercial	6734.24 birr per twenty meter

4.4. Sewer cad analysis

4.1.1. Ledita site

Due to a lack of available information, numerous assumptions of data were made. This section will discuss all the assumptions made in the design. The main assumptions made were on population, flow, peaking factor, slope, cover, and infiltration rate. But the total population is taken from Ledita housing agency. And infiltration, flow, cover, slope data are based on AAWSA current design figures. Elevation data for the Arada Sub city is taken from network map and GPS. The waste water use per person per day is based on type and use of buildings if we consider for residential case 80% of the water supply is waste.

Design flow sizing of infrastructure 300mm in diameter and smaller shall be calculated by using the average dry water unit flow factors listed in table below for the upstream service area (Ledita housing rehabilitation project and some downstream users) along with a peak factor of 2.0. These papers provide hydraulic calculation table for sizing the sewer 300mm in diameter with different capacity and gradients. The classification of the land use is directly derived from the proposed future plan of the area given by Ledita sub city land administration development. Sanitary sewer daily calculation is presented on the table 4.10. Based on design report for the case of the newly built areas of Ledita site the result indicates the maximum and minimum slopes, velocity, and cover, with respect to the constraint and also during running the program the result shows no warning and error. These indicate that Ledita sewage network is currently sufficient to dispose the incoming waste. But if we integrate the upstream inflow load and downstream existing boundary to the system, there appears a problem due to the increment of load and inefficiency of the downstream pipe capacity. Inclusion of the upstream load, Mericato site, leads to the observed overflow problems. The above conclusions are based on the design result. The detailed model results are elaborated in appendix-A and appendix-D.

Table 4.9 Sanitary sewer daily flow calculation (design for peak flow)

LAND USE	DESIGN PARAMETERS TAKEN			CALCULATION
	PER CAPITA DEMAND (LIT/PERSON/DAY)	NO. OF HOUSEHOLD	NO. OF PERSONS PER HOUSHOLD	(0.8*COL. II*COLIII*COL IV*2) (LIT/SEC.)
Mixed use lease development	110	2322	6	31.21
Reallocation site for private residential development	110	474	6	6.37
Condominium	110	1161	6	15.61
Other (Elementary school and community	110	387	6	5.20
Other user down stream	110	300	6	4.03
			Total expected flow	**62.43**

4.4.2. Felweha and Serategna Sefer area

These areas are investigated during site visit. The result of investigation indicate the length of the line around 1245 meter and the size of pipe is 250-300mm and the line start from some part of felwha area and end serategna sefer condominium but the line serves without any customer connection until it reaches to serategna sefer. Even without any connection of keybaher condominium. As the branch workers explained these problem has happened

because of the design and construction problem. The main problem not to deliver the service properly is due to the change in the direction of the alignment. The direction of the sewer line should be placed on the opposite of the existing line else it is difficult to receive waste from customers since the customer location is below the sewer line. This type of problem is not

only the characteristics of Felwha area but also it is happening in different areas of Arada branch especially in the newly constructed areas. To mention some of the problem areas: starting from main post office up to Churcher end, Casanches Menharea area. It ranges around 3000meters. Unless this problem gets solved, the line will run without service.

4.4.3. Sewer line at grand palace and part of Casanches area

This problem area is selected because of its huge customers than the other areas. Alike to ledita site this site has shortage of data. Except on the estimation of population the same procedure is followed. For this site, the population is estimated based on the AAWSA collected data but the type of data has shortage of the exact population service in the area. Some of the problem observed, without considering the analysis part, during data gathering is the distance between manhole to manhole is beyond the recommended range (90-100m). This makes difficult maintenance work during blockage of line or other problems. The analysis is carried out based on sewer cad and the length of the pipe is1120m, the diameter of the pipe is 200mm and the number of manholes is 14, the number of residential customers is four and the number of commercial and institutional customers is eight. After feeding the above all information and considering different alternatives, the result of the design indicates the line currently serves inefficiency.

For both group 80 l/c/d water consumption rate utilized by considering the existing city level total water supply volume to total population. By considering the 80 percent of water consumption goes to waste water, the total sum of the waste water per day is shown in Table 4.11.

As it is observed from the result of sewer cad analysis, most of the result is the incapable of minimum velocity constraint, these are directly related with shortage of load and can lead to the problem of under efficient. The other problem is slope constraint; it is related with topography, size, velocity, construction defect and design problem.

Table 4.10 Sewer cad software output

Element Label	Result Message
P-12	Warning: Pipe does not meet minimum slope constraint.
P-12	Warning: Pipe does not meet minimum velocity constraint.
P-4	Warning: Pipe does not meet minimum velocity constraint.
37GY	Warning: Structure bottom is above pipe invert(s).
P-5	Warning: Pipe does not meet maximum cover constraint.
P-5	Warning: Pipe does not meet maximum slope constraint.
P-5	Warning: Pipe does not meet minimum velocity constraint.
P-35	Warning: Pipe does not meet minimum slope constraint.
P-35	Warning: Pipe does not meet minimum velocity constraint.
P-11	Warning: Pipe does not meet minimum slope constraint.
P-11	Warning: Pipe does not meet minimum velocity constraint

.

Chapter Five

5. Conclusion and Recommendation

5.1. Conclusion

The conclusions are drawn based on the investigations done and the consequential results obtained from the four methods of evaluation. These evaluation techniques are field visits, questioner conducted, cost analysis and sewer cad analysis.

- From the result of field visits different types of problems are observed such as manhole rising, manhole cover problem, cover constraint, lost of manhole and infrastructure problem is observed.

- Cost analysis was done based on the current price of Arada Sub city and the result showed sewer line is better than vacuum truck line in terms of the service provided for customers.

- The result of questioner helps to identify two important problems: the awareness problem of the customer on the advantage and disadvantage of both sewer line and vacuum truck line and the customers demand increase to use vacuum truck line.

- The sewer cad analysis result which showed that currently no problem for both Lideta and Cassanchise sites and line serving without connection are identified.

Finally, it is concluded that there is shortage of well organized data and awareness problem of customers about the use of sewer line. With regard to the sewer line Arada branch can be considered efficient without considering upstream and downstream areas of Lideta site however the Casanchise site is under efficient. Coming to the service of vacuum truck line, the service has problems both due to shortage of service delivery and increased customer demands.

5.2 Recommendation

Based on the findings and limitations noted while doing this study the following outlooks towards the direction of future work are suggested for each evaluation technique. But before suggesting the recommendations for the main problems during investigation the problems identified are listed here for more emphasis on future studies i.e. shortage of available data such as number of customer for both vacuum truck line and sewer line, data necessary for

sewer cad analysis such as depth of manhole, length and size of pipe and type of pipes. The update pipe line should be included in the network. Generally the branch should have well organized data base management. All of the above problems are the main challenge during gathering data from Arada Sub city. Therefore for future studies these problems need to be addressed.

- For the case of field visit, the results indicated most of the problems in sewer line are problems of rising manhole, overflow, cover constraint, lost of manhole and infrastructure. These problems should be solved in coordination with other infrastructure offices especially with road authority, tele and EELPA. And the reform of the new work division for maintenance and operation workers needs to be revised for efficient operation.
- For the case of cost analysis, when we compare costs of both sewer line and vacuum truck almost the variation is low. But Arada Sub city is expected in the future to convince the customers to use sewer line by conducting more awareness creation mechanisms about the sewer facility. even they can pay for the service for long duration by using different alternative of paying system. Because the sewer line is more healthy, economical and durable than vacuum truck line.
- For the questioner result:-as it is observed in the questioner survey the two important problems should be solved to deliver current and future services efficiently. The problems are the awareness of the customer about the advantage and disadvantage of use of sewer line and the use vacuum truck line. These can be done by using news paper, advertizing on media, news paper and broachers.
- For the last case the result of sewer cad analysis: - with the consideration of size, load and slope the result of sewer cad analysis indicates generally acceptable design however the consideration of upstream and downstream areas will incur design problem. These problems will happen in the future unless the provision of another parallel sewer lines with the existing system are considered. The other problem is lines without serving connections; these lines can provide service for customers by implementing different methods such as using minimum slope and restructuring the customer flash toilets in order to coincide with the existing line.

References

Ana et al. (2000). Sewer asset management decision-support tools.

Ana, Jr. and W. Bauwens (2000), Sewer network asset management decision-support.

Anonymous (1982). American Society Civil Engineers (ASCE).

Anonymous (1994). American Society Civil Engineers (ASCE).

Anonymous (1984-2009), Addis Ababa Water and Sewerage Authority, Annual Report on Sewerage Service, Addis Ababa (Unpublished Doc.).

Anonymous (1999) Introduction of Ecological Sanitation for Large Scale Housing Programs in Ethiopia, PPP GTZ.

Anonymous (1999), Addis Ababa Water and Sewerage Authority, Draft Sect oral Development Program.

Anonymous (2004), Addis Ababa Water and Sewerage Authority, Draft Sect oral Development Program.

Anonymous (2005), Regional Drainage Policies- Volume 4, Inflow Infiltration & Exfiltration

Anonymous (2006), Ethiopia Community Profile.

Anonymous (2009), Sanitation Sector Status and Gap Analysis: Ethiopia.

Anonymous (SAC group, 2009). Fault tolerant optimal control of sewer networks: the Barcelona case study.

Badan,E.(2006).Service enhancement and development of sanitary sewerage system in urban and semi-urban setting in Nepal.

Baik et al. (2006). Markov chain-based deterioration models for wastewater systems.

BCEOM and GKW Consult (1993), Master Plan Study Document Preliminary Engineering Design Document, Addis Ababa (unpublished Doc).

Bengassem and Bennis. (2000).Development of a rehabilitation program

Christopher. (2009). Conducting condition assessment, it is important to understand the dynamics of pipe failure including the level, type, and severity of a failure mechanism.

Eddy Inc. (1991), Waste Water Engineering: Collection, Treatment and Reuse, 3rd edition, No. 8, McGraw-Hill, New York.

Ertl and Haberl. (2006) .Sewer rehabilitation planning to be carefully operated and Maintained in a rational, sustainable and scientifically based manner.

Hoffman, M and D. Lerner. (1992). "Leak Free Sewers." Water and Waste Treatment, Vol.

Mays. (2001). First documented separate sewer system in Knossos.

Metcalf and Eddy. (1914). Waste Water Engineering: Collection, Treatment and Reuse, 3rd edition, McGraw-Hill, New York35, Metcalf.

Nancy Choi, (2003), Design of a wastewater collection system for the historical center of Paraty, Brazil.

O'Brien and Gere (2004), Wastewater Collection, Pumping and conveyance Facilities.

SA Sinske and HL Zietsman (2002), Sewer-system analysis with the aid of a geographical information system.

Thomas M, Thomas E and Earic Haroland (2004), waste water collection system modeling and design.

Uttar Pradesh.(2010). The criteria adopted for design of sewerage system and sewage treatment .

APPENDICES

APPENDIX-A Gravity node report for Ledita site

APPENDIX-B Gravity node report for Palace site up to Casanches menharea site

APPENDIX-C Data collection for sewer cad analysis from Arada Sub city.

APPENDIX-D Questioner Result

APPENDIX-E Sewer line Connection Customer Information

APPENDIX-F Vacuum Truck Customers Information

APPENDIX-G Detail cost analysis

APPENDIX-H Profile for Lideta site

APPENDIX-I Profile for Palace site up to Casanches menharea site

APPENDIX – A: Gravity node report for ledita site

Label	X (m)	Y (m)	Groud Elevation (m)	Rim Elevation (m)	Structure Diameter (m)
RB36A8	470,991.46	996,682.35	2,370.50	2,370.50	1
MH-67	471,007.62	996,625.74	2,367.00	2,367.00	1
RB36A7	471,009.76	996,622.07	2,366.90	2,366.90	1
RB36A7A	471,097.32	996,646.22	2,370.10	2,370.10	1
MH-66	471,009.76	996,625.41	2,367.00	2,367.00	1
MH-70	471,009.92	996,580.64	2,364.50	2,364.50	1
RB36A6	471,010.07	996,539.77	2,362.20	2,362.20	1
RB30B5	470,776.21	996,059.80	2,361.10	2,361.10	1
RB30B4	470,768.57	995,998.09	2,359.80	2,359.80	1
RB30B3	470,827.21	995,989.63	2,356.40	2,356.40	1
RB30B2	470,901.03	996,043.64	2,353.40	2,353.40	1
RB30B1	470,892.70	995,980.22	2,353.60	2,353.60	1
RB34E	470,830.61	996,293.82	2,359.00	2,359.00	1
RB34D	470,821.13	996,205.24	2,357.70	2,357.70	1
RB34C	470,899.92	996,194.91	2,354.50	2,354.50	1
RB34B	470,978.81	996,184.57	2,351.50	2,351.50	1
RB34B1	470,986.43	996,251.57	2,351.50	2,351.50	1
RB34A	471,023.33	996,178.73	2,348.00	2,348.00	1
RB33B1	470,975.89	996,159.75	2,351.60	2,351.60	1
RB33E	470,811.47	996,117.77	2,358.00	2,358.00	1
RB33D	470,889.48	996,107.98	2,354.00	2,354.00	1
RB33C	470,932.02	996,102.65	2,351.60	2,351.60	1
RB33F	470,820.10	996,195.97	2,357.90	2,357.90	1
RB33B	470,968.42	996,098.10	2,350.10	2,350.10	1
RB32D	470,782.86	996,099.70	2,360.00	2,360.00	1
RB32C	470,843.46	996,092.09	2,356.40	2,356.40	1
RB32B	470,906.36	996,084.20	2,352.70	2,352.70	1
RB32A	470,986.53	996,074.17	2,349.00	2,349.00	1
RB36A4B	470,904.18	996,491.35	2,363.00	2,363.00	1
RB36A4C	470,819.05	996,490.25	2,367.50	2,367.50	1
RB36A4A	470,957.72	996,492.12	2,360.00	2,360.00	1
RB37	471,101.76	996,378.09	2,356.80	2,356.80	1
RB38	471,112.13	996,456.37	2,360.80	2,360.80	1
RB39	471,121.48	996,524.53	2,364.30	2,364.30	1
RB40	471,129.56	996,589.14	2,367.80	2,367.80	1
RB41	471,138.08	996,657.21	2,371.10	2,371.10	1
RB36A	471,018.72	996,308.18	2,353.00	2,353.00	1
RB36A1	471,030.22	996,384.08	2,355.90	2,355.90	1
RB36A3	470,984.26	996,466.02	2,358.50	2,358.50	1
RB36A4	471,010.14	996,492.89	2,359.40	2,359.40	1
RB36	471,091.59	996,298.87	2,353.50	2,353.50	1

Continued					
RB35	471,083.99	996,239.25	2,351.30	2,351.30	1
RB32	471,061.76	996,064.81	2,345.00	2,345.00	1
RB33	471,064.48	996,086.14	2,345.20	2,345.20	1
RB34	471,075.41	996,171.90	2,347.20	2,347.20	1
RB33A	471,020.77	996,091.58	2,347.00	2,347.00	1
RB36A4B1	470,904.95	996,532.26	2,364.70	2,364.70	1
RB36A4B2	470,855.53	996,553.79	2,368.60	2,368.60	1
RB36A4B3	470,845.93	996,584.76	2,371.00	2,371.00	1
MH-69	471,055.72	996,017.45	2,345.10	2,345.10	1
RB31	471,049.66	995,969.82	2,344.70	2,344.70	1
RB31A	471,006.86	995,975.12	2,347.20	2,347.20	1
RB31B	471,014.70	996,028.96	2,347.90	2,347.90	1
RB31C	470,929.86	996,039.91	2,352.00	2,352.00	1
RB31A1	471,005.38	995,964.99	2,347.20	2,347.20	1
RB31A2	470,949.73	995,972.51	2,351.00	2,351.00	1
RB30A1	471,045.73	995,939.62	2,344.80	2,344.80	1
RB30D	470,755.61	995,946.41	2,358.30	2,358.30	1
RB30C	470,818.82	995,938.40	2,356.00	2,356.00	1
RB30B	470,886.03	995,929.51	2,352.40	2,352.40	1
RB30A	470,965.23	995,919.33	2,347.90	2,347.90	1
RB30	471,041.92	995,909.06	2,344.50	2,344.50	1
O-1	471,045.60	995,868.33	2,344.90	2,344.90	
RB36C2	470,916.76	996,444.12	2,361.10	2,361.10	1
RB36C1	470,910.04	996,385.64	2,359.30	2,359.30	1
RB36C	470,902.88	996,323.32	2,357.40	2,357.40	1
RB36D	470,853.70	996,330.12	2,359.00	2,359.00	1
RB36E	470,771.40	996,341.36	2,363.00	2,363.00	1
RB36D1	470,862.44	996,410.57	2,362.20	2,362.20	1
RB36B	470,948.68	996,317.13	2,355.80	2,355.80	1
MH-68	470,993.15	996,311.45	2,353.00	2,353.00	1

Manhole report for ledita site

Label	Ground Elevation (m)	Rim Elevation (m)	Sump Elevation (m)	Head loss Method	Sanitary Load Type
RB36A8	2,370.50	2,370.50	2368.65	Standard	Base Load
MH-67	2,367.00	2,367.00	2365.7	Standard	<None>
RB36A7	2,366.90	2,366.90	2365.27	Standard	<None>
RB36A7A	2,370.10	2,370.10	2368.8	Standard	Base Load
MH-66	2,367.00	2,367.00	2365.64	Standard	<None>
MH-70	2,364.50	2,364.50	2362.95	Standard	<None>
RB36A6	2,362.20	2,362.20	2360.45	Standard	Base Load
RB30B5	2,361.10	2,361.10	2359.8	Standard	Base Load
RB30B4	2,359.80	2,359.80	2358.05	Standard	Base Load
RB30B3	2,356.40	2,356.40	2355.1	Standard	Base Load
RB30B2	2,353.40	2,353.40	2352.1	Standard	Base Load
RB30B1	2,353.60	2,353.60	2350.22	Standard	Base Load
RB34E	2,359.00	2,359.00	2357.7	Standard	Base Load
RB34D	2,357.70	2,357.70	2356.4	Standard	Base Load
RB34C	2,354.50	2,354.50	2353.2	Standard	Base Load
RB34B	2,351.50	2,351.50	2348.9	Standard	Base Load
RB34B1	2,351.50	2,351.50	2350.15	Standard	Base Load
RB34A	2,348.00	2,348.00	2346.65	Standard	Base Load
RB33B1	2,351.60	2,351.60	2350.3	Standard	Base Load
RB33E	2,358.00	2,358.00	2355.81	Standard	Base Load
RB33D	2,354.00	2,354.00	2352.45	Standard	Base Load
RB33C	2,351.60	2,351.60	2350.3	Standard	Base Load
RB33F	2,357.90	2,357.90	2356.6	Standard	Base Load
RB33B	2,350.10	2,350.10	2348.35	Standard	<None>
RB32D	2,360.00	2,360.00	2358.15	Standard	Base Load
RB32C	2,356.40	2,356.40	2354.57	Standard	Base Load
RB32B	2,352.70	2,352.70	2351.4	Standard	Base Load
RB32A	2,349.00	2,349.00	2347.5	Standard	Base Load
RB36A4B	2,363.00	2,363.00	2361.37	Standard	Base Load
RB36A4C	2,367.50	2,367.50	2365.95	Standard	Base Load
RB36A4A	2,360.00	2,360.00	2358.7	Standard	Base Load
RB37	2,356.80	2,356.80	2355.5	Standard	Base Load
RB38	2,360.80	2,360.80	2359.45	Standard	Composite
RB39	2,364.30	2,364.30	2362.95	Standard	Base Load
RB40	2,367.80	2,367.80	2366.25	Standard	Composite
RB41	2,371.10	2,371.10	2369.8	Standard	Composite
RB36A	2,353.00	2,353.00	2351.65	Standard	Base Load
RB36A1	2,355.90	2,355.90	2354.6	Standard	Base Load
RB36A2	2,357.80	2,357.80	2356.5	Standard	Base Load
RB36A3	2,358.50	2,358.50	2357.2	Standard	<None>
RB36A4	2,359.40	2,359.40	2358.1	Standard	Base Load
RB36	2,353.50	2,353.50	2350.91	Standard	Composite

Continued					
RB35	2,351.30	2,351.30	2349.25	Standard	Base Load
RB32	2,345.00	2,345.00	2343.53	Standard	Composite
RB33	2,345.20	2,345.20	2343.75	Standard	Composite
RB34	2,347.20	2,347.20	2345.8	Standard	Base Load
RB33A	2,347.00	2,347.00	2345.7	Standard	Base Load
RB36A4B1	2,364.70	2,364.70	2363.4	Standard	Base Load
RB36A4B2	2,368.60	2,368.60	2366.1	Standard	Base Load
RB36A4B3	2,371.00	2,371.00	2368.92	Standard	Base Load
MH-69	2,345.10	2,345.10	2343.06	Standard	Composite
RB31	2,344.70	2,344.70	2342.58	Standard	Composite
RB31A	2,347.20	2,347.20	2345.5	Standard	Base Load
RB31B	2,347.90	2,347.90	2346.6	Standard	Base Load
RB31C	2,352.00	2,352.00	2350.7	Standard	Base Load
RB31A1	2,347.20	2,347.20	2345.85	Standard	Base Load
RB31A2	2,351.00	2,351.00	2348.7	Standard	Base Load
RB30A1	2,344.80	2,344.80	2342.27	Standard	Composite
RB30D	2,358.30	2,358.30	2357	Standard	Base Load
RB30C	2,356.00	2,356.00	2354.5	Standard	Composite
RB30B	2,352.40	2,352.40	2350.6	Standard	Base Load
RB30A	2,347.90	2,347.90	2346.6	Standard	Composite
RB30	2,344.50	2,344.50	2341.96	Standard	Composite
RB36C2	2,361.10	2,361.10	2359.8	Standard	Base Load
RB36C1	2,359.30	2,359.30	2358	Standard	Base Load
RB36C	2,357.40	2,357.40	2356.1	Standard	Base Load
RB36D	2,359.00	2,359.00	2357.7	Standard	Base Load
RB36E	2,363.00	2,363.00	2361.7	Standard	Base Load
RB36D1	2,362.20	2,362.20	2360.9	Standard	Base Load
RB36B	2,355.80	2,355.80	2353.95	Standard	Base Load
MH-68	2,353.00	2,353.00	2351.7	Standard	Base Load

Node loading report for ledita site

Label	Sanitary Load Type	Sanitary Unit Load Type	Sanitary Unit Load Units	Sanitary Unit Load Count	Sanitary Base Load (l/d)
RB36A8	Base Load	Residential	Person	279	22,320.00
MH-67	<None>	<None>	N/A	N/A	0
RB36A7	<None>	<None>	N/A	N/A	0
RB36A7A	Base Load	School(Medium)	Student	1,000.00	60,000.00
MH-66	<None>	<None>	N/A	N/A	0
MH-70	<None>	<None>	N/A	N/A	0
RB36A6	Base Load	condominium	Person	279	22,320.00
RB30B5	Base Load	condominium	Person	4,984.00	398,720.00
RB30B4	Base Load	condominium	Person	279	22,320.00
RB30B3	Base Load	condominium	Person	279	22,320.00
RB30B2	Base Load	condominium	Person	279	22,320.00
RB30B1	Base Load	condominium	Person	279	22,320.00
RB34E	Base Load	School(Medium)	Student	1,000.00	60,000.00
RB34D	Base Load	condominium	Person	279	22,320.00
RB34C	Base Load	condominium	Person	278	22,240.00
RB34B	Base Load	condominium	Person	279	22,320.00
RB34B1	Base Load	condominium	Person	279	22,320.00
RB34A	Base Load	condominium	Person	279	22,320.00
RB33B1	Base Load	AAWSA	Capita	180	14,400.00
RB33E	Base Load	AAWSA	Capita	180	14,400.00
RB33D	Base Load	AAWSA	Capita	180	14,400.00
RB33C	Base Load	AAWSA	Capita	180	14,400.00
RB33F	Base Load	AAWSA	Capita	240	19,200.00
RB33B	<None>	<None>	N/A	N/A	0
RB32D	Base Load	AAWSA	Capita	120	9,600.00
RB32C	Base Load	AAWSA	Capita	180	14,400.00
RB32B	Base Load	AAWSA	Capita	180	14,400.00
RB32A	Base Load	AAWSA	Capita	180	14,400.00
RB36A4B	Base Load	condominium	Person	279	22,320.00
RB36A4C	Base Load	condominium	Person	279	22,320.00
RB36A4A	Base Load	condominium	Person	279	22,320.00
RB37	Base Load	AAWSA	Capita	180	14,400.00
RB38	Composite	<Composite>	N/A	N/A	16,950.00
RB39	Base Load	MIXED USER	Person	2,160.00	416,880.00
RB40	Composite	<Composite>	N/A	N/A	16,950.00
RB41	Composite	<Composite>	N/A	N/A	16,950.00
RB36A	Base Load	MIXED USER	Person	2,880.00	555,840.00
RB36A1	Base Load	AAWSA	Capita	120	9,600.00
RB36A2	Base Load	AAWSA	Capita	240	19,200.00
RB36A3	<None>	<None>	N/A	N/A	0
RB36A4	Base Load	condominium	Person	279	22,320.00

Continued					
RB36	Composite	<Composite>	N/A	N/A	24,870.00
RB35	Base Load	condominium	Person	279	22,320.00
RB32	Composite	<Composite>	N/A	N/A	16,950.00
RB33	Composite	<Composite>	N/A	N/A	16,950.00
RB34	Base Load	condominium	Person	279	22,320.00
RB33A	Base Load	condominium	Person	5,074.00	405,920.00
RB36A4B1	Base Load	condominium	Person	279	22,320.00
RB36A4B2	Base Load	condominium	Person	279	22,320.00
RB36A4B3	Base Load	condominium	Person	500	40,000.00
MH-69	Composite	<Composite>	N/A	N/A	16,950.00
RB31	Composite	<Composite>	N/A	N/A	16,950.00
RB31A	Base Load	condominium	person	3,613.00	289,040.00
RB31B	Base Load	AAWSA	capita	180	14,400.00
RB31C	Base Load	AAWSA	capita	120	9,600.00
RB31A1	Base Load	condominium	person	279	22,320.00
RB31A2	Base Load	condominium	person	279	22,320.00
RB30A1	Composite	<Composite>	N/A	N/A	16,950.00
RB30D	Base Load	Office	employee	300	16,500.00
RB30C	Composite	<Composite>	N/A	N/A	16,950.00
RB30B	Base Load	condominium	person	279	22,320.00
RB30A	Composite	<Composite>	N/A	N/A	139,360.00
RB30	Composite	<Composite>	N/A	N/A	17,550.00
RB36C2	Base Load	condominium	person	279	22,320.00
RB36C1	Base Load	condominium	person	279	22,320.00
RB36C	Base Load	condominium	person	279	22,320.00
RB36D	Base Load	Residential	person	279	22,320.00
RB36E	Base Load	Office	employee	300	16,500.00
RB36D1	Base Load	condominium	person	279	22,320.00
RB36B	Base Load	condominium	person	7,574.00	605,920.00
MH-68	Base Load	condominium	person	279	22,320.00

APPENDIXES-B: Gravity node report for Palace site up to Casanches menharea site

label	Upstream Invert Elevation (m)	Downstream Invert Elevation (m)	Constructed Slope (m/m)	Length (m)	Section Shape	Material	Section Size	Infiltration Load Type	Infiltration Unit Load	Total Flow (l/d)	Design Capacity (l/d)
P-1	2,426.90	2,423.97	0.03457	84.6	Circular	PVC	200mm	Pipe Diameter-Length	10	171.9	6,516,403.50
P-2	2,423.97	2,420.17	0.03491	108.9	Circular	PVC	200mm	Pipe Diameter-Length	10	221,936.70	6,548,206.00
P-3	2,420.17	2,417.75	0.02723	89	Circular	PVC	200mm	Pipe Diameter-Length	10	222,117.60	5,782,450.40
P-4	2,417.75	2,417.52	0.00347	66	Circular	PVC	200mm	Pipe Diameter-Length	10	222,731.70	2,064,315.10
P-5	2,417.52	2,417.65	-0.002	65	Circular	PVC	200mm	Pipe Diameter-Length	10	222,863.70	-1,585,255.80
P-35	2,417.65	2,417.83	-0.0028	65	Circular	PVC	200mm	Pipe Diameter-Length	10	223,475.80	-1,844,207.50
P-32	2,417.83	2,415.50	0.02913	80	Circular	PVC	200mm	Pipe Diameter-Length	10	224,118.40	5,980,853.70
P-8	2,415.50	2,414.56	0.01011	93	Circular	PVC	200mm	Pipe Diameter-Length	10	224,307.40	3,523,324.70
P-9	2,414.56	2,406.97	0.08827	86	Circular	PVC	200mm	Pipe Diameter-Length	10	224,482.10	10,411,911.90
P-10	2,406.97	2,404.74	0.02633	84.5	Circular	PVC	200mm	Pipe Diameter-Length	10	224,653.80	5,686,785.80
P-11	2,404.74	2,404.33	0.00414	100	Circular	PVC	200mm	Pipe Diameter-Length	10	224,857.00	2,254,916.10
P-12	2,404.33	2,404.26	0.00074	99	Circular	PVC	200mm	Pipe Diameter-Length	10	225,058.20	951,643.00
P-13	2,404.26	2,403.60	0.00669	99	Circular	PVC	200mm	Pipe Diameter-Length	10	225,259.40	2,865,771.80

Gravity pipe report for Palace site up to Casanches menharea site

Label	X (m)	Y (m)	Calculated Station (m)	Ground Elevation (m)	Rim Elevation (m)	Structure Diameter (m)	Total Flow (l/d)	Hydraulic Grade Line In (m)	Hydraulic Grade Line Out (m)
42GY	4,573.58	33.892	11+20.0	2,429.35	2,429.35	1	0	2,426.90	2,426.90
41GY	4,576.49	4.832	10+35.4	2,425.97	2,425.97	1	651.9	2,424.01	2,424.01
40GY	4,579.07	-26.656	9+26.5	2,422.92	2,422.92	1	221,936.70	2,420.21	2,420.21
39GY	4,579.57	-41.011	8+37.5	2,419.95	2,419.95	1	222,597.60	2,417.90	2,417.90
38GY	4,582.15	-61.178	7+71.5	2,420.32	2,420.32	1	222,731.70	2,417.90	2,417.90
37GY	4,609.12	-65.355	7+06.5	2,420.00	2,420.00	1	223,343.70	2,417.90	2,417.90
36GY	4,640.35	-71.749	6+41.5	2,419.73	2,419.73	1	223,955.80	2,417.87	2,417.87
35 GY	4,671.35	-80.688	5+61.5	2,417.00	2,417.00	1	224,118.40	2,415.54	2,415.54
34GY	4,702.40	-91.62	4+68.5	2,415.81	2,415.81	1	224,307.40	2,414.60	2,414.60
33GY	4,688.02	-111.64	3+82.5	2,409.97	2,409.97	1	224,482.10	2,407.01	2,407.01
32 GY	4,673.11	-132.64	2+98.0	2,405.94	2,405.94	1	224,653.80	2,404.79	2,404.79
31GY	4,649.75	-137.2	1+98.0	2,408.18	2,408.18	1	224,857.00	2,404.39	2,404.39
30GY	4,666.57	-163.43	0+99.0	2,407.21	2,407.21	1	225,058.20	2,404.30	2,404.30
O-1	4,686.01	-187.09		2,405.75	2,405.75		225,259.40	2,403.60	2,403.60

Manhole report for Palace site up to Casanches menharea site

Label	Ground Elevation (m)	Rim Elevation (m)	Sump Elevation (m)	Headloss Method	Sanitary Load Type	Total Flow (l/d)
42GY	2,429.35	2,429.35	2,426.90	Standard	Base Load	0
41GY	2,425.97	2,425.97	2,423.97	Standard	Base Load	651.9
40GY	2,422.92	2,422.92	2,420.17	Standard	Base Load	221,936.70
39GY	2,419.95	2,419.95	2,417.75	Standard	Base Load	222,597.60
38GY	2,420.32	2,420.32	2,417.52	Standard	Base Load	222,731.70
37GY	2,420.00	2,420.00	2,417.65	Standard	Base Load	223,343.70
36GY	2,419.73	2,419.73	2,417.83	Standard	Base Load	223,955.80
35 GY	2,417.00	2,417.00	2,415.50	Standard	Base Load	224,118.40
34GY	2,415.81	2,415.81	2,414.56	Standard	Base Load	224,307.40
33GY	2,409.97	2,409.97	2,406.97	Standard	Base Load	224,482.10
32 GY	2,405.94	2,405.94	2,404.74	Standard	<None>	224,653.80
31GY	2,408.18	2,408.18	2,404.33	Standard	Base Load	224,857.00

Node loading report for Palace site up to Casanches menharea site

Label	Sanitary Unit Load Type	Sanitary Unit Load Units	Sanitary Unit Load Count
42GY	Commercial	Person	300
41GY	Residential	Person	6
40GY	Commercial	Person	300
39GY	Residential	Person	6
38GY	Commercial	Person	300
37GY	Residential	Person	6
36GY	Residential	Person	6
35 GY	Commercial	Person	300
34GY	Commercial	Person	300
33GY	Commercial	Person	300
32 GY	<None>	N/A	N/A
31GY	Commercial	Person	300
30GY	Commercial	Person	300

APPENDIXES-C: Data collection for sewer cad analysis from Arada Branch

No.	Manhole ID	Diameter (m)	Depth	X-Coordinate	Y-Coordinate	Ground Elevation	D/S Manhole	U/S Manhole	Pipe Length
1	HS	1.000		473250.930	996578.016		HS	HV	
2	HV	1.000	3.400	473248.467	996613.961		HV	HV1	18.000
3	HV1	1.000	3.600	473247.870	996631.289	2344.217	HV1	HV2	79.000
4	HV2	1.000	3.100	473217.942	996707.578	2342.217	HV2	HV3	81.000
5	HV3	1.000	2.900	473169.446	996774.271	2339.217	HV3	HV4	70.500
6	HV4	1.000	2.830	473117.954	996839.222	2344.217	HV4	HV4 A	45.400
7	HV4 A	1.000	2.850	473109.157	996871.647	2348.217	HV4 A	HV4 B	51.500
8	HV4 B	1.000	2.850	473081.012	996911.473	2349.217	HV4 B	HV4 C	44.500
9	HV4 C	1.000	2.840	473057.090	996943.920	2349.217	HV4 C	HV4 D	26.100
10	HV4 D	1.000	2.850	473044.015	996968.438	2349.217	HV4 D	HV4 E	34.700
11	HV4 E	1.000	3.100	473041.012	997009.506	2353.217	HV4 E	HV4 E1	21.000
12	HV4 E1	1.000	2.700	473061.155	997015.257	2362.217	HV4 E1	HV4 E2	16.000
13	HV4 E2	1.000	2.910	473060.027	997051.033	2347.217	HV4 E2	HV4 F1	31.000
14	HV4 F	1.000	2.900	473051.759	997073.436	2354.217	HV4 F1	HV4 F	20.900
15	HV4 G	1.000	2.800	473080.141	997124.890	2351.217	HV4 F	HV4 G	53.350
16	HV4 H	1.000	2.640	473110.585	997174.971	2354.217	HV4 G	HV4 H	56.200
17	HV4 H1	1.000	2.400	473123.525	997196.747	2357.217	HV4 H	HV4 H1	26.300
18	HV4 J	1.000	1.660	473125.267	997198.821	2350.217	HV4 H1	HV4 J	7.000
19	HV4 K	1.000	2.600	473173.144	997253.460	2354.217	HV4 J	HV4 K	73.700
20	HV4 L	1.000	2.640	473182.321	997295.984	2355.217	HV4 K	HV4 L	36.200
21	HV4 M	1.000	2.550	473195.284	997339.304	2359.217	HV4 L	HV4 M	51.000
22	HV4 N	1.000	2.270	468619.733	987702.615	2342.254	HV4 M	HV4 N	51.000
23	HV4 O	1.000	2.700	473232.805	997432.644	2371.217	HV4 N	HV4 O	52.000
24	HV4 P	1.000	2.650	473246.368	997477.678	2372.217	HV4 O	HV4 P	41.600
25	HV4 P1	1.000	2.500	473246.332	997507.736	2373.217	HV4 P	HV4 P1	27.500
26	HV4 Q	1.000	2.600	473232.653	997564.639	2381.217	HV4 P1	HV4 Q	61.500
27	HV4 R	1.000	2.570	473226.974	9976423	2387.217	HV4 Q	HV4 R	69.000
28	HV4 S	1.000	3.000	473216.296	997641.021	2381.217	HV4 R	HV4 S	14.300
29	HV4 T	1.000	2.400	473198.370	997670.981	2377.217	HV4 S	HV4 T	48.000
30	HV4 U	1.000	2.100	473135.391	997708.792	2388.217	HV4 T	HV4 U	53.200
31	HV4 V	1.000	2.230	473107.097	997732.763	2394.217	HV4 U	HV4 V	43.700

Continued									
32	HV4 W	1.000	2.250	473069.678	997747.290	2399.217	HV4 V	HV4 W	41.200
33	HV4 X	1.000	2.260	473019.421	997758.229	2400.217	HV4 W	HV4 X	42.600
34	HV4 Y	1.000	2.280	472984.619	997761.218	2412.217	HV4 X	HV4 Y	41.400
35	HV4 Z	1.000	2.230	472934.752	997761.280	2412.217	HV4 Y	HV4 Z	63.800
36	HV4 F1	1.000	2.900	473038.721	997056.376	2349.217	HV4 F1	HV4 F2	36.200
37	HV4 F2	1.000	2.530	472999.002	997037.852	2346.217	HV4 F2	HV4 F3	103.400
38	HV4 F3	1.000	1.460	472886.459	997033.999	2349.217	HV4 F3	HV4 F4	68.000
39	HV4 F4	1.000	1.800	472829.551	997030.710	2348.217	HV4 F4	HV4 F7	59.700
40	HV4 F7	1.000	1.900	472765.103	997021.637	2353.217	HV4 F7	HV4 F8	69.800
41	HV4 F8	1.000	1.850	472709.470	997039.317	2351.217			
42	HV4 M1	1.000	3.700	473135.324	997372.998	2362.217	HV4M	HV4 M1	76.100
43	HV4 M2	1.000	2.170	473084.600	997359.383	2362.217	HV4 M1	HV4 M2	67.000
44	HV4 M3	1.000	1.760	473062.275	997354.533	2367.217	HV4 M2	HV4 M3	17.000
45	HV4 M4	1.000	1.390	473057.937	997355.657	2369.217	HV4 M3	HV4 M4	5.500
46	HV4 M5	1.000	1.230	473037.396	997348.379	2365.217	HV4 M4	HV4 M5	20.000
47	HV4 M6	1.000	1.250	472987.660	997337.580	2362.217	HV4 M5	HV4 M6	50.000
48	HV4 M7	1.000	1.750	472933.078	997325.821	2364.217	HV4 M6	HV4 M7	58.400
49	HV4 M8	1.000	2.400	472911.432	997331.710	2367.217	HV4 M7	HV4 M8	23.300
50	HV4 M9	1.000	2.350	472894.247	997366.433	2371.217	HV4 M8	HV4 M9	39.700
51	HV4 M10	1.000	2.500	472865.469	997425.171	2373.217	HV4 M9	HV4	62.400
52	HV4 M11	1.000	2.000	472849.900	997467.481	2379.217	HV4M10	HV4M11	44.700
53	HV4 M12	1.000	2.500	472825.883	997506.962	2380.217	HV4M11	HV4M12	48.200
54	HV4 M13	1.000	1.820	472848.748	997533.308	2380.217	HV4M12	HV4M13	35.000
55	HV4 M14	1.000	1.850	472867.391	997556.331	2377.217	HV4M13	HV4M14	30.000
56	HV4M12A	1.000	2.500	472806.208	997484.431	2382.217	HV4M12	HV4M12A	26.000
58	HV4 R1	1.000	2.330	473177.009	997619.884	2388.217	HV4 R	HV4 R1	56.550
59	HV4 R2	1.000	2.200	473120.493	997609.516	2388.217	HV4 R1	HV4 R2	62.800
60	HV4 R3	1.000	2.300	473052.111	997600.304	2390.217	HV4 R2	HV4 R3	67.300
61	HV4 R4	1.000	2.330	472996.935	997596.052	2393.217	HV4 R3	HV4 R4	60.200
62	HV4 R5	1.000	2.350	472947.123	997596.029	2394.217	HV4 R4	HV4 R5	50.000
63	HV4 R6	1.000	2.360	472896.412	997599.427	2395.217	HV4 R5	HV4 R6	50.300
64	HV4 R7	1.000	2.050	472844.716	997607.523	2395.217	HV4 R6	HV4 R7	50.100
65	HV4 R8	1.000	2.150	472799.820	997615.597	2399.217	HV4 R7	HV4 R8	39.000
66	HV4 R9	1.000	2.300	472766.145	997624.245	2400.217	HV4 R8	HV4 R9	38.700

Continued									
67	HV4 R11	1.000	2.300	472732.015	997627.197	2398.217	HV4 R9	HV4 R11	40.000
68	HV4 R10	1.000	2.120	472688.268	997631.693	2400.217	HV4R11	HV4 R10	39.800
69	HV4 Z1	1.000	2.280	472906.001	997749.188	2414.217	HV4 Z	HV4 Z1	36.000
70	HV4 Z2	1.000	2.280	472859.991	997757.122	2414.217	HV4 Z1	HV4 Z2	32.300
71	HV4 Z3	1.000	2.200	472833.437	997779.741	2411.217	HV4 Z2	HV4 Z3	42.250
72	HV4 Z4	1.000	2.270	472790.581	997862.247	2411.217	HV4 Z3	HV4 Z4	98.500
73	HV4 Z5	1.000	2.350	472776.804	997896.272	2419.217	HV4 Z4	HV4 Z5	32.000
74	HV4 Z6	1.000	2.550	472779.062	997938.144	2411.217	HV4 Z5	HV4 Z6	46.700
75	HV4 Z7	1.000	2.360	472787.164	997958.088	2429.217	HV4 Z6	HV4 Z7	24.600
76	HV4 Z8	1.000	2.300	472795.451	998006.748	2435.217	HV4 Z7	HV4 Z8	49.500
77	HV4 Z9	1.000	2.340	472784.843	998055.050	2438.217	HV4 Z8	HV4 Z9	50.800
78	HV4Z10	1.000	2.280	472785.038	998110.730	2438.217	HV4 Z9	HV4 Z10	49.800
79	HV4Z11	1.000	2.250	472778.352	998168.888	2444.217	HV4 Z10	HV4 Z11	50.200
80	HV4Z12	1.000	2.300	472764.285	998196.270	2444.217	HV4 Z11	HV4 Z12	36.000
81	HV4Z13	1.000	1.800	472761.182	998199.951	2409.217	HV4 Z12	HV4 Z13	40.700
82	HV4 Q1	1.000	2.600	473236.725	997607.112	2384.217	HV4 Q	HV4 Q1	38.800
83	HV4 Q2	1.000	3.400	473232.465	997628.566	2389.217	HV4 Q1	HV4 Q2	18.800
84	HV4 Q3	1.000	1.850	473265.237	997661.133	2387.217	HV4 Q2	HV4 Q3	55.800
85	HV4 Q4	1.000	1.150	473331.011	997700.499	2389.217	HV4 Q3	HV4 Q4	74.600
86	HV4 Q5	1.000	1.350	473353.909	997720.748	2388.217	HV4 Q4	HV4 Q5	27.500
87	HV4 Q6	1.000	1.340	473381.407	997747.074	2387.217	HV4 Q5	HV4 Q6	38.500
88	HV4 Q7	1.000	2.800	473353.163	997790.679	2394.217	HV4 Q6	HV4 Q7	49.300

APPENDIXES-D: Questionnaire of the Survey

Survey of the knowledge; attitude, practices, and behavior of the communiy in Assessm ent on the performance of AAWSA controled sewerage system the case of Arada Sub cit y.

A. Identification

1. Location : **Arada Sub city.**
2. kebele/Wereda _____ 3.House number _____
3. Name of the person who responds the questioner (optional) _____

B. Basic Information

1. Marital status

Single ☐ Married ☐

2. Respondents Age ☐ <20 ☐ 20-29 ☐ 30-49 ☐ >50 ☐

3. Sex: Male ☐ Female ☐

4. Attended education to grade level of Grade 1-6 ☐ Grade 7-12

Grade 12+ ☐ degree

5. Size of the family in number ☐ <6 ☐ 6-15 ☐ >15

6. Occupation _____

C. Dwelling house

1.Ownership of the dwelling house

Private ☐ Rented ☐ Shared ☐ Dependent ☐

If it is other than these, please explain it _____

2.How many septic thank does the dwelling house have? _____

3.Building condition of the house

Isolated ☐

Connected to other adjacent houses ☐

Apartments ☐

If it is in other form, please explain it _____

a. **Sewer line network service questioner result for authority**

1. Duration to get service

low ☐ medium ☐ high ☐

2. Awareness of the service

low ☐ medium ☐ high ☐

3. Quality of the service ?

low ☐ medium ☐ high ☐

4. Problem of the service related with operation and maintenance ?

low ☐ medium ☐ high ☐

5. Occurrence of the problem related to healthy ?

low ☐ medium ☐ high ☐

6. Satisfaction considering time, quality and cost ?

low ☐ medium ☐ high ☐

7. Demand of the service ?

low ☐ medium ☐ high ☐

8. Cost of the service ?

low ☐ medium ☐ high ☐

b. **For vacuum truck line sewerage service questioner result for customer**

1. Duration to get service

low ☐ medium ☐ high ☐

2. Awareness of the service

low ☐ medium ☐ high ☐

3. Quality of the service ?

low ☐ medium ☐ high ☐

4. Problem of the service with respect to vacuum truck operation and maintenance problem ?

low ☐ medium ☐ high ☐

5. Occurrence of the problem related to healthy ?

low ☐ medium ☐ high ☐

6. Satisfaction considering time, quality and cost ?

low ☐ medium ☐ high ☐

7. Demand of the service ?

low ☐ medium ☐ high ☐

8. Cost of the service ?

low ☐ medium ☐ high ☐

Thanks for your full cooperation and patience to fill in this questionnaire **Questioner /Interviewer**

Questionnaire ending time _____

Name of the interviewer _____ Signature _____

APPENDIXES-E: Sewer line Connection Customer Information

Id no.	Customer Name	Tele No.	Subcity	Wereda	Kebele	House No.	Date of connection	Type of Buildig
1	Ethiopian orthodox tewahido church	0111248016	Kirkos	15	11/12	662	10/7/01	government org.
2	Ato tessema negash	0911474887	Kirkos	15	17	NEW	17/03/01	Commercial
3	w/o saba worku zeleke	0911607405	Kirkos	15	16	204	10/501	Residence
4	Awash international bank	0912045045	Kirkos	15	15/16		10/5/01	Commercial
5	Ato yohannes kebede	0911248296	Kirkos	15	17/18	NEW	18/10/2000	Commercial
6	Ato habte woldegiorgis	0911157435	Kirkos	15	17/18	641	05/03/01	Commercial
7	Agency for government houses	0911153838	Kirkos	15	17/18	016	25/11/01	government org.
8	Ato kedir Ibrahim		Kirkos		17/18	1038		Residence
9	Ato mekonnen mengesha	0911504914	Kirkos	15	10	239	10/0501	Residence
10	Jupiter International hotel	0911426774	Kirkos	15			7/6/2001	Residence
11	Addis ababa hilton hotel		Kirkos	15	2630		12/08/86	Commercial
12	Akram company		Kirkos	15	26	977	10/03/93	Commercial
13	Audit services corporation		Kirkos	15	30		23/2/81	Commercial
14	Economic commission for Africa		Kirkos	15	26		30/01/86	Commercial
15	W/o Roman Asfaw		Kirkos	15	26	939	09/10/84	Commercial
16	W/o Ademseged kebede	517452	Kirkos	15	12	083	30/06/85	Residence
17	Asham Trade and Industry	0911221664		3		207		Residence
18	Radio Fana Share Company	0115516777	Arada	3	12/33		11/01/02	government org.
19	Ato hussien Abdulkadir	0911201184	Lideta	3	15	0335	12/03/02	Commercial
20	W/o Zewdie H/mariam	0111559184	Lideta	2	18	879/02	17/04/02	Residence
21	The Federal Republic of Ethiopia Palace	0912325752		14		0000	16/05/02	government org.
22	Ayat Private limited Company	0911238416	Kirkos	15	17/18		22/03/02	Commercial
23	Agency for government houses	0911603863	Kirkos	15	27	012/01	11/03/02	Residence
24	Ynegewsew sanitation service cooperative	0911733388/89	Arada	2	09			Commercial
25	Midroc construction ethiopia							Commercial
26	Ato Shibru Awash	117751	Arada	14	17	263	05/02/85	Residence

Continued								
28	Ato tewoldie kifleyesus	0911242722	Arada	14	07/14	116	18/05/2000	Residence
29	Ethiopian orthodox Theological college	0111233528	Arada	14	17		25/05/01	government org.
30	National Museium		Arada	14			02/07/2000	government org.
31	Ministry of foreign Affairs		Arada	14	15		21/03/97	government org.
32	Ancient ethiopian hero patroit association	0111113098	Arada	14	17		26/04/2000	commercial
33	Ato dawit Adnew	911204666	Arada	14	17	135	07/01/2000	commercial
34	Addis Ababa Diocese secratarit	0111563288	Arada	14	17	NEW	03/10/2000	commercial
35	Addis Ababa University		Arada	14	07		01/01/95	government org.
36	Saint Gabriel Church	115273	Arada	14	18		12/07/93	government org.
37	Ministry of foreign Affairs	517345	Arada	14	25			government org.
38	Saint Gabriel Church	0111248026	Arada	14	28			government org.
39	Midroc construction ethiopia		Arada	14	21		08/04/89	government org.
40	Peoples Democratic R. E. State Council		Arada	14	18			government org.
41	Birhanena Selam Printing press		Arada	14	07	984/4	20/12/88	government org.
42	Commercial Bank of Ethiopia	161315	Arada	14	07		16/10/89	government org.
43	Peoples Democratic R. E. State Council	553000	Arada	14	18		19/02/94	government org.
44	Midroc construction ethiopia	0111516956	Arada	14				commercial
45	Ministry of foreign Affairs	517345	Arada	14	25		07/01/88	government org.
46	Agency for government houses	441350	Arada	14	24	835		government org.
47	Peoples Democratic R. E. State Council	553000	Arada	14				government org.
48	Ethiopian Mapping authority		Arada	14	25		14/11/86	government org.
49	The childiren heart fund of Ethiopia	513636	Arada	14	24		15/11/82	government org.
50	Peoples Democratic R. E. State Council		Lideta	3	13			government org.
51	Ato kibebu admase		Lideta	3	15	217	11/11/1999	residence
52	Ato yosef Hailu	0913064354	Lideta	3	04/06	015	18/04/2000	residence
53	W/o Elizabeth Yihidegu	0911608890	Lideta	3			26/11/99	residence
54	W/o Kesila medihin	613208	Lideta	3	07	071	10/11/99	residence
55	Federal Police Office	560832	Lideta	3			03/03/99	government org.

56	Agency for government houses	0115504762	Lideta	3	14		27/09/96	government org.
57	ALTA Computer		Lideta	3	02		15/07/97	commercial
58	T.G. PLC.		Lideta	3			28/12/99	commercial
59	Saint mary University College		Lideta	3	07		14/05/01	commercial
60	ALSAM PLC.		Lideta	3	51	001	16/06/98	commercial
61	ETHIO-CUBA PLC.		Lideta	3	12	new	03/10/99	commercial
62	W/o Hirut Yilma		Lideta	3	05	2822	22/09/99	government org.
63	TAD.COB PLC		Lideta	3	14		25/02/2000	commercial
64	Ministry of Information		Lideta	3	51		17/08/88	government org.
65	ETH. Import and Export communication		Lideta	3	53		05/11/81	government org.
66	Commercial Bank of Ethiopia		Lideta	3	51		03/03/99	government org.
67	Sina View Apartment		kirkos	15	17/18			residence
68	Alemash		kirkos	15				

Continued

Depth	Diameter	Pipe length	Material Code	Connected by	Manhole ID.	D/S Manhole ID.	U/S Manhole ID.
2	150	10	PV	Saddle			
2	150	6	PV	Manhole			
1	150	3	PV	Saddle			
2	150	14	PV	Saddle			
2	150	14	PV	Saddle			
2	150	13	PV	Saddle			
	150	3	PV	Manhole			
	150	7	PV	Saddle			
2	150	4	PV	Saddle		09GY	11GY
2	150	7.5	PV	Manhole			
3	150	33	PV	Manhole		08GY	09GY
	150	12	PV	Saddle		07GY	08GY
	150	12	PV	Manhole		07GY	08GY
4	150	42	PV	Manhole		01GY	02GY
	150	4	PV	Manhole		12GY	13GY
	150	12	PV	Manhole		16GY	17GY
1	150	4	PV	Manhole			
2	150	3	PV	Saddle			
2	150	4	PV	Manhole			
2	150	8	PV	Manhole			
2	150	10	PV	Manhole			
6	150	70	PV	Saddle			
5	150	45	PV	Manhole			

Continued							
1	150	9	PV	Manhole	JH-JK		
	150	14	PV	Manhole		36GY	37GY
1	150	4.5	PV	Saddle			
2	200	146	PV	Saddle			
2	150	9	PV	Saddle			
	150	7	PV	Saddle			
2	150	33	PV	Manhole			
4	150	124	PV	Manhole			
4	200	47	PV				
	150	1	PV	Manhole			
1	150	7	PV	Manhole	23GY		
	150	7	PV	Saddle			
2	150	12	PV	Manhle			
2	150	63	PV	Manhole		32GY	34GY
4	150	74	PV	Manhole	42GY05		
1	150	20	PV	Manhole		42GY03	42GY04
2	150	15	PV	Saddle	12HU01-02-03	40GY	41GY
	150	30	PV	Manhole	12HU03		
2	150	30	PV	Manhole			
3	150	14	PV	Manhole			
	150	12	PV	Manhole			
			PV				
	150	3	PV	Manhole			
2	150	3	PV	Saddle			
	150	9	PV	Manhole			
	150	4	PV	manhole			
	200	75	PV	manhole			
	150	60	PV	manhole		25RB01	25RB02
	150	5	PV	manhole		25RB01	25RB02
	150	9.5	PV	manhole			
2	150	5	PV	saddle			
	150	22	PV	saddle			
	150	19	PV	manhole			
	150	5	PV	manhole			
	150	23	PV	manhole			
4	200	6	PV	manhole		19HD	20HD
2	150	65.6	PV	manhole	12HD22		
	150	31	PV	manhole		12HD22B	12HD22C

APPENDIXES-F: Vacuum Truck Customers Information

Id no.	Customer Name	Home Phone No.	Mobile Phone No.	Subcity	Wereda	Kebele	House No.	Type Building	Application Date	Date Surved
72	Silas Taddese	0112785448		lideta	4	27	015	residence	22/12/01	11/01/02
87	Tirunesh Keyar	0112783703		lideta	4	27	021	residence	27/12/01	17/01/02
14	W/o Genet Solomon	0112760881	0911063159	lideta	4	29	024	residence	23/02/02	20/03/02
177	W/senbet G/tsadik	0112137624		lideta	4	26	035	residence	25/12/01	
30	Abate Beyene	0112760513	0911342417	lideta	4	28	039	residence	20/02/02	27/03/02
51	Yeshi Bekele			lideta	4	28	051	residence	04/01/02	27/01/02
76	Sisay Endale		0911661686	lideta	4	27	052		17/11/01	
190	Mohammod Yassin Halil		0911968305	lideta	4	26	052	residence	15/12/2000	
79	Mengistu Kassahun	0112751457	0911958922	lideta	4	27	063	residence	02/13/01	24/01/02
148	Beyene Melka	0112137252		lideta	4	26	063	residence	25/02/02	
162	Bokan Benti	0112767770		lideta	4	26	067	residence	09/03/02	
235	Yassin Abdo	0112137221		lideta	4	26	069	residence	28/01/02	
95	Simiret Worku		0913790555	lideta	4	27	074	residence	04/01/02	
246	Zeberga Tohe		0911011553	lideta	4	26	074	residence	20/12/01	
3	W/o Bogalech Aschalew	0112760695		lideta	4	29	079	residence	02/02/02	
62	Tzera Geletu	0112135522	0911488752	lideta	4	27	086	residence	12/02/02	13/03/02
230	Birile Iticha	0112785968		lideta	4	26	099	residence	22/01/02	
234	Fessework Argaw	0112785759		lideta	4	26	104	residence	04/02/02	
84	Almaz Tedla	0112757942		lideta	4	27	116	residence	13/01/02	21/02/02
52	Asnakech Servesa			lideta	4	28	124	residence	22/12/01	11/01/02
113	Aregash Yimer	0112781474	0913834366	lideta	4	26	129	residence	22/01/02	25/02/02
74	Nefisa Hashim		0911540176	lideta	4	27	130	residence	08/12/01	13/12/01
60	Tesfaye Gizaw	0112130867	0911447149	lideta	4	27	131	residence	17/02/02	18/03/02
90	Solomon Alework	0112782525	0911457862	lideta	4	27	147	residence	14/01/02	17/02/02
33	Alemitu Survecha		0911097477	lideta	4	28	148	residence	04/03/02	
45	Abdu Hadi	0112789712	0913008625	lideta	4	28	152	residence	08/01/02	07/02/02
207	Desalegn Dissasa	0112764392		lideta	4	26	156	residence	02/11/01	
67	Haimanot Alemayehu	0112782448		lideta	4	27	172	residence	29/1101	18/12/01
18	Asfaw Idasa	0112760710	0911186679	lideta	4	29	182	residence	06/01/02	30/01/02
82	Desalegn Gereso		0911017559	lideta	4	27	193	residence	19/01/01	22/02/02
46	Zenebech Gebisa	0112789922		lideta	4	28	202	residence	29/12/01	08/02/02
68	Belaynesh	0112133866		lideta	4	27	203	residence	07/03/02	08/04/02

Continued										
49	Nejat Habas		0911503359	lideta	4	28	207			29/12/01
199	Fetya Rede	0112137766		lideta	4	26	210	residence	05/01/02	
37	Hailie Endale		0911714856	lideta	4	28	212	residence	01/03/02	03/04/02
44	Haileeyesus Endale		0911714856	lideta	4	28	212	residence	03/13/01	05/09/02
151	Hana Tola		0912329409	lideta	4	26	222	residence	16/02/02	
19	Kassahun Bekele		0913673953	lideta	4	29	233	residence	20/11/01	
179	Tsedale Habte	0112137776	0910184856	lideta	4	26	246	residence	06/12/01	
200	Kelemwa Arega	0112789072	0912329551	lideta	4	26	251	residence	05/01/02	
2	Ato Taddese Gorfu	0112775053	0912113117	lideta	4	29	255	residence	12/01/02	03/03/02
222	Mehedi Mahamud	0112780761	0913020733	lideta	4	26	255	residence	02/13/01	
15	Selefa Shikur		0911871098	lideta	4	29	259	residence	19/12/01	05/01/02
32	Solomon Demissie	0112786584	0912400908	lideta	4	28	261	residence	11/03/02	03/04/02
143	Adisu Gezahegn	0116542401	0911979596	lideta	4	26	266	residence	16/02/02	
139	Tsige Ginbisa	0112137219	0910532612	lideta	4	26	278	residence	25/01/02	
96	Alemnesh Mohamud	0112768216		lideta	4	26	280	residence	29/11/01	22/12/01
159	Britu Absa Ejeta	0112785766		lideta	4	26	283	residence	16/13/02	
59	Getachew Giza	0112763095	0911236286	lideta	4	27	286	residence	25/01/02	27/02/02
56	Yitagesu Assefa		0911449526	lideta	4	27	296	residence	01/03/02	11/03/02
149	Nardos Taddesse	0112766305	0910438181	lideta	4	26	306	residence	23/02/02	
135	Legesse Gurara		0911443972	lideta	4	26	312	residence	17/02/02	
25	Mulie Ago	0112760768	0913629380	lideta	4	29	317	residence	15/01/02	18/02/02
187	Yimegnushal			lideta	4	26	317	residence	07/12/01	
17	Hirut Tsegaye			lideta	4	29	318	residence	10/11/01	26/12/01
242	Smegn Abdisa	0112758254	0911988189	lideta	4	26	327	residence	13/02/02	
36	Betelhem Debela		0913180038	lideta	4	28	330	residence	23/03/02	09/04/02
66	Abinet Tefera		0911421346	lideta	4	27	331	residence	05/12/01	
58	Sofia Edris		0911421346	lideta	4	27	332	residence	19/01/02	
138	Woinshet	0112137315		lideta	4	26	340	residence	02/03/02	
85	Fatuma Nur	0112779359		lideta	4	27	345	residence	04/01/02	18/02/02
73	Mulat Banto	0112778291	0911473455	lideta	4	27	347	residence	14/12/01	03/13/01
7	Ato Muluneh Simie		0912082889	lideta	4	29	348	residence	08/01/02	12/02/02
21	Widinesh Sifir	0112760611	0913246624	lideta	4	29	351	residence	03/02/02	07/02/02
55	Wondimu Tekle		0911675386	lideta	4	27	377	residence	24/11/01	30/11/01
77	Nasir Hussien		0911675386	lideta	4	27	378	residence	05/01/02	07/01/02
88	Negash Haile	0112761583	0913312359	lideta	4	27	379	residence	04/13/01	26/01/02
174	Tewabech Nigussie	0112767887	0913103959	lideta	4	26	388	residence	27/11/01	
243	Behailu	0112782866	0912044763	lideta	4	26	389	residence	02/02/02	

Continued										
80	Atsede Mengesha	0112770503	0910869912	lideta	4	27	397	residence	02/13/01	23/01/02
8	Ato Gizachew Haile		0911426899	lideta	4	29	414	residence	29/01/02	03/03/02
9	W/o Drshaye Tamiru	0112770024	0911752439	lideta	4	29	428	residence	17/02/02	17/13/02
217	Wibishet Alemu		0913161296	lideta	4	26	429	residence	03/13/01	
86	Mohammed Meka	0112779404		lideta	4	27	430	residence	15/01/02	18/02/02
119	Rida Hussien	0112757194		lideta	4	26	430	residence	02/02/02	11/03/02
93	W/o Gene	0112779404	0913214180	lideta	4	27	431	residence	14/01/02	15/02/02
94	Sinidu Dubale	0112779454	0911158513	lideta	4	27	441	residence	07/01/02	06/02/02
108	Yonatan Balew	0112757594		lideta	4	26	445	residence	04/12/01	20/12/01
34	Tamene Abera	0112760752	0911983224	lideta	4	28	453	residence	26/02/02	27/03/02
160	Yeshi Berawork	0116544581		lideta	4	26	456	residence	23/03/02	
5	W/o Belenge nro	0112761261	0911172933	lideta	4	29	459	residence	27/02/02	01/03/02
23	Amaha Asfaw	0112789863	0911604324	lideta	4	29	459	residence		23/02/02
10	Ato Sultan Dile		0910571116	lideta	4	29	464	residence	03/02/02	16/03/02
212	Degu Asamere	0911638442	0911310063	lideta	4	26	464	residence	12/01/02	
65	Ayeta Seboka	0112765497	0912026861	lideta	4	27	466	residence	09/10/02	11/03/02
147	Ashenafi Belete	0112757982		lideta	4	26	467	residence	26/02/02	
42	Mamite Siyum	0116544668	0911047919	lideta	4	28	469	residence	21/11/01	
26	Teshalech Shikur	0112770096	0910444976	lideta	4	29	483	residence	22/12/01	16/01/02
4	Ato Fikadu Debela		0911935130	lideta	4	29	488	residence	22/11/01	04/12/01
54	Zenebech Wakjira	0112779950		lideta	4	27	489	residence	06/12/01	25/12/01
91	Yorgalem		0913955535	lideta	4	27	489	residence	12/01/02	17/02/02
28	Gemal Amza		0911133016	lideta	4	29	490	residence	11/01/02	12/02/02
39	Abeje Sewinet	0112769471	0911159645	lideta	4	28	497	residence	05/12/01	14/12/01
192	Shitu Melka	01127777		lideta	4	26	497	residence	11/12/01	
233	Giragn Hyar		0911397605	lideta	4	26	516	residence	11/01/02	
123	Abdurahiman Akmel	0112757655	0913011488	lideta	4	26	519	residence	11/02/02	15/03/02
12	W/o Yeshi Ayele		0911165078	lideta	4	29	528	residence	08/03/02	
140	Ashenafi Gizaw	0112756396	0911104230	lideta	4	26	531	residence	18/01/02	
43	Sefa Dama		0911875378	lideta	4	28	535	residence	18/12/01	01/01/01
41	Alemu Mengste		0912051156	lideta	4	28	548	residence	25/12/01	
105	Tsinu Tesfa	0112137865	0911070378	lideta	4	26	562	residence	21/12/01	15/01/02
244	Elfinesh Habte		0913532029	lideta	4	26	565	residence	14/01/02	
216	Misrak Zewdu	0112131327	0913470528	lideta	4	26	566	residence	06/01/02	
69	Yared Ayeta	0112779373	0913701673	lideta	4	27	577	residence	04/02/02	08/03/02

Continued										
106	Kebede H/mariam	0112782769		lideta	4	26	580	residence	12/12/01	15/01/02
22	Fintu Teklie	1112760725		lideta	4	29	593	residence	07/01/02	06/02/02
141	Woinshet Mamo	0112754475		lideta	4	26	597	residence	02/03/02	
20	Abaynesh Debalkie Bedanie	0112761347	0913880629	lideta	4	29	598	residence	08/01/02	07/02/02
92	Murga Ahimed	0112779458		lideta	4	27	600	residence	25/12/01	
164	Tamene Geda		0913156203	lideta	4	26	611	residence	07/03/02	
24	Adisu Dagnew	0112135654		lideta	4	29	614	residence	13/11/02	
63	Worku G/selassie		0911604870	lideta	4	27	619	commercial	10/02/02	13/03/02
161	Jemal Hassan		0910653965	lideta	4	26	626	residence	04/12/01	
13	Ato Yimer Desalegn	0112768691	0913689695	lideta	4	29	632	residence	27/02/02	26/03/02
170	Abebe Gemeda		0911375732	lideta	4	26	634	residence	15/10/01	
81	Setegn Abdisa	0112779365	0911411489	lideta	4	27	636	residence	02/13/01	25/01/02
16	Askale Desta		0911161170	lideta	4	29	638	residence	19/12/01	01/01/01
11	Ato Hassan Mohammed	0112761363	0911059013	lideta	4	29	640	residence	17/02/02	15/03/02
1	W/t Bizuayehu Bahiru	0112774450	0913305273	lideta	4	37	641	residence	23/11/01	09/12/01
64	Alem Bereda	0112134110		lideta	4	27	642	residence	09/02/02	10/03/02
75	Melaku Chala	0112785143		lideta	4	27	642	residence	16/11/01	
83	Alem Bereda	0112134110		lideta	4	27	642	residence	15/01/02	21/02/02
50	Fiseha Takele		0911083758	lideta	4	28	645	residence	18/07/01	
152	Solomon	0112137307	0913314624	lideta	4	26	649	residence	14/03/02	
189	Birihanu Lema		0911918441	lideta	4	26	655	residence	18/12/01	
188	Solomon Workineh		0913014624	lideta	4	26	679	residence	11/12/01	
40	Bahiru Wakjira	0112134238	0911377152	lideta	4	28	682	residence	01/12/01	
218	Genet Baysa		091305/01/33	lideta	4	26	698	residence	03/12/01	
158	Senya Mohammod	0112137278	0911725590	lideta	4	26	702	residence	16/02/02	
221	Adam Jebir	0112137411		lideta	4	26	703	residence	04/01/02	
134	Shewaye Gebre	0112137805	0911663754	lideta	4	26	705	residence	17/02/02	22/03/02
99	Jemal Mohamud		0910645985	lideta	4	26	706	residence	15/12/01	
70	Hailu Girma		0911463928	lideta	4	27	714	commercial	17/02/02	18/03/02
71	Hailu Girma	0112778293	0911463929	lideta	4	27	714	residence	28/11/01	22/12/01
48	Meseret Yirdaw		0911930840	lideta	4	28	715	residence	20/01/02	20/02/02
186	Tesfaye Demissie	0112137495		lideta	4	26	715	residence	30/11/01	
57	Asegedech Belay	0112771181		lideta	4	27	719	residence	09/02/02	10/03/02
193	Tadelech Bogale			lideta	4	26	719	residence	27/12/01	
206	Teshome		0911305714	lideta	4	26	720	residence	05/01/02	

Continued										
112	Shafi Ahimed	0112789310	0911937995	lideta	4	26	737	residence	21/01/02	26/02/02
109	Aman Hajshifa	0112137826		lideta	4	26	750	residence		19/12/01
35	Befikad Gedamu		0913556647	lideta	4	28	764	residence	07/03/02	
6	Ato Daniel Adinew	0112753106	0911000206	lideta	4	29	776	residence	22/01/02	26/02/02
89	Gulma Negasa		0911254724	lideta	4	27	781	residence	13/01/02	17/02/02
227	Shamil Hassan	0112137484		lideta	4	26	783	residence	15/12/01	
172	Hailu Damitew	0112764011		lideta	4	26	795	residence	06/01/02	
142	Tilahun Gizaw	0112137970		lideta	4	26	816	residence	20/02/02	
248	Hagosa G/selassie	0112786315	0911115600	lideta	4	26	822	residence	29/12/01	
27	Kidane Argawi	0112760616		lideta	4	29	825	residence	21/01/02	11/02/02
29	Mulu Getu	0112789715	0912336954	lideta	4	28	835	residence	21/01/02	24/02/02
195	Adamu Mekonnen	0112177540	0913557441	lideta	4	26	838	residence	25/12/01	
124	Mulatu Genana	0112137210		lideta	4	26	843	residence	16/02/02	15/03/02
31	Maregn Bireba		0913094588	lideta	4	28	881		05/02/02	25/03/02
153	Tegitu Andyihun	0112755827		lideta	4	26	891	residence	30/02/02	
38	Melaku	0112133937		lideta	4	28	896	residence	08/12/01	25/12/01
204	Fetya Temam		0910061385	lideta	4	26	901	residence	26/12/01	
238	Getachew G/selassie	0112755998	0913439192	lideta	4	26	910	residence	07/01/02	
169	Fantu Alemayehu	0112754907	0911889699	lideta	4	26	918	residence	04/12/01	
150	Legesse Kinato	0112137572		lideta	4	26	935	residence	12/02/02	
47	Girma Sitotaw			lideta	4	28	941			
182	Girma Arega		0911177878	lideta	4	26	954	residence	24/11/01	
155	Teginesh Negash	0112754912		lideta	4	26	997	residence	01/03/02	
219	Sintayehu Abdulkadir		0910504745	lideta	4	26	1000	residence	20/12/01	
226	Mekonnen Yilma	0112137464	0910185437	lideta	4	26	1006	residence	18/01/02	
201	Belaynesh Jelide	0112780755		lideta	4	26	1030	residence	22/12/01	
185	Reshad Ahimed	0112765451		lideta	4	26	1039	residence	22/11/01	
117	Abinet W/Giorgis	0112131856		lideta	4	26	1048	residence	28/01/02	13/03/02
232	Tirunesh Ayfeki	0112137602	0911149338	lideta	4	26	1051	residence	07/01/02	
178	Ayele Abebe		0911311059	lideta	4	26	1101	residence	18/12/01	
205	Ismael Kedir	0112764553	0913822362	lideta	4	26	1116	residence	05/01/02	
107	Yehualaeshet Abebe	0112764726		lideta	4	26	1127	residence	13/12/01	02/13/01
213	Daniel Bekele		0911400740	lideta	4	26	1139	residence	11/01/02	
168	Keru Tabor	0112767914	0913924787	lideta	4	26	1162	residence	05/12/01	

Continued										
130	Kibru Mengesha	0112786619	0911826695	lideta	4	26	1194	residence	19/02/02	19/03/02
225	Woldie Ilala	0112764299		lideta	4	26	1196	residence	15/01/02	
202	Daniel Abebe	0112769901	0913615622	lideta	4	26	1198	residence	21/12/01	
250	Fitsum Gemini	0112780342		lideta	4	26	1216	residence	04/13/01	
191	Askale Assefa	0112780247		lideta	4	26	1220	residence	11/12/01	
157	Kedija Kebede	0112786025	0913284397	lideta	4	26	1231	residence	15/03/02	
224	H/marim Woldie	0112764710	0911147734	lideta	4	26	1275	residence	17/02/02	
166	Dagnachew Geremew			lideta	4	26	1290	residence		
181	Fikirte Gugsa		0913767474	lideta	4	26	1296	residence	27/11/02	
247	Seifa Berega	0112764812		lideta	4	26	1302	residence	11/01/02	
116	Amelework Tsige	0112764652	0913694770	lideta	4	26	1308	residence		13/03/02
209	Solomon Tadege		0911636079	lideta	4	26	1339	residence	28/12/01	
163	Letebrihan Berihe	0112762453	0911945226	lideta	4	26	1342	residence	09/03/02	
229	Nega Zeleke	0112750912	0912349422	lideta	4	26	1350	residence		
111	Tamene Assefa			lideta	4	26	1368	residence		
231	Tamene Assefa	0112760769	0911605929	lideta	4	26	1368	residence	05/13/01	
127	Ibrahim Ahimedin	0112761182	0911950909	lideta	4	26	1388	residence	01/03/02	
145	Zenebech Tilahun	0112780640	0911821745	lideta	4	26	1397	residence	14/03/02	
154	Felekech	0112780546	0912050626	lideta	4	26	1420	residence	07/03/02	
132	Asfaw Lema	0112764489	0910283467	lideta	4	26	1425	residence	11/02/02	21/03/02
214	Emebet Beyene		0913505095	lideta	4	26	1449	residence	20/12/01	
245	Feleke Tadesse		0911011553	lideta	4	26	1451	residence	20/12/01	
118	Girma Assefa	0112133243	0911106308	lideta	4	26	1462	residence	12/02/02	13/03/02
1236	Freweyn Getachew	0112780481		lideta	4	26	1529	residence	06/01/02	
173	Jemal Sebto	0112780679	0911996085	lideta	4	26	1543	residence	04/11/02	
101	Shambel Basha Tilahun Tulu	0112757625	0913440597	lideta	4	26	1546	residence	05/12/01	23/12/01
137	Alemu Debela	0112764242		lideta	4	26	1548	residence	21/03/02	
102	Nebiat Ali	0112870436	0913722023	lideta	4	26	1556	residence	05/12/01	25/12/01
114	Negash G/mariam		0913174732	lideta	4	26	1559	residence	27/01/02	24//02/02
176	Negash G/mariam	0112780558	0913174732	lideta	4	26	1559	residence	26/11/01	
120	Dino Habib	0112786136		lideta	4	26	1575	residence	04/02/02	10/03/02
184	Zinash Gebre		0911444021	lideta	4	26	1576	residence		
115	Umer Woraki	0112778495	0911233454	lideta	4	26	1581	residence	29/01/01	24//02/02
198	Ali Indris	0112780525	0911644995	lideta	4	26	1588	residence	05/01/02	
104	Tessem		0912077729	lideta	4	26	1591	residence	28/11/01	24/12/01
249	Aster Hailu	0112764370		lideta	4	26	1624	residence	18/12/01	

Continued										
220	Ayelech Mekonnen			lideta	4	26	1647	residence	02/01/02	
237	Ayelech Mekonnen	0112780496		lideta	4	26	1647	residence	07/01/02	
239	Lula Shemsu		0913656203	lideta	4	26	1661	residence	07/01/02	
223	Abebech Itana		0912713622	lideta	4	26	1686	residence	18/01/02	
121	Alem kelkle	0112780367		lideta	4	26	1694	residence	26/01/02	03/03/02
97	Marye Trefe		0910342319	lideta	4	26	1695	residence	18/12/01	21/12/01
194	Tiruwork Mengistu	011275514		lideta	4	26	1700	residence	25/12/01	
240	Ahimedin Muktar		0910135654	lideta	4	26	1721	residence	13/01/02	
208	Wondimu G/kidan	0112764353	0912286739	lideta	4	26	1748	residence	28/12/01	
241	Wbet Kassa	0112764254		lideta	4	26	1749	residence	12/01/02	
129	Melaku Gari	0112780473		lideta	4	26	1763	residence	17/02/02	20/03/02
98	Mewhiba Zumekan	0112755853	0911145190	lideta	4	26	1775	residence	24/11/01	
126	Rahel Abebe		0911071606	lideta	4	26	1783	residence	02/02/02	
180	Rahel Abebe	0112764527	0911863145	lideta	4	26	1783	residence	16/11/01	
128	Yilma Agonafir	0112764241		lideta	4	26	1791	residence	12/02/02	20/03/02
131	Musliya Halil	0112764603		lideta	4	26	1795	residence	18/02/02	18/03/02
167	Kedir Hassan		0911912459	lideta	4	26	1806	residence	01/12/01	
215	Geremew Feleke		0911058251	lideta	4	26	1820	residence	03/13/01	
196		0112755611	0911891206	lideta	4	26	1832	residence	25/12/01	
100	Fikadu Fikiremariam	0112764445	0911132707	lideta	4	26	1916	residence	07/12/01	
136	Beletu Feleke	0112780456		lideta	4	26	1928	residence	03/02/02	22/03/02
210	Surur Feris	0112751839	0911793403	lideta	4	26	1969	residence	28/12/01	
165	Semu Wakene		0911732534	lideta	4	26	1978	residence	21/03/02	
156	Tesfaye Kefyalew	0116541873	0910045292	lideta	4	26	2002	residence	02/03/02	
211	Tesfaye Kefyalew	0116541873		lideta	4	26	2002	residence	27/12/01	
171	Kassahun Kebede		0913613341	lideta	4	26	2009	residence	21/12/01	
228	Yeumer Iblun Hetab Mosque		0913375943	lideta	4	26	2060	commercial	03/02/02	
103	Gebiru Indeta	0112764002	0911455814	lideta	4	26	2062	residence	05/12/01	25/12/01
175	Gebru Indeta	0112764002	0911455814	lideta	4	26	2062	residence	05/12/01	
122	Demene Basha	0112763788	0910989451	lideta	4	26	2075	residence	09/02/02	18/03/02
133	Genanaw Alemu	0116545639	0911075974	lideta	4	26	2075	residence	16/02/02	21/03/02
144	Abonesh Tessema	0112137366		lideta	4	26	443/	residence	18/02/02	
61	Tsion Semanew	0112779330	0911190937	lideta	4	27	538/6	residence	16/02/02	13/03/02
125	Fikremariam Teshome	0112781770	0913072014	lideta	4	26	991/	residence	11/02/02	
146	Yeumar Ablin Woreda 4		0913375943	lideta	4	26		commercial		

Continued										
197	Omedla School	0112135189		lideta	4	26		commercial	08/01/02	
203	Tesfa Kokob School			lideta	4	26		commercial	28/01/02	

APPENDIXES-G: Detail cost analysis

Table 4.8 Detail cost analysis for the case of sewer line for Residential case

SEWER LINE CONNECTION FIXED COST RATE
CUST.NAM FOR RESIDENTIAL
CONNECTION TYPE
K/K KEBELE HOUSE NO

1	150mm PVC pipe	m	5	90.1	450.50
2	Clamp saddle 150*250	No.	1	282.35	282.35
3	Gasket 150mm	No.	1	17.57	17.57
4	Rubber Ring 150mm	No.	1	20.29	20.29
5	Lubricating paste	No.	0.5	163.64	81.82
6	**Total**				**832.24**
7	15% Sales Tax				124.84
8	Red ash	m^3	1.7	37.15	63.16
9	**Total**				**1020.23**
10	40%Technical cost				408.09
11	600mm Concrete manhole	No.	2	180	360.00
12	**Excavation work**				
13	Excavation of soil for the first 1.5m depth	m^3	4.2	9	37.80
14	Soft Rock excavation	m^3	4.2	34	142.80
15	Hard Rock excavation	m^3	4.2	60	252.00
16	Concrete work	m^3	1	300	300.00
17	Red ash placing and compacting	m^3	1.7	24	40.80
18	Back filling and compacting	m^3	10.7	5	53.50
19	Cart away of surplus material	m^3	2.45	12	29.40
20	Total				2392.62
21	15% Contingency				358.89
22	**Grand Total**				**2771.81 birr**

Table 4.9 Detail cost analysis for the case of sewer line for Commercial case

SEWER LINE CONNECTION FIXED COST RATE

CUST.NAME FOR COMMERCIAL

CONNECTION TYPE (MANHOLE)

K/K KEBELE HOUSE NO

ITEM NO.	WORK AND MATERIAL DESCRIBTION	Unit	Qty	Unit Price	Total cost
1	150mm PVC pipe	M	20	90.1	1802.00
2	Clamp saddle 150*200	No.		144.59	0.00
3	Clamp saddle 150*250	No.	1	282.35	282.35
4	Gasket 150mm	No.	1	17.57	17.57
5	Rubber Ring 150mm	No.	4	20.29	81.16
6	Lubricating paste	No.	1	163.64	163.64
7	**Total**				**2318.27**
8	15% Sales Tax				347.74
9	Red ash	m3	6.8	37.15	252.62
10	**Total**				**2918.63**
11	40%Technical cost				1167.45
12	600mm Concrete manhole	No.	1	180	180.00
13	**Excavation work**				
14	Excavation of soil for the first 1.5m depth	m3	16.8	9	151.20
15	Soft Rock excavation	m3	16.8	34	571.20
16	Hard Rock excavation	m3	16.8	60	1008.00
17	Concrete work	m3	1	300	300.00
18	Red ash placing and compacting	m3	6.8	24	163.20
19	Back filling and compacting	m3	43.2	5	216.00
20	Cart away of surplus material	m3	9.8	12	117.60
21	Total				5785.28
22	15% Contingency				867.79
23	Asphalt cutting	m2		374	
24	**Grand Total**				**6734.24 birr**