Hydraulic Performance Assessment of Urban Water Supply System: The Case of Batu Town, Ethiopia

Aleye Esak Boru

A Thesis Submitted to The
Department of Water Resources Engineering
School of Civil Engineering and Architecture

In Partial Fulfillment of the Requirement for the Degree of Master's in Water Resources Engineering (Specialization in Water Supply and Environmental Engineering)

Office of Graduate Studies
Adama Science and Technology University

May, 2023
Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled "Hydraulic Performance Assessment of Urban Water Supply System; the Case of Batu Town, Ethiopia" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through Citation.

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Name	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Hydraulic Performance Assessment of Urban Water Supply System; the Case of Batu Town, Ethiopia” prepared under my guidance by Aleye Esak Boru submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in Water Supply and Environmental Engineering.

Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Andinet Kebede (PhD)	______________________	_______________
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APPROVAL PAGE

I, the advisor of the thesis entitled "Hydraulic Performance Assessment of Urban Water Supply System; the Case of Batu Town, Ethiopia" and developed by Aleye Esak Boru, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Aleye Esak Boru have read and evaluated the thesis entitled "Hydraulic Performance Assessment of Urban Water Supply System; the Case of Batu Town, Ethiopia" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Water Supply and Environmental Engineering.

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ACRONYMS AND ABBREVIATIONS

ARV	Air Release Valve
AWWA	American Water Works Association
CSA	Central Statistical Agency of Ethiopia
DCI	Ductile Cast Iron
DEM	Digital Elevation Model
DN	Nominal Diameter
EPA	Environmental Protection Agency
EPS	Environmental Protection Agency
GI	Galvanized Iron
GIS	Geographical Information System
HC	House Connection
HDPE	High Density Polyethylene
IWA	International Water Association
Km	Kilo Meter
L/c/d	liter per capital per day
l/s	liters per second
MDF	Maximum Day Demand Factor
MoWE	Ministry of Water and Energy
MOWIE	Ministry of Water, Irrigation and Electricity
MOWR	Ministry of Water Resources
mwc	meter water column
NRW	Non- Revenue Water
OWRDB	Oromia Water Resource Development Bureau
PHF	Peak Hour Factor
PLC	Private Limited Company
PRV	Pressure Regulating Valve
PT	Public Tab
PVC	Polyvinyl Chloride Pipe
R^2	Correlation Coefficient
UFW	Unaccounted for Water
UNICEF	United Nation Child Fund
USA	United States of America

UTM	Universal Transverse Mercator
UWD	Unaccounted Water Demand
WDN	Water Distribution Network
WDS	Water Distribution System
WHO	World Health Organization
YC	Yard Connection
YSC	Yard Shared Connection

ABSTRACT.

In ensuring the supply of safe drinking water, the distribution system is as important as the water resources and treatment facilities. This study was initiates the objective of assessing the hydraulic performance of the water distribution network of Batu town by modeling and analyzing the existing water distribution system. Water CAD/GEMS software was used in evaluating the hydraulic performance of the water distribution system of Batu town. Steady- state and extended- period simulation analyses were carried out to determine hydraulic parameters such as pressure and velocity. Both primary and secondary data were collected and software such as water CAD V8i, AutoCAD ArcGIS version10.4, and others like Geographic positioning system were used. The Hydraulic performance of existing Batu water supply simulated result for steady-state analyses showed that 31% operated under15mwc, 10.5% with pressure > 60m, and the remaining 59% for pressure values 15-60m which is the optimum adopted pressure. 76% of distribution pipes have a velocity between 0.6- 2m/s, or 3% of the distribution system performs with an optimum velocity above 2m/s. For extended period simulation 25.76% is negative pressure,10.5%>60mwc which is greater than the maximum adopted pressure and this caused water losses in the system. Only 63.75% pressure in the adopted range 15-60m that the distribution hydraulic performs within the optimum adopted pressure. 52 pipes in the systems have a velocity > 2m/s and the remaining have a velocity between 0.60-2.0m/s during high demand time. The average per capita water consumption of Batu town in 2021 was 23.59 l/c/d which is much lower than 50 l/c/d. The hydraulic problem that arose in the system resulted from incorrect nodal placement and improper pipe connection during designing the system and when expanding the network to the newly settlement area. The potential of the projected water demand increment in Batu town is greater than the current supply potential of water sources. Batu town's water demand averagely increases by 26.1% every five years up to the year 2035. Finally, Poor hydraulic performance of the town should be improved by conducting elegant operation and maintenance, water quality test and leakage and water losses management.

Keywords: Water demand, *water distribution*, hydraulic performance, *CAD/GEMS,* Batu town

1. Introduction

1.1. Background

Safe drinking water is one of the necessities for human beings. However, today in the 21th century most people, especially those belonging to the third world do not have potable water for their household usage. More than one thousand million people in the world do not have access to clean drinking water (Ibrahim *et al*., 2014). The majorities of the population in developing countries are inadequately supplied with potable water and are thus bound to use water from sources that have a high potential for contamination and provide unsafe water for domestic and drinking purposes (WHO, 2011). In ensuring the supply of safe drinking water, the distribution system is as important as the water resources and treatment facilities.

Problems in providing satisfactory water supply to the rapidly growing population especially that of the developing countries is increasing from time to time. Water supply systems in urban areas are often unable to meet existing demands and are not available to everyone rather some consumers take disproportionate amounts of water and the poor is the first victim of the problem (Bereket, 2006). Moreover, managing and reducing losses of water at all levels of a distribution system remains one of the major challenges facing many water utilities in most developing countries including Ethiopia. As a result of the overall shortage of water many water utilities are facing a problem in distributing the available water impartially among the residents. Besides to this poor management of the existing infrastructural asset increases the level of water losses in the water supply (Mebet, 2007).

The water supply system is hydraulic transportation consisting of different fundamentals such as pipes, tanks, reservoirs, pumps, and valves. All of them are vital in supplying water of satisfactory quality with meticulous pressure. The distribution systems can either be looped or branched. Water is a crucial need to sustain living; every resident in the countryside has the right to access potable water. The provision of secure and sufficient water supply services is a necessary mechanism for sustainable development. The demand for supplies in developing countries has been on the rise over time because of rising standards of living that occur with economic progress and population increase resulting from natural growth, rural-urban migration, and rising per capita income (EPA., 2010).

The estimated water supply service level of Ethiopia in terms of coverage, quantity, quality and reliability is very low. A well-performing urban water supply system should provide water supply for human being and livestock consumption, for industrial and other uses in terms of coverage, quantity, reliability, and acceptable quality taking the existing and future realities of the city in to consideration. Analysis of a pipe network is essential to understand or assessing urban water distribution systems. The analysis of a looped network is carried out by using additional equations found from the fact that while traversing along a loop, as one reaches the starting node, the net head loss is zero (Sharma, 2008).

However, the town population is growing rapidly with the expansion of the town to pre-urban areas associated with demand-supply misbalance. Due to the burden on the water distribution system now, it is facing some problems. The main problem encountering the water supply service is frequent burst (break) of the main gravity distribution line that goes from O'itu to Batu Town. Moreover, there are gullies that cross the pipes and gully-crossing columns are usually collapsing which reveals a high water loss problem in the system. The analyses of pipe systems using models are a recent approach to evaluate the performance of water distribution networks. The Water CAD/GEMS software provide a required standard and economic environment for the design, analysis and troubleshooting of new and existing supply network with accuracy and minimum time duration. The software is also used for solving problems in the existing network and in the expansion of the existing water supply network (AWWA. (2005).

Therefore, this study assessed and evaluated the hydraulic performance of the Batu Town water supply system using Water CAD/GEMS and recommended solutions for improving the water supply service of the current source (Tufa Spring) not previous sources (Ziway Lake which is currently malfunctioning).

1.2. Statement of the Problem

Stipulation of clean water supply is one of the major factors that greatly contribute to the socioeconomic transformation of the town by improving the living standard and health and thereby increasing the productivity of the community. The main objective of water utilities is to deliver water of the required quantity to individual customers under sufficient pressure through a distribution network. Batu town is among the towns of Oromia that have fast socioeconomic development. There are residential, different governmental and non-governmental organizations, institutions and commercial activities within the town. One of the major challenges to the performance of the urban water supply system is the increase in demand due to the unexpected growth of population and urbanization of the town.

The distribution of water in distribution networks is challenging in providing a sufficient quantity of water. It is essential that the distribution network be supplied without an invariable flow of water complying with all the qualitative and quantitative parameters. The problem with the water supply in Batu town is not only the problem of the distribution system but also the age of the pipeline, which may affect the quality of water distributed (AYJEF, 2012).The water supply is intermittent that it is only available for a few hours per day and to a specific area of the town and pressure is irregular. Intermittent water supply, insufficient pressure and unpredictable service impose additional financial costs on Batu town dwellers. Thus, this study aims at analyzing Batu town's hydraulic performance.

1.3. Objectives

1.3.1 General objective

The overall purpose of this study was to improve the hydraulic performance of the existing water supply system of Batu town.

1.3.2 Specific objectives

To achieve the general objective, the following specific objectives are set as operational steps.

- To evaluate the existing water demand and forecasting future demand.
- Analysis of existing water distribution network for extended period simulation.
- To evaluate the hydraulic parameters of the existing distribution system.

1.4. Research Question

In line with the specific objectives, the research tries to get answers to the following research questions.

- What is the Hydraulic performance of Batu Town's water distribution system and how is the water supply system convenience and service consistency?
- What are the main factors that cause water loss in distribution networks of water supply system recognizable in Batu Town?
- Is the existing water supply satisfying current demand and future demand for the next decade?

1.5. Significance of the Study.

It is expected that the insufficiency of the water supply system, which includes the approximate of unaccounted water and causes for the high-water loss, is assessed and known, and water supply coverage and water quality level will be determined. Besides customer, satisfaction with the service and operation and maintenance condition will also be analyzed. The assessed and analyzed results and estimates were in turn contributed to know the overall hydraulic performance level of the system. Besides the result help decision makers and especially the town water utility (water supply service office) in the planning of future expansions and to know areas of water loss and develop corrective measures to reduce the high water loss, improve coverage, service, and reliability and water quality so as to make the system more efficient and increase water supply service level. It may also give a clue for further research.

1.6. Delimitations and Limitations of the Study

This study work was limited to assess the hydraulic performance of the water distribution network of Batu Town water supply system in the Eastern Oromia region of Ethiopia and it mainly focuses on and will assess to identify the hydraulic performance and the factors for intermittent supply, water loss, and leakage management strategy of the town water distribution system with respect to operation and maintenance practice. This will be achieved with hydraulic modeling (Water CAD/GEMS software), water loss analysis, and by made of discussion with the town water utility personnel to gather relevant information on the subject area. However, due to a lack of enough budgets, water quality analysis in the distribution system, detail sources evaluation and model calibration and validation was not carriedout.

2. LITERATURE REVIEW

2.1 Urban Water Supply and Demand

Safe drinking water is the birthright of all humankind as much a birthright as clean air, while access to clean water can consider as one of the basic needs and rights of a human being. The health of people and dignified life is based on access to clean water (Swamee and Sharma, 2008).

Water demand is defined as the volume of water quested by users to satisfy their needs. In another way, it is often considered equal to water consumption, although conceptually the two terms do not have the same meaning (H. R., 2003). In most developing countries, the theoretical water demand considerably exceeds the actual consumptive water use. Urban water demand is classified in to different categories: the domestic water demand that includes in-house use and out of-house use is among the others. Urban water demand is usually quoted in terms of a liter per capita per day (l/cap/day). In many African towns, urban water demands are often non-homogeneous (Desselegn, 2015).

2.2 Water Distribution System

The distribution system can be categorized into gravity type and pump boosting type, depending on the height relationship between the service reservoir and the distribution area. A water network system is created or expanded to supply a sufficient volume of water at adequate pressure from the supply source to consumers for domestic, irrigation, industrial, fire-fighting, and sanitary purposes. Pipe failure in water distribution systems disrupts the water supply to consumers and reduces the reliability of the system. It has been found that about 35% to 60% of the supplied volume is wasted due to pipe leakages (Gregory, 2002). Therefore, inspection, control and planned maintenance and rehabilitation programs are necessary to properly operate existing water distribution systems.

2.2.1 Types of urban water demand

It is common to categorize water demand in various sorts depending on the characteristics of the consumers. The most common types are domestic, commercial, industrial, firefighting and unaccounted water demand (MoWR, 2006).

2.2.2. Domestic water demand

Domestic water demand includes the water required in the private building for drinking, cooking, bathing, flushing and washing clothes (WHO, 2000). Domestic water consumption varies according to the living standard of consumers' economic status of the community, climatic conditions, mode of service, affordability and accessibility of service. Daily per capita, water consumption in Ethiopia is generally very low throughout the country. Actual water demand is expected to be greater than present consumption if greater supplies were available to the community (MoWE, 2011).

2.3 Urban Water Demand and Coverage

Water delivery coverage presents a mirror of the water delivery scenario of one particular country or city and helps to examine one united states of America with others and the inter and intra-metropolis distribution with-in the specific USA chances of the population without or with pipe water connection are an applicable indicator to compare the insurance of water supply in urban areas. Even though the water delivery coverage is better in city areas at the same time as compared with the rural, the actual water delivery insurance in cities of growing countries in popular and African towns especially is very low at the same time as in comparison to the demand. in keeping with the worldwide Water deliver and Sanitation evaluation 2000 document, the African largest towns are having forty three% house connection or yard tap, 21 % are served by means of public tap while 31% of the population are un-served (WHO, 2000).

A household is considered to have to get admission to advanced ingesting water if it has a sufficient amount of water (201iters/character/day) for its own family use, at a less expensive price (much less than 10% of the total household profits). However, a minimal amount of 25 liters of potable water in line with character according to day furnished at a minimum drift rate of now not less than 10 liters consistent with minute with the supply being to be had inside (NRC, 2006).

According to Bhadbhade (2009), two hundred meters from a household and the delivery not interrupted for extra than seven days consistent with a year (i.e. water must be available ninety-eight% of the time) is considered a fundamental service for southern African cities" domestic water supply). Ethiopia has long been characterized with the aid of limited get entry to secure drinking water services. In 1990, as an example, the handiest 19 percent of the population of the use had to get the right of entry to a secure consuming water delivery.

2.4 Water Demand Management

The demand-side management of both energy and water has recently attracted much attention. In particular, smart meters have facilitated the availability of detailed water usage data for users Many studies have examined the potential for encouraging energy- and water-saving behaviors by sharing the household's data, as well as peer usage data. This strategy of providing usage feedback via social comparison is more effective in changing water usage behaviors than educational or awareness campaigns (Kruszynski and Dawidowicz, 2020).

Water demand is the quantity of water asked by customers to satisfy their desires. In a simplified way it's far often considered same to water consumption, despite the fact that conceptually the two terms do no longer have the identical meaning (H. R., 2003). According to Bhadbhade, (2009), in most developing countries, the theoretical water call for appreciably exceeds the real consumptive water use. Water call for control refers to any socially beneficial motion that reduces common or height water withdrawals or consumption form surface and floor water, regular with the protection or enhancement of water excellent. Water demand management is the version and implementation of an approach via a water group to steer the water call for and usage so that you can meet any of the subsequent targets, financial efficiency, social development, and social equity. City water call for is classified in to special class that home water demand that includes in house use and out-of-house-use is most of the others. In-residence-use includes needs for drinking, cooking, sanitation, residence cleaning, laundry and vehicle washing at the same time as out-of-house-use consists of like garden watering, swimming pools, public stand pipes for public uses and fountains, etc. urban water call for is usually quoted in phrases of liter in line with capita in keeping with day (1/cap/day). regardless of the version in residential indoor water use from household to family, an ordinary sample (called the water use profile) can be developed to offer an inexpensive illustration of indoor water use, based at the unique indoor water use components (kitchen, rest room, laundry, and bathroom) and household occupancy.

2.5 Water Losses in Distribution System

Water utilities worldwide lost 128 billion cubic meters annually, causing annual monetary losses estimated at USD 40 billion. Most of these losses occur in developing countries (74%). This calls for rethinking the challenges facing water utilities in developing countries, foremost of which is the assessment of water losses in intermittent supply networks (Lambert. 2002). Water losses occur in all water distribution networks, even new one and it is simplest the volume that varies. Thereby, the quantity of those losses reflects the capacity of water authorities to manipulate their distribution networks (Motiee et al., 2007). The are many factors contributing to water losses in water distribution system ,such as ageing infrastructure, high pressure, external and internal pipeline corrosion, service tank overflows, poorly designed and constructed WDSs metering errors illegal use and poor operation and maintenance practices (Sharma, 2008). The water losses in the distribution system vary widely between different countries, regions and system from as low as 3-7% to as high as 50% of distribution input volume in the well maintained system developed countries and less maintained system in developing countries respectively (Lambert, 2002).

In standard, water losses consist of actual and obvious losses. In addition, to maximum water utilities, the extent of Non-revenue Water (NRW) is a key overall performance indicator of efficiency. Software managers should use the water stability to calculate each element and determine where water losses are happening. by means of quantifying NRW from the water stability concept, volumes of lost water into machine may be calculate and they'll then prioritize and put into effect the specified policy modifications and operational practices which result in the right understood and take the required actions (Farley et al., 2008). According to Lambert, (2002) the water balance can guides water loss estimation inside the distribution device at the same time as additionally indicating the level of accuracy of the Non- revenue Water calculation. A high level of real losses reduces the amount of precious water reaching customers, increase the operating costs of the utility and makes capital investment in new resource schemes larger. Reducing water losses are a special concern of every water supply utility

2.5.1 Component of water losses

According to Babić (2011) water losses have two main components: apparent losses and real losses. Real losses consist of water lost through burst pipes, leaking joints, fittings, service pipes, and connections, whereas apparent losses result from illegal connections, under-registration of customers‟ meters inaccurate meters, by passing meters, billing errors, inadequate meter reading policy, bribery and corruption of meter readers. Real losses increase the water utility production costs and water resource since they represent water that is extracted and treated but never reaches beneficial use. It is recommended as a standard practice to split water losses into real and apparent losses when studding water losses (McKenzie and Seago 2005).

2.5.2 Apparent losses

Apparent losses are commercial losses which are from an improper recording of total water consumed due to meter errors, inaccurate assumption of unmeasured and unauthorized consumption and these deficiencies is attributed to administrative inefficiencies of the water utility (Motiee et al., 2007).

According to Lambert and Hirner (2000), these losses occur as a result of errors in water flow measurement, errors in water accounting and unauthorized use or theft. Assessment of apparent losses has a direct impact of real losses and therefore it is important to pay attention to both components of water loss.

According to Seago et al. (2004), apparent losses recommended limit was 20% of the total water losses from the water distribution system in South Africa. On the other hand, according to Lambert and Taylor (2010) the amount of apparent losses from the water distribution system was 30 to 40% of the total losses.

2.5.3 Real losses

Real losses are “the annual volumes lost from transmission and distribution system through all types of leaks, bursts and overflows on mains, service reservoirs and service connections up to the point of customer metering”. Real losses are attributed to varying pressure, inefficient leak detection system, poor workmanship and maintenance of the distribution network (Sharma, 2008). According to Tabesh and Asadiani (2005), real losses are categorized as water losses from reported and unreported bursts, background losses, reservoir leakage and overflow and leakage from connections.

2.5.4 Causes of water losses

Leakage is commonly the essential factor of water loss in developed international locations; however this isn't always usually the case in developing or partially evolved nations, in which unlawful connections, meter blunders, or an accounting blunders are frequently greater enormous (Motiee et al., 2007). The other additives of overall water loss are non-physical losses, example meter below registration, unlawful connections and illegal and unknown use (WHO, 2001).

According to Tabesh and Asadiani Y (2005), there are many factors contributing to water losses in water distribution system, such as ageing of infrastructure, high pressure, and external and internal pipeline corrosion, service reservoir over flow, poorly designed and constructed, WDS metering errors and poor operational and maintenance practice.

2.5.5 Causes of real losses

Real losses are water volumes lost within a given period through all types of leaks bursts and overflows. It can be classified according to their location within the system and their size and runtime (Fallis et al., 2011). Leakage from transmission and distribution mains may occur at pipes, joints and valves (McKenzie and Seago, 2005). According to McKenzie and Seago (2005), real losses from transmission and distribution mains have short to medium run times because of it repaired within the shortest time possible. Leakage from service connections up to the point of consumer and on storage tanks is difficult to detect due to their comparatively low flow rates and often have long run times.

2.5.6 Cause of apparent losses

Apparent losses are caused by different factors, such as metering inaccuracies due to broken or incorrect customers and bulk water meters, data handling and accounting errors and poor customer accountabilities in billing systems and unauthorized consumption due to water theft and illegal connections (Xin et al., 2014). Apparent loss may consider as all water that was successfully delivered to the consumer but which is not metered or recorded correctly and these causes an error of consumer consumption (Lambert and Taylor, 2010).

2.5.7 Effects of non-revenue water

The main concern of NRW is the physical loss of water after a huge investment involved in the whole process of withdrawing the water, treatment and delivery to the distribution network in addition to the revenue loss (Sastry, 2006). This is also supported by Fallis et al., (2011) who classify water lost on its way to consumers as an economic cost as the lost amount of water must be provided again and technically the production capacities of installations must be increased. This is a huge financial burden on the water utilities, in light of the increasing financial scarcity (Frauendorfer and Lierberger, 2010). Real losses have also been identified as a route of contamination in the water distribution systems.

2.5.8 Unaccounted for water (UFW)

Considering the crisis of water supply issues in large cities owing to increases in population, quantifying the UFW in terms of both physical and non-physical losses of water in the network to improve the system efficiency represents an important issue that managers need to consider. A pilot site is used to demonstrate the methodology, including the spectrum of network data for spatial and attributed data stored in a GIS database. Via use of an interface extension tool, the data were transformed into the water Cad model. After hydraulic simulation using mathematical formulae, leakage discharges from the network are quantified and the results provide estimates of the percentage of physical UFW, allowing comparison with the modeling and the measurements of total UFW in the network Physical losses in the pilot site area are determined to be 13% and the non-physical losses (e.g. under-registering of metered amounts) as 19.7%, for a total of 32.7% of the total water supplied. There is no universally implemented or popular definition of unaccounted for water. In popular, UFW is the difference between the water provided to a distribution gadget and the water that leaves the device through its meant use. The UFW may be described as percentage of the water made from the raw water source, which is no longer accounted for. UFW is defined as the distinction among water introduced to the distribution machine and water bought (Yepes., 1995).

The term UFW refers to a gathered range of losses so that it will be skilled with the aid of Water software while evaluating the gadget call for of a hydraulic water network with the quantity of water this is stated as ate up through the water clients dwelling within the network (UNEP, 2000).

2.5.9 The benefits of reducing non-revenue water

Quantifying the water losses items of both physical and non-physical water losses in the network were to improve the system efficiency represents an important issue that managers need to consider (Motiee et al.,, 2007).Water loss reduction should be the aim of every water utilities since it leads to improved economic and ecological efficiency and better service for customers (Fallis et al., 2011). The reduction of apparent losses was increased income for the water utility. Water loss reduction also results in an extended life span of pumps and equipment due to reducing pumping. Reduction of water loss results in the need for less water production, translating into cost savings in operation and maintenance (McKenzie and Seago, 2005).

2.5.10 Water losses evaluation

In a developed country water losses have been assessed before and after leakage detection surveying by two different approaches; which are top-down annual water balance and bottom-up approach based on minimum night flow analysis . In developing countries mostly top-down water losses auditing was conducted as per the guide-line suggested by IWA. Due to lack of accurate input data and advanced technology and equipment, it is very difficult to detect real losses in the distribution system as a result; separation of water loss into real and apparent loss was a big challenge for strategic planning (Dighade et al., 2014).

2.5.11 Strategy for water loss management in developing countries

A problem solving approach was implemented for water loss management, which is practicable and achievable, can be applied to any water distribution system in developing countries (EPA, 2010). The key developing strategy for management of water loss is to gain a better understanding of the reason for water loss and the factors which influence its component (Makaya and Hensel, 2015). According to Makaya and Hensel (2015).There are different components to effective management water loss strategy:-

- Water auditing
- Intervention
- Upgrading the Network
- Evaluation

Water auditing

Water auditing determines the amount of water lost from a water distribution system due to leakage and other reasons. To a quantify water lost from water distribution systems, water utilities should undertake water auditing where the total water supplied was compared with the amount of water billed (Lambert, 2001)

Intervention

The intervention process puts the options selected in to action. More than one action selected was beneficial to water utilities. Selecting the order of these actions should be based on budget constraint, public benefits and priority of other scheduled capital improvements (EPA, 2010).Intervention include:-

- Gathering future information
- Metering assessment, testing or meter replacement program
- Detecting and locating leaks
- Repairing or replacing pipe
- Operational and maintenance program
- Administrative processes or policy changes

Evaluation

Evaluation is necessary to ensure that whatever the intervention was, it succeeded in its goal (Liemberger et al.,2007). The major portion of the evaluation was benchmarking (EPA, 2010).

2.6 Hydraulic Modeling for Distribution Network Aassessments

Hydraulic analysis of water distribution networks is an important problem in civil engineering. A widely used approach in steady-state analysis of water distribution networks is the global gradient algorithm (GGA). However, when the GGA is applied to solve these networks, zero flows cause a computation failure. On the other hand, there are different mathematical formulations for hydraulic analysis under pressure-driven demand and leakage simulation (Frauendorfer and Liemberger, 2010). According to Frauendorfer and Liemberger (2010), this paper introduces an optimization model for the hydraulic analysis of water distribution networks using a met heuristic method called shuffled complex evolution (SCE) algorithm. In this method, applying if-then rules in the optimization model is a simple way in handling pressure-driven demand and leakage simulation, and there is no need for an initial solution vector which must be chosen carefully in many other procedures if numerical convergence is to be achieved. The overall results indicate that the proposed method has the capability of handling various pipe networks problems without changing in model or mathematical formulation. Application of SCE in optimization model can lead to accurate solutions in pipes with zero flows. Finally, it can be concluded that the proposed method is a suitable alternative optimizer challenging other methods especially in terms of accuracy.

Water utilities are going through the high level of water loss of their distribution networks. For many utilities, reducing loss ought to be the primary option to pursue when addressing low carrier coverage levels and improved call for piped water deliver. However, expanding water distribution networks without addressing water losses will only cause a cycle of waste and inefficiency. but, there is no easy strategy to lessen water losses in the distribution system in particular inside the growing world, it have to be regarding improvements not best regard to the water device, but also required a alternate in attitudes .Further expertise how leakages are currently acting on components of water distribution network (Hussni and Zyoud, 2003).

Follow the overall topology and alignment of the town streets. Exceptional fittings consisting of elbows, tees, reducers, crosses and numerous other add-ons are used in the principle to attach pipes. Even as different renovation and operational appurtenances, including hearth hydrants and valves are also related directly to the distribution mains. In addition, offerings additionally referred to as carrier line had been laid and transmit water from the distribution mains to quit clients (Bhadbhade, 2009).

To meet the fluctuations of water demand and to stabilize stress within the distribution budget. Similarly, those components were reserve water for emergency requirements. consequently, the not unusual reservoirs hooked up in the water deliver machine are round and/or rectangular kind which builds either from concrete or steel substances. In addition, the advocated region of such centers is particularly in extended location beyond the middle of provider region (NRC, 2006).

2.6.1 Factors causing lack of hydraulic integrity in water distribution community

In maximum of the growing regions, the design of water distribution systems is primarily based on the idea of direct supply, despite the fact that most of these structures are intermittent systems which bring about extreme supply, inadequate pressure within the distribution gadget (strain losses in several regions in the community), inequitable distribution of the to be had water and really quick period of deliver (Bhadbhade, 2009).

Excessive stress throughout low demand conditions can purpose pipe bursting, leakage and massive quantity of water losses via the distribution networks. Therefore, whilst handling high pressures, PRVs should be used to reduce and adjust strain in the device (Tomas, 2003). Accordingly, pipes and pumps have to be sized to overcome those problem and to offer suitable strain within the devices. Although, sizing of control valves primarily based at the desired drift situations and strain differential is vital (NRC, 2006).

2.6.2 Basic concepts of hydraulic modeling

Hydraulic modeling is a form of physical modeling used to investigate design and operation issues in hydraulic engineering. It entails the use of a scaled model for replicating flow and fluid-transport processes in diverse natural flow systems and for evaluating the performance of hydraulic structures and hydraulic machines. An advantage of hydraulic model is its potential capacity to replicate many features of a complicated flow situation. The manual is intended to be a useful reference for the hydraulic engineering conducting a hydraulic model study and for the sponsor or client of a hydraulic model study wishing to become conversant with the concepts supporting model design and operation (Robert, 2000).

According to Jalal (2008), the principle reason for modeling a system is to assist designers, managers and planners to discover the governing legal guidelines of such structures and to correctly analyze their conduct. Hence, models are hired to resolve issues in machine's layout and operation. Model-based simulation is a technique for mathematically approximating the conduct of real water distribution structures. To effectively make use of the capabilities of distribution system simulation software program and interpret the consequences produced, the modeler should recognize the mathematical standards involved.

2.7 Water Distribution Simulation

The term model classically refers to the method of imitating the carry out of device via the capabilities of any other. It can be used to predict device responses to occasions beneath a wide range of situations without disrupting the real device. The usage of simulations, troubles can be expected in proposed or present structures, and can be evaluated earlier than time, money, and materials are invested in a real-global task (Tomas, 2003).

According to Tomas (2003), in water distribution networks the maximum basic kind of model simulations are both constant state and extended period simulation. Constant state simulations represent a particular view of factor in time and are used to decide the working behavior of a machine under static conditions. It compute the hydraulic parameters along with flows, pressures, pump working traits, and others with the aid of assuming that needs and boundary conditions were not trade with admire to time. In popular, this kind of evaluation is used to determining the quick-term impact of demand conditions at the system.

2.8. Modeling with Water CAD/GEMS

Water CAD gives and permitting modeling practically for any distribution device issue. Consequently, operating with Water CAD used as for decision-help tool for water infrastructures and were assisting to evaluate and/or perform (Dawe, 2000).

According to Dawe, (2000) the hydraulic evaluation at a regular country or an extended length simulation, stress, glide and needs within the device and to see how behaves through the years, the scale of pipes, pump and laptop device head curves, tank, pump and valve conduct within the machine, leakage and water loss from the network, calibration the model both manually or use the Darwin Calibrator strategies and, generate completely customizable in graphs, charts and reviews form.In practice, pipe networks consist not handiest of pipes, however composed of range fittings, services, storage tanks and reservoirs, meters, regulating valves, pumps, and electronic and mechanical controls. For modeling purposes, these machine's factors were organized into the following categories.

For many experts, water GEMS V8i more than an evolution of water CAD is essentially a super (which is already included in water CAD), adds seamless integration with GIS environments and includes in a single commercial version all the advanced analysis modules which can only acquires separately in water CAD. In this sense, it is software whose target user is the company that operates supplies, regulators and / or important consulting projects.

In terms of basic and intermediate tasks Hydraulic Modeling, water CAD and Water GEMS are similar products (in fact share the same engine hydraulic calculation) and the same structure data model, so a model created in water CAD can be read in water GEMS V8i and vice versa. While water CAD, supports an autonomous platform (Stand Alone) and Micro Station and AutoCAD (as an addition to the product). Water GEMS V8i adds support for ArcGIS to previous environments. In recent years, the software has had a great evolution especially in features such as interoperability, ease of use, productivity tools, connection to external data; consultation processes multi-criteria, operations of spatial analysis, graphics capabilities, integration with Systems Geographic information (GIS), etc. (Tomas, et al., 2003)

Integration with Analysis of Hydraulic performance, water GEMS V8i is a hydraulic modeling application for water distribution systems with advanced interoperability, geospatial model building, optimization, and asset management tools. From fire flow and constituent concentration analyses, to energy consumption and capital cost management. Water GEMS V8i provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems. Water GEMS V8i is a multi-platform hydraulic and water quality modeling solution for water distribution systems with advanced interoperability, geospatial model building, optimization, and asset management tools. From fire flow and constituent concentration analyses, to energy consumption and capital cost management, water GEMS V8i provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems. water GEMS V8i is useful for managing the water system data, time-series hydraulic result, current and future scenarios and other core infrastructure data all within the same GIS environment (Calvin et al., 1996).

2.9 Water Demand Modeling

The principal query in the layout and operation of Water Distribution Network is how awful lot water is needed. The solution to this question is difficult because the required water is a function of various factors. Even though numbers of the factors are completely unbiased and time various. Therefore, water call for modeling is one of the most vital demanding situations inside the layout of Water Distribution Network, because it displays the modifications in population, weather, land use, the range of carrier connections and client lifestyles (Jalal, 2008).

2.9.1 Deterministic water demand

The actual water demand for all customers is envisioned based on expected water consumption over the provider time. One easy approach for deterministic water call for is estimating individual wishes based totally on type of customers and their sports and ultimately including these result in general water call for as an example, the water call for can be estimated on the premise of consistent with capita demand in small city regions (Jalal, 2008)

2.9.2 Stochastic demand forecasting

This approach generally considers and adopts the uncertain fluctuations on demand through the years and vicinity spans. Risks and sensitivity of forecasts such as the outcome of total lack of deliver and the impact of variations in fees profits should be considered and blanketed. hence, demand estimation based on historical consumption in line with person class (home, business/industrial) and predicted modifications (growing or lowering) in consumer class over the forecasting duration is correct instance of stochastic demand for forecasting (Jalal, 2008).

The reliable with capita call for of a particular metropolitan area is the average spending of water for 12 months. In practice it has been noticeable that this demand does not remain homogeneous at some stage in the year, however it numerous from season to season, even hour to hour (Venkateswara, 2005).

Seasonal version: Water demand varies from season to season. In dry season the water demand is most due to the fact the people will use greater water for bathing, cooling, garden watering and street sprinkling. Whilst, call for will becomes minimum in wet/wet season due to the fact less water is utilized in bathing and there is no garden watering. Consequently, „maximum day water demand is taken into consideration to meet water consumption changes with seasons and it used to length supply, treatment plant and growing mains. Subsequently, maximum day needs can be obtained by way of multiplying the common-day needs to the peaking aspect applied to the node‟ (Venkateswara, 2005).

This alteration specially relies upon on the general behavior of human beings, climatic situations and individual of town as business, commercial or residential. Greater water call for is on Sundays and vacations due to greater at ease bathing, washing and so forth compared to other operating days. Hence, average each day water demand for is the sum of the domestic, non-domestic and NRW that is used to estimate the maximum day and the peak hour call for (Venkateswara, 2005). It expressed as financial calculations over the projects lifetime.

Hourly variant: In most growing international locations the most hour water call for is happen throughout morning and night time over 24 hour, because in these time the general public use water for bathing, washing and cooking cause. Consequently, height hour demand is the maximum demand of anyone hour over the most day. In addition, it represents the hourly variations in water demand because of the behavioral patterns of the neighborhood populace (Venkateswara, 2005). Hence, the height hour is computed following Eq. (2.1).

$$Qp = PF * Qa \text{ --- } (2.1)$$

where, Qp is height hour call for (m^3/s), PF is peaking element between maximum hour and average day demand (m^3/s) and Qa is average day demand (m^3/s)

2.10 Calibration and Validation of Modeling

Adaptation calibration is the method of improvement a version until it simulates subject situations for a accurate time possibility to a longtime qualification of accuracy. Exceptional tuning consists of making minor changes to the input records to reap the favored output information (Bhadbhade, 2009). Therefore, version will not be hundred percent correct and to be calibrating it should be accurately simulate the observed facts. In order that, calibration is a primary portion of modeling procedure and proper calibration had been done through accurate discipline records. In addition and in consistent with Tomas, (2003), hydraulic version calibration is the vital procedure of modeling and the miles calibrated with the goal to have better self-belief, awareness and identifying errors made in the course of the version-constructing method.

2.11 Operation and Protection

Proper operation and maintenance are indispensable to ensure that capital investments on new infrastructure result in sustainable service provision. Without it, a new water distribution system will soon decline to a point where service provision is compromised, leading to greater water losses, financial losses and health risks to consumers. If operation and maintenance are neglected for long enough, it may become necessary to replace the system, requiring a new injection capital that could otherwise be used for other needs or stimulating economic development. The purpose of a water distribution system is to provide an adequate and reliable supply of safe water to its users. Operation and maintenance are those activities needed to continuously fulfill this purpose. As in step with manual on operation and renovation of water delivery systems, world health business enterprise, January 2005, in an engineering experience, operation refers to hourly and day by day operations of the components of a device such as plant, equipment and system (valves and so forth.) that is accomplished by means of an operator or his assistant. This is a habitual painting. The time period upkeep is defined because the art of maintaining the plant, equipment, structures and other related centers in most appropriate operating order. Maintenance consists of preventive maintenance or corrective renovation, mechanical adjustments, repairs and corrective action and planned maintenance. Frequently maintenance, replacements and corrections of defects (of cloth or workmanship) are taken into consideration as movements excluded from preventive protection. In some companies the regular actions taken by operation team of workers are considered as upkeep activities whereas a separate unit or cell does upkeep and replacements. Often each corrective and preventives are blanketed in the activity functions of operators and boundaries to which operators are expected to do everyday preservation are set forth for diverse system (Venkateswara, 2005).

According to Venkateswara (2005), Budgetary provisions of operation and maintenance organizations additionally include heads of expenditure underneath maintenance for value of spare parts and cost of exertions or agreement amount for maintenance and replacements and the goal of an efficient operation and upkeep of a Water delivery system is to provide secure and easy drinking water in good enough amount and desired first-rate, at ok stress at handy vicinity and time and as economically as possible on a sustainable foundation. In engineering parlance, operation refers to well-timed and each day operation of the components of a Water supply gadget consisting of headwork, remedy plant, equipment and gadget, conveying mains, carrier reservoirs and distribution gadget and many others. Correctly, by means of numerous technical personnel, that is a routine feature.

The term renovation is described because the art of keeping the structures, flowers, equipment and device and other facilities in a most useful running order. Renovation consists of preventive renovation or corrective upkeep, mechanical adjustments, upkeep, corrective movement and deliberate maintenance. However, replacements, correction of defects and so on are taken into consideration as movements excluded from preventive preservation. On this have a look at the prevailing operation and renovation exercise of Batu city water deliver device is assessed and pointers are given to enhance the operation and preservation exercise. Besides as said earlier than there may be very excessive water loss in water supply system and this could additionally be decreased through enhancing the operation and protection system (Bhadbhade, 2009).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

Batu, formerly known as Zeway town, is located at 7°56' N Latitude and 38°42' E Longitude, at an average altitude of 1657 masl. It is the capital City administration of Adami Tullu Jiddo Kombolcha (ATJK) district which is located on the western shore of the lake Zeway, Oromia Regional State along the main road from Addis-Hawasa, about 160 km south of Addis Ababa (Fig. 3-1). As per the hydro-metrological data, Batu is one of the regions in the country with potentially low rainfall throughout the year.

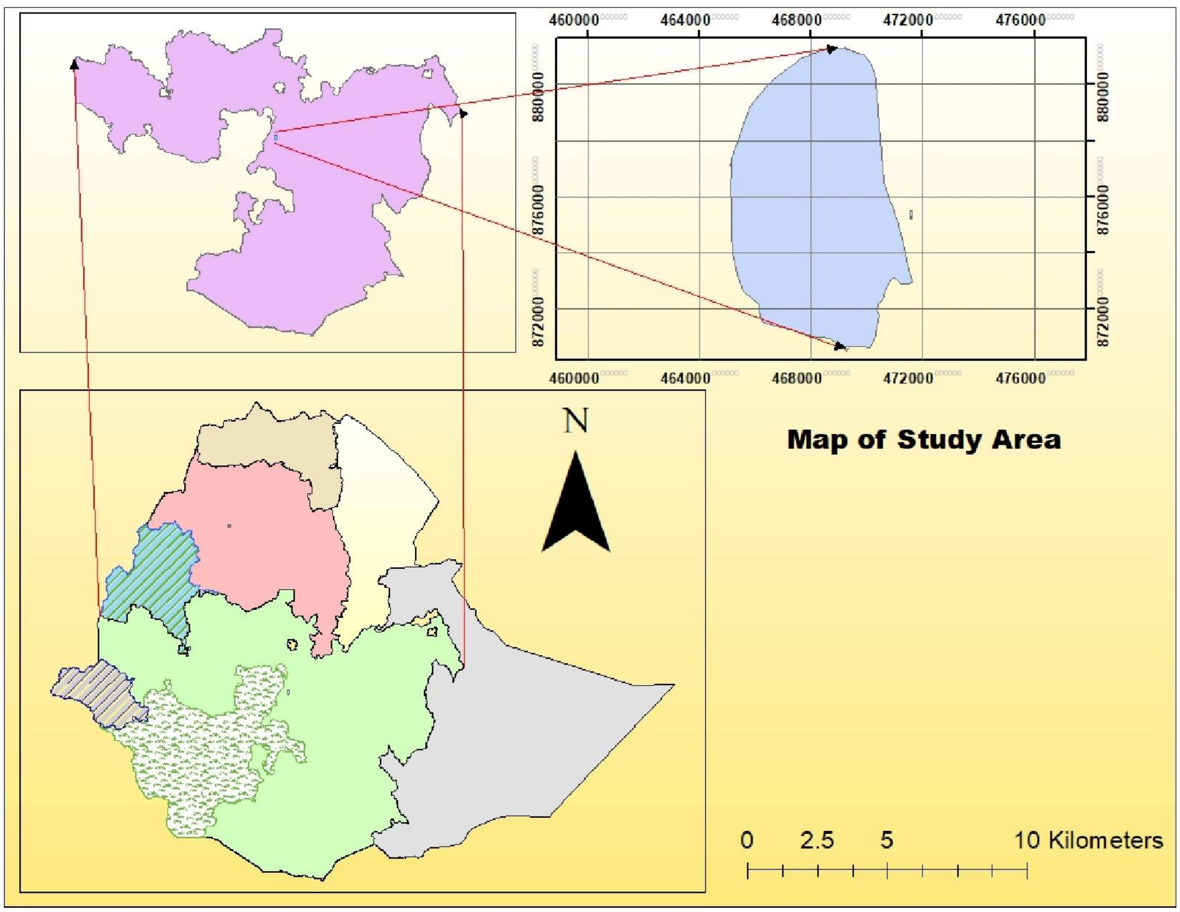

Figure 3- 1 Map of the study area

According to the Batu Town water supply design report, the existing classified land use and land cover of Batu town are indicated in the Figure (3-2).

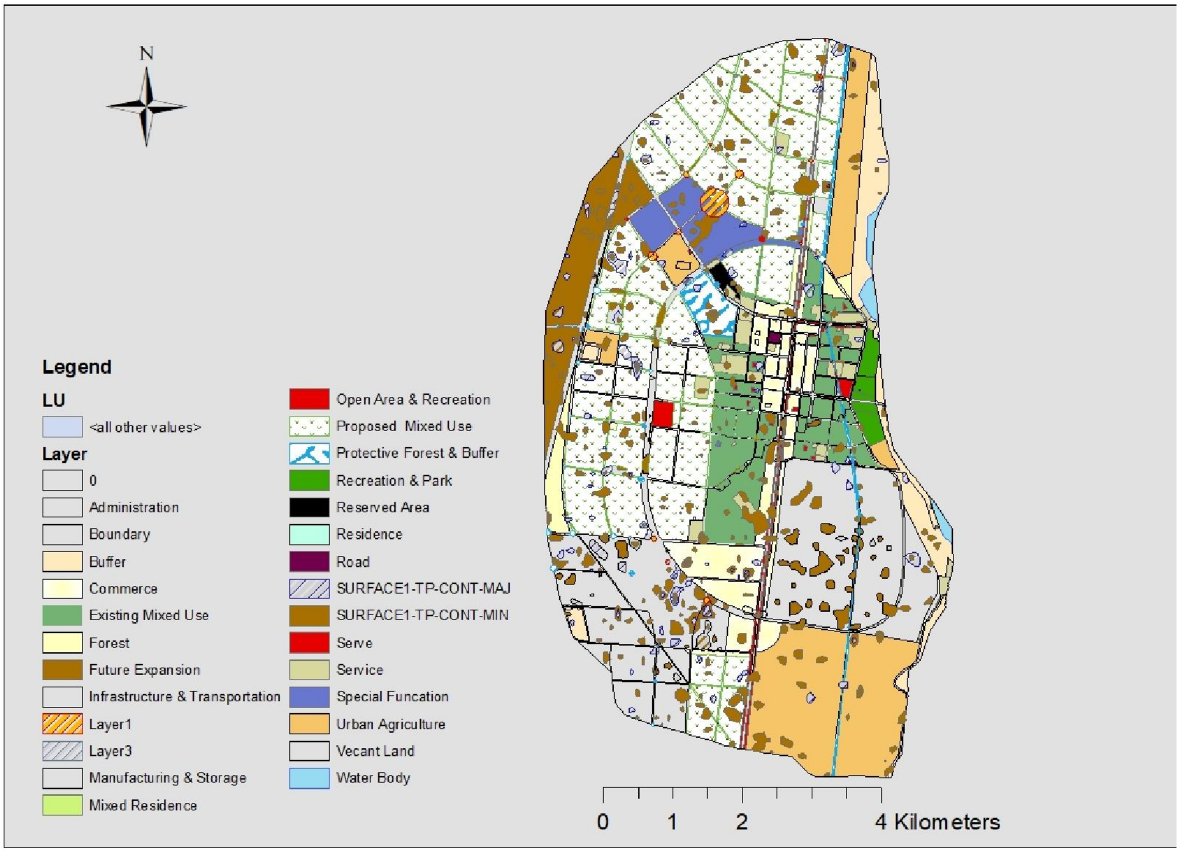

Figure 3-2 Existing land uses of Batu

Batu town is found in the Main Ethiopian Rift Valley basin. The formation of the Rift Valley has separated the Ethiopian Highlands and Lowlands in to two. Because of its altitudinal variation and positional differences, the climate also varies from warm, hot and dry to cool and moderately moist conditions.

Batu town is one of the dynamic areas of Oromia that is experiencing a high degree of urbanization and fast development. It is one of the areas that have changed from a mere rural locality to a big and modern developing urban center in a very short period (Fig. 3-2). Its proximity to Addis Ababa coupled with its merger with the neighboring small towns of Abosa and Adami Tulu and a rural village has made the town more prominent. Batu town has undergone a high rate of expansion in terms of area coverage and population growth. Future demand projection in turn depends on forecasting the expected future population based on statistical models considering possible potential variations and appropriate adjustments to reflect possible future changes. It is observed that currently Batu town hosts the development of different infrastructures, industries and housing projects owned by government and private investors. It is apparent that the development has a direct bearing on the water consumption of the town and hence, every determining factor has been considered in light of their effects on the water demand of the town.

3.2 Materials

To conduct the research the following materials were used for data collection, processing and evaluation:-

- ❖ Water GEMS\ CAD8i software to determine velocity, nodal pressure, and other parameters
- ❖ Arc GIS for delineation of the study area,
- ❖ GPS to check coordinates points of reservoir and sources of water supply
- ❖ Global Mapper and Google Earth to check the elevation of the network,
- ❖ End note, is automatically formatted in text-citation that is used as a personal database to gather and store citation records from different information sources.
- ❖ Water meter: to measure the flow of water in the pipe,
- ❖ Pressure gage: to measure the pressure at the nodes and pump outlet
- ❖ DEM, calculator, and AutoCAD 2007

While measuring pressure, the Global Positioning System (GPS) is used to determine the x, y, and elevation of the node. A pressure-measuring device is also employed to measure nodal pressure for model calibration. WaterGEMS provides a comprehensive yet easy-to-use decision-support tool for water distribution networks. The software helps to know how infrastructure behaves as a system, how it reacts to operational strategies, and how it should grow as population and demands increase. From fire flow and water quality simulations; to criticality and energy cost analysis. The WaterGEMS has a flexible multiplatform environment and provides numerous software capabilities for intelligent planning for system reliability and optimized operations for system efficiency. Water GEMS was chosen for this investigation because it has less graphical user interferences and is compatible AutoCAD and

ArcGIS. ArcGIS was also employed in this study to prepare pipe network and junction shape files with attribute tables.

3.3 Data Collection, Preparation and Analysis

There are two kinds of data used as input for the analysis and simulation of a water supply network. They are primary and secondary data. Primary data collection was done through direct measurement of nodes and link on the field is one of the important requirements to simulate the hydraulic characteristics of water in the distribution system. Node elevation data were collected from the town water service office, as well as from the site during the study. During the pressure measurement, the GPS was used to get the elevation data. The secondary data encompass pipe material, pipe length; scanned pipe network, pipe roughness coefficients, water production and water consumption are some of the input data required for modeling the water distribution network. The hard copy of these data was taken from the Batu town water supply office. The scanned water distribution network was geo-referenced using ArcGIS 10.8.2 and an attribute table was prepared for further use in Water GEMS. A Digital Elevation Model (DEM) of 12.5m was downloaded from Earth data. Using Arc GIS 10.8.2, the DEM mosaic king was done for later use in generating nodal elevation by TRex WaterGEMS tool. Design reports from the previous consulting offices were also used as secondary data in this research. The other input data associated are population data and layout maps.

To analyze the data which was collected from different sources, both qualitative and quantitative methods were used to do this research. From the quantitative methods, descriptive statistical methods like percentages, graphs and cross-tabulation were used in order to come up with the appropriate result. The field survey data for the distribution system was evaluated by using engineering software such as Water GEMS/ CADV8i, Global Mapper and GIS. The method of analysis was based on nodal pressure and velocity parameters. During data analysis, the nodal pressure and pipe link velocity were determined to identify the higher or lower pressure zone of the area. The standard value of nodal pressure and velocity was determined. The value which was under normal value was taken as acceptable and below and above the standard values was taken as unacceptable

3.4 Batu Town Existing Water supply Network

The entire water supply network of the town, including their attribute like pipe length, diameter and material type, pipes roughness coefficient, and reservoir and tank section has been collected from Batu water supply design Report and utility offices.

The Existing the water supply of Batu construction was started in 2012 and commenced after six year in 2018 to serve user costumers by Oromia water, mineral and energy bureau to intend the water supply improvement of Batu town. The sources are from Tufa and Gimechu, springs and water conveyed from Tufa (100 l/s) and Gimecho (6 l/s) springs through pressurized pipe to the 400 m^3 capacity wet well located at 1598 m.a.s.l. Then the water from the wet well conveyed through various sizes of collector pipes to the 2000 m^3 capacity reservoir at a distance of 2.7 km from the wet well. This reservoir was interconnected to reservoir capacity 2000 m^3 which is situated at 1770 m.a.s.l. at a distance of 37 km from tufa reservoir. The pressure line from wet well to tanker of 1770 m, whose, size is DN 350, DCI pipe of 2.7 km length. In addition gravity line shall be laid from 1770 m.a.s.l. tank to 1700 m.a.s.l. tank whose size is DN 400, PN 16 and OD 400 PN 16 uPVC pipe of 37km length with 57km PVC distribution pipe line 16 Water points for serving beneficiaries and 16, 100 house hold connection.

3.4.1 Water sources and water pump station

Water sources

Water sources will be selected to meet the expected maximum day demand for the relevant design period. A 24-hourbasis is not mandatory given the need for consideration of maintenance and operation activities when pumping is involved. Gravity spring sources, however, should operate 24 hours per day.

The two springs are found in west Arsi Zone in the southeast direction of the town with a total discharge capacity of 106 l/s as per design report. According to the information found during field visit and interview with the concerned bodies of the town water supply office, no other sources of water for potable drinking water, except the two springs. According to design report (2012), Tufa provides 100l/s and Gemechu 6 l/s as per design report. However, during the study period, the Tufa spring source provides only 75 l/s. This yield is also obtained from overflow of the spring after which the Bulbula water supply demand is contented and 6 l/s from Gemechu spring in combination which the total yields production from both springs are 81 l/s.

As per the design report of Batu Town with actual, there were three stainless submersible pumps for Tufa spring (two operational and one standby) and two pumps (one operational and one standby) in Gemechu spring but actually only one pump is installed and working in the raw water pumping station. These pumps draw water from the Tufa and Gemechu spring boosting to the 400m^3 collection chamber (wet well).

Water pump station

In the pumping station, there were six surface horizontal centrifugal types of pumps in which four operational and two are standby to boost water through 350mm pipe to the 2000 m^3 reservoir. However, currently only 3 pumps are in operational while one pump is unfunctional. Each of these installed pumps has a maximum discharge of 25.8 l/s at 9.78 m of maximum head capacities. The pumps have a 3.3 kW of motor power.

Water production

The water production has been evaluated as the total annual water supplied to the water distribution system (WDS). According to the water utility office of the town, the design gross water production capacity of developed spring and boreholes was 9,158.4 m^3/day but, currently around 7,257.6 m^3/day production is produced from developed spring and boreholes with average working for 23 hours per day (Batu water Utility Office).

3.4.2 Reservoirs

Clear water shall be transported to the reservoir in the system directly through the transmission main line. There are two new and one old circular reinforced concrete (RC) type reservoirs to serving the Batu Town. In addition, 400m^3 wet well from which the booster pumps suck water to the new 2000m^3 service reservoir.

The information on location of most of the water reservoirs were collected in conjunction with the main water network from the town. The reservoir's data including their capacity years of construction and material of construction were also collected. A reservoir provides the upstream energy or hydraulic head by its water surface elevation, and any amount of water volume required for the system continuity. From the Tufa and Batu reservoirs, the water is distributed to the surrounding kebeles and Batu town by gravity. The capacity of reservoir is designed to balance the peak hour demand of the beneficiaries. The service reservoir is a storage facility that is designed to equalize the hourly fluctuation of flow, make uniform pumping rate possible, provide uniform water pressure, reduce operating cost by operating pumps at the rate for the maximum efficiency and for emergency reason, etc. Reservoir capacity can be taken for maximum daily water demand at the end of design period.

3.4.3 Distribution pipe line network

The use of distribution system is to deliver water to user with proper quality, quantity and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage.

As per information obtained from the town water service office and based on as built drawing; the existing distribution system consists of a network of mains with total length 92.7km. The system contains pipe ranging from 25mm to 400mm in diameter, although the majority of the system consists of 50 and 80 mm in diameter of pipe. The material type of the water distribution network of town was consisting of PVC, HDPE, GI and DCI.

Water consumption

According to the information gathered during town water supply office visit and discussion with experts, the water sources for Batu town and distribution network system was from springs. The water production for the entire study area on monthly water distributed to systems has been collected from water meter installed at the source reservoir outlet.

In order to evaluate the water loss in the distribution system consumption, data of the entire customer were collected from billed data. The rate of water consumption at a node depends on the population served by the node, type of demands and time of year.

3.5 Analysis of Population and Water Demand

The project area population and respective water demand requirements are basis for deciding the capacity and cost of the overall water supply system. Data required for estimating the growing water demands of population have been collected from design report of Batu Town Water Supply Project. These include population size, growth rate, density, distribution and socio- economic data like public and commercial institutions and livestock population.

The design period (planning horizon) is the length of time for which the system is expected to provide a community with good quality and sufficient quantity of water. This period should be neither too short, nor less than ten years or too long because of economic reasons and the difficulty of predicting future water demand. The design period also fixes the target date in the future for which a given project should serve before it is abandoned or expanded. The design period has a direct impact on the overall capacity, complexity as well as cost of water supply systems. Accordingly, Batu town Water Supply project was planned to serve the target community for the coming 20 years, which failed to satisfy GTP-2 for the water supply and sanitation sub-sector (2015/16-2019/20) goal and hence evaluated system performance. A population count is used to interpret the town's yearly water usage to average daily per person use.

3.5.1 Batu town population forecasting

Elements of water supply systems are designed to serve present and future population. Therefore, population forecasting is mandatory in water supply design and hydraulic performance analysis. The two important data for population forecasting are base population (initial population) and growth rate. From common methods of population forecasting, Exponential increase method is selected. This method is used by the central statistics authority of Ethiopia. Because percentage error of exponential increases method is the lowest value (minimum value) than other methods. Also this method is good for developing countries as well as developing town or city like Batu town. The exponential increases method is growth rate of population for calculation of the future population of town and also corresponding to population growth rate of given town. For these reason exponential increase method is best method for forecasting Batu town population for water supply, sewerage system and any infrastructure of the town based these population numbers. The base or current population of the Batu Town and surrounding 11 kebeles water supply project were based on the 2007 population and housing census of Ethiopian published by the Central Statistical Agency (CSA) of Ethiopia. According to CSA of Ethiopia, the population of Batu Town as per 2007-

census count is 43,660 and growth rate of 2.9% is used for this study to project water demand of the town.

In this research, geometric increase method was applied to project future population, since this method is mostly applicable for growing towns and cities having vast scope of expansion. Considering the growth rate of Batu Town, population projection for the design period was done using the following formula.

$$P_f = P_o(1 + \frac{r}{100})^n \qquad \text{......................................} \ \mathbf{(3.1)}$$

where, P_f is future population; P_0 is current population; r is growth rate and n is time in decade or year

Over estimation of water demand risks investment viability and affordability of operation and Maintenance management costs resulting idle investment or wastage of limited resource. Whereas, under estimation leads to service deficiency ahead of the design period. Hence, rational and realistic population estimation is both imperative and of paramount importance that has to be carried out following standard steps. Estimation of population at the end of design period requires utilization of projection methods. The choice of methods to be adopted in each particular case depends on the nature and potential for development of the town.

3.5.2 Water demand Analysis

The water demand forecast was used to ensure better water management, furthering and distribution of the resource there by preventing crisis often associated with water accessibility, to overcome challenges of urban and suburban growth and to provide information about the past and future water use . Water demand was classified into two major categories as domestic and non-domestic water demand.

Water demand is the rate of water consumption for various purposes. The total water requirement of a town is usually estimated by its uses for domestic and non-domestic purposes. The amount of Batu Town water used for domestic purposes were derived by translating yearly consumption statistics into an average daily per capita consumption rate based on the expected total population for the year 2035 G.C of the design period. The average amount of water used per person per day varies from rural to urban. The major important factors for these variations are level of water supply service, per capita demand, and climatic conditions, level of socio-economic development and affordability and willingness to pay for the services.

3.5.3 Domestic water demand analysis

The domestic water demand was the portion of municipal water supply, which is used in the home and largest portion of the total demand for most water systems. There are four modes of services identified for domestic water consumption of Batu town such as, house connection, yard connection, yard shared connection and public tap. Domestic water demand includes water used for basic needs such as drinking, cooking, ablution/baths, washing clothes and utensils, and cleaning houses. The domestic water demand is calculated using this formula and presented by assuming all of the total populations at every yearly are beneficiary from the project. The average amount of water used per person per day varies from country to country as well as from region to region within a country. These variations are due to climate conditions, water quality, willingness of people to pay water supply services, level of socio economic development etc.

Per capital water demand for various categories of the Batu town was adopted by taking into account the different development factors and standards used by the Ministry of Water Resources (MOWR, 2006b).

In the town, non- domestic water demand includes use of water for industrial demand, domestic animal demand, and firefighting and unaccounted for water. Since there is no distinct data for the study area, 20% of the domestic water demand, was taken from previous study report.

Commercial demand includes water requirement for restaurants, Cinema houses, railways, bus stations, shopping centers, local drinks etc. Since there are no quantified commercial institutions, its demand was taken as 40% of domestic demand from Batu town water supply Design report. Public demand includes water required by schools, hospitals, public offices, military camps, public parks, dispensaries, day-care centers and so on (MOWR, 2006b).

Water demand for firefighting purposes should be studied on existing condition of a town depending on the presence of equipment and the capacity of any firefighting services. Fire hydrants should be installed at public and municipality interest such as schools, shops, hospitals, fuel stations and at salient points of distribution network. This demand has been taken by increasing the volume of the storage tanks by 10 % (MOWR, 2006b).

3.6 Mode of Water Supply Services

Water demand of the users can be affected by level of water supply service. If the level of service is excellent like house connection, the demand for water is also very high due to its multipurpose such as watering plants, washing compounds, toilet flushing and bathing rooms. The water demand of the users decreases as the level of the water supply service decreases and vice versa.

According to Ethiopian urban water supply design manual, there are three common types of service levels (MOWR, 2006a):

1. House connections (HC)
2. Yard connections (YC) and
3. Public fountains (PT).

According to Batu Town Design Report (AYJEF, 2012), there are three major modes of services for domestic water consumers of Batu Town. These are house connections (HC), yard connections (YC), and public fountains (PT). The percentage of population served by each mode of service is varying with time. This variation is caused because of the changes in living standards, improvement of the service level, changes in building standards and capacity of the water supply service to expand. The percentage of water demand for the following categories of consumer (stage I) were HC 5% (40l/c/day), YC 65% (30l/c/day) and PT 30% (20l/c/day) (AYJEF, 2012).

3.7 Per capita domestic water demand

The per-capita water consumption for various demand categories varies depending on the size of the town and the level of development. The water demand in Batu Town is high due to socio-economic activity in both governmental and private sectors. Using the daily water consumption and population figures, the average per capita consumption of the town water demand was calculated as:

Adjusted domestic demand = total domestic demand ∗ socio economic factor ∗ climate factor. …**(3.2)**

Therefore, adjustment factors should be considered referring Tables (3-1) to (3-.3)

Table 3- 1 Socio economic adjustment factor

Group	Description	Factor
A	Towns enjoying high living standards and with high potential for development	1.1
B	Towns having a very high potential for development, but lower living standards at present	1.05
C	Towns under normal Ethiopian conditions	1
D	Advanced rural towns	0.9

(Source: MoWR,(2006)

Table 3- 2 Climatic effects factors

Mean Annual Temp. (^{0}C)	Description	Altitude	Factor
<10	Cool	>3,300	0.8
10-15	Cool temperate	2,300-3,300	0.9
15-20	Temperate	1,500-2,300	1
20-25	Warm temperate	500-1,500	1.3
25 and above	Hot	<500	1.5

Source: MoWR,(2006)

Table 3- 3 Peak hour factors

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

Source: MoWR,(2006)

Batu Town is considered as towns having a very high potential for development but lower living standards at present since it is found near Lake Ziway and therefore is categorized with the towns of group B with a factor of 1.05.

3.8 Design Demands

The rate of demand of water represents by the average consumption or demand of water per head per day. The rate of demand of water, however, does not remain constant but it varies with the seasons or month of the year, with the days of the week, and with the hours of the day. These variations in the rate of demand of water are termed as seasonal or monthly variations, daily variations and hourly variations. Poor estimation of these factors can lead to under or over design of water supply systems. To evaluate the different elements of a water supply scheme, the following design demands was considered.

Seasonal peak

Towns in Ethiopia are characterized by widely varying climatic conditions and so the variations in consumption during the year, reflected by a peak seasonal factor, will similarly vary. It is expected that seasonal peak factors will vary between 1.0 and 1.2, representing the relative increase in the average daily demand during the dry and/or hot season months compared with the average annual demand (MoWR, 2006). Therefore, for this research 1.2 seasonal peak factors was used.

Peak day factor

Many communities exhibit a demand cycle that is higher in one day of the week than in others. This situation shall be taken into account by the use of a peak day factor. The water supply, treatment plant and transmission lines shall be designed to handle the maximum day demand. It is determined by multiplying the total average daily demand by a factor of 1.0 to 1.3 depending on local situation (MoWR, 2006). For this particular study town a factor of 1.1 was adopted depending design report.

Peak hour factor

Water demand varies greatly during the day. The distribution system must be designed to cope with the peak demand, which is taken into account by the use of a peak hour factor. .During peak hourly flows, storage reservoirs supply the demand in excess of the maximum day demand. The peak hour factor varies inversely with the size of the consumer base (Table (3-4)).

Table 3- 4 Peak factors

Population Range	Peak hour factor
< 20000	2
20001 to 50000	1.9
50001 to 100,000	1.8
>100,000	1.6

Source: MoWR, (2006)

Depending on the Table (3-4) peak hour factor of 1.6 was considered for this study.

3.9 Estimation of domestic water consumption

Average per-capita water consumption was used to assess the domestic water supply coverage of the town. Data on individual domestic water consumptions, total water consumption (m^3) and total production (m^3) were collected from Batu town. Water Supply and sewerage office bill documents were used for analyzing average per-capita water consumption. The following formula was applied for the determination of per-capita water consumption (liter/person/day) (Desselegn Eshetu, 2015).

Domestic consumption (L/P/d = annual consumption (m3)*1000 l/s/m3/pop.No*365…...**(3.3)**

3.10 Water loss analysis

The sum of water loss in a delivery pipe and pipe fittings between two points of consideration is called head loss which either surface or form resistance. Unlike the water consumption, the water production of Batu town was only recorded at the town level. Hence, the water loss analysis in Batu was assessed at the town level based on the percentage of non-revenue water which was obtained from the total production and actual used figure.

There are two different approaches to assess water losses. The first is top-down annual water balance and the second is bottom-up approaches based on minimum night flow analysis. In developing countries, mostly top-down water audit is conducted as per the guideline suggested by Lambert and Hirner, (2000), because of the assessment of real loss of bottom-up approach during the night does not hold the best result since, in intermittent supply system consumer always keeps tap open in the house connection to fill storage tank.

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water losses of the town (EPA, 2010).

3.11. Model development

After setting the character for the model, the model was constructed to simulate base/normal network operation conditions. The construction process began with assembling the required data to populate the model. Data required included; the geographic configuration of the network mains, the geospatial distribution of demands, physical element attributes and other relevant data. The modeling process are input data collection, model building in Bentley water cad, data entry (Elevations, XY coordinates, base demand, pump data, tank data and pipe data), model testing, hydraulic modeling and problem analysis. Input data for the analysis of distribution system included:-

- ❖ Nodes:- Elevations and base demand
- ❖ Pipes:- Pipe diameters, lengths, material type and the friction coefficient factors
- ❖ Tanks:- Base , minimum and maximum elevation and diameter of the tank
- ❖ Pumps:- The most important parameter defining the pump operation is the pump curve. Other input needed is the elevation of the pump
- ❖ Reservoir:- Elevation

3.12 Demand Distribution

The regular water peak demand for the study area was distributed among the nodal nodes which apply the proportional area distribution method by using water GEMS/ CAD v8i. The proportional areas for each node were determined by generating Thiessen polygon for that node using manual loading. For this purpose, at first the bounding areas for demand distribution were determined over the geo-referenced aerial image by using Global Mapper software. Then this bounding polygon was segmented into Thiessen polygons for the model nodes.

3.13 Modeling the existing distribution system

3.13.1 Water GEMS /CADV8i

The hydraulic analysis was done by Water GEMS/ CADV8i software. The analysis is used to confirm that there is a reasonable head of water (Residual pressure) at junctures, water points, etc. The static pressure heads and the PN are also checked in the analysis. The hydraulic analysis was done based on Hazen-William's formula to construct and imitate the hydraulic model. The Hazen–Williams **equation** is an empirical relationship which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction

The Water GEMS software was used in water distribution modeling. In modeling using Water GEMS, the first step is population forecasting. To prevent model over estimation or under estimation of future demand, the future population was estimated based on 2007 CSA estimation. Then the demand of each node assigned using thiessen polygon method. The water supply network map was obtained from the town water utility office. The set-up model was taken extended periods by contemplation of hourly demand variation pattern over 24-hour flow duration analysis work. For this study, the network-outfitted set-up was done by SI unit and the project liquid was taken as water at 20°C.

The input parameter needed by Water GEMS/CAD 8i for performing the hydraulic simulation are pipe characteristics, pipe lengths, junction water demands, junction and reservoir elevations and pump characteristics. After performing the hydraulics simulation for a particular time period, such as 24 hours, Water CAD produced output data such as pipe water flows, junction water pressure and change in reservoir elevations during the 24 hours with an interval of one hour.

3.13.2 Hydraulic network simulation

Hydraulic simulation is the simulation of hydraulic and water quality behavior of each system. Hydraulic simulation was determined using the hydraulic parameters such as velocity, pressure, head loss, flow etc. Most small and medium towns do not have complex network as compared to cities. However, they have poor data records regarding to water distribution system. Computer models, making use of hydraulic simulation software are capable of representing the behavior of real time system and have a capability of predicting the performance of the same system for future “what if scenarios” (AWWA, 2005). Simulation can be used for analysis of the existing system to improve the supply in terms of pressure, flow and minimize leakage. There is various types of simulation that a model may perform, depending on what the modeler trying to observe or predict. The two most types of simulation are:

3.13.2.1 Steady-state simulation

It is the simplest simulation type and solves the system of equations as if the system is in equilibrium. It provides information regarding the equilibrium flows, pressure and other variables defining the state of network for the unique set of hydraulic demands and boundary conditions. Steady state models are generally used to analyze specific worst-case condition such as peak demand time, fire protection usage, and system component failures in which the effect of time are not particularly significant (Dawe, 2000).

3.13.2.2 Extended-period simulations

Extended-period simulations (EPS) break up the simulation into time-steps. Each time step may feature different values for the dynamic variables (tank levels, pump operation, and junction demand). The amount of water that is consumed in the morning when everyone is getting ready for work is different at midnight. The EPS allows simulating the system response over time through hydraulic time steps. The EPS was chosen for this analysis because of its capability to model varying demands. The total simulation time was 24 hours with a one-hour time-step

3.13.3 Model calibration

Model calibration involves adjusting model parameter values until an acceptable match is achieved between measured (field) data and the model predicted values (Walski, *et al.*, 2003). Calibration runs were finished when the model outputs agree with field data according to predefined requirements. The main parameters adjusted during the calibration process where pipe roughness coefficients, nodal demands, pattern of demand, pump curves and initial water tank levels. According to Walski, *et al.*, (2003), the calibration process was performed by adjusting sensitive parameters related to flow; like pipe roughness coefficient, water demand and pattern of demand and other. Until it was becoming within the acceptable limit of 85% of field test measurements (it should be within 0.5 m or 5% of the maximum head loss across the system).

Pipe roughness:- It varies with material types, the corrosiveness of water and aging of the pipe. The Williams and Hazen (1906) equation was developed for the action of friction at the pipe wall; because its formula used a pipe carrying capacity factor C. Different pipe materials have different range of C values. Pipe roughness was increase with decrease in C value. Usually the newer pipes are smoother and therefore have the large C values than the older pipes.

For distribution modeling network in this study Williams and Hazen (1906) C factor was assumed a bit conservative from the standard ranges in order to account for the system uncertainties and to incorporate minor loss effects. This ensured adequate reliability of the model results against the impact of pipe friction of the system pressure.

Initial estimates of pipe roughness values may be obtained using average literature values or directly from field measurements. Various researchers and pipe manufacturers have developed tables that provide estimates of pipe roughness as a function of various pipe characteristics such as pipe material, pipe diameter, and pipe age. As a result, initial estimates of pipe roughness for all pipes other than relatively new pipes should normally come directly from field testing. Even when new pipes are being used, it is helpful to verify the roughness values in the field since the roughness coefficient used in the model may actually represent a composite of several secondary factors such as fitting losses and system skeletonize. For calibration of water distribution system, pip roughness was considered as the calibration parameter in this study. Models were simulated considering the starting roughness coefficient C of 100 and modified at each simulation at an interval of 5 up to 150 for newly built pipes and matched with observed data.

Nodal demand distribution:- The second major calibration parameter that dictates the calibration process is the average demand to be assigned to each junction node. Initial average estimates of nodal demands can be obtained by identifying a region of influence associated with each junction node, identifying the types of demand units in the service area, and multiplying the number of each type by an associated demand factor. Alternatively, the estimate can be obtained by first identifying the area associated with each type of land use in the service area and then multiplying the area of each type by an associated demand factor. In either case, the sum of these products will provide an estimate of the demand at the junction node.

3.13.4 Hydraulic parameters

The main hydraulic parameters in water distribution networks are the pressure and the flow rate. Other relevant design factors are the pipe diameters, velocities, and the hydraulic gradients.

Pressure:-Water distribution networks must maintain adequate water pressure throughout the network. The water pressure on nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances and the size of the network (Samani and Taghi, 1996). Water pressure was typically maintained between 25 and 75 psi (Mays *et al.*, 2000). The minimum pressure should maintain to ensure that customers "demand" provided at all times. The maximum pressure also contains a limitation of leakage and lead to water loss in the distribution system.

Flow:- It is the quantity of water passing within a certain time through certain sections. The velocity is directly proportional to the flow rate. For a known pipe diameter and a known velocity, the flow rate through a section can be estimated. Maximum velocities in distribution system is 2 m/s and minimum 0.6 m/s. Low velocities affect water consumption and severe to disease problems. The velocity is directly proportional to the flow rate factor or a known pipe diameter and a known velocity, the flow rate through a section can be estimated as (Mamush , 2016)

$$V = {}^{4D}\!\big/_{\pi D2} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

where, D is diameter of pipe (mm), Q is discharge (m^3/s) and V is velocity (m/s).

From the above equation it is clear that to increase velocity, pipe diameter should be decreased. When the velocity increases the head loss increases.

3.13.5 Simulation Analysis

Water CAD/ GEMS can perform steady state and extended period simulation. For twenty-four hours, the system conditions were calculated using a one-hour time increment and a 12:00 PM start time. The program used the idea of mass and energy conservation simulates non-steady state hydraulic calculation. Simulated models were run for each one-hour period throughout the 24-hour period. Peak and minimum hour demand were simulated to discover present system faults and find key areas in an existing water supply distribution network.

4 RESULT AND DISCUSSIONS

4.1 Evaluating the Current Water Supply in Batu Town

The annual water consumption data converted to average per-capita consumption using the population data of Batu town with its surrounding 11 kebeles was shown in Table 4.1. In Batu town, because of the growth of socio economic activities in both governmental and private sectors, there was high water demand in the town compared to the supply.

The yearly consumption of the town was obtained from the total of individual water meters and public taps, and this yield the average per capita water use. The town's total yearly recorded water usage in 2021 G.C. was used to compute the average daily per-capita water consumption by using Eq. 3.3 as shown below.

Per capita consumption (LCD) = $\left(\frac{1193722\ m3 * 1000\, l / m3}{138636\ * 365\, days}\right)$ =23.59l/c/day

The average domestic water supply coverage of the Batu town was 23.59 l/c/day. This average per capita consumption is very low as compared to the value set by MoWIE (2015) for GTP-2 which was set to 60 l/c/d for category-3 towns/cities within a distance of 250 m. The annual water demand for the year 2021 is and the annual water production of the town in 2020 G.C is 1626759 $m^{3.}$

According to WHO (2011), the minimum quantity of domestic water required in urban area of a developing country was taken as 20 l/c/day within a 0.5 km radius. Regarding this value, the per-capital domestic water consumption of the town was not satisfied the standard value. According to the WHO (2011), the optimal water consumption rate per person per day was given as 100 liters. Regarding this value, the water consumption of the town satisfies only with 23.59% of the standard value. The quantity of domestic water required in urban areas of Ethiopia was taken at 50 l/c/day (MOWIE, 2019).

Based on this value, per- capita domestic water consumption of the town was not satisfied the standard value. From this result, it can be concluded that the per capita water consumption of the town was low, so it needs to be improved.

According to the water utility office of the town, the 2021 water consumption of the town was obtained from the total of individual water meters and public taps, and this yielded the average consumption of 1193722 m^3 and production 1626759 m^3. Water supply duration is for 23 hours. According to Batu town water service office report, the design of water distribution of the system was based on continuous supply to users. Power–supply shutoff events do not occur due to large and frequent water demand and full times supplied water to the users.

4.2 Population Forecasting and Water Demand Analysis

4.2.1 Population projection

According to CSA of Ethiopia, the population of Batu Town as per the 2007-census count was 43,660 and the 11 surrounding Kebele was 51944 respectively (Table 4.1). Using CSA (2007) census data as a base, the current (2021) population and the population at the end of the design period (2035) of the town were estimated and shown Table (4.2). An average growth rate of 2.9 % was used for this study to project the water demand of the town. The projected population for the years 2015, 2020 and 2035 becomes 120171, 138636, and 212867, respectively. Table (4-2) summarizes the population projection of Batu Town and the surrounding 11 Kebeles starting from the year 2015 to 2035.

The water demand of a particular town is proportionally related to the population to be served. The per-capital water consumption for different demand categories varies depending on the size of the town and the level of development.

Table 4.1 Population data

Settlement	2007
Batu Town	43660
Xufa	2449
Oetu Basuma	4882
Areresa Kelbo	2149
Habule Gutema	2999
Jela Aluto	4820
Golba Aleto	3249
Aneno Shisho	4197
Admi Tulu Agr.Reserch	10000
Adami Tulu Town	9081
Gerbi wedina Boremo	3119
Zeway Agricultural Development	5000
Total Default Beneficiaries	51944
Total Batu and Default Beneficiaries	95604

Sourse: CSA and Batu water supply Project

Table 4.2 Batu town and default beneficiaries projected population

Settlement	2007	2012	2015	2020	2035
Batu Town	43660	50369	54879	63312	97211
Xufa	2449	2825	3078	3551	5452
Oetu Basuma	4882	5632	6137	7079	10870
Areresa Kelbo	2149	2479	2701	3116	4784
Habule Gutema	2999	3459	3769	4348	6677
Jela Aluto	4820	5561	6059	6990	10733
Golba Aleto	3249	3748	4084	4711	7234
Aneno Shisho	4197	4842	5276	6087	9345
Admi Tulu Agr.Reserch	10000	11536	12569	14501	22265
Adami Tulu Town	9081	10476	11414	13168	20219
Gerbi wedina Boremo	3119	3598	3920	4523	6944
Zeway Agricultural Development	5000	5768	6285	7250	11132
Total Default beneficiaries	51944	59926	65292	75324	115656
Total Batu and Default Beneficiaries	95604	110295	120171	138636	212867

4.2.2 Domestic water demand analysis

Applying all the aforementioned factors, the total daily domestic water demand of the town is summarized in Table (4-3).

Table 4.3 Total adjusted domestic demand (TADD)

Year	2012	2015	2020	2035
Batu town population	50369	54879	63312	97211
Total default beneficiaries population	59926	65292	75324	115656
total Batu and default beneficiaries population	110295	120171	138636	212867
Per capita Water Demand by Categories				
House connection (5%) 40l/c/d	220589	240342	277273	425733
Yard connection (65%) 30l/c/d	2150743	2343337	2703408	4150899
Public taps users (30%) 20l/c/d	661767	721027	831818	1277200
Total domestic demand (litre/day)	3033099	3304705	3812498	5853832
Total domestic demand (m^3/day)	3033	3305	3812	5854
climate factor	1.3	1.3	1.3	1.3
Socio economic factor	1.05	1.05	1.05	1.05
Total adjusted domestic demand (m^3/day)	4140	4511	5204	7990
Public water demands, 15%DD, (m^3/day)	621	677	781	1199
Water demand for fire-fighting, 10%DD (m^3/day)	414	451	520	799
Unaccounted for water or loses, 25%DD, (m^3/day)	1035	1128	1301	1998

Table 4.4 Summary of water demand

Type of Demand	Unit	2012	2015	2020	2035
Domestic Demand (DD)	m^3/day	4140	4511	5204	7990
Public Demand (PD)	m^3/day	621	677	781	1199

Commercial Demand (CD)	m^3/day	1656	1804	2082	3196
Industrial Demand (ID)	m^3/day	828	902	1041	1598
Water Demand for Fire fighting	m^3/day	414	451	520	799
Sub total	m^3/day	7659	8345	9628	14782
Un-accounted for water	%	25%	25%	25%	25%
Un-accounted for water	m^3/day	1035	1128	1301	1998
Average Day Demand	m^3/day	8694	9473	10929	16780
Average Day Demand	l/s	101	110	126	194
Max Day Factor	1.1	25%	25%	25%	
Max Day Demand	m^3/day	9564	10420	12021	18458
Max Day Demand	l/s	111	121	139	214
Peak Hour Factor for Batu Town	1.6	1.6	1.6	1.6	1.6
Peak Hour Demand	m^3/hour	13911	15157	17486	26848
Peak Hour Demand	l/s	161	175	202	311

Based on Table (4.4) output result, the maximum day demand for 2020 and 2035 were 139 l/s and 214 l/s, respectively. But the source of water supply for Batu Town is with a total discharge capacity of 106 l/s as per the design report. This implies that, Batu town water supply needs additional yield for current and future demand. Where quantity is not a limitation, springs have to be developed to satisfy at least the maximum day demand of the design perspective.

According to (MoWIE, 2006), water sources have to be selected to meet the expected maximum day demand for the relevant design period. A 24-hour basis is not mandatory given the need for consideration of maintenance and operation activities when pumping is involved. Gravity spring sources, however, should operate 24 hours per day. In order to provide and secure the supplies, reservoir capacity need to be balanced with minimum total reservoir storage capacity which is in the range of 30% to 50% of the average daily demand. As indicated in Table (4.3) reservoir capacity should be within 5000-8000 m^3 at the end of design period. But the current capacity of Batu water supply reservoirs was within the range of 1000-2000 m^3 which is far below the required capacity based on needed maximum day demand of the Batu town.

4.3 Water Losses Analysis

The total consumption of water is less than the total production. The difference between the amount of produced water and the amount of total consumed water gives total loss. For the purpose of the water loss study, the total quantity of water generated and utilized in Batu town was collected. Hence, the total loss of water in the town for the year 2021 was 1626759m^3 - 1193722m^3 which gives 433037m^3.There are three methods for determining total water loss, as discussed below.

4.3.1 Total water loss

Total water production and distribution for 2021 G.C. is 1626759 cubic meters, and yearly water loss is 433037 cubic meters, which accounts for 26.62 percent of the total water production for 2021 G.C. Due to the ageing of pipes, which causes leaks, and burst pipes, new installations, and illegal connections, non-revenue water from the system.

4.3.2 Water loss expressed as per number of connection

The water loss per connection for the same time period was calculated using the town's total of 16,100 connections. As Water loss = 433037 x 1000 ÷ (16,100×365) = 73.69 litters/Connection/day. This number shows as litters per service connection per day increase water losses also increases. A percentage is a helpful approach to express how much water has been lost in a certain location, but it isn't a good way to compare losses across other areas.

4.3.3 Water Loss expressed as per length of pipes

A total of 92.7 kilometers of pipes with a diameter of 400 to 50 millimeters were utilized to calculate the town’s total water loss. Using the total pipe length of the entire town, the water loss per kilometer length of main pipes was derived to be 433037 ÷ (92.7 km×365days) = 12.798 m3/km/day. The quantity of water lost per kilometer of the main pipe is another method to compare the amount of water lost. For areas that aren't very crowded, this is a good indication.

4.4 Network Distribution Modeling

The Fig. 4.1 indicate water distribution network that include the pipes, the junction (node), and storage tanks. As revealed in Fig. (4.1), the model of the distribution network was created using survey data of nodes, pipes, pumps, tanks and reservoirs. Junctions, reservoirs and tanks are usually represented as nodes. Pipes, pumps and valves are represented as links. Modelling provide estimation and prediction of the network behavior, calculating pipe flows, velocities, head loss, pressure and tank levels for Batu town distribution network. The network representation indicates all physical components of the water distribution system and defines how these systems of elements are interconnected. Network distribution system is sketched as a combination of different system components. It commonly includes; a reservoir, pipe, tank, pumps, and valves. With little difference, the real water distribution system is represented as a combination of nodes and links. Junctions, reservoirs and tanks are usually represented as nods. Pipes, Pumps, and valves are represented as links.

4.5 Hydraulic Parameter of Water Supply Distribution Network

4.5.1 Analysis of pressure in the network for steady-state analysis.

The Fig. 4.2 indicates the pressure distribution for steady-state simulation. The model has been analyzed in steady state run for the average daily demand, which is the demand at every node not changing throughout 24 hours of a day. The very important parameter used in hydraulic performance evaluation and modeling in water supply system is pressure. The Ethiopian urban water supply projects feasibility and detailed design manual limits for normal conditions are 15m water head is set as minimum and 60m water head is set as maximum. For exceptional conditions 10m water head is set as minimum and 70m water head is set as maximum. From the simulation of the Water GEMS model, the pressure was found to be outside of the standard range of 15m to 70m head of water. It is determined that nodes are operating at or below the minimum acceptable system pressure.

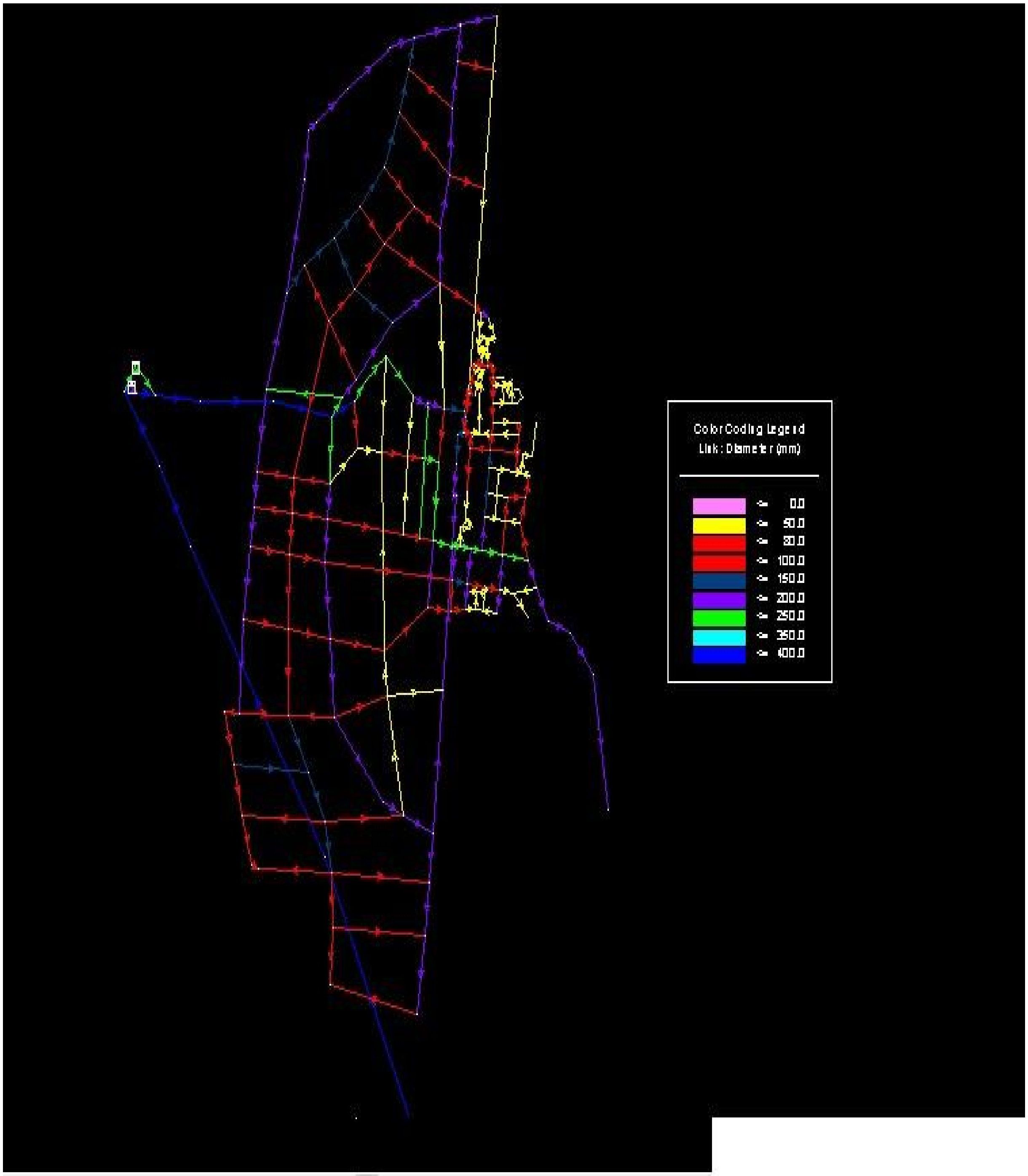

Figure 4.1 Batu distribution Layout

The result of the simulation run was obtained after the model was constructed from the input data of existing data with a total node of 229 was reported from the study inventory dialog box software. All nodes that have negative pressures indicated not able to deliver the required demand to customers. As a result of simulations carried out in the existing models, it was found that it is possible to re-adding up sources and constructs the actual working conditions of the water supply network. These problems resulted from incorrect nodal placement and improper pipe connection, sources under needed demand during designing the system and when expanding the network to the newly settlement area. The potential of the projected water demand increment in Batu Town is greater than the current supply potential of water sources even. The Town water demand averagely increases by 26.1% every five years up to the year 2035.

In the Fig. (4.2), nodes with red color represent negative pressure (<=1 mwc); nodes with blue light color show pressure in the range of 1 to15 mwc; nodes with aqua color represent pressure 15-60 mwc and with yellow color shows the pressure greater than 60 mwc.

From the simulated result for steady-state analysis, 71 junctions have negative pressure. The negative pressure indicates that the area supplied water by these nodes is not gating water. The minimum pressure adopted for this study is 15 mwc. As shown in Fig. (4.3), 71 nodes from 229 (31%) fell below the minimum adopted system pressure. This indicates that the pressure within these junctions is low and not sufficient enough for effective hydraulic performance. Twenty four Junctions (10.5%) have greater than 60 mwc pressure which is more than the maximum adopted pressure of 60 mwc. The remaining 98 nodes (59%) have pressure in the range 15 – 60 mwc which is optimum adopted pressure which showed that the hydraulic performance of distribution system related to pressure indicates, more than half percent is in the acceptable pressure limits.

Velocity Analysis in steady state simulation

The Fig. 4.3 indicates velocity of water in steady-state condition. Velocity is one of the major factors affecting the hydraulic performance of the water supply distribution system. The relationship between velocity and head loss means that variations in the head surface are associated with the flow velocities of the distribution system. In water supply distribution, system design the velocity must be within specific range. This range is indicated in the urban water supply design of Ethiopia as a minimum of 0.6 m/s and velocity shall be maintained at less than 2m/s except in short sections. Very high velocities may have negative structural consequences on the pipes and very low velocities may induce excessive deposit or stagnation of flow.

Figure 4-2 Model pressure analysis for steady-state simulation

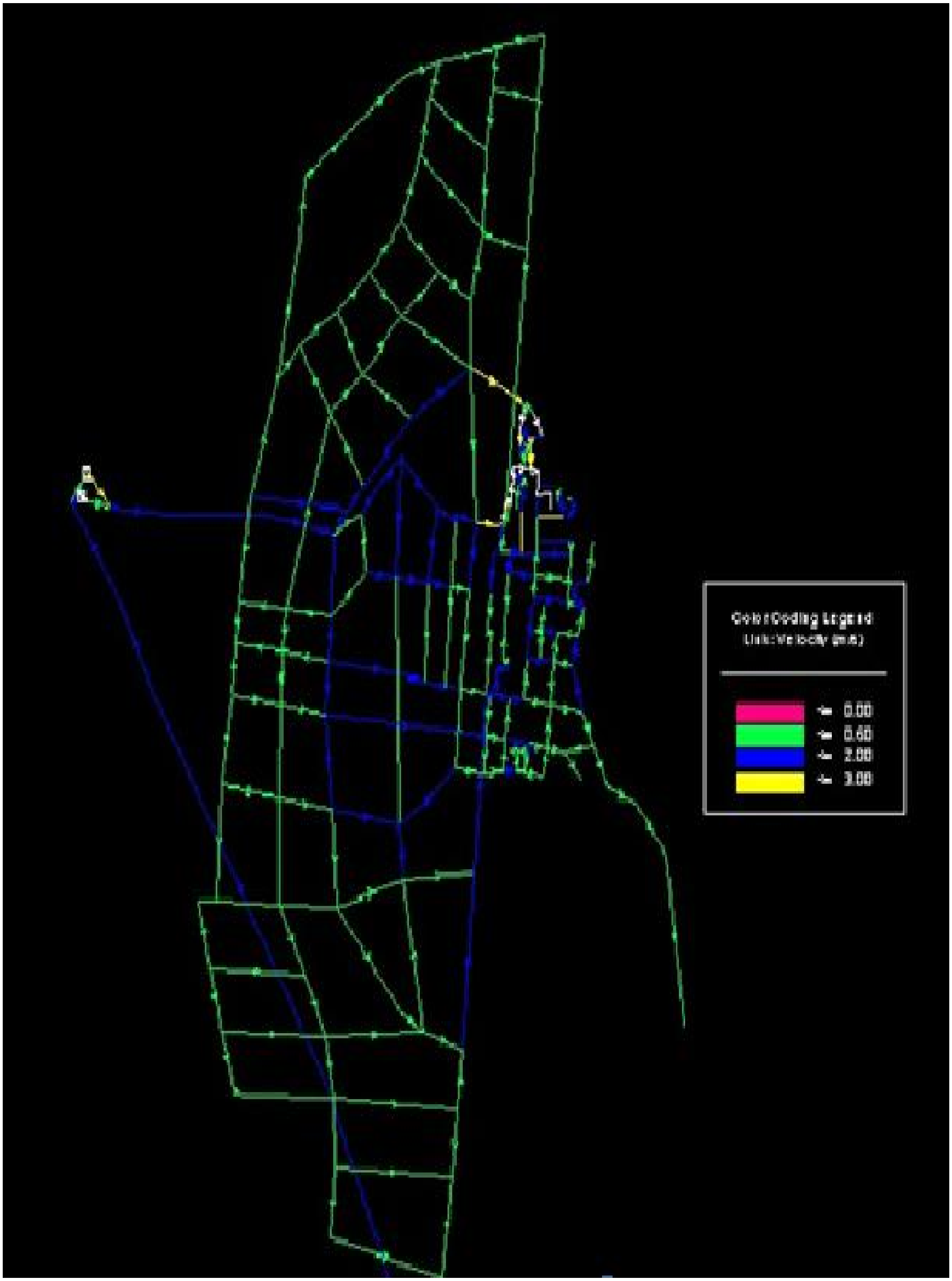

Figure 4.3 Velocity analyses for steady-state condition

In the Fig. (4.3), the steady state condition analysis, pipes with red color stand for velocity less than 0.6m/s, which was not found in the system, 67 pipes with blue color have velocity of 1 m/s to 2 m/s which is around 29 %. Pipes (247) with aqua color have a velocity of 0.60 - 2.0 m/s which is around 76%. Only 10 pipes with yellow color or 3% of the distribution system perform with an optimum velocity above 2 m/s. Since steady-state analysis considers continuous supply and the same demand in 24 hours, no tank level fluctuation in this condition which means that no change in hydraulic grade line.

The higher velocity causes a pipe burst and subsequent entering of water into the system, which leads to leakage in the system. The lower velocity leads to water quality deterioration. To maintain an adequate flow velocity in the system pipe diameter should be adjusted mean progress decrease in the size of the pipes is required so that a higher flow velocity can be achieved in the entire loop or system. This would also help to maintain a consistent pressure throughout the system.

4.5.2 Pressure for extended period simulation

It is complex to discuss all 229 nodes in 24 hours. The low and high pressure occurs at low and high demand time. High daily demand for this study area occurs at 7:00 to 9:00 hrs and 17:00 to 19:00 hrs. Low daily demand also recorded in 0:00 to 3:00 hrs and 22:00 to 24:00 hrs. In the Fig. (4.3), the red color represents areas with pressure less than 1 mwc at peak hour demand, pink color shows area with pressure above 60 mwc, blue color represent 15 to 60 mwc at peak demand time. Nodes (54) with red color in Fig. (4.3) have negative pressure at maximum demand time. This indicates that the pressure within these junctions is low and not sufficient enough for effective hydraulic performance.

Figure 4.4 Pressure for EPS at maximum demand time

Flow Velocity for EPS

As showed in Fig. (4.4), 52 pipes in the systems with blue color have velocity > 2m/s and the remaining has velocity 0.6 – 2 m/s during high demand time. There is no pipe with velocity less than 0.6 m/s in the distribution system.

Figure 4.5 Velocity result for EPS simulation

The minimum velocity at high demand hours with red color has not occurred in Fig. (4.5). The maximum velocity at high demand hours pipes are indicated in P-186,P-190,P-204,P-213,P-256,P-268,P-310,P-253,P-254,P-299,P-289,P-297 and P-296 with blue color represents velocity >2 m/s and the Aqua color shows velocity 0.6 – 2 m/s at peak demand hours.

Simulation analysis pressure by area.

The pressure simulation result as indicated in Fig. (4.6), the white color area have above 60 mwc while the blue color have 15 - 60 mwc and red color have negative pressure in the distribution system to be modified by reducing high observed pressure and to increase low pressure and velocity. One mechanism to reduce high pressure is providing pressure reducing valves (PRV). The PRVs (11) should be provided at P-250, P- 252, P- 254, P- 253, P- 255,P-266, P- 265, P- 173, P- 218, P-245 and P-204 to reduced pressure to the acceptable range around these areas. Another alternative to increase pressure in negative pressure (red area) is the diameters (80 mm) of P-83, P-137, P-117, P-80, P-96, P-107 should be increased to 100 mm and the diameters (50mm) P-317, P-318, P-120, P-119, P-128 and P-79 were resized increase to 80 mm. In addition to this additional water should be injected in to the system by providing a storage tank at an appropriate location.

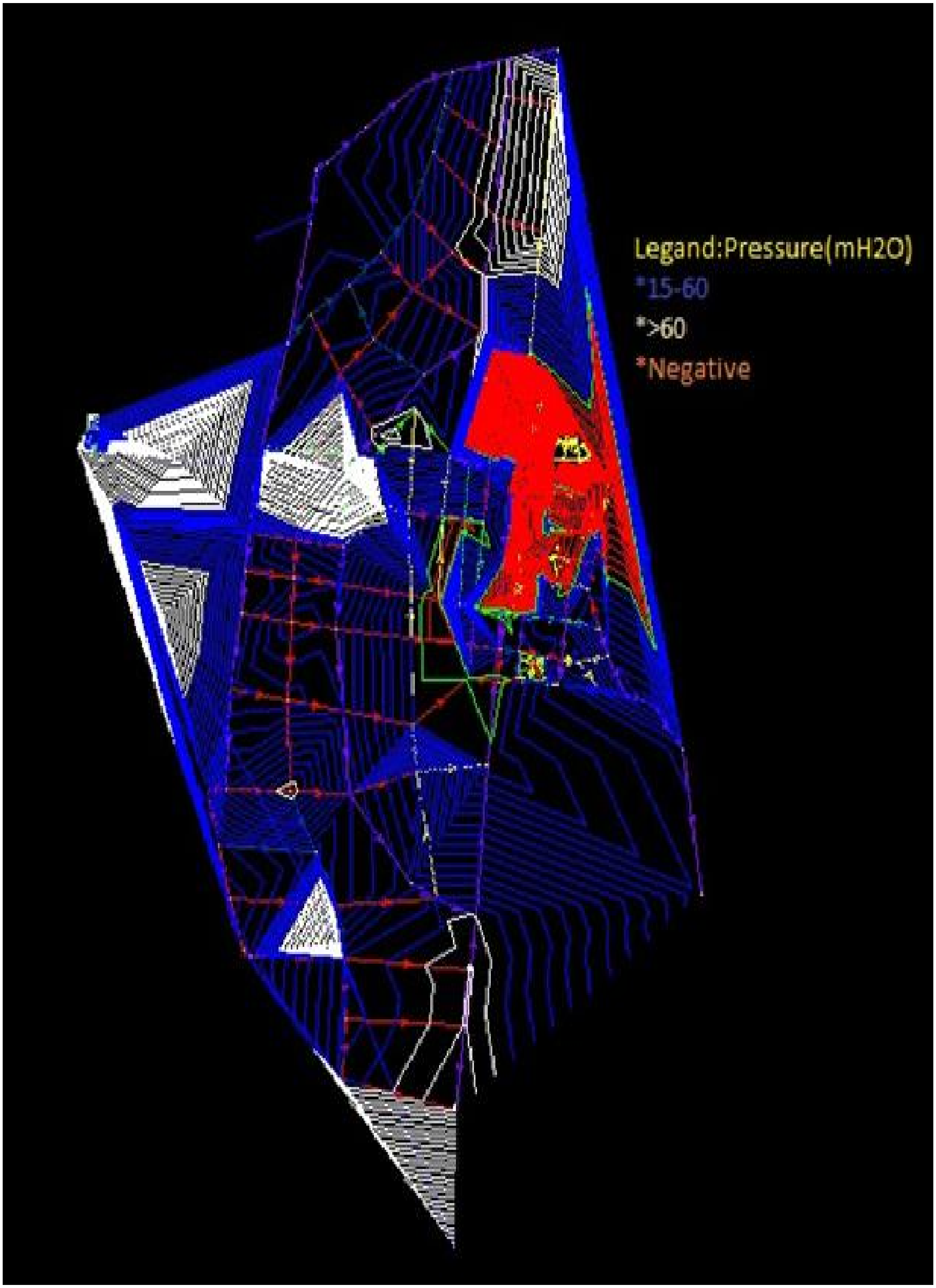

Figure 4-6 Pressure by area

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study is based on hydraulic performance assessment by building Water CAD/GEMS modeling of the distribution network of Batu town, simulating the network to evaluate the hydraulic performance of the distribution and upgrading the distribution network. The population and water demand of the town has been projected up to 2035 and projected demand exceeds the current production capacity of the town (48l/s) in the year 2012 which shows the requirement of additional water sources. In some node there was insufficient pressure to satisfy the required demand at all times. The simulated result for steady state analysis showed that (31%) operating under15mwc, (10.5%) with pressure > 60m and the remaining (59%) for pressure value 15- 60m which is optimum adopted pressure. 76% of distribution pipes have velocity 0.6- 2m/s, or 3% of the distribution system perform with optimum velocity above 2m/s. For extended period simulation 25.76% is negative pressure,10.5%>60mwc which is greater than maximum adopted pressure and this caused water losses in the system. Only 63.75% pressure in adopted range (15-60m) that the distribution hydraulic performs within the optimum adopted pressure. 52 pipes in the systems have velocity > 2m/s and the remaining have velocity 0.6-2m/s during high demand time. Average per capital water consumption of Batu town in 2021 was 23.59 l/c/d which is much lower than 50l/c/d. From the results, it can be concluded that hydraulically the distribution system has limitation. Finally the network was modified by providing PRV, resizing pipes diameter and alternative connection of pipes and additional water sources to reduce observed problems. As a result, Bentley water GEMS/CAD V8i was utilized in this research to assess the hydraulic performance of Batu town's water supply distribution system. It is possible that the distribution system's pressure may fall below the allowable minimum need during long period simulations of peak hour use, resulting in water shortages in certain areas.

One of the best hydraulic performance indicators for water supply distribution modeling results are pressure head at nodes (15-90m head) and flow velocity in pipes (0.6-2m/s)

(Ministry of Water Resources, 2006). In this research the following findings has been acquired and concluded:

- The future population and water demand of the town has been projected up to the year 2035 using year 2012 as base year. The projected water demand shows an increment greater than the current water supply potential of existing water sources. The demand for the year 2035 exceeds by 92.07% as compared to year 2012 production capacity of existing yields
- The water distribution system performance has shown that 41.5% of consumption nodes have out of the indicated range of pressure performance. Only 58.5% nodes have acceptable pressure limits between (15-60mH2o)
- In the distribution network system same velocity can be less than permitted level of MoWR and the negative pressure junction can also occur in the systems of networking distribution. Some of the nodes have low values of pressure, steady state analysis Demand for water is greater as in the future, due to pressure and velocity fluctuation Due to low flow velocity there may be sedimentation of the pipe, which may reduces pipe capacity.
- From two springs used as sources of water supply for Batu Town, Tufa spring source was actually operational for Bulbul Town water supply that mean Batu water supply could take only it's overflow.

5.2 Recommendations

Based on the results of this research, to improve on hydraulic performance of water distribution system of the Batu town, the following recommendations were given.

Current yield of two springs is 100 l/s, but in 2035 the town demand will be 194l/s. thus, additional Water sources should be added in to the system .More of the pipes are found under 0.6m/s flow velocity which can affect the quality of water in the system . So that, the town water utility office should regularly treat the water, examine and test water quality in the system. Based on the modified network after new network mixing with old network upgrading by Water CAD/GEMS, some pipes diameter should be increased to correct pressure and flow velocity in the system.

Poor hydraulic performance of the town water utility should be improved in operation and maintenance, leakage and water losses management, water quality test.

Detail study should be conducted to identify the current actual water production capacity and the critical cause for water losses and water quality .Some specific points to be focused:-

- The water supply office should have to gather x, y, coordinates of all of the components of water supply distribution network, its customers water meter to prepare population layer by shape file which is very important in modeling the distribution system using Water CAD/GEMS. When working with high quality GIS data the demand precisely assigned to nodes.
- The simulated result has shown low pressure at a nodes supplied by storage tank one; therefore the water supply office should have to construct additional reservoir or have to increase zoning around the area of the town
- The pipe diameter should be adjusted to maintain discharge and velocity within the limit.
- The water supply office should have to find water sources which going with customers water demand fit.

6. REFERENCE

ADB (Asian Development Bank), (2006). Urban water supply design criteria. Water. Asian Development Bank. Mandaluyong, Philippines

AWWA (*American Water Works Association*), (2005). Computer modeling of water distribution systems. *American Water Works*, 95-124.

AYJEF. (2012). *Batu Town and surrounding 11 Kebeles Water supply Project.* Batu, Oromia, Ethiopia. BoOWE, Addis Ababa, Ethiopia

Babić, B. D,, (2011) Estimation of water balance and water losses in water utilities – experiences from the Belgrade water works. Water Research and Management. 40: 1173-1178.

Bereket Tesfatsion, (2006). *Evaluation of water supply systems in selected urban poor areas of Addis Ababa. MSC Thesis.* UNESCO-IHE Institute for Water Education, Delft, The Nether lands.

Bhadbhade, N. M., (2009). Performance evaluation of a drinking water distribution system using hydraulic simulation software for the city of Oilton, Oklahoma State University, Oklahoma, USA.

Calvin R. S., Yacov Y. H., Duan L and James H. L, (1996). Capacity reliability of water distribution networks and optimum rehabilitation decision making..University of California. California. USA.

Dawe, P. (2000). Workshop on hydraulic network modeling with water CAD. Netherland University. The Netherland.

Dayessa Leta (2019). Assessment of the water distribution network of Adam city w*ater* supply system. MSc Thesis. School of civil and environmental engineering. Water supply and Environmental Engineering. Addis Ababa university. Addis Ababa, Ethiopia

Desselegn Eshetu, (2015). Urban water supply system performance assessment: The case of BahirDar Town. EPA, Ethiopia. https://doi.org/10.5194/dwes

Dighade, R., Kadu, M. and Pande, A., (2014). Challenges in water loss management in water distribution system in developing country. *International journal of inovative Reaserche in science*: 3:456-568.

EPA (Environmental Protection Authority), (2010). Control and mitigation of drinking water loss in distribution system.. International Journal of Innovative Research in Science, Engineering and Technology. 3: 138-146.

Fallis, P., Hübschen, K. and Oertlé. E, (2011) Guidelines for water loss reduction. A focus on pressure management. Federal ministry for economic cooperation and development (giz). Germany.

Farley, M., Wyeth G., Ghazali Z. B. M. and Sarma, H., (2011). Guidelines for water loss reduction. A focus on pressure management. Federal ministry for economic cooperation and development (giz). and the United States Agency for International Developement, Bangkok, Thailand.

Farley, M., Wyeth, G. and Ghazali, Z. B. M,, (2008). A guide to understanding water loss: The managers' non-revenue water hand book. USAID. Bangkok. Thailand.

Fontanazza, M., (2008). Hydrualic performance assessment of urban water supply for Paleno, Italy. Univesty of Paleno, Paleno. Italy.

Frauendorfer, R. and Lierberger, R., (2010). The issues and challenges of reducing nonrevenue water. *Asian Development Bank.* http://hdl.handle.net/11540/1003.

Gregory, H. J., (2002). Water distribution model calibration for the design of the Ortley beach and seaside heights. MSc Thesis. Environmental and Natural Resources Engineering. Purdue University, Purdue. USA.

H. R. (Hydrualic Research), (2003). Handbook for the Assessment of Catchments Water Demand and Use. 1st Edition. H R. Wallingford. U. K.

Hussni, S. and Zyoud, A. R., (2003). Hydraulic performance of Palestinian water distribution. Journal of water and health 5:491-512.

Ibrahim, A. Q., Onyenekwe, P. C. and Nwaedozie, I. M., (2014). An efficiency assessment of lower Usuma water treatment plant in Abuja Metropolis. Journal of Environmental Science, Toxicology and Food Technology 8(12):46-53.

Jalal, A., (2008). Performance measurement of water distribution systems: A critical and constructive appraisal of the state of the art. MSc Thesis. Civil engineering department. University of Toronto. Toronto, Canada.

Keshavarzi, A., Sharifzadeh, M. and Haghighi, A. K., (2006). Rural domestic water consumption behavior: A case study in Ramjerd. Water Research 40(6):1173 - 1178

Kruszynski, W. and Dawidowicz, J., (2020). Computer modeling of water supply and sewerage networks as a tool in an integrated water and wastewater management system in municipal enterprises. Journal of Ecological Engineering 4:152-212.

Lambert, A. (2001). What do we know about pressure: Leakage relationships in distribution systems. Proceeding of IWA approach to leakage control and water distribution system management. Brno, Czech Republic.

Lambert, A. and Hirner, W., (2000). Losses from water supply systems: A standard terminology and recommended performance measures: IWA, London, UK.

Lambert, A. and Taylor, R., (2010). Water loss guidelines. *Water New Zealand, New Zealand*.

Lambert, A., (2002). A review of performance indicators for real losses from water supply systems. *water supply reaserch and Technology:* 4: 54-84.

Lema, Kefyalew (2018). Urban water supply system performance assesment: The case of Alem Gena town. MSc Thesis. Architecture and Civil Engineering. A A Science and Technology University. Addis Ababa, Ethiopia.

Liemberger, R., Brothers, K. and Lambert, A., (2007). Water loss performance indicators. Proceeding of IWA specialized conference on water. Bucharest-cyprus, London. UK.

Makaya, E. and Hensel, O., (2015). Modelling flow dynamics in water distribution networks. *Science and Technology* 2:36-45.

Mamush Tekle, (2016). Hydraulic modeling of water supply distribution nework: A case study on Debre Birhan town, Amhara regional state, Ethiopia. MSc Thesis. School of civil and environmental engineering. Arba-Minch University, Arba-Minch, Ethiopia.

Mays, L. W., Mays, L. W., and Bouchart, F. (2000). Distribution systems. A handbook. *McGraw-Hill New York.*, USA 78.

McKenzie R and Seago C., (2005). Assessment of real losses in potable water distribution systems: some recent developments. Water Science and Technology. 5: 33-40.

McKenzie, R. and Seago, C., (2005). Assessment of real losses in potable water distribution. *Water Science and Technology*. 1:56-62.

Mebet Admass Dinku (2007). Assessment of water loss in water supply network: A case of Debre Markos town. MSc Thesis. Engineering and Technology, Arba Minch University, Arba Minch, Ethiopia.

Monji, Taha (2021). Water Loss Assessment in Distribution Networks: Methods, Applications and Implications in Intermittent Supply. Earth Sciences, Engineering and Technology. 1st edition. London. UK.

Moosavian, N. and Jaefarzadeh, M. R., (2014). Hydraulic analysis of water distribution network using shuffled complex evolution. Journal of Fluids 4:1 - 12 http://dx.doi.org/10.1155/2014/979706

Motiee, H., McBean, E. and Motiei A., (2007). Estimating physical unaccounted for water in distribution networks using simulation models and GIS. Urban Water Journal 4: 43-52.

Motiee, H., Mc Bean, E. and Motiei, A., (2007). Estimating physical unaccounted for water in distribution networks using simulation models and GIS. Urban Water Journal 4: 55-68.

MoWE (Ministry of Water and Energy), (2011) .Urban water supply universal access plan PART III. Water Resources Administration. Urban Water Supply and Sanitation Department. *MoWE. Addis Abab, Ethiopia*

MoWIE (Ministry of Water, Irrigation and Energy) (2015) *Urban Water Supply Design Criteria.* Water Resources Administration. Urban Water Supply and Sanitation Department. *MoWR. Addis Abab, Ethiopia*

MoWIE. (2006). *Urban water supply design criteria.* Water resources administration. Water Resources Administration Urban Water Supply and Sanitation Department.".

MoWR (Ministry of Water Resources), (2006). *Urban Water Supply Design Criteria: Water Resources Administration. Urban Water Supply and Sanitation Department. MoWR. Addis Abab, Ethiopia*

MoWR (Ministry of Water Resources), (2006b). *Urban Water Supply Design Criteria: Water Resources Administration. Urban Water Supply and Sanitation Department. MoWR. Addis Abab, Ethiopia*

NRC (National Reaserch Council), (2006). Drinking water distribution systems: Assessing and reducing risks. The national academics press, Washington, D.C. USA.

Pravinkumar Shinde 1, P. P. (2018). Design and analysis of water distribution network using Water GEMS. *International Journal of Advance Research in Science and Engineering, 7(3):545 - 552*

Pravinkumar Shinde, 1, P. P., (2008). *Design and analysis of water distribution network using Water GEMS. International Journal of Advanced Research in Science and Engineering.* 4:125-248.

Robert, E., (2000). Hydraulic modeling: concepts and practice. *Journal of Applied water Engineering and Research*. 5:78-98

Samani, H. M. .and Taghi, N., (1996). Optimization of water distribution networks. *Hydraulic research 34: 623-632*

Sastry, G., (2006) Issues of unaccounted for water in the urban water sector. Institute for Social and Economic Change. Working Paper 176. Banglore, India

Seago, C., (2005). Assessment of real losses in potable water distribution . *Water Science and Technology 4:* 56-62.

Seago, C., Bhagwan, J. and McKenzie, R., (2004) Benchmarking leakage from water reticulation systems in South Africa. Water SA 30: 25-32

Sharma, S. and Sarka, H., (2008). Urban water supply hydrualic performance assassment. *Engineering sream 3:*45-63.

Sharma, S., (2008). Design of water supply pipe network. *Engineering stream* 3: 35-56.

Swamee, P. K. and Sharma, A. K., (2008). *Design of water supply pipe networks. John Wiley and Son Inc.,* New Jersey, USA.

Tabesh, M. and Asadiani Yekta, A. H., (2005). A software tool for non-revenue water calculations in urban water systems in conjunction with hydraulic and GIS models. Conference Proceedings paper. Civil Engineering Department, University of Tehran, Tehran, Iran. Pp. 11.

Tomas, M. and (2003). Advanced Water Distribution Modelling and Management: Haested Press Berkeley. USA.

UNEP (United Nation Environmental Protection), (2000). Malta water services corporation: Leakage control and unaccounted for. UN environmental program, Nairobi, Kenya

Venkateswara, P., (2005). Water Supply Engineering. Water Supply and Sanitary Engineering. Intermediate vocational Course. Andhra Pradesh. Hyderabad, India.

VIadan, B., Asadiani, Y and John, P., (2002). A data mining approach to modelling of water supply assets. Asian Development Bank. Mandaluyong, Philippines.

Walski, T., Totsuka, M. and Niet, T., (2003). Advanced water distribution modeling and management. *Water research and Technology 4:*85-92.

WHO *(World Health Organization presses*), (2011). *Guidelines for drinking-water quality. 4th edition, Geneva, Switzerland,*

WHO (*World Health Organization),* (2000). *Global water suppl and sanitation sector assessment. WHO,* Geneva, Switzerland.

WHO (*World Health Organization)*, (2001), Leakage management and control: A best practice training manual. second edition. Vol.3. WHO. Geneva, Switzerland.

WHO (*World Health Organization),* (2011). *Guidelines for Drinking Water Quality.* WHO, Geneva, Switzerland.

Williams, G. S and Hazen, A., (1906). Hydraulic Tables: Empirical formula flow rate in pipe. John Wiley and Sons, New York. USA

Xin, K., Tao, T., and Lu, Y., (2014). Apparent losses analysis in district metered areas of water . *Water resources management 2:* 682-690.

Yepes, G., (1995). Reduction of unaccounted for water, best practices. The world bank retrieved on July 6, 2004. (Gelijkwaardige pagina's). *4th edition*.

7. APPENDICES

Appendix 1. Table 1 junction recorded and analysis output of Batu hydraulic system

~~Table 7.1~~

Label	Elevation (m)	Base Flow (l/s)	Demand (Calculated) (l/s)	Calculated Hydraulic Grade (m)	Pressure (m H2O)	X (m)	Y (m)
J 5	1,656.00	0.61	0.61	1,670.60	16.52	467,932.35	877,407.11
J 39	1,656.00	0.61	0.61	1,657.43	18.45	467,847.28	876,790.79
J 15	1,645.00	0.61	0.61	1,652.86	14.21	469,644.18	875,719.80
J 21	1,647.00	0.62	0.62	1,651.98	4.969	469,185.00	875,187.00
J 1	1,655.00	1.2	1.2	1,640.05	14.924	468,711.00	877,198.47
J 6	1,656.00	0.61	0.61	1,667.37	11.343	468,150.67	877,295.46
J 37	1,654.00	12	0.62	1,654.33	40.333	468,325.40	876,730.97
J 28	1,652.00	3	0.61	1,653.72	51.72	468,510.88	875,516.32
J 13	1,644.00	0.62	0.62	1,648.59	4.576	469,595.69	876,362.64
J 14	1,644.00	0.62	0.62	1,649.83	45.813	469,529.74	876,105.05
J 2	1,645.00	1	1	1,635.96	39.019	469,768.68	877,131.37
J 20	1,648.00	0.61	0.61	1,650.84	42.83	469,648.50	875,141.09
J 12	1,644.00	0.61	0.61	1,648.25	34.245	469,660.73	876,590.26
J 16	1,645.00	0.61	0.61	1,652.76	47.743	469,763.22	875,447.66
J 25	1,653.00	0.61	0.61	1,653.42	50.416	468,741.49	875,494.63
J 38	1,656.00	0.61	0.61	1,654.34	21.653	468,076.92	876,760.05
J 40	1,656.00	0.61	0.61	1,659.88	53.871	467,467.14	876,831.62
J 46	1,659.00	0.61	0.61	1,674.90	55.868	467,084.25	877,575.40
J 45	1,659.00	0.6	0.6	1,675.50	16.466	467,233.04	877,560.71
J 4	1,658.00	3	3	1,673.35	15.322	467,530.25	877,812.94
J 42	1,657.00	0.61	0.61	1,674.82	17.783	467,107.83	876,867.70
1000M3 R1	1,690.00	0	0	1,693.78	3.769	463,926.31	877,639.55
J 26	1,650.00	0.61	0.61	1,651.64	1.638	469,425.33	875,390.41
J 29	1,654.00	0.61	0.61	1,653.77	-0.233	468,558.84	875,865.23
J 19	1,647.00	0.61	0.61	1,652.50	5.485	470,610.00	874,558.00
J 18	1,643.00	0.61	0.61	1,652.59	9.571	470,265.70	874,990.94
J 27	1,654.00	0.62	0.62	1,653.69	-0.312	468,491.73	875,208.02
J 22	1,653.00	0.62	0.62	1,653.42	0.417	468,712.54	875,232.24
J 17	1,646.00	0.61	0.61	1,652.66	6.65	469,933.60	875,098.48
J 11	1,645.00	0.62	0.62	1,638.02	-6.97	469,704.55	876,795.97
J 31	1,648.00	0.6	0.6	1,653.01	5.003	469,260.97	875,786.65
J 34	1,649.00	0.61	0.61	1,652.67	3.66	468,997.35	876,166.58
J 30	1,652.00	0.62	0.62	1,653.40	1.396	468,800.19	875,840.84
J 9	1,649.00	3	3	1,508.64	-140.074	469,110.56	877,138.33
T	1,648.00	3	3	1,650.48	2.479	469,066.84	876,667.36
J 3	1,654.00	1	1	1,654.03	0.029	468,227.00	875,918.00
J 10	1,654.00	5	5	1,667.30	13.276	468,042.31	875,947.28
back sch	1,651.00	1	1	1,648.05	-2.945	469,341.62	876,374.54
J-57	1,650.00	0.61	0.61	1,648.47	-1.531	469,298.58	876,133.57
J-59	1,649.00	0.62	0.62	1,651.98	22.973	469,262.17	875,774.09
J-60	1,649.00	0.61	0.61	1,651.98	22.974	469,225.34	875,420.85
batu hi sch	1,648.00	0.1	0.1	1,645.35	-2.644	469,457.85	876,624.54
osu main get	1,648.00	0.2	0.2	1,645.34	-2.654	469,517.68	877,132.01
youth center	1,646.00	0.1	0.1	1,649.96	3.952	469,113.78	877,136.45
T Osho	1,645.00	0.1	0.1	1,645.30	0.301	469,497.40	877,001.23
End tap	1,646.00	0.2	0.2	1,637.61	-8.376	469,104.85	877,018.66
batu ws office	1,648.00	0.3	0.3	1,650.06	2.06	469,484.54	876,820.89
J-67	1,648.00	0.61	0.61	1,650.09	2.087	469,081.66	876,843.38
Batu no 1	1,650.00	0.2	0.2	1,653.14	3.134	468,960.50	875,822.61
J-69	1,650.00	0.62	0.62	1,640.13	-9.854	469,561.11	876,799.56
J-70	1,648.00	0.61	0.61	1,645.12	-2.872	469,543.06	876,613.96
end tap unkuro	1,649.00	0.3	0.3	1,641.52	-7.47	469,061.03	876,400.01
end barecha	1,649.00	0.4	0.4	1,641.36	-7.625	469,151.22	876,186.32
Cross T	1,649.00	1	1	1,641.59	-7.398	469,171.87	876,392.28
tap	1,646.00	1	1	1,640.31	-5.679	469,192.50	876,603.65
Hara Danbal	1,651.00	1	1	1,641.31	-9.673	468,783.16	876,872.15
bekale mola bend	1,653.00	1	1	1,644.85	-8.134	468,642.57	876,061.88

T Yeroke	1,653.00	1	1	1,653.64	0.635	468,633.14	875,861.27
J-78	1,652.00	0.61	0.61	1,642.21	29.773	468,773.62	876,053.96
J-79	1,652.00	0.62	0.62	1,641.43	-10.544	468,776.20	876,131.93
J-80	1,652.00	0.62	0.62	1,641.24	-10.74	468,711.76	876,139.67
Bochesa g.tara	1,653.00	1	1	1,641.23	-11.75	468,730.54	876,422.22
p.station	1,652.00	1	1	1,640.38	-11.601	468,799.37	877,027.71
J-82	1,652.00	0.62	0.62	1,640.29	-11.689	468,699.51	877,029.29
end of lut	1,651.00	1	1	1,649.90	-1.097	468,969.41	875,231.37
J-83	1,651.00	0.62	0.62	1,652.23	1.223	469,024.95	875,453.68
J-84	1,651.00	0.62	0.62	1,650.83	-0.168	469,002.39	875,382.79
J-85	1,651.00	0.61	0.61	1,650.52	-0.478	468,776.84	875,411.79
J-86	1,652.00	0.61	0.61	1,650.79	-1.211	468,886.39	875,398.90
J-87	1,651.00	0.61	0.61	1,651.83	0.826	468,863.84	875,224.91
d limat	1,648.00	2	2	1,543.47	-104.321	469,124.19	877,709.46
Gubaye l.e church	1,648.00	1	1	1,586.63	-61.247	468,840.06	877,734.45
sosina Hotel	1,650.00	1	1	1,629.31	-20.651	468,803.15	877,481.22
curve	1,648.00	1	1	1,471.99	75.655	469,479.66	877,333.92
J-92	1,647.00	0.62	0.62	1,509.55	37.175	469,113.81	877,332.44
bend to end	1,648.00	1	1	1,467.68	59.955	469,504.79	877,470.40
Tanker house	1,649.00	0	0	1,469.88	-178.76	469,561.34	877,386.46
end tap atanker	1,646.00	1	1	1,467.28	-178.358	469,438.49	877,472.91
u1	1,646.00	1	1	1,473.31	-172.337	469,391.26	877,526.78
u2	1,646.00	1	1	1,473.27	-172.378	469,339.66	877,521.67
J-98	1,645.00	0.62	0.62	1,475.30	-169.358	469,407.84	877,333.73
J-99	1,647.00	0.62	0.62	1,473.03	-173.619	469,338.93	877,423.63
T Health center 1	1,647.00	1	1	1,515.47	-131.266	469,118.75	877,514.07
J-101	1,646.00	0.61	0.61	1,473.95	-171.7	469,268.95	877,519.45
E	1,645.00	6	6	1,450.41	-194.196	469,270.02	877,377.87
K/LOONII FUULLEE	1,645.00	2	2	1,521.82	-122.927	469,269.48	877,593.00
J-104	1,646.00	0.62	0.62	1,525.05	-120.708	469,120.91	877,592.67
bEND 1	1,647.00	2	2	1,594.34	52.559	468,960.00	877,664.40
front of life song	1,647.00	1	1	1,604.83	42.082	468,927.30	877,391.97
J-107	1,647.00	0.62	0.62	1,595.42	51.479	468,831.82	877,675.03
el	1,646.00	1	1	1,593.68	52.216	468,894.00	877,612.00
J-109	1,647.00	0.62	0.62	1,593.17	53.726	468,866.50	877,406.88
J-110	1,645.00	0.62	0.62	1,594.56	50.337	468,953.97	877,607.92
NOC	1,646.00	1	1	1,645.61	20.387	468,943.33	878,247.43
TT	1,646.00	1	1	1,586.40	59.481	469,044.70	877,989.32
K	1,646.00	2	2	1,587.75	58.133	468,918.00	878,010.00
LAGA	1,646.00	3	3	1,595.25	50.65	469,163.00	877,990.00
J-115	1,645.00	0.62	0.62	1,561.53	23.303	469,028.53	877,718.36
J-116	1,646.00	0.61	0.61	1,645.43	20.569	469,060.83	878,199.49
GREEN	1,646.00	2	2	1,578.31	27.556	468,904.32	877,890.71
J-118	1,646.00	0.62	0.62	1,576.68	39.181	469,037.53	877,878.84
J-119	1,647.00	0.61	0.61	1,576.96	29.903	468,965.87	877,884.70
J-120	1,647.00	0.61	0.61	1,576.62	40.234	468,950.71	877,747.58
MOBEL	1,651.00	4	4	1,641.65	19.334	468,753.46	877,438.99
J DA	1,653.00	2	2	1,656.14	3.13	468,691.73	877,253.54
J-123	1,652.00	0.63	0.63	1,639.70	-12.274	468,785.24	877,428.89
BEND AT IBSA	1,652.00	2.5	2.5	1,655.19	3.181	468,682.36	877,019.70
TELECENTER	1,650.00	1.6	1.6	1,654.14	4.132	468,584.49	876,704.35
J-126	1,652.00	0.62	0.62	1,654.95	2.945	468,599.47	877,016.57
ABDALA	1,653.00	2	2	1,653.98	0.974	468,570.15	876,382.84
B	1,653.00	1	1	1,653.99	0.984	468,543.77	876,386.24
J-129	1,652.00	0.61	0.61	1,653.85	1.847	468,523.06	875,873.26
DR,BARI	1,653.00	1	1	1,664.32	11.3	468,390.63	877,275.38
BENT TO TECH	1,655.00	1	1	1,666.88	11.858	468,156.88	877,339.23
CWPH	1,648.00	5	5	1,652.30	4.293	470,832.00	873,171.00
J 36	1,651.00	0.61	0.61	1,634.74	-16.228	468,924.58	877,017.79
J-146	1,651.00	0.62	0.62	1,684.52	33.451	464,784.64	877,347.06
J-N-187	1,663.00	0.61	0.61	1,669.80	6.785	466,390.63	873,568.86
J-149	1,652.00	0.61	0.61	1,666.60	14.567	467,546.37	874,340.05
J-N -167	1,651.00	0.6	0.6	1,668.22	17.184	467,998.36	871,088.12
J-N-168	1,655.00	0.6	0.6	1,668.46	13.43	466,701.81	871,390.65
J-N-170	1,652.00	0.61	0.61	1,668.22	16.186	468,110.73	871,900.63
J-N-326	1,652.00	0.62	0.62	1,668.22	16.186	468,179.88	872,445.18

J-N-171	1,653.00	0.61	0.61	1,668.21	15.183	468,231.74	872,946.52
J-N-169	1,656.00	0.6	0.6	1,668.60	12.577	466,744.55	871,966.38
J-N-185	1,656.00	0.63	0.63	1,669.19	13.161	466,732.03	872,540.67
J-N-362	1,664.00	0.61	0.61	1,669.24	5.23	465,655.92	872,574.84
J-N-172	1,654.00	0.62	0.62	1,668.63	14.605	467,790.91	873,110.75
J-N173	1,657.00	0.62	0.62	1,668.93	11.909	467,497.03	873,266.34
J-N-361	1,667.00	0.5	0.5	1,669.44	2.437	465,413.90	873,110.75
J-N-360	1,666.00	0.62	0.62	1,669.87	3.858	465,284.24	873,629.37
J-N-359	1,667.00	0.5	0.5	1,671.50	4.495	465,145.94	874,173.92
ELB	1,666.00	0.25	0.25	1,669.27	3.261	465,552.96	872,625.33
J-N-174	1,661.00	0.61	0.61	1,670.02	9.005	466,775.95	874,118.49
J-N-186	1,661.00	0.23	0.23	1,669.42	8.407	466,632.66	873,058.89
J-166	1,654.00	0.63	0.63	1,670.11	16.075	466,094.05	874,142.08
J-N-190	1,667.00	0.5	0.5	1,672.73	5.714	465,422.54	875,133.38
J-N-	1,658.00	4	4	1,659.14	1.14	467,505.67	874,796.27
J-169	1,661.00	0.62	0.62	1,672.28	11.26	465,362.53	874,167.49
J-N 175	1,663.00	0.5	0.5	1,671.11	8.098	466,717.69	874,927.33
J-172	1,665.00	0.61	0.61	1,671.61	6.595	466,087.85	875,025.14
J-N-191	1,668.00	0.56	0.56	1,673.22	5.211	465,534.91	875,859.45
J-N-176	1,664.00	0.45	0.45	1,672.81	8.788	466,632.66	875,703.86
J-175	1,663.00	0.25	0.25	1,672.94	9.921	466,110.51	875,780.32
J-N-192	1,668.00	0.61	0.61	1,673.57	5.559	465,584.34	876,273.97
J-N-177	1,664.00	0.5	0.5	1,675.84	11.815	466,710.45	876,507.75
J-N-193	1,668.00	0.6	0.6	1,673.87	5.858	465,629.99	876,628.74
J-178	1,664.00	0.5	0.5	1,674.13	10.111	466,173.37	876,566.51
J-179	1,667.00	0.25	0.25	1,673.70	6.689	466,142.99	876,211.61
J-180	1,666.00	0.25	0.25	1,674.14	8.125	466,673.79	876,143.51
J-N-181	1,667.00	0.6	0.6	1,674.49	7.478	465,770.48	877,476.56
J-N Y	1,667.00	0.2	0.2	1,673.01	5.993	466,069.92	878,456.31
J-N-364	1,667.00	0.62	0.62	1,672.13	5.117	466,337.96	879,617.80
J-N-E	1,667.00	0.6	0.6	1,671.79	4.776	466,397.52	880,124.09
J-N-365	1,666.00	0.62	0.62	1,671.70	5.69	466,516.65	880,193.58
J-N-366	1,665.00	0.6	0.6	1,671.39	6.379	466,973.30	880,531.11
J-N-167	1,663.00	0.5	0.5	1,671.02	8.009	467,588.79	880,957.98
J-188	1,661.00	0.6	0.6	1,670.85	9.834	467,956.09	881,067.18
J-N-370	1,659.00	0.5	0.5	1,670.49	11.471	469,187.07	881,275.65
J-N-0	1,663.00	0.5	0.5	1,676.01	12.986	466,900.61	877,380.74
2	1,660.00	2	2	1,672.35	12.322	467,638.42	878,148.57
3	1,655.00	4	4	1,670.42	15.393	468,333.33	878,555.59
4	1,655.00	2	2	1,670.37	15.338	468,333.33	879,111.51
5	1,653.00	5	5	1,670.33	17.291	468,482.24	879,657.51
6	1,654.00	4.5	4.5	1,670.33	16.298	468,512.02	880,332.56
7	1,654.00	0.6	0.6	1,670.50	16.47	468,641.07	881,196.23
J 8	1,654.00	3	3	1,670.39	16.353	468,601.36	880,828.92
J-N196	1,666.00	0.6	0.6	1,672.78	6.762	466,328.03	878,724.35
J-N197	1,665.00	0.5	0.5	1,672.24	7.221	466,774.75	879,012.24
J-N198	1,666.00	0.56	0.56	1,671.56	5.553	467,151.99	879,329.91
J-N-199	1,662.00	0.61	0.61	1,671.18	9.159	467,519.30	879,746.85
J-N-200	1,660.00	0.42	0.42	1,670.95	10.928	467,737.70	880,292.85
J-N-201	1,660.50	0.32	0.32	1,670.87	10.348	467,866.75	880,749.50
J-N-214	1,664.35	0.15	0.15	1,673.37	8.998	466,685.41	878,178.35
J-N-123	1,664.00	0.62	0.62	1,672.28	8.262	467,062.64	878,496.02
J-N-212	1,662.00	0.4	0.4	1,671.22	9.2	467,519.30	878,962.60
J-E	1,656.00	0.51	0.51	1,670.87	14.838	467,956.09	879,329.91
J-N-217	1,650.00	0.51	0.51	1,649.36	-0.634	468,859.47	878,317.33
J-N-204	1,648.00	0.4	0.4	1,670.32	22.277	469,167.22	880,719.72
J-N-338	1,648.00	0.62	0.62	1,670.19	22.147	468,998.45	879,518.53
OOOOO	1,663.00	0	0	1,676.96	13.934	467,072.57	877,354.39
2000M3 R	1,689.00	0	0	1,687.99	-1.006	463,851.00	877,440.00
converjuntion	1,662.00	0	0	1,687.79	25.734	464,114.00	877,410.00
L3	1,648.00	0	0	1,680.48	32.41	465,878.00	877,347.00
Cross TEE	1,639.00	12	12	1,677.26	38.185	466,734.00	877,196.00
ARV							
1,632.00	Zone	Fixed	1,755.57	123.319	476,936.17	851,787.33	
ARV							

1,668.00	Zone	Fixed	1,759.46	91.275	477,588.24	850,234.59	
FV 9	1,672.00	0	0	1,726.95	54.841	468,532.57	861,304.20
FV 12	1,659.00	0	0	1,706.10	47.01	466,634.90	872,692.68
ARV							
1,658.00	Zone	Fixed	1,718.95	60.828	467,928.65	865,724.71	
FV 10	1,653.00	0	0	1,720.85	67.715	468,314.00	864,720.00
ARV							
1,651.00	Zone	Fixed	1,711.77	60.65	467,987.61	869,783.68	
ARV							
1,656.00	Zone	Fixed	1,737.77	81.608	470,470.45	855,972.53	
FV 1	1,679.00	0	0	1,760.26	81.1	477,656.35	849,891.69
FV 11	1,652.00	0	0	1,715.52	63.395	468,044.29	867,661.51
ARV							
1,671.00	Zone	Fixed	1,699.49	28.431	464,639.63	875,861.89	
FV 2	1,635.00	0	0	1,755.91	120.664	477,027.50	851,671.39
ARV							
1,629.00	Zone	Fixed	1,744.10	114.871	472,639.72	854,284.42	
ARV							
1,663.00	Zone	Fixed	1,736.61	73.458	469,986.48	856,326.79	
FV 4	1,598.00	0	0	1,750.86	152.554	475,191.74	852,834.94
FV FV 7	1,665.00	0	0	1,736.34	71.198	469,865.49	856,415.36
ARV							
1,650.00	Zone	Fixed	1,739.96	89.778	471,226.74	855,398.37	
FV 5	1,651.00	0	0	1,739.38	88.206	471,029.15	855,551.36
FV 6	1,660.00	0	0	1,737.31	77.157	470,309.13	856,090.62
ARV							
1,598.00	Zone	Fixed	1,750.40	152.095	475,011.91	852,922.28	
ARV							
1,664.00	Zone	Fixed	1,733.79	69.648	468,865.97	857,458.38	
ARV							
1,598.00	Zone	Fixed	1,752.93	154.622	476,001.53	852,443.00	
						852,443.00	
ARV						852,443.00	
1,668.00	Zone	Fixed	1,724.14	56.026	468,659.33	862,891.52	862,891.52
1,673.00	Zone	Fixed	1,727.83	54.724	468,502.48	860,805.46	860,805.46
FV 8	1,666.00	0	0	1,733.35	67.212	468,798.17	857,698.90
FV 3	1,613.00	0	0	1,754.76	141.476	476,667.98	852,012.00
FV 13	1,688.00	0	0	1,697.81	9.791	464,188.58	876,697.57
J-to share	1,654.00	0	0	1,654.06	0.056	468,163.85	875,237.26
R Tufa site	1,761.00	0	0	1,765.93	4.921	478,609.84	847,622.92
J-237	1,661.00	0.62	0.62	1,696.20	35.124	463,667.81	877,449.02
J-235	1,661.00	0.62	0.62	1,661.27	0.269	468,375.07	874,400.23
J-229	1,660.00	0.62	0.62	1,658.18	-1.815	467,801.96	875,980.25
MEMERE HAMDE	1,650.00	0.2	0.2	1,648.46	-1.542	469,263.83	875,779.75

Appendix 1 Table 2. Junction report and Analysis Result for EPS

Label	Elevation (m)	Demand (Calculated) (l/s)	Calculated Hydraulic Grade (m)	Pressure (m H2O)	X (m)	Y (m)
J 5	1,656.00	0.61	1,670.60	14.572	467,932.35	877,407.11
J 39	1,656.00	0.61	1,657.43	1.426	467,847.28	876,790.79
J 15	1,645.00	0.61	1,652.86	7.845	469,644.18	875,719.80
J 21	1,647.00	0.62	1,651.98	4.969	469,185.00	875,187.00
J 1	1,655.00	2	1,640.05	15	468,711.00	877,198.47

J 6	1,656.00	0.61	1,667.37	11.343	468,150.67	877,295.46
J 37	1,654.00	0.62	1,654.33	0.333	468,325.40	876,730.97
J 28	1,652.00	0.61	1,653.72	1.72	468,510.88	875,516.32
J 13	1,644.00	0.62	1,648.59	4.576	469,595.69	876,362.64
J 14	1,644.00	0.62	1,649.83	5.813	469,529.74	876,105.05
J 2	1,645.00	1	1,635.96	-9.019	469,768.68	877,131.37
J 20	1,648.00	0.61	1,650.84	2.83	469,648.50	875,141.09
J 12	1,644.00	0.61	1,648.25	4.245	469,660.73	876,590.26
J 16	1,645.00	0.61	1,652.76	7.743	469,763.22	875,447.66
J 25	1,653.00	0.61	1,653.42	0.416	468,741.49	875,494.63
J 38	1,656.00	0.61	1,654.34	-1.653	468,076.92	876,760.05
J 40	1,656.00	0.61	1,659.88	3.871	467,467.14	876,831.62
J 46	1,659.00	0.61	1,674.90	15.868	467,084.25	877,575.40
J 45	1,659.00	0.6	1,675.50	16.466	467,233.04	877,560.71
J 4	1,658.00	3	1,673.35	15.322	467,530.25	877,812.94
J 42	1,657.00	0.61	1,674.82	17.783	467,107.83	876,867.70
1000M3 R1	1,690.00	0	1,693.78	3.769	463,926.31	877,639.55
J 26	1,650.00	0.61	1,651.64	1.638	469,425.33	875,390.41
J 29	1,654.00	0.61	1,653.77	-0.233	468,558.84	875,865.23
J 19	1,647.00	0.61	1,652.50	5.485	470,610.00	874,558.00
J 18	1,643.00	0.61	1,652.59	9.571	470,265.70	874,990.94
J 27	1,654.00	0.62	1,653.69	-0.312	468,491.73	875,208.02
J 22	1,653.00	0.62	1,653.42	0.417	468,712.54	875,232.24
J 17	1,646.00	0.61	1,652.66	6.65	469,933.60	875,098.48
J 11	1,645.00	0.62	1,638.02	-6.97	469,704.55	876,795.97
J 31	1,648.00	0.6	1,653.01	5.003	469,260.97	875,786.65
J 34	1,649.00	0.61	1,652.67	3.66	468,997.35	876,166.58
J 30	1,652.00	0.62	1,653.40	1.396	468,800.19	875,840.84
J 9	1,649.00	3	1,508.64	-140.074	469,110.56	877,138.33
T	1,648.00	3	1,650.48	2.479	469,066.84	876,667.36
J 3	1,654.00	1	1,654.03	0.029	468,227.00	875,918.00
J 10	1,654.00	5	1,667.30	13.276	468,042.31	875,947.28
back sch	1,651.00	1	1,648.05	-2.945	469,341.62	876,374.54
J-57	1,650.00	0.61	1,648.47	-1.531	469,298.58	876,133.57
J-59	1,649.00	0.62	1,651.98	2.973	469,262.17	875,774.09
J-60	1,649.00	0.61	1,651.98	2.974	469,225.34	875,420.85
batu hi sch	1,648.00	0.1	1,645.35	-2.644	469,457.85	876,624.54
osu main get	1,648.00	0.2	1,645.34	-2.654	469,517.68	877,132.01
youth center	1,646.00	0.1	1,649.96	3.952	469,113.78	877,136.45
T Osho	1,645.00	0.1	1,645.30	0.301	469,497.40	877,001.23
End tap	1,646.00	0.2	1,637.61	-8.376	469,104.85	877,018.66
batu ws office	1,648.00	0.3	1,650.06	2.06	469,484.54	876,820.89
J-67	1,648.00	0.61	1,650.09	2.087	469,081.66	876,843.38
Batu no 1	1,650.00	0.2	1,653.14	3.134	468,960.50	875,822.61
J-69	1,650.00	0.62	1,640.13	-9.854	469,561.11	876,799.56
J-70	1,648.00	0.61	1,645.12	-2.872	469,543.06	876,613.96
end tap unkuro	1,649.00	0.3	1,641.52	-7.47	469,061.03	876,400.01
end barecha	1,649.00	0.4	1,641.36	-7.625	469,151.22	876,186.32
Cross T	1,649.00	1	1,641.59	-7.398	469,171.87	876,392.28
Tap	1,646.00	1	1,640.31	-5.679	469,192.50	876,603.65
Hara Danbal	1,651.00	1	1,641.31	-9.673	468,783.16	876,872.15
bekale mola bend	1,653.00	1	1,644.85	-8.134	468,642.57	876,061.88
T Yeroke	1,653.00	1	1,653.64	0.635	468,633.14	875,861.27
J-78	1,652.00	0.61	1,642.21	-9.773	468,773.62	876,053.96
J-79	1,652.00	0.62	1,641.43	-10.544	468,776.20	876,131.93
J-80	1,652.00	0.62	1,641.24	-10.74	468,711.76	876,139.67
Bochesa g.tara	1,653.00	1	1,641.23	-11.75	468,730.54	876,422.22
p.station	1,652.00	1	1,640.38	-11.601	468,799.37	877,027.71
J-82	1,652.00	0.62	1,640.29	-11.689	468,699.51	877,029.29

end of lut	1,651.00	1	1,649.90	-1.097	468,969.41	875,231.37
J-83	1,651.00	0.62	1,652.23	1.223	469,024.95	875,453.68
J-84	1,651.00	0.62	1,650.83	-0.168	469,002.39	875,382.79
J-85	1,651.00	0.61	1,650.52	-0.478	468,776.84	875,411.79
J-86	1,652.00	0.61	1,650.79	-1.211	468,886.39	875,398.90
J-87	1,651.00	0.61	1,651.83	0.826	468,863.84	875,224.91
d limat	1,648.00	2	1,543.47	-104.321	469,124.19	877,709.46
Gubaye l.e church	1,648.00	1	1,586.63	-61.247	468,840.06	877,734.45
sosina Hotel	1,650.00	1	1,629.31	-20.651	468,803.15	877,481.22
curve	1,648.00	1	1,471.99	-175.655	469,479.66	877,333.92
J-92	1,647.00	0.62	1,509.55	-137.175	469,113.81	877,332.44
bend to end	1,648.00	1	1,467.68	-179.955	469,504.79	877,470.40
Tanker house	1,649.00	0	1,469.88	-178.76	469,561.34	877,386.46
end tap atanker	1,646.00	1	1,467.28	-178.358	469,438.49	877,472.91
u1	1,646.00	1	1,473.31	-172.337	469,391.26	877,526.78
u2	1,646.00	1	1,473.27	-172.378	469,339.66	877,521.67
J-98	1,645.00	0.62	1,475.30	-169.358	469,407.84	877,333.73
J-99	1,647.00	0.62	1,473.03	-173.619	469,338.93	877,423.63
T Health center 1	1,647.00	1	1,515.47	-131.266	469,118.75	877,514.07
J-101	1,646.00	0.61	1,473.95	-171.7	469,268.95	877,519.45
E	1,645.00	6	1,450.41	-194.196	469,270.02	877,377.87
K/LOONII FUULLEE	1,645.00	2	1,521.82	-122.927	469,269.48	877,593.00
J-104	1,646.00	0.62	1,525.05	-120.708	469,120.91	877,592.67
bEND 1	1,647.00	2	1,594.34	-52.559	468,960.00	877,664.40
front of life song	1,647.00	1	1,604.83	-42.082	468,927.30	877,391.97
J-107	1,647.00	0.62	1,595.42	-51.479	468,831.82	877,675.03
El	1,646.00	1	1,593.68	-52.216	468,894.00	877,612.00
J-109	1,647.00	0.62	1,593.17	-53.726	468,866.50	877,406.88
J-110	1,645.00	0.62	1,594.56	-50.337	468,953.97	877,607.92
NOC	1,646.00	1	1,645.61	-0.387	468,943.33	878,247.43
TT	1,646.00	1	1,586.40	-59.481	469,044.70	877,989.32
K	1,646.00	2	1,587.75	-58.133	468,918.00	878,010.00
LAGA	1,646.00	3	1,595.25	-50.65	469,163.00	877,990.00
J-115	1,645.00	0.62	1,561.53	-83.303	469,028.53	877,718.36
J-116	1,646.00	0.61	1,645.43	-0.569	469,060.83	878,199.49
GREEN	1,646.00	2	1,578.31	-67.556	468,904.32	877,890.71
J-118	1,646.00	0.62	1,576.68	-69.181	469,037.53	877,878.84
J-119	1,647.00	0.61	1,576.96	-69.903	468,965.87	877,884.70
J-120	1,647.00	0.61	1,576.62	-70.234	468,950.71	877,747.58
MOBEL	1,651.00	4	1,641.65	-9.334	468,753.46	877,438.99
J DA	1,653.00	2	1,656.14	3.13	468,691.73	877,253.54
J-123	1,652.00	0.63	1,639.70	-12.274	468,785.24	877,428.89
BEND AT IBSA	1,652.00	2.5	1,655.19	3.181	468,682.36	877,019.70
TELECENTER	1,650.00	1.6	1,654.14	4.132	468,584.49	876,704.35
J-126	1,652.00	0.62	1,654.95	2.945	468,599.47	877,016.57
ABDALA	1,653.00	2	1,653.98	0.974	468,570.15	876,382.84
B	1,653.00	1	1,653.99	0.984	468,543.77	876,386.24
J-129	1,652.00	0.61	1,653.85	1.847	468,523.06	875,873.26
DR,BARI	1,653.00	1	1,664.32	11.3	468,390.63	877,275.38
BENT TO TECH	1,655.00	1	1,666.88	11.858	468,156.88	877,339.23
CWPH	1,648.00	5	1,652.30	4.293	470,832.00	873,171.00
J 36	1,651.00	0.61	1,634.74	-16.228	468,924.58	877,017.79
J-146	1,651.00	0.62	1,684.52	33.451	464,784.64	877,347.06
J-N-187	1,663.00	0.61	1,669.80	6.785	466,390.63	873,568.86
J-149	1,652.00	0.61	1,666.60	14.567	467,546.37	874,340.05
J-N -167	1,651.00	0.6	1,668.22	17.184	467,998.36	871,088.12
J-N-168	1,655.00	0.6	1,668.46	13.43	466,701.81	871,390.65
J-N-170	1,652.00	0.61	1,668.22	16.186	468,110.73	871,900.63
J-N-326	1,652.00	0.62	1,668.22	16.186	468,179.88	872,445.18

J-N-171	1,653.00	0.61	1,668.21	15.183	468,231.74	872,946.52
J-N-169	1,656.00	0.6	1,668.60	12.577	466,744.55	871,966.38
J-N-185	1,656.00	0.63	1,669.19	13.161	466,732.03	872,540.67
J-N-362	1,664.00	0.61	1,669.24	5.23	465,655.92	872,574.84
J-N-172	1,654.00	0.62	1,668.63	14.605	467,790.91	873,110.75
J-N173	1,657.00	0.62	1,668.93	11.909	467,497.03	873,266.34
J-N-361	1,667.00	0.5	1,669.44	2.437	465,413.90	873,110.75
J-N-360	1,666.00	0.62	1,669.87	3.858	465,284.24	873,629.37
J-N-359	1,667.00	0.5	1,671.50	4.495	465,145.94	874,173.92
ELB	1,666.00	0.25	1,669.27	3.261	465,552.96	872,625.33
J-N-174	1,661.00	0.61	1,670.02	9.005	466,775.95	874,118.49
J-N-186	1,661.00	0.23	1,669.42	8.407	466,632.66	873,058.89
J-166	1,654.00	0.63	1,670.11	16.075	466,094.05	874,142.08
J-N-190	1,667.00	0.5	1,672.73	5.714	465,422.54	875,133.38
J-N-	1,658.00	4	1,659.14	1.14	467,505.67	874,796.27
J-169	1,661.00	0.62	1,672.28	11.26	465,362.53	874,167.49
J-N 175	1,663.00	0.5	1,671.11	8.098	466,717.69	874,927.33
J-172	1,665.00	0.61	1,671.61	6.595	466,087.85	875,025.14
J-N-191	1,668.00	0.56	1,673.22	5.211	465,534.91	875,859.45
J-N-176	1,664.00	0.45	1,672.81	8.788	466,632.66	875,703.86
J-175	1,663.00	0.25	1,672.94	9.921	466,110.51	875,780.32
J-N-192	1,668.00	0.61	1,673.57	5.559	465,584.34	876,273.97
J-N-177	1,664.00	0.5	1,675.84	11.815	466,710.45	876,507.75
J-N-193	1,668.00	0.6	1,673.87	5.858	465,629.99	876,628.74
J-178	1,664.00	0.5	1,674.13	10.111	466,173.37	876,566.51
J-179	1,667.00	0.25	1,673.70	6.689	466,142.99	876,211.61
J-180	1,666.00	0.25	1,674.14	8.125	466,673.79	876,143.51
J-N-181	1,667.00	0.6	1,674.49	7.478	465,770.48	877,476.56
J-N Y	1,667.00	0.2	1,673.01	5.993	466,069.92	878,456.31
J-N-364	1,667.00	0.62	1,672.13	5.117	466,337.96	879,617.80
J-N-E	1,667.00	0.6	1,671.79	4.776	466,397.52	880,124.09
J-N-365	1,666.00	0.62	1,671.70	5.69	466,516.65	880,193.58
J-N-366	1,665.00	0.6	1,671.39	6.379	466,973.30	880,531.11
J-N-167	1,663.00	0.5	1,671.02	8.009	467,588.79	880,957.98
J-188	1,661.00	0.6	1,670.85	9.834	467,956.09	881,067.18
J-N-370	1,659.00	0.5	1,670.49	11.471	469,187.07	881,275.65
J-N-0	1,663.00	0.5	1,676.01	12.986	466,900.61	877,380.74
2	1,660.00	2	1,672.35	12.322	467,638.42	878,148.57
3	1,655.00	4	1,670.42	15.393	468,333.33	878,555.59
4	1,655.00	2	1,670.37	15.338	468,333.33	879,111.51
5	1,653.00	5	1,670.33	17.291	468,482.24	879,657.51
6	1,654.00	4.5	1,670.33	16.298	468,512.02	880,332.56
7	1,654.00	0.6	1,670.50	16.47	468,641.07	881,196.23
J 8	1,654.00	3	1,670.39	16.353	468,601.36	880,828.92
J-N196	1,666.00	0.6	1,672.78	6.762	466,328.03	878,724.35
J-N197	1,665.00	0.5	1,672.24	7.221	466,774.75	879,012.24
J-N198	1,666.00	0.56	1,671.56	5.553	467,151.99	879,329.91
J-N-199	1,662.00	0.61	1,671.18	9.159	467,519.30	879,746.85
J-N-200	1,660.00	0.42	1,670.95	10.928	467,737.70	880,292.85
J-N-201	1,660.50	0.32	1,670.87	10.348	467,866.75	880,749.50
J-N-214	1,664.35	0.15	1,673.37	8.998	466,685.41	878,178.35
J-N-123	1,664.00	0.62	1,672.28	8.262	467,062.64	878,496.02
J-N-212	1,662.00	0.4	1,671.22	9.2	467,519.30	878,962.60
J-E	1,656.00	0.51	1,670.87	14.838	467,956.09	879,329.91
J-N-217	1,650.00	0.51	1,649.36	-0.634	468,859.47	878,317.33
J-N-204	1,648.00	0.4	1,670.32	22.277	469,167.22	880,719.72
J-N-338	1,648.00	0.62	1,670.19	22.147	468,998.45	879,518.53
OOOOO	1,663.00	0	1,676.96	13.934	467,072.57	877,354.39
2000M3 R	1,689.00	0	1,687.99	-1.006	463,851.00	877,440.00

converjuntion	1,662.00	0	1,687.79	25.734	464,114.00	877,410.00
L3	1,648.00	0	1,680.48	32.41	465,878.00	877,347.00
Cross TEE	1,639.00	12	1,677.26	38.185	466,734.00	877,196.00
ARV						
1,632.00	Zone	1,755.57	123.319	476,936.17	851,787.33	
ARV						
1,668.00	Zone	1,759.46	91.275	477,588.24	850,234.59	
FV 9	1,672.00	0	1,726.95	54.841	468,532.57	861,304.20
FV 12	1,659.00	0	1,706.10	47.01	466,634.90	872,692.68
ARV						
1,658.00	Zone	1,718.95	60.828	467,928.65	865,724.71	
FV 10	1,653.00	0	1,720.85	67.715	468,314.00	864,720.00
ARV						
1,651.00	Zone	1,711.77	60.65	467,987.61	869,783.68	
ARV						
1,656.00	Zone	1,737.77	81.608	470,470.45	855,972.53	
FV 1	1,679.00	0	1,760.26	81.1	477,656.35	849,891.69
FV 11	1,652.00	0	1,715.52	63.395	468,044.29	867,661.51
ARV						
1,671.00	Zone	1,699.49	28.431	464,639.63	875,861.89	
FV 2	1,635.00	0	1,755.91	120.664	477,027.50	851,671.39
ARV						
1,629.00	Zone	1,744.10	114.871	472,639.72	854,284.42	
ARV						
1,663.00	Zone	1,736.61	73.458	469,986.48	856,326.79	
FV 4	1,598.00	0	1,750.86	152.554	475,191.74	852,834.94
FV FV 7	1,665.00	0	1,736.34	71.198	469,865.49	856,415.36
ARV						
1,650.00	Zone	1,739.96	89.778	471,226.74	855,398.37	
FV 5	1,651.00	0	1,739.38	88.206	471,029.15	855,551.36
FV 6	1,660.00	0	1,737.31	77.157	470,309.13	856,090.62
ARV						
1,598.00	Zone	1,750.40	152.095	475,011.91	852,922.28	
ARV						
1,664.00	Zone	1,733.79	69.648	468,865.97	857,458.38	
ARV						
1,598.00	Zone	1,752.93	154.622	476,001.53	852,443.00	
ARV						
1,668.00	Zone	1,724.14	56.026	468,659.33	862,891.52	
ARV						
1,673.00	Zone	1,727.83	54.724	468,502.48	860,805.46	
FV 8	1,666.00	0	1,733.35	67.212	468,798.17	857,698.90
FV 3	1,613.00	0	1,754.76	141.476	476,667.98	852,012.00
FV 13	1,688.00	0	1,697.81	9.791	464,188.58	876,697.57
J-to share	1,654.00	0	1,654.06	0.056	468,163.85	875,237.26
R Tufa site	1,761.00	0	1,765.93	4.921	478,609.84	847,622.92
J-237	1,661.00	0.62	1,696.20	35.124	463,667.81	877,449.02
J-235	1,661.00	0.62	1,661.27	0.269	468,375.07	874,400.23
J-229	1,660.00	0.62	1,658.18	-1.815	467,801.96	875,980.25

MEMERE HAMDE	1,650.00	0.2	1,648.46	-1.542	469,263.83	875,779.75

Appendice 2 Junction report and Analysis Result for EPS

Label	Elevation (m)	Demand (Calculated) (l/s)	Calculated Hydraulic Grade (m)	Pressure (m H2O)	X (m)	Y (m)
J 5	1,656.00	0.61	1,670.60	14.572	467,932.35	877,407.11
J 39	1,656.00	0.61	1,657.43	1.426	467,847.28	876,790.79
J 15	1,645.00	0.61	1,652.86	7.845	469,644.18	875,719.80
J 21	1,647.00	0.62	1,651.98	4.969	469,185.00	875,187.00
J 1	1,655.00	1.2	1,640.05	-14.924	468,711.00	877,198.47
J 6	1,656.00	0.61	1,667.37	11.343	468,150.67	877,295.46
J 37	1,654.00	0.62	1,654.33	0.333	468,325.40	876,730.97
J 28	1,652.00	0.61	1,653.72	1.72	468,510.88	875,516.32
J 13	1,644.00	0.62	1,648.59	4.576	469,595.69	876,362.64
J 14	1,644.00	0.62	1,649.83	5.813	469,529.74	876,105.05
J 2	1,645.00	1	1,635.96	-9.019	469,768.68	877,131.37
J 20	1,648.00	0.61	1,650.84	2.83	469,648.50	875,141.09
J 12	1,644.00	0.61	1,648.25	4.245	469,660.73	876,590.26
J 16	1,645.00	0.61	1,652.76	7.743	469,763.22	875,447.66
J 25	1,653.00	0.61	1,653.42	0.416	468,741.49	875,494.63
J 38	1,656.00	0.61	1,654.34	-1.653	468,076.92	876,760.05
J 40	1,656.00	0.61	1,659.88	3.871	467,467.14	876,831.62
J 46	1,659.00	0.61	1,674.90	15.868	467,084.25	877,575.40
J 45	1,659.00	0.6	1,675.50	16.466	467,233.04	877,560.71
J 4	1,658.00	3	1,673.35	15.322	467,530.25	877,812.94
J 42	1,657.00	0.61	1,674.82	17.783	467,107.83	876,867.70
1000M3 R1	1,690.00	0	1,693.78	3.769	463,926.31	877,639.55
J 26	1,650.00	0.61	1,651.64	1.638	469,425.33	875,390.41
J 29	1,654.00	0.61	1,653.77	-0.233	468,558.84	875,865.23
J 19	1,647.00	0.61	1,652.50	5.485	470,610.00	874,558.00
J 18	1,643.00	0.61	1,652.59	9.571	470,265.70	874,990.94
J 27	1,654.00	0.62	1,653.69	-0.312	468,491.73	875,208.02
J 22	1,653.00	0.62	1,653.42	0.417	468,712.54	875,232.24
J 17	1,646.00	0.61	1,652.66	6.65	469,933.60	875,098.48
J 11	1,645.00	0.62	1,638.02	-6.97	469,704.55	876,795.97
J 31	1,648.00	0.6	1,653.01	5.003	469,260.97	875,786.65
J 34	1,649.00	0.61	1,652.67	3.66	468,997.35	876,166.58
J 30	1,652.00	0.62	1,653.40	1.396	468,800.19	875,840.84
J 9	1,649.00	3	1,508.64	-140.074	469,110.56	877,138.33
T	1,648.00	3	1,650.48	2.479	469,066.84	876,667.36
J 3	1,654.00	1	1,654.03	0.029	468,227.00	875,918.00
J 10	1,654.00	5	1,667.30	13.276	468,042.31	875,947.28
back sch	1,651.00	1	1,648.05	-2.945	469,341.62	876,374.54
J-57	1,650.00	0.61	1,648.47	-1.531	469,298.58	876,133.57
J-59	1,649.00	0.62	1,651.98	2.973	469,262.17	875,774.09
J-60	1,649.00	0.61	1,651.98	2.974	469,225.34	875,420.85
batu hi sch	1,648.00	0.1	1,645.35	-2.644	469,457.85	876,624.54
osu main get	1,648.00	0.2	1,645.34	-2.654	469,517.68	877,132.01
youth center	1,646.00	0.1	1,649.96	3.952	469,113.78	877,136.45
T Osho	1,645.00	0.1	1,645.30	0.301	469,497.40	877,001.23
End tap	1,646.00	0.2	1,637.61	-8.376	469,104.85	877,018.66
batu ws office	1,648.00	0.3	1,650.06	2.06	469,484.54	876,820.89
J-67	1,648.00	0.61	1,650.09	2.087	469,081.66	876,843.38
Batu no 1	1,650.00	0.2	1,653.14	3.134	468,960.50	875,822.61
J-69	1,650.00	0.62	1,640.13	-9.854	469,561.11	876,799.56

J-70	1,648.00	0.61	1,645.12	-2.872	469,543.06	876,613.96
end tap unkuro	1,649.00	0.3	1,641.52	-7.47	469,061.03	876,400.01
end barecha	1,649.00	0.4	1,641.36	-7.625	469,151.22	876,186.32
Cross T	1,649.00	1	1,641.59	-7.398	469,171.87	876,392.28
tap	1,646.00	1	1,640.31	-5.679	469,192.50	876,603.65
Hara Danbal	1,651.00	1	1,641.31	-9.673	468,783.16	876,872.15
bekale mola bend	1,653.00	1	1,644.85	-8.134	468,642.57	876,061.88
T Yeroke	1,653.00	1	1,653.64	0.635	468,633.14	875,861.27
J-78	1,652.00	0.61	1,642.21	-9.773	468,773.62	876,053.96
J-79	1,652.00	0.62	1,641.43	-10.544	468,776.20	876,131.93
J-80	1,652.00	0.62	1,641.24	-10.74	468,711.76	876,139.67
Bochesa g.tara	1,653.00	1	1,641.23	-11.75	468,730.54	876,422.22
p.station	1,652.00	1	1,640.38	-11.601	468,799.37	877,027.71
J-82	1,652.00	0.62	1,640.29	-11.689	468,699.51	877,029.29
end of lut	1,651.00	1	1,649.90	-1.097	468,969.41	875,231.37
J-83	1,651.00	0.62	1,652.23	1.223	469,024.95	875,453.68
J-84	1,651.00	0.62	1,650.83	-0.168	469,002.39	875,382.79
J-85	1,651.00	0.61	1,650.52	-0.478	468,776.84	875,411.79
J-86	1,652.00	0.61	1,650.79	-1.211	468,886.39	875,398.90
J-87	1,651.00	0.61	1,651.83	0.826	468,863.84	875,224.91
d limat	1,648.00	2	1,543.47	-104.321	469,124.19	877,709.46
Gubaye l.e church	1,648.00	1	1,586.63	-61.247	468,840.06	877,734.45
sosina Hotel	1,650.00	1	1,629.31	-20.651	468,803.15	877,481.22
curve	1,648.00	1	1,471.99	-175.655	469,479.66	877,333.92
J-92	1,647.00	0.62	1,509.55	-137.175	469,113.81	877,332.44
bend to end	1,648.00	1	1,467.68	-179.955	469,504.79	877,470.40
Tanker house	1,649.00	0	1,469.88	-178.76	469,561.34	877,386.46
end tap atanker	1,646.00	1	1,467.28	-178.358	469,438.49	877,472.91
u1	1,646.00	1	1,473.31	-172.337	469,391.26	877,526.78
u2	1,646.00	1	1,473.27	-172.378	469,339.66	877,521.67
J-98	1,645.00	0.62	1,475.30	-169.358	469,407.84	877,333.73
J-99	1,647.00	0.62	1,473.03	-173.619	469,338.93	877,423.63
T Health center 1	1,647.00	1	1,515.47	-131.266	469,118.75	877,514.07
J-101	1,646.00	0.61	1,473.95	-171.7	469,268.95	877,519.45
E	1,645.00	6	1,450.41	-194.196	469,270.02	877,377.87
K/LOONII FUULLEE	1,645.00	2	1,521.82	-122.927	469,269.48	877,593.00
J-104	1,646.00	0.62	1,525.05	-120.708	469,120.91	877,592.67
bEND 1	1,647.00	2	1,594.34	-52.559	468,960.00	877,664.40
front of life song	1,647.00	1	1,604.83	-42.082	468,927.30	877,391.97
J-107	1,647.00	0.62	1,595.42	-51.479	468,831.82	877,675.03
El	1,646.00	1	1,593.68	-52.216	468,894.00	877,612.00
J-109	1,647.00	0.62	1,593.17	-53.726	468,866.50	877,406.88
J-110	1,645.00	0.62	1,594.56	-50.337	468,953.97	877,607.92
NOC	1,646.00	1	1,645.61	-0.387	468,943.33	878,247.43
TT	1,646.00	1	1,586.40	-59.481	469,044.70	877,989.32
K	1,646.00	2	1,587.75	-58.133	468,918.00	878,010.00
LAGA	1,646.00	3	1,595.25	-50.65	469,163.00	877,990.00
J-115	1,645.00	0.62	1,561.53	-83.303	469,028.53	877,718.36
J-116	1,646.00	0.61	1,645.43	-0.569	469,060.83	878,199.49
GREEN	1,646.00	2	1,578.31	-67.556	468,904.32	877,890.71
J-118	1,646.00	0.62	1,576.68	-69.181	469,037.53	877,878.84
J-119	1,647.00	0.61	1,576.96	-69.903	468,965.87	877,884.70
J-120	1,647.00	0.61	1,576.62	-70.234	468,950.71	877,747.58
MOBEL	1,651.00	4	1,641.65	-9.334	468,753.46	877,438.99
J DA	1,653.00	2	1,656.14	3.13	468,691.73	877,253.54
J-123	1,652.00	0.63	1,639.70	-12.274	468,785.24	877,428.89
BEND AT IBSA	1,652.00	2.5	1,655.19	3.181	468,682.36	877,019.70
TELECENTER	1,650.00	1.6	1,654.14	4.132	468,584.49	876,704.35
J-126	1,652.00	0.62	1,654.95	2.945	468,599.47	877,016.57

ABDALA	1,653.00	2	1,653.98	0.974	468,570.15	876,382.84
B	1,653.00	1	1,653.99	0.984	468,543.77	876,386.24
J-129	1,652.00	0.61	1,653.85	1.847	468,523.06	875,873.26
DR,BARI	1,653.00	1	1,664.32	11.3	468,390.63	877,275.38
BENT TO TECH	1,655.00	1	1,666.88	11.858	468,156.88	877,339.23
CWPH	1,648.00	5	1,652.30	4.293	470,832.00	873,171.00
J 36	1,651.00	0.61	1,634.74	-16.228	468,924.58	877,017.79
J-146	1,651.00	0.62	1,684.52	33.451	464,784.64	877,347.06
J-N-187	1,663.00	0.61	1,669.80	6.785	466,390.63	873,568.86
J-149	1,652.00	0.61	1,666.60	14.567	467,546.37	874,340.05
J-N -167	1,651.00	0.6	1,668.22	17.184	467,998.36	871,088.12
J-N-168	1,655.00	0.6	1,668.46	13.43	466,701.81	871,390.65
J-N-170	1,652.00	0.61	1,668.22	16.186	468,110.73	871,900.63
J-N-326	1,652.00	0.62	1,668.22	16.186	468,179.88	872,445.18
J-N-171	1,653.00	0.61	1,668.21	15.183	468,231.74	872,946.52
J-N-169	1,656.00	0.6	1,668.60	12.577	466,744.55	871,966.38
J-N-185	1,656.00	0.63	1,669.19	13.161	466,732.03	872,540.67
J-N-362	1,664.00	0.61	1,669.24	5.23	465,655.92	872,574.84
J-N-172	1,654.00	0.62	1,668.63	14.605	467,790.91	873,110.75
J-N173	1,657.00	0.62	1,668.93	11.909	467,497.03	873,266.34
J-N-361	1,667.00	0.5	1,669.44	2.437	465,413.90	873,110.75
J-N-360	1,666.00	0.62	1,669.87	3.858	465,284.24	873,629.37
J-N-359	1,667.00	0.5	1,671.50	4.495	465,145.94	874,173.92
ELB	1,666.00	0.25	1,669.27	3.261	465,552.96	872,625.33
J-N-174	1,661.00	0.61	1,670.02	9.005	466,775.95	874,118.49
J-N-186	1,661.00	0.23	1,669.42	8.407	466,632.66	873,058.89
J-166	1,654.00	0.63	1,670.11	16.075	466,094.05	874,142.08
J-N-190	1,667.00	0.5	1,672.73	5.714	465,422.54	875,133.38
J-N-	1,658.00	4	1,659.14	1.14	467,505.67	874,796.27
J-169	1,661.00	0.62	1,672.28	11.26	465,362.53	874,167.49
J-N 175	1,663.00	0.5	1,671.11	8.098	466,717.69	874,927.33
J-172	1,665.00	0.61	1,671.61	6.595	466,087.85	875,025.14
J-N-191	1,668.00	0.56	1,673.22	5.211	465,534.91	875,859.45
J-N-176	1,664.00	0.45	1,672.81	8.788	466,632.66	875,703.86
J-175	1,663.00	0.25	1,672.94	9.921	466,110.51	875,780.32
J-N-192	1,668.00	0.61	1,673.57	5.559	465,584.34	876,273.97
J-N-177	1,664.00	0.5	1,675.84	11.815	466,710.45	876,507.75
J-N-193	1,668.00	0.6	1,673.87	5.858	465,629.99	876,628.74
J-178	1,664.00	0.5	1,674.13	10.111	466,173.37	876,566.51
J-179	1,667.00	0.25	1,673.70	6.689	466,142.99	876,211.61
J-180	1,666.00	0.25	1,674.14	8.125	466,673.79	876,143.51
J-N-181	1,667.00	0.6	1,674.49	7.478	465,770.48	877,476.56
J-N Y	1,667.00	0.2	1,673.01	5.993	466,069.92	878,456.31
J-N-364	1,667.00	0.62	1,672.13	5.117	466,337.96	879,617.80
J-N-E	1,667.00	0.6	1,671.79	4.776	466,397.52	880,124.09
J-N-365	1,666.00	0.62	1,671.70	5.69	466,516.65	880,193.58
J-N-366	1,665.00	0.6	1,671.39	6.379	466,973.30	880,531.11
J-N-167	1,663.00	0.5	1,671.02	8.009	467,588.79	880,957.98
J-188	1,661.00	0.6	1,670.85	9.834	467,956.09	881,067.18
J-N-370	1,659.00	0.5	1,670.49	11.471	469,187.07	881,275.65
J-N-0	1,663.00	0.5	1,676.01	12.986	466,900.61	877,380.74
2	1,660.00	2	1,672.35	12.322	467,638.42	878,148.57
3	1,655.00	4	1,670.42	15.393	468,333.33	878,555.59
4	1,655.00	2	1,670.37	15.338	468,333.33	879,111.51
5	1,653.00	5	1,670.33	17.291	468,482.24	879,657.51
6	1,654.00	4.5	1,670.33	16.298	468,512.02	880,332.56
7	1,654.00	0.6	1,670.50	16.47	468,641.07	881,196.23
J 8	1,654.00	3	1,670.39	16.353	468,601.36	880,828.92
J-N196	1,666.00	0.6	1,672.78	6.762	466,328.03	878,724.35

J-N197	1,665.00	0.5	1,672.24	7.221	466,774.75	879,012.24
J-N198	1,666.00	0.56	1,671.56	5.553	467,151.99	879,329.91
J-N-199	1,662.00	0.61	1,671.18	9.159	467,519.30	879,746.85
J-N-200	1,660.00	0.42	1,670.95	10.928	467,737.70	880,292.85
J-N-201	1,660.50	0.32	1,670.87	10.348	467,866.75	880,749.50
J-N-214	1,664.35	0.15	1,673.37	8.998	466,685.41	878,178.35
J-N-123	1,664.00	0.62	1,672.28	8.262	467,062.64	878,496.02
J-N-212	1,662.00	0.4	1,671.22	9.2	467,519.30	878,962.60
J-E	1,656.00	0.51	1,670.87	14.838	467,956.09	879,329.91
J-N-217	1,650.00	0.51	1,649.36	-0.634	468,859.47	878,317.33
J-N-204	1,648.00	0.4	1,670.32	22.277	469,167.22	880,719.72
J-N-338	1,648.00	0.62	1,670.19	22.147	468,998.45	879,518.53
OOOOO	1,663.00	0	1,676.96	13.934	467,072.57	877,354.39
2000M3 R	1,689.00	0	1,687.99	-1.006	463,851.00	877,440.00
converjuntion	1,662.00	0	1,687.79	25.734	464,114.00	877,410.00
L3	1,648.00	0	1,680.48	32.41	465,878.00	877,347.00
Cross TEE	1,639.00	12	1,677.26	38.185	466,734.00	877,196.00
ARV						
1,632.00	Zone	1,755.57	123.319	476,936.17	851,787.33	
ARV						
1,668.00	Zone	1,759.46	91.275	477,588.24	850,234.59	
FV 9	1,672.00	0	1,726.95	54.841	468,532.57	861,304.20
FV 12	1,659.00	0	1,706.10	47.01	466,634.90	872,692.68
ARV						
1,658.00	Zone	1,718.95	60.828	467,928.65	865,724.71	
FV 10	1,653.00	0	1,720.85	67.715	468,314.00	864,720.00
ARV						
1,651.00	Zone	1,711.77	60.65	467,987.61	869,783.68	
ARV						
1,656.00	Zone	1,737.77	81.608	470,470.45	855,972.53	
FV 1	1,679.00	0	1,760.26	81.1	477,656.35	849,891.69
FV 11	1,652.00	0	1,715.52	63.395	468,044.29	867,661.51
ARV						
1,671.00	Zone	1,699.49	28.431	464,639.63	875,861.89	
FV 2	1,635.00	0	1,755.91	120.664	477,027.50	851,671.39
ARV						
1,629.00	Zone	1,744.10	114.871	472,639.72	854,284.42	
ARV						
1,663.00	Zone	1,736.61	73.458	469,986.48	856,326.79	
FV 4	1,598.00	0	1,750.86	152.554	475,191.74	852,834.94
FV FV 7	1,665.00	0	1,736.34	71.198	469,865.49	856,415.36
ARV						
1,650.00	Zone	1,739.96	89.778	471,226.74	855,398.37	
FV 5	1,651.00	0	1,739.38	88.206	471,029.15	855,551.36
FV 6	1,660.00	0	1,737.31	77.157	470,309.13	856,090.62
ARV						
1,598.00	Zone	1,750.40	152.095	475,011.91	852,922.28	
ARV						

1,664.00	Zone	1,733.79	69.648	468,865.97	857,458.38	
ARV						
1,598.00	Zone	1,752.93	154.622	476,001.53	852,443.00	
					852,443.00	
ARV					852,443.00	
1,668.00	Zone	1,724.14	56.026	468,659.33	862,891.52	862,891.52
1,673.00	Zone	1,727.83	54.724	468,502.48	860,805.46	860,805.46
FV 8	1,666.00	0	1,733.35	67.212	468,798.17	857,698.90
FV 3	1,613.00	0	1,754.76	141.476	476,667.98	852,012.00
FV 13	1,688.00	0	1,697.81	9.791	464,188.58	876,697.57
J-to share	1,654.00	0	1,654.06	0.056	468,163.85	875,237.26
R Tufa site	1,761.00	0	1,765.93	4.921	478,609.84	847,622.92
J-237	1,661.00	0.62	1,696.20	35.124	463,667.81	877,449.02
J-235	1,661.00	0.62	1,661.27	0.269	468,375.07	874,400.23
J-229	1,660.00	0.62	1,658.18	-1.815	467,801.96	875,980.25
MEMERE HAMDE	1,650.00	0.2	1,648.46	-1.542	469,263.83	875,779.75

Appendix 3 Link result

Table 7-3 Link Result

Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Discharge (l/s)	Upstream Structure Hydraulic Grade (m)	Downstream Structure Hydraulic Grade (m)	Pressure Pipe Headloss (m)	Headloss Gradient (m/km)	Velocity (m/s)
P-1	553.21	200	PVC	150	-5.61	1,652.50	1,652.59	0.09	0.17	0.18
P-2	349	200	PVC	150	-6.22	1,652.59	1,652.66	0.07	0.21	0.2
P-3	388.62	200	PVC	150	-6.83	1,652.66	1,652.76	0.1	0.25	0.22
P-4	297.18	200	PVC	150	-8.16	1,652.76	1,652.86	0.1	0.34	0.26
P-5	402.03	100	PVC	150	7	1,652.86	1,649.83	3.04	7.55	0.89
P-6	265.79	100	PVC	150	5.4	1,649.83	1,648.59	1.24	4.66	0.69
P-7	236.83	100	PVC	150	2.82	1,648.59	1,648.25	0.33	1.4	0.36
P-11	388.92	250	PVC	150	-15.77	1,652.86	1,653.01	0.15	0.39	0.32
P-17	222.2	100	PVC	150	-2.61	1,653.42	1,653.69	0.27	1.22	0.33
P-18	308.76	100	PVC	150	-0.73	1,653.69	1,653.72	0.04	0.12	0.09
P-19	352.04	200	PVC	150	-4.72	1,653.72	1,653.77	0.04	0.12	0.15
P-20	263.96	200	PVC	150	0.64	1,653.42	1,653.42	0	0	0.02
P-21	351.13	200	PVC	150	2.9	1,653.42	1,653.40	0.02	0.05	0.09
P-22	231.65	150	PVC	150	7.94	1,653.72	1,653.42	0.31	1.32	0.45
P-24	342.6	50	PVC	150	-0.72	1,651.64	1,652.76	1.12	3.26	0.37
P-29	505.66	150	PVC	150	-15.04	1,650.48	1,652.67	2.18	4.32	0.85
P-33	819	250	PVC	150	-15.32	1,654.03	1,654.33	0.3	0.37	0.31
P-34	250.24	250	PVC	150	-4.68	1,654.33	1,654.34	0.01	0.04	0.1
P-35	231.65	80	PVC	150	-5.29	1,654.34	1,657.43	3.08	13.32	1.05
P-36	382.22	80	PVC	150	-3.56	1,657.43	1,659.88	2.45	6.41	0.71
P-37	1,352.40	250	PVC	150	-5	1,667.30	1,667.37	0.06	0.05	0.1
P-38	245.36	200	PVC	150	-58.55	1,667.37	1,670.60	3.24	13.19	1.86
P-39	571.2	250	PVC	150	-61.14	1,670.60	1,673.35	2.75	4.82	1.25
P-41	302.97	50	PVC	150	1.57	1,652.67	1,648.47	4.2	13.87	0.8
P-42	232.87	50	PVC	150	-0.98	1,648.47	1,649.83	1.36	5.84	0.5
P-44	244.75	80	PVC	150	1.74	1,648.47	1,648.05	0.42	1.71	0.35
P-45	254.2	80	PVC	150	-1.96	1,648.05	1,648.59	0.54	2.11	0.39
P-47	355.09	200	PVC	150	-0.62	1,651.98	1,651.98	0	0	0.02
P-48	237.44	200	PVC	150	0.87	1,651.98	1,651.98	0	0.01	0.03
P-50	202.39	50	PVC	150	0.5	1,651.98	1,651.64	0.34	1.67	0.26
P-53	378.87	100	PVC	150	0.78	1,645.35	1,645.30	0.05	0.13	0.1
P-54	132.28	100	PVC	150	-1.21	1,645.30	1,645.34	0.04	0.29	0.15
P-55	392.89	50	PVC	150	1.89	1,645.30	1,637.61	7.69	19.58	0.96
P-56	294.74	100	PVC	150	-1.51	1,649.96	1,650.09	0.13	0.44	0.19
P-57	176.78	150	PVC	150	-10.52	1,650.09	1,650.48	0.39	2.23	0.6
P-58	403.56	80	PVC	150	-0.3	1,650.06	1,650.09	0.03	0.07	0.06
P-59	302.67	250	PVC	150	-16.37	1,653.01	1,653.14	0.13	0.42	0.33
P-60	161.24	250	PVC	150	-33.78	1,653.14	1,653.40	0.26	1.61	0.69
P-61	345.95	200	PVC	150	-17.22	1,652.67	1,653.14	0.47	1.37	0.55
P-62	143.56	50	PVC	150	-1.62	1,638.02	1,640.13	2.11	14.7	0.83
P-63	120.09	50	PVC	150	2.21	1,648.25	1,645.12	3.13	26.07	1.12
P-64	85.95	50	PVC	150	-0.64	1,645.12	1,645.35	0.23	2.65	0.33
P-65	186.54	50	PVC	150	-2.24	1,640.13	1,645.12	5	26.78	1.14
P-9	341.38	50	PVC	150	1	1,638.02	1,635.96	2.05	6.02	0.51
P-66	403.86	50	PVC	150	-1.41	1,645.34	1,649.96	4.62	11.44	0.72
P-67	170.69	50	PVC	150	2.7	1,648.05	1,641.59	6.46	37.85	1.38
P-68	111.25	50	PVC	150	0.3	1,641.59	1,641.52	0.07	0.65	0.15
P-69	206.96	50	PVC	150	-0.4	1,641.36	1,641.59	0.23	1.1	0.2

P-70	393.5	50	PVC	150	-1.52	1,645.35	1,650.48	5.13	13.05	0.77
P-71	212.45	50	PVC	150	1	1,641.59	1,640.31	1.28	6.01	0.51
P-72	299.92	80	PVC	150	8.09	1,650.09	1,641.31	8.78	29.28	1.61
P-73	168.25	250	PVC	150	-31.51	1,653.40	1,653.64	0.24	1.41	0.64
P-74	74.37	250	PVC	150	-35.43	1,653.64	1,653.77	0.13	1.75	0.72
P-75	200.86	50	PVC	150	2.92	1,653.64	1,644.85	8.79	43.74	1.49
P-76	131.37	50	PVC	150	1.92	1,644.85	1,642.21	2.64	20.12	0.98
P-77	78.03	50	PVC	150	1.31	1,642.21	1,641.43	0.77	9.91	0.67
P-78	64.92	50	PVC	150	0.69	1,641.43	1,641.24	0.2	3.02	0.35
P-79	283.16	50	PVC	150	0.07	1,641.24	1,641.23	0.01	0.04	0.04
P-80	452.93	100	PVC	150	-0.93	1,641.23	1,641.31	0.08	0.18	0.12
P-81	156.36	100	PVC	150	6.16	1,641.31	1,640.38	0.93	5.96	0.78
P-82	99.97	100	PVC	150	2.2	1,640.38	1,640.29	0.09	0.89	0.28
P-83	169.47	80	PVC	150	1.58	1,640.29	1,640.05	0.24	1.42	0.31
P-84	286.51	100	PVC	150	5.07	1,653.42	1,652.23	1.19	4.16	0.65
P-85	203	100	PVC	150	2.6	1,652.23	1,651.98	0.25	1.21	0.33
P-86	154.84	50	PVC	150	-1	1,649.90	1,650.83	0.93	6.02	0.51
P-87	74.37	50	PVC	150	-1.85	1,650.83	1,652.23	1.39	18.75	0.94
P-88	117.04	50	PVC	150	0.23	1,650.83	1,650.79	0.05	0.39	0.12
P-89	110.34	50	PVC	150	0.61	1,650.79	1,650.52	0.27	2.41	0.31
P-92	175.56	50	PVC	150	-0.99	1,650.79	1,651.83	1.04	5.93	0.51
P-91	334.67	50	PVC	150	0.61	1,651.64	1,650.84	0.81	2.41	0.31
P-96	194.16	80	PVC	150	-3	1,508.64	1,509.55	0.91	4.66	0.6
P-99	97.23	50	PVC	150	2	1,471.99	1,469.88	2.11	21.71	1.02
P-100	101.19	50	PVC	150	2	1,469.88	1,467.68	2.2	21.71	1.02
P-101	66.45	50	PVC	150	1	1,467.68	1,467.28	0.4	6.02	0.51
P-102	71.93	50	PVC	150	-3	1,471.99	1,475.30	3.31	46.01	1.53
P-103	294.13	50	PVC	150	-4.95	1,475.30	1,509.55	34.25	116.44	2.52
P-104	193.85	50	PVC	150	-1.33	1,473.31	1,475.30	1.99	10.24	0.68
P-105	51.82	50	PVC	150	0.33	1,473.31	1,473.27	0.04	0.78	0.17
P-106	98.15	50	PVC	150	0.62	1,473.27	1,473.03	0.24	2.48	0.32
P-107	181.66	80	PVC	150	-8.57	1,509.55	1,515.47	5.92	32.59	1.71
P-109	70.71	50	PVC	150	-1.29	1,473.27	1,473.95	0.68	9.6	0.66
P-110	150.27	50	PVC	150	-7.9	1,473.95	1,515.47	41.52	276.28	4.02
P-111	141.73	50	PVC	150	6	1,473.95	1,450.41	23.54	166.1	3.06
P-112	78.64	80	PVC	150	-17.47	1,515.47	1,525.05	9.58	121.81	3.48
P-113	116.74	80	PVC	150	-20.09	1,525.05	1,543.47	18.42	157.79	4
P-114	148.44	50	PVC	150	-2	1,521.82	1,525.05	3.22	21.71	1.02
P-116	60.05	80	PVC	150	-19.29	1,586.63	1,595.42	8.79	146.35	3.84
P-117	195.99	80	PVC	150	-21.11	1,595.42	1,629.31	33.89	172.92	4.2
P-118	128.63	50	PVC	150	-1.2	1,594.34	1,595.42	1.08	8.41	0.61
P-119	206.96	50	PVC	150	-0.62	1,593.17	1,593.68	0.51	2.48	0.32
P-120	217.63	50	PVC	150	3.04	1,604.83	1,594.56	10.27	47.2	1.55
P-121	56.69	50	PVC	150	0.8	1,594.56	1,594.34	0.23	3.99	0.41
P-122	60.05	50	PVC	150	-1.62	1,593.68	1,594.56	0.88	14.7	0.83
P-123	96.01	80	PVC	150	-22.09	1,543.47	1,561.53	18.06	188.11	4.39
P-124	189.28	80	PVC	150	-18.29	1,561.53	1,586.63	25.1	132.61	3.64
P-126	118.26	50	PVC	150	3.9	1,595.25	1,586.40	8.85	74.82	1.99
P-127	128.32	50	PVC	150	-1.35	1,586.40	1,587.75	1.35	10.53	0.69
P-128	238.66	50	PVC	150	-7.36	1,587.75	1,645.61	57.86	242.45	3.75
P-129	233.17	50	PVC	150	-6.9	1,595.25	1,645.43	50.18	215.22	3.51
P-130	120.09	50	PVC	150	4.01	1,587.75	1,578.31	9.44	78.62	2.04
P-131	110.64	50	PVC	150	4.25	1,586.40	1,576.68	9.72	87.85	2.17
P-132	160.63	50	PVC	150	4.42	1,576.68	1,561.53	15.15	94.32	2.25
P-133	61.87	50	PVC	150	2.01	1,578.31	1,576.96	1.35	21.84	1.02

P-134	71.93	50	PVC	150	0.79	1,576.96	1,576.68	0.28	3.85	0.4
P-135	138.07	50	PVC	150	0.61	1,576.96	1,576.62	0.33	2.41	0.31
P-136	55.17	80	PVC	150	-22.11	1,629.31	1,639.70	10.39	188.4	4.4
P-137	242.01	80	PVC	150	-1.58	1,639.70	1,640.05	0.34	1.42	0.31
P-138	33.22	100	PVC	150	-21.16	1,639.70	1,641.65	1.95	58.57	2.69
P-139	195.38	100	PVC	150	-24.03	1,641.65	1,656.14	14.49	74.16	3.06
P-140	234.09	150	PVC	150	14.53	1,656.14	1,655.19	0.95	4.05	0.82
P-141	312.72	150	PVC	150	-11.41	1,654.14	1,654.95	0.81	2.59	0.65
P-142	82.91	150	PVC	150	-12.03	1,654.95	1,655.19	0.24	2.86	0.68
P-143	320.65	200	PVC	150	9.81	1,654.14	1,653.99	0.15	0.48	0.31
P-144	26.52	200	PVC	150	8.81	1,653.99	1,653.98	0.01	0.4	0.28
P-145	36.58	250	PVC	150	-40.76	1,653.77	1,653.85	0.08	2.27	0.83
P-146	299.31	250	PVC	150	-19.84	1,653.85	1,654.03	0.18	0.6	0.4
P-147	511.76	200	PVC	150	6.81	1,653.98	1,653.85	0.13	0.25	0.22
P-148	301.75	150	PVC	150	-40.56	1,656.14	1,664.32	8.19	27.13	2.3
P-149	242.32	200	PVC	150	-51.94	1,664.32	1,666.88	2.56	10.56	1.65
P-150	44.2	200	PVC	150	-52.94	1,666.88	1,667.37	0.48	10.94	1.69
P-151	1,404.52	200	PVC	150	-5	1,652.30	1,652.50	0.19	0.14	0.16
P-152	1,331.37	80	PVC	150	-0.52	1,668.22	1,668.46	0.24	0.18	0.1
P-153	820.22	200	PVC	150	-0.08	1,668.22	1,668.22	0	0	0
P-154	548.94	200	PVC	150	-0.04	1,668.22	1,668.22	0	0	0
P-155	504.14	200	PVC	150	1.23	1,668.22	1,668.21	0.01	0.01	0.04
P-156	577.29	100	PVC	150	-1.12	1,668.46	1,668.60	0.15	0.25	0.14
P-157	1,367.64	80	PVC	150	0.66	1,668.60	1,668.22	0.38	0.28	0.13
P-158	1,450.85	100	PVC	150	-1.89	1,668.22	1,669.19	0.97	0.67	0.24
P-159	1,076.55	100	PVC	150	-0.46	1,669.19	1,669.24	0.05	0.05	0.06
P-160	114.6	100	PVC	150	-1.07	1,669.24	1,669.27	0.03	0.24	0.14
P-161	505.05	100	PVC	150	-1.32	1,669.27	1,669.44	0.17	0.35	0.17
P-162	534.62	100	PVC	150	-2.07	1,669.44	1,669.87	0.42	0.79	0.26
P-163	561.75	100	PVC	150	-4.19	1,669.87	1,671.50	1.64	2.92	0.53
P-164	470.31	200	PVC	150	-13.69	1,668.21	1,668.63	0.42	0.89	0.44
P-165	332.54	200	PVC	150	-13.74	1,668.63	1,668.93	0.3	0.9	0.44
P-166	1,116.18	200	PVC	150	-14.36	1,668.93	1,670.02	1.09	0.98	0.46
P-168	527.61	150	PVC	150	-4.43	1,669.19	1,669.42	0.24	0.45	0.25
P-169	564.49	150	PVC	150	-5.47	1,669.42	1,669.80	0.37	0.66	0.31
P-171	682.45	100	PVC	150	0.76	1,670.11	1,670.02	0.08	0.12	0.1
P-172	645.26	150	PVC	150	-4.58	1,669.80	1,670.11	0.31	0.48	0.26
P-173	574.55	100	PVC	150	-2.37	1,668.60	1,669.19	0.59	1.02	0.3
P-174	1,219.81	100	PVC	150	-0.25	1,669.42	1,669.44	0.02	0.02	0.03
P-175	1,107.95	150	PVC	150	-1.5	1,669.80	1,669.87	0.07	0.06	0.08
P-178	216.71	100	PVC	150	-4.69	1,671.50	1,672.28	0.78	3.59	0.6
P-179	731.82	100	PVC	150	4.23	1,672.28	1,670.11	2.18	2.97	0.54
P-180	967.74	200	PVC	150	9.54	1,672.73	1,672.28	0.44	0.46	0.3
P-181	811.07	200	PVC	150	-17.07	1,670.02	1,671.11	1.09	1.35	0.54
P-182	637.34	80	PVC	150	-1.14	1,671.11	1,671.61	0.49	0.77	0.23
P-183	673.91	80	PVC	150	-1.72	1,671.61	1,672.73	1.12	1.66	0.34
P-184	883.01	80	PVC	150	-1.75	1,670.11	1,671.61	1.5	1.7	0.35
P-185	734.57	200	PVC	150	-11.76	1,672.73	1,673.22	0.5	0.67	0.37
P-186	781.2	200	PVC	150	-22.07	1,671.11	1,672.81	1.69	2.16	0.7
P-187	527.61	80	PVC	150	-0.63	1,672.81	1,672.94	0.14	0.26	0.13
P-188	580.95	80	PVC	150	-0.88	1,672.94	1,673.22	0.28	0.48	0.18
P-189	755.6	80	PVC	150	-1.78	1,671.61	1,672.94	1.33	1.76	0.35
P-190	1,887.63	80	PVC	150	4.56	1,672.81	1,653.72	19.08	10.11	0.91
P-193	357.84	200	PVC	150	13.21	1,673.87	1,673.57	0.3	0.84	0.42
P-194	417.58	200	PVC	150	13.2	1,673.57	1,673.22	0.35	0.84	0.42

P-195	540.41	100	PVC	150	4.37	1,675.84	1,674.13	1.71	3.16	0.56
P-196	546.81	100	PVC	150	1.58	1,674.13	1,673.87	0.26	0.48	0.2
P-197	432.51	80	PVC	150	-1.77	1,672.94	1,673.70	0.76	1.76	0.35
P-198	356.31	80	PVC	150	-1.44	1,673.70	1,674.13	0.43	1.2	0.29
P-199	562.05	80	PVC	150	-0.6	1,673.57	1,673.70	0.13	0.23	0.12
P-200	441.66	200	PVC	150	-26.44	1,672.81	1,674.14	1.34	3.03	0.84
P-201	366.06	200	PVC	150	-33.3	1,674.14	1,675.84	1.7	4.64	1.06
P-202	535.23	80	PVC	150	-1.18	1,673.70	1,674.14	0.44	0.82	0.23
P-204	859.23	200	PVC	150	-12.24	1,673.87	1,674.49	0.62	0.73	0.39
P-205	1,024.43	200	PVC	150	17.79	1,674.49	1,673.01	1.49	1.45	0.57
P-206	1,192.07	200	PVC	150	12.33	1,673.01	1,672.13	0.88	0.74	0.39
P-207	509.93	200	PVC	150	11.71	1,672.13	1,671.79	0.34	0.67	0.37
P-208	137.77	200	PVC	150	11.11	1,671.79	1,671.70	0.08	0.61	0.35
P-209	567.84	200	PVC	150	10.49	1,671.70	1,671.39	0.31	0.55	0.33
P-210	748.89	200	PVC	150	9.89	1,671.39	1,671.02	0.37	0.49	0.31
P-211	383.13	200	PVC	150	9.39	1,671.02	1,670.85	0.17	0.45	0.3
P-213	1,134.16	250	PVC	150	-30.63	1,674.49	1,676.01	1.52	1.34	0.62
P-216	267.61	200	PVC	150	31.4	1,676.01	1,674.90	1.11	4.16	1
P-218	3,861.21	50	PVC	150	1.12	1,670.49	1,641.65	28.85	7.47	0.57
P-219	797.36	200	PVC	150	27.26	1,674.90	1,672.35	2.55	3.2	0.87
P-220	805.28	200	PVC	150	23.27	1,672.35	1,670.42	1.92	2.39	0.74
P-221	555.96	200	PVC	150	4.19	1,670.42	1,670.37	0.06	0.1	0.13
P-222	566.01	200	PVC	150	3.6	1,670.37	1,670.33	0.04	0.08	0.11
P-223	675.74	200	PVC	150	-0.99	1,670.33	1,670.33	0	0.01	0.03
P-224	504.44	200	PVC	150	-4.42	1,670.33	1,670.39	0.06	0.11	0.14
P-225	369.42	200	PVC	150	-7.82	1,670.39	1,670.50	0.12	0.32	0.25
P-226	697.08	200	PVC	150	10.04	1,670.85	1,670.50	0.35	0.5	0.32
P-227	551.69	200	PVC	150	1.62	1,670.50	1,670.49	0.01	0.02	0.05
P-228	372.16	150	PVC	150	5.26	1,673.01	1,672.78	0.23	0.62	0.3
P-229	531.57	150	PVC	150	6.89	1,672.78	1,672.24	0.54	1.02	0.39
P-230	493.17	150	PVC	150	8.06	1,672.24	1,671.56	0.67	1.36	0.46
P-231	555.65	150	PVC	150	5.61	1,671.56	1,671.18	0.39	0.7	0.32
P-232	587.96	150	PVC	150	4.09	1,671.18	1,670.95	0.23	0.39	0.23
P-233	474.57	150	PVC	150	2.64	1,670.95	1,670.87	0.08	0.17	0.15
P-234	330.1	150	PVC	150	1.25	1,670.87	1,670.85	0.01	0.04	0.07
P-235	768.4	80	PVC	150	1.08	1,670.87	1,670.33	0.54	0.7	0.21
P-236	978.71	80	PVC	150	1.02	1,670.95	1,670.33	0.62	0.64	0.2
P-237	603.81	80	PVC	150	0.91	1,671.18	1,670.87	0.31	0.51	0.18
P-238	435.86	80	PVC	150	1.41	1,670.87	1,670.37	0.5	1.14	0.28
P-239	1,691.34	80	PVC	150	0.85	1,674.13	1,673.37	0.77	0.45	0.17
P-240	493.17	80	PVC	150	2	1,673.37	1,672.28	1.09	2.2	0.4
P-241	652.88	80	PVC	150	1.7	1,672.28	1,671.22	1.06	1.62	0.34
P-242	570.59	80	PVC	150	1	1,671.22	1,670.87	0.35	0.61	0.2
P-243	577.6	100	PVC	150	16.38	1,670.42	1,649.36	21.06	36.46	2.09
P-244	576.38	80	PVC	150	0.4	1,670.39	1,670.32	0.06	0.11	0.08
P-245	534.62	80	PVC	150	0.62	1,670.33	1,670.19	0.13	0.25	0.12
P-247	261.52	250	PVC	150	66.3	1,676.96	1,675.50	1.46	5.6	1.35
P-248	389.84	250	PVC	150	65.7	1,675.50	1,673.35	2.15	5.5	1.34
P-249	93.57	152.4	Ductile Iron	130	68.16	1,696.00	1,687.99	8.01	85.59	3.74
P-250	264.57	400	Ductile Iron	130	68.16	1,687.99	1,687.79	0.21	0.78	0.54
P-251	110.03	250	Ductile Iron	130	114.91	1,696.00	1,693.78	2.22	20.2	2.34
P-252	296.57	250	Ductile Iron	130	114.91	1,693.78	1,687.79	5.99	20.2	2.34
P-253	1,093.32	400	PVC	150	-182.45	1,680.48	1,684.52	4.04	3.7	1.45
P-254	673.61	400	Ductile Iron	130	-183.07	1,684.52	1,687.79	3.27	4.85	1.46
P-255	869.29	400	PVC	150	182.45	1,680.48	1,677.26	3.21	3.7	1.45

P-256	373.68	400	Ductile Iron	130	69.2	1,677.26	1,676.96	0.3	0.8	0.55
P-257	722.99	100	PVC	150	3.53	1,674.90	1,673.37	1.53	2.12	0.45
P-258	652.58	100	PVC	150	2.23	1,673.37	1,672.78	0.59	0.9	0.28
P-259	591.01	150	PVC	150	-1.67	1,672.24	1,672.28	0.04	0.07	0.09
P-260	672.39	150	PVC	150	-1.99	1,672.28	1,672.35	0.07	0.1	0.11
P-261	519.38	100	PVC	150	1.89	1,671.56	1,671.22	0.35	0.67	0.24
P-262	910.13	100	PVC	150	2.18	1,671.22	1,670.42	0.79	0.87	0.28
P-263	109.12	100	PVC	150	15.87	1,649.36	1,645.61	3.75	34.39	2.02
P-264	126.8	152.4	Ductile Iron	130	7.51	1,645.61	1,645.43	0.18	1.44	0.41
P-265	688.54	250	PVC	150	-38.71	1,675.84	1,677.26	1.42	2.07	0.79
P-266	248.72	250	PVC	150	62.53	1,677.26	1,676.01	1.25	5.02	1.27
P-267	683.67	152.4	Ductile Iron	130	-1.07	1,654.03	1,654.06	0.03	0.04	0.06
P-268	329.18	100	PVC	150	2.5	1,654.06	1,653.69	0.37	1.12	0.32
P-269	792.18	80	PVC	150	-3.57	1,654.06	1,659.14	5.09	6.42	0.71
P-270	798.88	80	PVC	150	-5.64	1,659.14	1,671.11	11.97	14.99	1.12
P-271	29.87	400	Ductile Iron	130	122.45	1,766.00	1,765.93	0.07	2.3	0.97
P-272	2,460.96	400	Ductile Iron	130	122.45	1,765.93	1,760.26	5.67	2.3	0.97
P-273	349.61	400	Ductile Iron	130	122.45	1,760.26	1,759.46	0.81	2.3	0.97
P-274	1,542.29	400	Ductile Iron	130	122.45	1,759.46	1,755.91	3.55	2.3	0.97
P-275	147.52	400	Ductile Iron	130	122.45	1,755.91	1,755.57	0.34	2.3	0.97
P-276	349.91	400	Ductile Iron	130	122.45	1,755.57	1,754.76	0.81	2.3	0.97
P-277	793.7	400	Ductile Iron	130	122.45	1,754.76	1,752.93	1.83	2.3	0.97
P-278	899.77	400	Ductile Iron	130	122.45	1,752.93	1,750.86	2.07	2.3	0.97
P-279	199.95	400	Ductile Iron	130	122.45	1,750.86	1,750.40	0.46	2.3	0.97
P-280	2,735.58	400	Ductile Iron	130	122.45	1,750.40	1,744.10	6.3	2.3	0.97
P-281	1,799.23	400	Ductile Iron	130	122.45	1,744.10	1,739.96	4.14	2.3	0.97
P-282	249.94	400	Ductile Iron	130	122.45	1,739.96	1,739.38	0.58	2.3	0.97
P-283	699.52	400	Ductile Iron	130	122.45	1,739.38	1,737.77	1.61	2.3	0.97
P-284	199.95	400	Ductile Iron	130	122.45	1,737.77	1,737.31	0.46	2.3	0.97
P-285	399.9	400	PVC	150	122.45	1,737.31	1,736.61	0.71	1.77	0.97
P-286	149.96	400	PVC	150	122.45	1,736.61	1,736.34	0.26	1.77	0.97
P-287	1,444.75	400	PVC	150	122.45	1,736.34	1,733.79	2.55	1.77	0.97
P-288	249.94	400	PVC	150	122.45	1,733.79	1,733.35	0.44	1.77	0.97
P-289	3,120.54	400	PVC	150	122.45	1,733.35	1,727.83	5.51	1.77	0.97
P-290	499.57	400	PVC	150	122.45	1,727.83	1,726.95	0.88	1.77	0.97
P-291	1,592.28	400	PVC	150	122.45	1,726.95	1,724.14	2.81	1.77	0.97
P-292	1,860.80	400	PVC	150	122.45	1,724.14	1,720.85	3.29	1.77	0.97
P-293	1,075.94	400	PVC	150	122.45	1,720.85	1,718.95	1.9	1.77	0.97
P-294	1,940.36	400	PVC	150	122.45	1,718.95	1,715.52	3.43	1.77	0.97
P-295	2,122.93	400	PVC	150	122.45	1,715.52	1,711.77	3.75	1.77	0.97
P-296	3,208.02	400	PVC	150	122.45	1,711.77	1,706.10	5.67	1.77	0.97
P-297	3,745.08	400	PVC	150	122.45	1,706.10	1,699.49	6.62	1.77	0.97
P-298	949.76	400	PVC	150	122.45	1,699.49	1,697.81	1.68	1.77	0.97
P-299	914.4	400	PVC	150	122.45	1,697.81	1,696.20	1.62	1.77	0.97
P-300	297.79	250	Ductile Iron	130	18.05	1,696.20	1,696.00	0.2	0.66	0.37
P-301	115.21	400	Ductile Iron	130	103.77	1,696.20	1,696.00	0.2	1.69	0.83
P-302	548.34	100	PVC	150	-11.26	1,654.33	1,664.32	9.99	18.22	1.43
P-303	983.28	50	PVC	150	1.56	1,673.35	1,659.88	13.47	13.7	0.79
P-304	2,035.76	50	PVC	150	0.22	1,659.88	1,659.14	0.74	0.36	0.11
P-305	458.11	50	PVC	150	-1.71	1,659.14	1,666.60	7.45	16.27	0.87
P-306	1,253.34	50	PVC	150	-0.49	1,666.60	1,668.63	2.04	1.63	0.25
P-307	622.1	50	PVC	150	1.97	1,670.60	1,657.43	13.17	21.17	1
P-308	801.62	80	PVC	150	2.86	1,670.02	1,666.60	3.43	4.28	0.57
P-309	1,480.41	152.4	Ductile Iron	130	-14.73	1,653.85	1,661.27	7.42	5.01	0.81
P-310	1,460.91	152.4	Ductile Iron	130	-14.31	1,661.27	1,668.21	6.94	4.75	0.78

P-311	830.88	50	PVC	150	1.04	1,666.60	1,661.27	5.33	6.41	0.53
P-312	1,159.46	80	PVC	150	1.06	1,669.42	1,668.63	0.79	0.68	0.21
P-313	487.98	80	PVC	150	2.91	1,676.96	1,674.82	2.14	4.39	0.58
P-314	536.14	50	PVC	150	0.54	1,675.84	1,674.82	1.02	1.9	0.27
P-315	361.19	50	PVC	150	2.83	1,674.82	1,659.88	14.94	41.36	1.44
P-316	1,281.38	50	PVC	150	0.88	1,670.42	1,664.32	6.1	4.76	0.45
P-317	374.29	50	PVC	150	-4.04	1,604.83	1,634.74	29.91	79.9	2.06
P-318	180.14	50	PVC	150	-1.69	1,634.74	1,637.61	2.87	15.92	0.86
P-319	125.58	50	PVC	150	2.96	1,640.38	1,634.74	5.64	44.88	1.51
P-320	1,139.95	80	PVC	150	5.43	1,674.14	1,658.18	15.96	14	1.08
P-321	429.46	80	PVC	150	4.45	1,658.18	1,654.03	4.15	9.67	0.88
P-322	811.68	50	PVC	150	-0.36	1,657.43	1,658.18	0.75	0.93	0.19
P-43	355.4	80	PVC	150	-0.2	1,648.46	1,648.47	0.01	0.03	0.04
P-323	151.49	50	PVC	150	1.35	1,653.42	1,651.83	1.59	10.49	0.69
P-324	323.39	50	PVC	150	-0.25	1,651.83	1,651.98	0.15	0.47	0.13

Appendices 4 Link Result for steady state simulation

Table7-4 Link Result for steady Estate simulation

Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Discharge (l/s)	Upstream Structure Hydraulic Grade (m)	Downstream Structure Hydraulic Grade (m)	Pressure Pipe Headloss (m)	Headloss Gradient (m/km)	Velocity (m/s)
P-1	553.21	200	PVC	150	-5.61	1,652.50	1,652.59	0.09	0.17	0.18
P-2	349	200	PVC	150	-6.22	1,652.59	1,652.66	0.07	0.21	0.2
P-3	388.62	200	PVC	150	-6.83	1,652.66	1,652.76	0.1	0.25	0.22
P-4	297.18	200	PVC	150	-8.16	1,652.76	1,652.86	0.1	0.34	0.26
P-5	402.03	100	PVC	150	7	1,652.86	1,649.83	3.04	7.55	0.89
P-6	265.79	100	PVC	150	5.4	1,649.83	1,648.59	1.24	4.66	0.69
P-7	236.83	100	PVC	150	2.82	1,648.59	1,648.25	0.33	1.4	0.36
P-11	388.92	250	PVC	150	-15.77	1,652.86	1,653.01	0.15	0.39	0.32
P-17	222.2	100	PVC	150	-2.61	1,653.42	1,653.69	0.27	1.22	0.33
P-18	308.76	100	PVC	150	-0.73	1,653.69	1,653.72	0.04	0.12	0.09
P-19	352.04	200	PVC	150	-4.72	1,653.72	1,653.77	0.04	0.12	0.15
P-20	263.96	200	PVC	150	0.64	1,653.42	1,653.42	0	0	0.02
P-21	351.13	200	PVC	150	2.9	1,653.42	1,653.40	0.02	0.05	0.09
P-22	231.65	150	PVC	150	7.94	1,653.72	1,653.42	0.31	1.32	0.45
P-24	342.6	50	PVC	150	-0.72	1,651.64	1,652.76	1.12	3.26	0.37
P-29	505.66	150	PVC	150	-15.04	1,650.48	1,652.67	2.18	4.32	0.85
P-33	819	250	PVC	150	-15.32	1,654.03	1,654.33	0.3	0.37	0.31
P-34	250.24	250	PVC	150	-4.68	1,654.33	1,654.34	0.01	0.04	0.1
P-35	231.65	80	PVC	150	-5.29	1,654.34	1,657.43	3.08	13.32	1.05
P-36	382.22	80	PVC	150	-3.56	1,657.43	1,659.88	2.45	6.41	0.71
P-37	1,352.40	250	PVC	150	-5	1,667.30	1,667.37	0.06	0.05	0.1
P-38	245.36	200	PVC	150	-58.55	1,667.37	1,670.60	3.24	13.19	1.86
P-39	571.2	250	PVC	150	-61.14	1,670.60	1,673.35	2.75	4.82	1.25
P-41	302.97	50	PVC	150	1.57	1,652.67	1,648.47	4.2	13.87	0.8
P-42	232.87	50	PVC	150	-0.98	1,648.47	1,649.83	1.36	5.84	0.5
P-44	244.75	80	PVC	150	1.74	1,648.47	1,648.05	0.42	1.71	0.35
P-45	254.2	80	PVC	150	-1.96	1,648.05	1,648.59	0.54	2.11	0.39
P-47	355.09	200	PVC	150	-0.62	1,651.98	1,651.98	0	0	0.02
P-48	237.44	200	PVC	150	0.87	1,651.98	1,651.98	0	0.01	0.03
P-50	202.39	50	PVC	150	0.5	1,651.98	1,651.64	0.34	1.67	0.26
P-53	378.87	100	PVC	150	0.78	1,645.35	1,645.30	0.05	0.13	0.1
P-54	132.28	100	PVC	150	-1.21	1,645.30	1,645.34	0.04	0.29	0.15
P-55	392.89	50	PVC	150	1.89	1,645.30	1,637.61	7.69	19.58	0.96
P-56	294.74	100	PVC	150	-1.51	1,649.96	1,650.09	0.13	0.44	0.19
P-57	176.78	150	PVC	150	-10.52	1,650.09	1,650.48	0.39	2.23	0.6
P-58	403.56	80	PVC	150	-0.3	1,650.06	1,650.09	0.03	0.07	0.06
P-59	302.67	250	PVC	150	-16.37	1,653.01	1,653.14	0.13	0.42	0.33
P-60	161.24	250	PVC	150	-33.78	1,653.14	1,653.40	0.26	1.61	0.69
P-61	345.95	200	PVC	150	-17.22	1,652.67	1,653.14	0.47	1.37	0.55
P-62	143.56	50	PVC	150	-1.62	1,638.02	1,640.13	2.11	14.7	0.83
P-63	120.09	50	PVC	150	2.21	1,648.25	1,645.12	3.13	26.07	1.12
P-64	85.95	50	PVC	150	-0.64	1,645.12	1,645.35	0.23	2.65	0.33
P-65	186.54	50	PVC	150	-2.24	1,640.13	1,645.12	5	26.78	1.14
P-9	341.38	50	PVC	150	1	1,638.02	1,635.96	2.05	6.02	0.51
P-66	403.86	50	PVC	150	-1.41	1,645.34	1,649.96	4.62	11.44	0.72
P-67	170.69	50	PVC	150	2.7	1,648.05	1,641.59	6.46	37.85	1.38
P-68	111.25	50	PVC	150	0.3	1,641.59	1,641.52	0.07	0.65	0.15
P-69	206.96	50	PVC	150	-0.4	1,641.36	1,641.59	0.23	1.1	0.2
P-70	393.5	50	PVC	150	-1.52	1,645.35	1,650.48	5.13	13.05	0.77
P-71	212.45	50	PVC	150	1	1,641.59	1,640.31	1.28	6.01	0.51

P-72	299.92	80	PVC	150	8.09	1,650.09	1,641.31	8.78	29.28	1.61
P-73	168.25	250	PVC	150	-31.51	1,653.40	1,653.64	0.24	1.41	0.64
P-74	74.37	250	PVC	150	-35.43	1,653.64	1,653.77	0.13	1.75	0.72
P-75	200.86	50	PVC	150	2.92	1,653.64	1,644.85	8.79	43.74	1.49
P-76	131.37	50	PVC	150	1.92	1,644.85	1,642.21	2.64	20.12	0.98
P-77	78.03	50	PVC	150	1.31	1,642.21	1,641.43	0.77	9.91	0.67
P-78	64.92	50	PVC	150	0.69	1,641.43	1,641.24	0.2	3.02	0.35
P-79	283.16	50	PVC	150	0.07	1,641.24	1,641.23	0.01	0.04	0.04
P-80	452.93	100	PVC	150	-0.93	1,641.23	1,641.31	0.08	0.18	0.12
P-81	156.36	100	PVC	150	6.16	1,641.31	1,640.38	0.93	5.96	0.78
P-82	99.97	100	PVC	150	2.2	1,640.38	1,640.29	0.09	0.89	0.28
P-83	169.47	80	PVC	150	1.58	1,640.29	1,640.05	0.24	1.42	0.31
P-84	286.51	100	PVC	150	5.07	1,653.42	1,652.23	1.19	4.16	0.65
P-85	203	100	PVC	150	2.6	1,652.23	1,651.98	0.25	1.21	0.33
P-86	154.84	50	PVC	150	-1	1,649.90	1,650.83	0.93	6.02	0.51
P-87	74.37	50	PVC	150	-1.85	1,650.83	1,652.23	1.39	18.75	0.94
P-88	117.04	50	PVC	150	0.23	1,650.83	1,650.79	0.05	0.39	0.12
P-89	110.34	50	PVC	150	0.61	1,650.79	1,650.52	0.27	2.41	0.31
P-92	175.56	50	PVC	150	-0.99	1,650.79	1,651.83	1.04	5.93	0.51
P-91	334.67	50	PVC	150	0.61	1,651.64	1,650.84	0.81	2.41	0.31
P-96	194.16	80	PVC	150	-3	1,508.64	1,509.55	0.91	4.66	0.6
P-99	97.23	50	PVC	150	2	1,471.99	1,469.88	2.11	21.71	1.02
P-100	101.19	50	PVC	150	2	1,469.88	1,467.68	2.2	21.71	1.02
P-101	66.45	50	PVC	150	1	1,467.68	1,467.28	0.4	6.02	0.51
P-102	71.93	50	PVC	150	-3	1,471.99	1,475.30	3.31	46.01	1.53
P-103	294.13	50	PVC	150	-4.95	1,475.30	1,509.55	34.25	116.44	2.52
P-104	193.85	50	PVC	150	-1.33	1,473.31	1,475.30	1.99	10.24	0.68
P-105	51.82	50	PVC	150	0.33	1,473.31	1,473.27	0.04	0.78	0.17
P-106	98.15	50	PVC	150	0.62	1,473.27	1,473.03	0.24	2.48	0.32
P-107	181.66	80	PVC	150	-8.57	1,509.55	1,515.47	5.92	32.59	1.71
P-109	70.71	50	PVC	150	-1.29	1,473.27	1,473.95	0.68	9.6	0.66
P-110	150.27	50	PVC	150	-7.9	1,473.95	1,515.47	41.52	276.28	4.02
P-111	141.73	50	PVC	150	6	1,473.95	1,450.41	23.54	166.1	3.06
P-112	78.64	80	PVC	150	-17.47	1,515.47	1,525.05	9.58	121.81	3.48
P-113	116.74	80	PVC	150	-20.09	1,525.05	1,543.47	18.42	157.79	4
P-114	148.44	50	PVC	150	-2	1,521.82	1,525.05	3.22	21.71	1.02
P-116	60.05	80	PVC	150	-19.29	1,586.63	1,595.42	8.79	146.35	3.84
P-117	195.99	80	PVC	150	-21.11	1,595.42	1,629.31	33.89	172.92	4.2
P-118	128.63	50	PVC	150	-1.2	1,594.34	1,595.42	1.08	8.41	0.61
P-119	206.96	50	PVC	150	-0.62	1,593.17	1,593.68	0.51	2.48	0.32
P-120	217.63	50	PVC	150	3.04	1,604.83	1,594.56	10.27	47.2	1.55
P-121	56.69	50	PVC	150	0.8	1,594.56	1,594.34	0.23	3.99	0.41
P-122	60.05	50	PVC	150	-1.62	1,593.68	1,594.56	0.88	14.7	0.83
P-123	96.01	80	PVC	150	-22.09	1,543.47	1,561.53	18.06	188.11	4.39
P-124	189.28	80	PVC	150	-18.29	1,561.53	1,586.63	25.1	132.61	3.64
P-126	118.26	50	PVC	150	3.9	1,595.25	1,586.40	8.85	74.82	1.99
P-127	128.32	50	PVC	150	-1.35	1,586.40	1,587.75	1.35	10.53	0.69
P-128	238.66	50	PVC	150	-7.36	1,587.75	1,645.61	57.86	242.45	3.75
P-129	233.17	50	PVC	150	-6.9	1,595.25	1,645.43	50.18	215.22	3.51
P-130	120.09	50	PVC	150	4.01	1,587.75	1,578.31	9.44	78.62	2.04
P-131	110.64	50	PVC	150	4.25	1,586.40	1,576.68	9.72	87.85	2.17
P-132	160.63	50	PVC	150	4.42	1,576.68	1,561.53	15.15	94.32	2.25
P-133	61.87	50	PVC	150	2.01	1,578.31	1,576.96	1.35	21.84	1.02
P-134	71.93	50	PVC	150	0.79	1,576.96	1,576.68	0.28	3.85	0.4
P-135	138.07	50	PVC	150	0.61	1,576.96	1,576.62	0.33	2.41	0.31
P-136	55.17	80	PVC	150	-22.11	1,629.31	1,639.70	10.39	188.4	4.4
P-137	242.01	80	PVC	150	-1.58	1,639.70	1,640.05	0.34	1.42	0.31
P-138	33.22	100	PVC	150	-21.16	1,639.70	1,641.65	1.95	58.57	2.69
P-139	195.38	100	PVC	150	-24.03	1,641.65	1,656.14	14.49	74.16	3.06

P-140	234.09	150	PVC	150	14.53	1,656.14	1,655.19	0.95	4.05	0.82
P-141	312.72	150	PVC	150	-11.41	1,654.14	1,654.95	0.81	2.59	0.65
P-142	82.91	150	PVC	150	-12.03	1,654.95	1,655.19	0.24	2.86	0.68
P-143	320.65	200	PVC	150	9.81	1,654.14	1,653.99	0.15	0.48	0.31
P-144	26.52	200	PVC	150	8.81	1,653.99	1,653.98	0.01	0.4	0.28
P-145	36.58	250	PVC	150	-40.76	1,653.77	1,653.85	0.08	2.27	0.83
P-146	299.31	250	PVC	150	-19.84	1,653.85	1,654.03	0.18	0.6	0.4
P-147	511.76	200	PVC	150	6.81	1,653.98	1,653.85	0.13	0.25	0.22
P-148	301.75	150	PVC	150	-40.56	1,656.14	1,664.32	8.19	27.13	2.3
P-149	242.32	200	PVC	150	-51.94	1,664.32	1,666.88	2.56	10.56	1.65
P-150	44.2	200	PVC	150	-52.94	1,666.88	1,667.37	0.48	10.94	1.69
P-151	1,404.52	200	PVC	150	-5	1,652.30	1,652.50	0.19	0.14	0.16
P-152	1,331.37	80	PVC	150	-0.52	1,668.22	1,668.46	0.24	0.18	0.1
P-153	820.22	200	PVC	150	-0.08	1,668.22	1,668.22	0	0	0
P-154	548.94	200	PVC	150	-0.04	1,668.22	1,668.22	0	0	0
P-155	504.14	200	PVC	150	1.23	1,668.22	1,668.21	0.01	0.01	0.04
P-156	577.29	100	PVC	150	-1.12	1,668.46	1,668.60	0.15	0.25	0.14
P-157	1,367.64	80	PVC	150	0.66	1,668.60	1,668.22	0.38	0.28	0.13
P-158	1,450.85	100	PVC	150	-1.89	1,668.22	1,669.19	0.97	0.67	0.24
P-159	1,076.55	100	PVC	150	-0.46	1,669.19	1,669.24	0.05	0.05	0.06
P-160	114.6	100	PVC	150	-1.07	1,669.24	1,669.27	0.03	0.24	0.14
P-161	505.05	100	PVC	150	-1.32	1,669.27	1,669.44	0.17	0.35	0.17
P-162	534.62	100	PVC	150	-2.07	1,669.44	1,669.87	0.42	0.79	0.26
P-163	561.75	100	PVC	150	-4.19	1,669.87	1,671.50	1.64	2.92	0.53
P-164	470.31	200	PVC	150	-13.69	1,668.21	1,668.63	0.42	0.89	0.44
P-165	332.54	200	PVC	150	-13.74	1,668.63	1,668.93	0.3	0.9	0.44
P-166	1,116.18	200	PVC	150	-14.36	1,668.93	1,670.02	1.09	0.98	0.46
P-168	527.61	150	PVC	150	-4.43	1,669.19	1,669.42	0.24	0.45	0.25
P-169	564.49	150	PVC	150	-5.47	1,669.42	1,669.80	0.37	0.66	0.31
P-171	682.45	100	PVC	150	0.76	1,670.11	1,670.02	0.08	0.12	0.1
P-172	645.26	150	PVC	150	-4.58	1,669.80	1,670.11	0.31	0.48	0.26
P-173	574.55	100	PVC	150	-2.37	1,668.60	1,669.19	0.59	1.02	0.3
P-174	1,219.81	100	PVC	150	-0.25	1,669.42	1,669.44	0.02	0.02	0.03
P-175	1,107.95	150	PVC	150	-1.5	1,669.80	1,669.87	0.07	0.06	0.08
P-178	216.71	100	PVC	150	-4.69	1,671.50	1,672.28	0.78	3.59	0.6
P-179	731.82	100	PVC	150	4.23	1,672.28	1,670.11	2.18	2.97	0.54
P-180	967.74	200	PVC	150	9.54	1,672.73	1,672.28	0.44	0.46	0.3
P-181	811.07	200	PVC	150	-17.07	1,670.02	1,671.11	1.09	1.35	0.54
P-182	637.34	80	PVC	150	-1.14	1,671.11	1,671.61	0.49	0.77	0.23
P-183	673.91	80	PVC	150	-1.72	1,671.61	1,672.73	1.12	1.66	0.34
P-184	883.01	80	PVC	150	-1.75	1,670.11	1,671.61	1.5	1.7	0.35
P-185	734.57	200	PVC	150	-11.76	1,672.73	1,673.22	0.5	0.67	0.37
P-186	781.2	200	PVC	150	-22.07	1,671.11	1,672.81	1.69	2.16	0.7
P-187	527.61	80	PVC	150	-0.63	1,672.81	1,672.94	0.14	0.26	0.13
P-188	580.95	80	PVC	150	-0.88	1,672.94	1,673.22	0.28	0.48	0.18
P-189	755.6	80	PVC	150	-1.78	1,671.61	1,672.94	1.33	1.76	0.35
P-190	1,887.63	80	PVC	150	4.56	1,672.81	1,653.72	19.08	10.11	0.91
P-193	357.84	200	PVC	150	13.21	1,673.87	1,673.57	0.3	0.84	0.42
P-194	417.58	200	PVC	150	13.2	1,673.57	1,673.22	0.35	0.84	0.42
P-195	540.41	100	PVC	150	4.37	1,675.84	1,674.13	1.71	3.16	0.56
P-196	546.81	100	PVC	150	1.58	1,674.13	1,673.87	0.26	0.48	0.2
P-197	432.51	80	PVC	150	-1.77	1,672.94	1,673.70	0.76	1.76	0.35
P-198	356.31	80	PVC	150	-1.44	1,673.70	1,674.13	0.43	1.2	0.29
P-199	562.05	80	PVC	150	-0.6	1,673.57	1,673.70	0.13	0.23	0.12
P-200	441.66	200	PVC	150	-26.44	1,672.81	1,674.14	1.34	3.03	0.84
P-201	366.06	200	PVC	150	-33.3	1,674.14	1,675.84	1.7	4.64	1.06
P-202	535.23	80	PVC	150	-1.18	1,673.70	1,674.14	0.44	0.82	0.23
P-204	859.23	200	PVC	150	-12.24	1,673.87	1,674.49	0.62	0.73	0.39
P-205	1,024.43	200	PVC	150	17.79	1,674.49	1,673.01	1.49	1.45	0.57

P-206	1,192.07	200	PVC	150	12.33	1,673.01	1,672.13	0.88	0.74	0.39
P-207	509.93	200	PVC	150	11.71	1,672.13	1,671.79	0.34	0.67	0.37
P-208	137.77	200	PVC	150	11.11	1,671.79	1,671.70	0.08	0.61	0.35
P-209	567.84	200	PVC	150	10.49	1,671.70	1,671.39	0.31	0.55	0.33
P-210	748.89	200	PVC	150	9.89	1,671.39	1,671.02	0.37	0.49	0.31
P-211	383.13	200	PVC	150	9.39	1,671.02	1,670.85	0.17	0.45	0.3
P-213	1,134.16	250	PVC	150	-30.63	1,674.49	1,676.01	1.52	1.34	0.62
P-216	267.61	200	PVC	150	31.4	1,676.01	1,674.90	1.11	4.16	1
P-218	3,861.21	50	PVC	150	1.12	1,670.49	1,641.65	28.85	7.47	0.57
P-219	797.36	200	PVC	150	27.26	1,674.90	1,672.35	2.55	3.2	0.87
P-220	805.28	200	PVC	150	23.27	1,672.35	1,670.42	1.92	2.39	0.74
P-221	555.96	200	PVC	150	4.19	1,670.42	1,670.37	0.06	0.1	0.13
P-222	566.01	200	PVC	150	3.6	1,670.37	1,670.33	0.04	0.08	0.11
P-223	675.74	200	PVC	150	-0.99	1,670.33	1,670.33	0	0.01	0.03
P-224	504.44	200	PVC	150	-4.42	1,670.33	1,670.39	0.06	0.11	0.14
P-225	369.42	200	PVC	150	-7.82	1,670.39	1,670.50	0.12	0.32	0.25
P-226	697.08	200	PVC	150	10.04	1,670.85	1,670.50	0.35	0.5	0.32
P-227	551.69	200	PVC	150	1.62	1,670.50	1,670.49	0.01	0.02	0.05
P-228	372.16	150	PVC	150	5.26	1,673.01	1,672.78	0.23	0.62	0.3
P-229	531.57	150	PVC	150	6.89	1,672.78	1,672.24	0.54	1.02	0.39
P-230	493.17	150	PVC	150	8.06	1,672.24	1,671.56	0.67	1.36	0.46
P-231	555.65	150	PVC	150	5.61	1,671.56	1,671.18	0.39	0.7	0.32
P-232	587.96	150	PVC	150	4.09	1,671.18	1,670.95	0.23	0.39	0.23
P-233	474.57	150	PVC	150	2.64	1,670.95	1,670.87	0.08	0.17	0.15
P-234	330.1	150	PVC	150	1.25	1,670.87	1,670.85	0.01	0.04	0.07
P-235	768.4	80	PVC	150	1.08	1,670.87	1,670.33	0.54	0.7	0.21
P-236	978.71	80	PVC	150	1.02	1,670.95	1,670.33	0.62	0.64	0.2
P-237	603.81	80	PVC	150	0.91	1,671.18	1,670.87	0.31	0.51	0.18
P-238	435.86	80	PVC	150	1.41	1,670.87	1,670.37	0.5	1.14	0.28
P-239	1,691.34	80	PVC	150	0.85	1,674.13	1,673.37	0.77	0.45	0.17
P-240	493.17	80	PVC	150	2	1,673.37	1,672.28	1.09	2.2	0.4
P-241	652.88	80	PVC	150	1.7	1,672.28	1,671.22	1.06	1.62	0.34
P-242	570.59	80	PVC	150	1	1,671.22	1,670.87	0.35	0.61	0.2
P-243	577.6	100	PVC	150	16.38	1,670.42	1,649.36	21.06	36.46	2.09
P-244	576.38	80	PVC	150	0.4	1,670.39	1,670.32	0.06	0.11	0.08
P-245	534.62	80	PVC	150	0.62	1,670.33	1,670.19	0.13	0.25	0.12
P-247	261.52	250	PVC	150	66.3	1,676.96	1,675.50	1.46	5.6	1.35
P-248	389.84	250	PVC	150	65.7	1,675.50	1,673.35	2.15	5.5	1.34
P-249	93.57	152.4	Ductile Iron	130	68.16	1,696.00	1,687.99	8.01	85.59	3.74
P-250	264.57	400	Ductile Iron	130	68.16	1,687.99	1,687.79	0.21	0.78	0.54
P-251	110.03	250	Ductile Iron	130	114.91	1,696.00	1,693.78	2.22	20.2	2.34
P-252	296.57	250	Ductile Iron	130	114.91	1,693.78	1,687.79	5.99	20.2	2.34
P-253	1,093.32	400	PVC	150	-182.45	1,680.48	1,684.52	4.04	3.7	1.45
P-254	673.61	400	Ductile Iron	130	-183.07	1,684.52	1,687.79	3.27	4.85	1.46
P-255	869.29	400	PVC	150	182.45	1,680.48	1,677.26	3.21	3.7	1.45
P-256	373.68	400	Ductile Iron	130	69.2	1,677.26	1,676.96	0.3	0.8	0.55
P-257	722.99	100	PVC	150	3.53	1,674.90	1,673.37	1.53	2.12	0.45
P-258	652.58	100	PVC	150	2.23	1,673.37	1,672.78	0.59	0.9	0.28
P-259	591.01	150	PVC	150	-1.67	1,672.24	1,672.28	0.04	0.07	0.09
P-260	672.39	150	PVC	150	-1.99	1,672.28	1,672.35	0.07	0.1	0.11
P-261	519.38	100	PVC	150	1.89	1,671.56	1,671.22	0.35	0.67	0.24
P-262	910.13	100	PVC	150	2.18	1,671.22	1,670.42	0.79	0.87	0.28
P-263	109.12	100	PVC	150	15.87	1,649.36	1,645.61	3.75	34.39	2.02

P-264	126.8	152.4	Ductile Iron	130	7.51	1,645.61	1,645.43	0.18	1.44	0.41
P-265	688.54	250	PVC	150	-38.71	1,675.84	1,677.26	1.42	2.07	0.79
P-266	248.72	250	PVC	150	62.53	1,677.26	1,676.01	1.25	5.02	1.27
P-267	683.67	152.4	Ductile Iron	130	-1.07	1,654.03	1,654.06	0.03	0.04	0.06
P-268	329.18	100	PVC	150	2.5	1,654.06	1,653.69	0.37	1.12	0.32
P-269	792.18	80	PVC	150	-3.57	1,654.06	1,659.14	5.09	6.42	0.71
P-270	798.88	80	PVC	150	-5.64	1,659.14	1,671.11	11.97	14.99	1.12
P-271	29.87	400	Ductile Iron	130	122.45	1,766.00	1,765.93	0.07	2.3	0.97
P-272	2,460.96	400	Ductile Iron	130	122.45	1,765.93	1,760.26	5.67	2.3	0.97
P-273	349.61	400	Ductile Iron	130	122.45	1,760.26	1,759.46	0.81	2.3	0.97
P-274	1,542.29	400	Ductile Iron	130	122.45	1,759.46	1,755.91	3.55	2.3	0.97
P-275	147.52	400	Ductile Iron	130	122.45	1,755.91	1,755.57	0.34	2.3	0.97
P-276	349.91	400	Ductile Iron	130	122.45	1,755.57	1,754.76	0.81	2.3	0.97
P-277	793.7	400	Ductile Iron	130	122.45	1,754.76	1,752.93	1.83	2.3	0.97
P-278	899.77	400	Ductile Iron	130	122.45	1,752.93	1,750.86	2.07	2.3	0.97
P-279	199.95	400	Ductile Iron	130	122.45	1,750.86	1,750.40	0.46	2.3	0.97
P-280	2,735.58	400	Ductile Iron	130	122.45	1,750.40	1,744.10	6.3	2.3	0.97
P-281	1,799.23	400	Ductile Iron	130	122.45	1,744.10	1,739.96	4.14	2.3	0.97
P-282	249.94	400	Ductile Iron	130	122.45	1,739.96	1,739.38	0.58	2.3	0.97
P-283	699.52	400	Ductile Iron	130	122.45	1,739.38	1,737.77	1.61	2.3	0.97
P-284	199.95	400	Ductile Iron	130	122.45	1,737.77	1,737.31	0.46	2.3	0.97
P-285	399.9	400	PVC	150	122.45	1,737.31	1,736.61	0.71	1.77	0.97
P-286	149.96	400	PVC	150	122.45	1,736.61	1,736.34	0.26	1.77	0.97
P-287	1,444.75	400	PVC	150	122.45	1,736.34	1,733.79	2.55	1.77	0.97
P-288	249.94	400	PVC	150	122.45	1,733.79	1,733.35	0.44	1.77	0.97
P-289	3,120.54	400	PVC	150	122.45	1,733.35	1,727.83	5.51	1.77	0.97
P-290	499.57	400	PVC	150	122.45	1,727.83	1,726.95	0.88	1.77	0.97
P-291	1,592.28	400	PVC	150	122.45	1,726.95	1,724.14	2.81	1.77	0.97
P-292	1,860.80	400	PVC	150	122.45	1,724.14	1,720.85	3.29	1.77	0.97
P-293	1,075.94	400	PVC	150	122.45	1,720.85	1,718.95	1.9	1.77	0.97
P-294	1,940.36	400	PVC	150	122.45	1,718.95	1,715.52	3.43	1.77	0.97
P-295	2,122.93	400	PVC	150	122.45	1,715.52	1,711.77	3.75	1.77	0.97
P-296	3,208.02	400	PVC	150	122.45	1,711.77	1,706.10	5.67	1.77	0.97
P-297	3,745.08	400	PVC	150	122.45	1,706.10	1,699.49	6.62	1.77	0.97
P-298	949.76	400	PVC	150	122.45	1,699.49	1,697.81	1.68	1.77	0.97
P-299	914.4	400	PVC	150	122.45	1,697.81	1,696.20	1.62	1.77	0.97
P-300	297.79	250	Ductile Iron	130	18.05	1,696.20	1,696.00	0.2	0.66	0.37
P-301	115.21	400	Ductile Iron	130	103.77	1,696.20	1,696.00	0.2	1.69	0.83
P-302	548.34	100	PVC	150	-11.26	1,654.33	1,664.32	9.99	18.22	1.43
P-303	983.28	50	PVC	150	1.56	1,673.35	1,659.88	13.47	13.7	0.79
P-304	2,035.76	50	PVC	150	0.22	1,659.88	1,659.14	0.74	0.36	0.11
P-305	458.11	50	PVC	150	-1.71	1,659.14	1,666.60	7.45	16.27	0.87

P-306	1,253.34	50	PVC	150	-0.49	1,666.60	1,668.63	2.04	1.63	0.25
P-307	622.1	50	PVC	150	1.97	1,670.60	1,657.43	13.17	21.17	1
P-308	801.62	80	PVC	150	2.86	1,670.02	1,666.60	3.43	4.28	0.57
P-309	1,480.41	152.4	Ductile Iron	130	-14.73	1,653.85	1,661.27	7.42	5.01	0.81
P-310	1,460.91	152.4	Ductile Iron	130	-14.31	1,661.27	1,668.21	6.94	4.75	0.78
P-311	830.88	50	PVC	150	1.04	1,666.60	1,661.27	5.33	6.41	0.53
P-312	1,159.46	80	PVC	150	1.06	1,669.42	1,668.63	0.79	0.68	0.21
P-313	487.98	80	PVC	150	2.91	1,676.96	1,674.82	2.14	4.39	0.58
P-314	536.14	50	PVC	150	0.54	1,675.84	1,674.82	1.02	1.9	0.27
P-315	361.19	50	PVC	150	2.83	1,674.82	1,659.88	14.94	41.36	1.44
P-316	1,281.38	50	PVC	150	0.88	1,670.42	1,664.32	6.1	4.76	0.45
P-317	374.29	50	PVC	150	-4.04	1,604.83	1,634.74	29.91	79.9	2.06
P-318	180.14	50	PVC	150	-1.69	1,634.74	1,637.61	2.87	15.92	0.86
P-319	125.58	50	PVC	150	2.96	1,640.38	1,634.74	5.64	44.88	1.51
P-320	1,139.95	80	PVC	150	5.43	1,674.14	1,658.18	15.96	14	1.08
P-321	429.46	80	PVC	150	4.45	1,658.18	1,654.03	4.15	9.67	0.88
P-322	811.68	50	PVC	150	-0.36	1,657.43	1,658.18	0.75	0.93	0.19
P-43	355.4	80	PVC	150	-0.2	1,648.46	1,648.47	0.01	0.03	0.04
P-323	151.49	50	PVC	150	1.35	1,653.42	1,651.83	1.59	10.49	0.69
P-324	323.39	50	PVC	150	-0.25	1,651.83	1,651.98	0.15	0.47	0.13

Link Result for Extended period Simulation

Table 7-5 Link Result for EPS

Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Discharge (l/s)	Upstream Structure Hydraulic Grade (m)	Downstream Structure Hydraulic Grade (m)	Pressure Pipe Headloss (m)	Headloss Gradient (m/km)	Velocity (m/s)
P-1	553.21	200	PVC	150	5.61	1,652.50	1,652.59	0.09	0.17	1
P-2	349	200	PVC	150	6.22	1,652.59	1,652.66	0.07	0.21	0.2
P-3	388.62	200	PVC	150	6.83	1,652.66	1,652.76	0.1	0.25	0.22
P-4	297.18	200	PVC	150	8.16	1,652.76	1,652.86	0.1	0.34	0.26
P-5	402.03	100	PVC	150	7	1,652.86	1,649.83	3.04	7.55	0.89
P-6	265.79	100	PVC	150	5.4	1,649.83	1,648.59	1.24	4.66	0.69
P-7	236.83	100	PVC	150	2.82	1,648.59	1,648.25	0.33	1.4	0.36
P-11	388.92	250	PVC	150	-15.77	1,652.86	1,653.01	0.15	0.39	0.32
P-17	222.2	100	PVC	150	2.61	1,653.42	1,653.69	0.27	1.22	0.33
P-18	308.76	100	PVC	150	0.73	1,653.69	1,653.72	0.04	0.12	0.09
P-19	352.04	200	PVC	150	4.72	1,653.72	1,653.77	0.04	0.12	0.15
P-20	263.96	200	PVC	150	0.64	1,653.42	1,653.42	0	0	0.02
P-21	351.13	200	PVC	150	2.9	1,653.42	1,653.40	0.02	0.05	0.09
P-22	231.65	150	PVC	150	7.94	1,653.72	1,653.42	0.31	1.32	0.45
P-24	342.6	50	PVC	150	0.72	1,651.64	1,652.76	1.12	3.26	0.37
P-29	505.66	150	PVC	150	15.04	1,650.48	1,652.67	2.18	4.32	0.85
P-33	819	250	PVC	150	15.32	1,654.03	1,654.33	0.3	0.37	0.31
P-34	250.24	250	PVC	150	4.68	1,654.33	1,654.34	0.01	0.04	0.1
P-35	231.65	80	PVC	150	5.29	1,654.34	1,657.43	3.08	13.32	1.05
P-36	382.22	80	PVC	150	3.56	1,657.43	1,659.88	2.45	6.41	0.71
P-37	1,352.40	250	PVC	150	5	1,667.30	1,667.37	0.06	0.05	0.1
P-38	245.36	200	PVC	150	8.55	1,667.37	1,670.60	3.24	13.19	1.86
P-39	571.2	250	PVC	150	1.14	1,670.60	1,673.35	2.75	4.82	1.25
P-41	302.97	50	PVC	150	1.57	1,652.67	1,648.47	4.2	13.87	0.8
P-42	232.87	50	PVC	150	0.98	1,648.47	1,649.83	1.36	5.84	0.5
P-44	244.75	80	PVC	150	1.74	1,648.47	1,648.05	0.42	1.71	0.35
P-45	254.2	80	PVC	150	1.96	1,648.05	1,648.59	0.54	2.11	0.39
P-47	355.09	200	PVC	150	0.62	1,651.98	1,651.98	0	0	0.02
P-48	237.44	200	PVC	150	0.87	1,651.98	1,651.98	0	0.01	0.03
P-50	202.39	50	PVC	150	0.5	1,651.98	1,651.64	0.34	1.67	0.26
P-53	378.87	100	PVC	150	0.78	1,645.35	1,645.30	0.05	0.13	0.1
P-54	132.28	100	PVC	150	1.21	1,645.30	1,645.34	0.04	0.29	0.15
P-55	392.89	50	PVC	150	1.89	1,645.30	1,637.61	7.69	19.58	0.96
P-56	294.74	100	PVC	150	1.51	1,649.96	1,650.09	0.13	0.44	0.19
P-57	176.78	150	PVC	150	10.52	1,650.09	1,650.48	0.39	2.23	0.6
P-58	403.56	80	PVC	150	0.3	1,650.06	1,650.09	0.03	0.07	0.06
P-59	302.67	250	PVC	150	16.37	1,653.01	1,653.14	0.13	0.42	0.33
P-60	161.24	250	PVC	150	33.78	1,653.14	1,653.40	0.26	1.61	0.69
P-61	345.95	200	PVC	150	17.22	1,652.67	1,653.14	0.47	1.37	0.55
P-62	143.56	50	PVC	150	1.62	1,638.02	1,640.13	2.11	14.7	0.83
P-63	120.09	50	PVC	150	2.21	1,648.25	1,645.12	3.13	26.07	1.12
P-64	85.95	50	PVC	150	0.64	1,645.12	1,645.35	0.23	2.65	0.33
P-65	186.54	50	PVC	150	2.24	1,640.13	1,645.12	5	26.78	1.14
P-9	341.38	50	PVC	150	1	1,638.02	1,635.96	2.05	6.02	0.51
P-66	403.86	50	PVC	150	1.41	1,645.34	1,649.96	4.62	11.44	0.72
P-67	170.69	50	PVC	150	2.7	1,648.05	1,641.59	6.46	37.85	1.38
P-68	111.25	50	PVC	150	0.3	1,641.59	1,641.52	0.07	0.65	0.15
P-69	206.96	50	PVC	150	-0.4	1,641.36	1,641.59	0.23	1.1	0.2

P-70	393.5	50	PVC	150	-1.52	1,645.35	1,650.48	5.13	13.05	0.77
P-71	212.45	50	PVC	150	1	1,641.59	1,640.31	1.28	6.01	0.51
P-72	299.92	80	PVC	150	8.09	1,650.09	1,641.31	8.78	29.28	1.61
P-73	168.25	250	PVC	150	-31.51	1,653.40	1,653.64	0.24	1.41	0.64
P-74	74.37	250	PVC	150	-35.43	1,653.64	1,653.77	0.13	1.75	0.72
P-75	200.86	50	PVC	150	2.92	1,653.64	1,644.85	8.79	43.74	1.49
P-76	131.37	50	PVC	150	1.92	1,644.85	1,642.21	2.64	20.12	0.98
P-77	78.03	50	PVC	150	1.31	1,642.21	1,641.43	0.77	9.91	0.67
P-78	64.92	50	PVC	150	0.69	1,641.43	1,641.24	0.2	3.02	0.35
P-79	283.16	50	PVC	150	0.07	1,641.24	1,641.23	0.01	0.04	0.04
P-80	452.93	100	PVC	150	-0.93	1,641.23	1,641.31	0.08	0.18	0.12
P-81	156.36	100	PVC	150	6.16	1,641.31	1,640.38	0.93	5.96	0.78
P-82	99.97	100	PVC	150	2.2	1,640.38	1,640.29	0.09	0.89	0.28
P-83	169.47	80	PVC	150	1.58	1,640.29	1,640.05	0.24	1.42	0.31
P-84	286.51	100	PVC	150	5.07	1,653.42	1,652.23	1.19	4.16	0.65
P-85	203	100	PVC	150	2.6	1,652.23	1,651.98	0.25	1.21	0.33
P-86	154.84	50	PVC	150	-1	1,649.90	1,650.83	0.93	6.02	0.51
P-87	74.37	50	PVC	150	-1.85	1,650.83	1,652.23	1.39	18.75	0.94
P-88	117.04	50	PVC	150	0.23	1,650.83	1,650.79	0.05	0.39	0.12
P-89	110.34	50	PVC	150	0.61	1,650.79	1,650.52	0.27	2.41	0.31
P-92	175.56	50	PVC	150	-0.99	1,650.79	1,651.83	1.04	5.93	0.51
P-91	334.67	50	PVC	150	0.61	1,651.64	1,650.84	0.81	2.41	0.31
P-96	194.16	80	PVC	150	-3	1,508.64	1,509.55	0.91	4.66	0.6
P-99	97.23	50	PVC	150	2	1,471.99	1,469.88	2.11	21.71	1.02
P-100	101.19	50	PVC	150	2	1,469.88	1,467.68	2.2	21.71	1.02
P-101	66.45	50	PVC	150	1	1,467.68	1,467.28	0.4	6.02	0.51
P-102	71.93	50	PVC	150	-3	1,471.99	1,475.30	3.31	46.01	1.53
P-103	294.13	50	PVC	150	4.95	1,475.30	1,509.55	34.25	116.44	2.52
P-104	193.85	50	PVC	150	-1.33	1,473.31	1,475.30	1.99	10.24	0.68
P-105	51.82	50	PVC	150	0.33	1,473.31	1,473.27	0.04	0.78	0.17
P-106	98.15	50	PVC	150	0.62	1,473.27	1,473.03	0.24	2.48	0.32
P-107	181.66	80	PVC	150	-8.57	1,509.55	1,515.47	5.92	32.59	1.71
P-109	70.71	50	PVC	150	-1.29	1,473.27	1,473.95	0.68	9.6	0.66
P-110	150.27	50	PVC	150	-7.9	1,473.95	1,515.47	41.52	276.28	4.02
P-111	141.73	50	PVC	150	6	1,473.95	1,450.41	23.54	166.1	3.06
P-112	78.64	80	PVC	150	-17.47	1,515.47	1,525.05	9.58	121.81	3.48
P-113	116.74	80	PVC	150	-20.09	1,525.05	1,543.47	18.42	157.79	4
P-114	148.44	50	PVC	150	-2	1,521.82	1,525.05	3.22	21.71	1.02
P-116	60.05	80	PVC	150	-19.29	1,586.63	1,595.42	8.79	146.35	3.84
P-117	195.99	80	PVC	150	-21.11	1,595.42	1,629.31	33.89	172.92	4.2
P-118	128.63	50	PVC	150	-1.2	1,594.34	1,595.42	1.08	8.41	0.61
P-119	206.96	50	PVC	150	-0.62	1,593.17	1,593.68	0.51	2.48	0.32
P-120	217.63	50	PVC	150	3.04	1,604.83	1,594.56	10.27	47.2	1.55
P-121	56.69	50	PVC	150	0.8	1,594.56	1,594.34	0.23	3.99	0.41
P-122	60.05	50	PVC	150	-1.62	1,593.68	1,594.56	0.88	14.7	0.83
P-123	96.01	80	PVC	150	-22.09	1,543.47	1,561.53	18.06	188.11	4.39
P-124	189.28	80	PVC	150	-18.29	1,561.53	1,586.63	25.1	132.61	3.64
P-126	118.26	50	PVC	150	3.9	1,595.25	1,586.40	8.85	74.82	1.99
P-127	128.32	50	PVC	150	-1.35	1,586.40	1,587.75	1.35	10.53	0.69
P-128	238.66	50	PVC	150	-7.36	1,587.75	1,645.61	57.86	242.45	3.75
P-129	233.17	50	PVC	150	-6.9	1,595.25	1,645.43	50.18	215.22	3.51
P-130	120.09	50	PVC	150	4.01	1,587.75	1,578.31	9.44	78.62	2.04
P-131	110.64	50	PVC	150	4.25	1,586.40	1,576.68	9.72	87.85	2.17
P-132	160.63	50	PVC	150	4.42	1,576.68	1,561.53	15.15	94.32	2.25
P-133	61.87	50	PVC	150	2.01	1,578.31	1,576.96	1.35	21.84	1.02

P-134	71.93	50	PVC	150	0.79	1,576.96	1,576.68	0.28	3.85	0.4
P-135	138.07	50	PVC	150	0.61	1,576.96	1,576.62	0.33	2.41	0.31
P-136	55.17	80	PVC	150	-22.11	1,629.31	1,639.70	10.39	188.4	4.4
P-137	242.01	80	PVC	150	-1.58	1,639.70	1,640.05	0.34	1.42	0.31
P-138	33.22	100	PVC	150	-21.16	1,639.70	1,641.65	1.95	58.57	2.69
P-139	195.38	100	PVC	150	-24.03	1,641.65	1,656.14	14.49	74.16	3.06
P-140	234.09	150	PVC	150	14.53	1,656.14	1,655.19	0.95	4.05	0.82
P-141	312.72	150	PVC	150	-11.41	1,654.14	1,654.95	0.81	2.59	0.65
P-142	82.91	150	PVC	150	-12.03	1,654.95	1,655.19	0.24	2.86	0.68
P-143	320.65	200	PVC	150	9.81	1,654.14	1,653.99	0.15	0.48	0.31
P-144	26.52	200	PVC	150	8.81	1,653.99	1,653.98	0.01	0.4	0.28
P-145	36.58	250	PVC	150	-40.76	1,653.77	1,653.85	0.08	2.27	0.83
P-146	299.31	250	PVC	150	-19.84	1,653.85	1,654.03	0.18	0.6	0.4
P-147	511.76	200	PVC	150	6.81	1,653.98	1,653.85	0.13	0.25	0.22
P-148	301.75	150	PVC	150	-40.56	1,656.14	1,664.32	8.19	27.13	2.3
P-149	242.32	200	PVC	150	-51.94	1,664.32	1,666.88	2.56	10.56	1.65
P-150	44.2	200	PVC	150	-52.94	1,666.88	1,667.37	0.48	10.94	1.69
P-151	1,404.52	200	PVC	150	-5	1,652.30	1,652.50	0.19	0.14	0.16
P-152	1,331.37	80	PVC	150	-0.52	1,668.22	1,668.46	0.24	0.18	0.1
P-153	820.22	200	PVC	150	-0.08	1,668.22	1,668.22	0	0	0
P-154	548.94	200	PVC	150	-0.04	1,668.22	1,668.22	0	0	0
P-155	504.14	200	PVC	150	1.23	1,668.22	1,668.21	0.01	0.01	0.04
P-156	577.29	100	PVC	150	-1.12	1,668.46	1,668.60	0.15	0.25	0.14
P-157	1,367.64	80	PVC	150	0.66	1,668.60	1,668.22	0.38	0.28	0.13
P-158	1,450.85	100	PVC	150	-1.89	1,668.22	1,669.19	0.97	0.67	0.24
P-159	1,076.55	100	PVC	150	-0.46	1,669.19	1,669.24	0.05	0.05	0.06
P-160	114.6	100	PVC	150	-1.07	1,669.24	1,669.27	0.03	0.24	0.14
P-161	505.05	100	PVC	150	-1.32	1,669.27	1,669.44	0.17	0.35	0.17
P-162	534.62	100	PVC	150	-2.07	1,669.44	1,669.87	0.42	0.79	0.26
P-163	561.75	100	PVC	150	-4.19	1,669.87	1,671.50	1.64	2.92	0.53
P-164	470.31	200	PVC	150	-13.69	1,668.21	1,668.63	0.42	0.89	0.44
P-165	332.54	200	PVC	150	-13.74	1,668.63	1,668.93	0.3	0.9	0.44
P-166	1,116.18	200	PVC	150	-14.36	1,668.93	1,670.02	1.09	0.98	0.46
P-168	527.61	150	PVC	150	-4.43	1,669.19	1,669.42	0.24	0.45	0.25
P-169	564.49	150	PVC	150	-5.47	1,669.42	1,669.80	0.37	0.66	0.31
P-171	682.45	100	PVC	150	0.76	1,670.11	1,670.02	0.08	0.12	0.1
P-172	645.26	150	PVC	150	-4.58	1,669.80	1,670.11	0.31	0.48	0.26
P-173	574.55	100	PVC	150	-2.37	1,668.60	1,669.19	0.59	1.02	0.3
P-174	1,219.81	100	PVC	150	-0.25	1,669.42	1,669.44	0.02	0.02	0.03
P-175	1,107.95	150	PVC	150	-1.5	1,669.80	1,669.87	0.07	0.06	0.08
P-178	216.71	100	PVC	150	-4.69	1,671.50	1,672.28	0.78	3.59	0.6
P-179	731.82	100	PVC	150	4.23	1,672.28	1,670.11	2.18	2.97	0.54
P-180	967.74	200	PVC	150	9.54	1,672.73	1,672.28	0.44	0.46	0.3
P-181	811.07	200	PVC	150	-17.07	1,670.02	1,671.11	1.09	1.35	0.54
P-182	637.34	80	PVC	150	-1.14	1,671.11	1,671.61	0.49	0.77	0.23
P-183	673.91	80	PVC	150	-1.72	1,671.61	1,672.73	1.12	1.66	0.34
P-184	883.01	80	PVC	150	-1.75	1,670.11	1,671.61	1.5	1.7	0.35
P-185	734.57	200	PVC	150	-11.76	1,672.73	1,673.22	0.5	0.67	0.37
P-186	781.2	200	PVC	150	-22.07	1,671.11	1,672.81	1.69	2.16	0.7
P-187	527.61	80	PVC	150	-0.63	1,672.81	1,672.94	0.14	0.26	0.13
P-188	580.95	80	PVC	150	-0.88	1,672.94	1,673.22	0.28	0.48	0.18
P-189	755.6	80	PVC	150	-1.78	1,671.61	1,672.94	1.33	1.76	0.35
P-190	1,887.63	80	PVC	150	4.56	1,672.81	1,653.72	19.08	10.11	0.91
P-193	357.84	200	PVC	150	13.21	1,673.87	1,673.57	0.3	0.84	0.42
P-194	417.58	200	PVC	150	13.2	1,673.57	1,673.22	0.35	0.84	0.42

P-195	540.41	100	PVC	150	4.37	1,675.84	1,674.13	1.71	3.16	0.56
P-196	546.81	100	PVC	150	1.58	1,674.13	1,673.87	0.26	0.48	0.2
P-197	432.51	80	PVC	150	-1.77	1,672.94	1,673.70	0.76	1.76	0.35
P-198	356.31	80	PVC	150	-1.44	1,673.70	1,674.13	0.43	1.2	0.29
P-199	562.05	80	PVC	150	-0.6	1,673.57	1,673.70	0.13	0.23	0.12
P-200	441.66	200	PVC	150	-26.44	1,672.81	1,674.14	1.34	3.03	0.84
P-201	366.06	200	PVC	150	-33.3	1,674.14	1,675.84	1.7	4.64	1.06
P-202	535.23	80	PVC	150	-1.18	1,673.70	1,674.14	0.44	0.82	0.23
P-204	859.23	200	PVC	150	-12.24	1,673.87	1,674.49	0.62	0.73	0.39
P-205	1,024.43	200	PVC	150	17.79	1,674.49	1,673.01	1.49	1.45	0.57
P-206	1,192.07	200	PVC	150	12.33	1,673.01	1,672.13	0.88	0.74	0.39
P-207	509.93	200	PVC	150	11.71	1,672.13	1,671.79	0.34	0.67	0.37
P-208	137.77	200	PVC	150	11.11	1,671.79	1,671.70	0.08	0.61	0.35
P-209	567.84	200	PVC	150	10.49	1,671.70	1,671.39	0.31	0.55	0.33
P-210	748.89	200	PVC	150	9.89	1,671.39	1,671.02	0.37	0.49	0.31
P-211	383.13	200	PVC	150	9.39	1,671.02	1,670.85	0.17	0.45	0.3
P-213	1,134.16	250	PVC	150	-30.63	1,674.49	1,676.01	1.52	1.34	0.62
P-216	267.61	200	PVC	150	31.4	1,676.01	1,674.90	1.11	4.16	1
P-218	3,861.21	50	PVC	150	1.12	1,670.49	1,641.65	28.85	7.47	0.57
P-219	797.36	200	PVC	150	27.26	1,674.90	1,672.35	2.55	3.2	0.87
P-220	805.28	200	PVC	150	23.27	1,672.35	1,670.42	1.92	2.39	0.74
P-221	555.96	200	PVC	150	4.19	1,670.42	1,670.37	0.06	0.1	0.13
P-222	566.01	200	PVC	150	3.6	1,670.37	1,670.33	0.04	0.08	0.11
P-223	675.74	200	PVC	150	-0.99	1,670.33	1,670.33	0	0.01	0.03
P-224	504.44	200	PVC	150	-4.42	1,670.33	1,670.39	0.06	0.11	0.14
P-225	369.42	200	PVC	150	-7.82	1,670.39	1,670.50	0.12	0.32	0.25
P-226	697.08	200	PVC	150	10.04	1,670.85	1,670.50	0.35	0.5	0.32
P-227	551.69	200	PVC	150	1.62	1,670.50	1,670.49	0.01	0.02	0.05
P-228	372.16	150	PVC	150	5.26	1,673.01	1,672.78	0.23	0.62	0.3
P-229	531.57	150	PVC	150	6.89	1,672.78	1,672.24	0.54	1.02	0.39
P-230	493.17	150	PVC	150	8.06	1,672.24	1,671.56	0.67	1.36	0.46
P-231	555.65	150	PVC	150	5.61	1,671.56	1,671.18	0.39	0.7	0.32
P-232	587.96	150	PVC	150	4.09	1,671.18	1,670.95	0.23	0.39	0.23
P-233	474.57	150	PVC	150	2.64	1,670.95	1,670.87	0.08	0.17	0.15
P-234	330.1	150	PVC	150	1.25	1,670.87	1,670.85	0.01	0.04	0.07
P-235	768.4	80	PVC	150	1.08	1,670.87	1,670.33	0.54	0.7	0.21
P-236	978.71	80	PVC	150	1.02	1,670.95	1,670.33	0.62	0.64	0.2
P-237	603.81	80	PVC	150	0.91	1,671.18	1,670.87	0.31	0.51	0.18
P-238	435.86	80	PVC	150	1.41	1,670.87	1,670.37	0.5	1.14	0.28
P-239	1,691.34	80	PVC	150	0.85	1,674.13	1,673.37	0.77	0.45	0.17
P-240	493.17	80	PVC	150	2	1,673.37	1,672.28	1.09	2.2	0.4
P-241	652.88	80	PVC	150	1.7	1,672.28	1,671.22	1.06	1.62	0.34
P-242	570.59	80	PVC	150	1	1,671.22	1,670.87	0.35	0.61	0.2
P-243	577.6	100	PVC	150	16.38	1,670.42	1,649.36	21.06	36.46	2.09
P-244	576.38	80	PVC	150	0.4	1,670.39	1,670.32	0.06	0.11	0.08
P-245	534.62	80	PVC	150	0.62	1,670.33	1,670.19	0.13	0.25	0.12
P-247	261.52	250	PVC	150	66.3	1,676.96	1,675.50	1.46	5.6	1.35
P-248	389.84	250	PVC	150	65.7	1,675.50	1,673.35	2.15	5.5	1.34
P-249	93.57	152.4	Ductile Iron	130	68.16	1,696.00	1,687.99	8.01	85.59	3.74
P-250	264.57	400	Ductile Iron	130	68.16	1,687.99	1,687.79	0.21	0.78	0.54
P-251	110.03	250	Ductile Iron	130	114.91	1,696.00	1,693.78	2.22	20.2	2.34
P-252	296.57	250	Ductile Iron	130	114.91	1,693.78	1,687.79	5.99	20.2	2.34
P-253	1,093.32	400	PVC	150	-182.45	1,680.48	1,684.52	4.04	3.7	1.45
P-254	673.61	400	Ductile Iron	130	-183.07	1,684.52	1,687.79	3.27	4.85	1.46
P-255	869.29	400	PVC	150	182.45	1,680.48	1,677.26	3.21	3.7	1.45

P-256	373.68	400	Ductile Iron	130	69.2	1,677.26	1,676.96	0.3	0.8	0.55
P-257	722.99	100	PVC	150	3.53	1,674.90	1,673.37	1.53	2.12	0.45
P-258	652.58	100	PVC	150	2.23	1,673.37	1,672.78	0.59	0.9	0.28
P-259	591.01	150	PVC	150	-1.67	1,672.24	1,672.28	0.04	0.07	0.09
P-260	672.39	150	PVC	150	-1.99	1,672.28	1,672.35	0.07	0.1	0.11
P-261	519.38	100	PVC	150	1.89	1,671.56	1,671.22	0.35	0.67	0.24
P-262	910.13	100	PVC	150	2.18	1,671.22	1,670.42	0.79	0.87	0.28
P-263	109.12	100	PVC	150	15.87	1,649.36	1,645.61	3.75	34.39	2.02
P-264	126.8	152.4	Ductile Iron	130	7.51	1,645.61	1,645.43	0.18	1.44	0.41
P-265	688.54	250	PVC	150	-38.71	1,675.84	1,677.26	1.42	2.07	0.79
P-266	248.72	250	PVC	150	62.53	1,677.26	1,676.01	1.25	5.02	1.27
P-267	683.67	152.4	Ductile Iron	130	-1.07	1,654.03	1,654.06	0.03	0.04	0.06
P-268	329.18	100	PVC	150	2.5	1,654.06	1,653.69	0.37	1.12	0.32
P-269	792.18	80	PVC	150	-3.57	1,654.06	1,659.14	5.09	6.42	0.71
P-270	798.88	80	PVC	150	-5.64	1,659.14	1,671.11	11.97	14.99	1.12
P-271	29.87	400	Ductile Iron	130	122.45	1,766.00	1,765.93	0.07	2.3	0.97
P-272	2,460.96	400	Ductile Iron	130	122.45	1,765.93	1,760.26	5.67	2.3	0.97
P-273	349.61	400	Ductile Iron	130	122.45	1,760.26	1,759.46	0.81	2.3	0.97
P-274	1,542.29	400	Ductile Iron	130	122.45	1,759.46	1,755.91	3.55	2.3	0.97
P-275	147.52	400	Ductile Iron	130	122.45	1,755.91	1,755.57	0.34	2.3	0.97
P-276	349.91	400	Ductile Iron	130	122.45	1,755.57	1,754.76	0.81	2.3	0.97
P-277	793.7	400	Ductile Iron	130	122.45	1,754.76	1,752.93	1.83	2.3	0.97
P-278	899.77	400	Ductile Iron	130	122.45	1,752.93	1,750.86	2.07	2.3	0.97
P-279	199.95	400	Ductile Iron	130	122.45	1,750.86	1,750.40	0.46	2.3	0.97
P-280	2,735.58	400	Ductile Iron	130	122.45	1,750.40	1,744.10	6.3	2.3	0.97
P-281	1,799.23	400	Ductile Iron	130	122.45	1,744.10	1,739.96	4.14	2.3	0.97
P-282	249.94	400	Ductile Iron	130	122.45	1,739.96	1,739.38	0.58	2.3	0.97
P-283	699.52	400	Ductile Iron	130	122.45	1,739.38	1,737.77	1.61	2.3	0.97
P-284	199.95	400	Ductile Iron	130	122.45	1,737.77	1,737.31	0.46	2.3	0.97
P-285	399.9	400	PVC	150	122.45	1,737.31	1,736.61	0.71	1.77	0.97
P-286	149.96	400	PVC	150	122.45	1,736.61	1,736.34	0.26	1.77	0.97
P-287	1,444.75	400	PVC	150	122.45	1,736.34	1,733.79	2.55	1.77	0.97
P-288	249.94	400	PVC	150	122.45	1,733.79	1,733.35	0.44	1.77	0.97
P-289	3,120.54	400	PVC	150	122.45	1,733.35	1,727.83	5.51	1.77	0.97
P-290	499.57	400	PVC	150	122.45	1,727.83	1,726.95	0.88	1.77	0.97
P-291	1,592.28	400	PVC	150	122.45	1,726.95	1,724.14	2.81	1.77	0.97
P-292	1,860.80	400	PVC	150	122.45	1,724.14	1,720.85	3.29	1.77	0.97
P-293	1,075.94	400	PVC	150	122.45	1,720.85	1,718.95	1.9	1.77	0.97
P-294	1,940.36	400	PVC	150	122.45	1,718.95	1,715.52	3.43	1.77	0.97
P-295	2,122.93	400	PVC	150	122.45	1,715.52	1,711.77	3.75	1.77	0.97
P-296	3,208.02	400	PVC	150	122.45	1,711.77	1,706.10	5.67	1.77	0.97
P-297	3,745.08	400	PVC	150	122.45	1,706.10	1,699.49	6.62	1.77	0.97
P-298	949.76	400	PVC	150	122.45	1,699.49	1,697.81	1.68	1.77	0.97
P-299	914.4	400	PVC	150	122.45	1,697.81	1,696.20	1.62	1.77	0.97
P-300	297.79	250	Ductile Iron	130	18.05	1,696.20	1,696.00	0.2	0.66	0.37
P-301	115.21	400	Ductile Iron	130	103.77	1,696.20	1,696.00	0.2	1.69	0.83
P-302	548.34	100	PVC	150	-11.26	1,654.33	1,664.32	9.99	18.22	1.43
P-303	983.28	50	PVC	150	1.56	1,673.35	1,659.88	13.47	13.7	0.79
P-304	2,035.76	50	PVC	150	0.22	1,659.88	1,659.14	0.74	0.36	0.11
P-305	458.11	50	PVC	150	-1.71	1,659.14	1,666.60	7.45	16.27	0.87
P-306	1,253.34	50	PVC	150	-0.49	1,666.60	1,668.63	2.04	1.63	0.25
P-307	622.1	50	PVC	150	1.97	1,670.60	1,657.43	13.17	21.17	1
P-308	801.62	80	PVC	150	2.86	1,670.02	1,666.60	3.43	4.28	0.57
P-309	1,480.41	152.4	Ductile Iron	130	-14.73	1,653.85	1,661.27	7.42	5.01	0.81
P-310	1,460.91	152.4	Ductile Iron	130	-14.31	1,661.27	1,668.21	6.94	4.75	0.78

P-311	830.88	50	PVC	150	1.04	1,666.60	1,661.27	5.33	6.41	0.53
P-312	1,159.46	80	PVC	150	1.06	1,669.42	1,668.63	0.79	0.68	0.21
P-313	487.98	80	PVC	150	2.91	1,676.96	1,674.82	2.14	4.39	0.58
P-314	536.14	50	PVC	150	0.54	1,675.84	1,674.82	1.02	1.9	0.27
P-315	361.19	50	PVC	150	2.83	1,674.82	1,659.88	14.94	41.36	1.44
P-316	1,281.38	50	PVC	150	0.88	1,670.42	1,664.32	6.1	4.76	0.45
P-317	374.29	50	PVC	150	-4.04	1,604.83	1,634.74	29.91	79.9	2.06
P-318	180.14	50	PVC	150	-1.69	1,634.74	1,637.61	2.87	15.92	0.86
P-319	125.58	50	PVC	150	2.96	1,640.38	1,634.74	5.64	44.88	1.51
P-320	1,139.95	80	PVC	150	5.43	1,674.14	1,658.18	15.96	14	1.08
P-321	429.46	80	PVC	150	4.45	1,658.18	1,654.03	4.15	9.67	0.88
P-322	811.68	50	PVC	150	-0.36	1,657.43	1,658.18	0.75	0.93	0.19
P-43	355.4	80	PVC	150	-0.2	1,648.46	1,648.47	0.01	0.03	0.04
P-323	151.49	50	PVC	150	1.35	1,653.42	1,651.83	1.59	10.49	0.69
P-324	323.39	50	PVC	150	-0.25	1,651.83	1,651.98	0.15	0.47	0.13