

**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES**



**ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**WATER SUPPLY COVERAGE AND PERFORMANCE EVALUATION
OF DISTRIBUTION SYSTEM USING HYDRAULIC SIMULATION
SOFTWARE**

(The Case of Jijiga Town)

By:

Demelash Mulu

Advisor:

Daniel F/Silassie (Dr.Ing)

**A thesis Submitted to the School of Graduate Studies of Addis
Ababa University in Partial Fulfillment of the Degree of Master of
Science in
Civil Engineering.**

Feb., 2020

Addis Ababa, Ethiopia



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Feb., 2020

Addis Ababa, Ethiopia

Declaration

This thesis is my original work and has not been presented for a degree in any other university and that all sources of material used for this thesis have been dully acknowledged.

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Abstract:

Most Ethiopian cities are characterized by having old water distribution networks upon which new extensions are linked in order to serve new areas, adding complexity to an aging network where full rehabilitation may not be practical due to economic constraints. In this research, the water distribution network of Jijiga City, one of the major Cities in Somali regional state, was studied for analyzing and optimizing its design and extension taking into consideration the effect of aging of the network, local conditions such as intermittent pumping, which is a way of operating the water distribution systems in most towns of developing world.

The main objective of this study is to improve hydraulics performance of Jijiga city water supply distribution system and control its operation, Water CAD software was used as tool to model water distribution system analysis. The modeling effort included only hydraulic performance modeling. Simulation results for maximum and minimum pressures were used as base tool to evaluate the hydraulic performance in the distribution system. The modeling results showed violation of maximum and minimum pressure requirements. Along with this, the model analysis result shows the different problems of the system. These are aged pipes, oversized and undersized pipes, low and high pressures and water demand and supply status. The modeling of the system as continuous supply system depending on assumptions considering with future water consumption, availability of water, overcoming the problems of high pressures by using pressure reducing valves at specific locations, and assuming steady state analysis, shows the ability of the existing system to serve the Jijiga area and to cope the future extension. The output values of velocities are parallel reasonably to the assumed limits of velocities (0.1 m/s – 0.3 m/s) to avoid stagnation and quality water problems, also the pressure values are within the limits of the design pressures in the residential areas. Further evaluation has been carried out to investigate the total average day demand, peak hour demand factors and maximum day demand factor and to study the water supply coverage in Jijiga town. The peak hour demand factor was calculated to be 1.6, and a value of 25 l/c/d was

recorded as average daily water consumption. Present nominal water supply coverage is calculated to be 49.6% and actual water supply coverage of the service is computed to be 43.11%.

Generally, the model analysis result shows the different problems of the system. These are aged pipes, oversized and undersized pipes, low and high pressures and shortage of water from the source. The system should be modified using the design criteria of velocity, pressure and demand required. High pressures in the existing system caused by customers at too low demand have to be identified and solution is established using pressure-reducing valves. To retrieve the situation there is a need to intervene. Modification in operation, design and finding another reliable water source and injecting to the system will improve the current situation of the Jijiga town water distribution system.

Key Words: *Water distribution system, modeling, Hydraulic performance, optimum pipe flow velocity, Maximum pressure, Minimum pressure, Pipe age, Jijiga.*

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LIST OF ABBREVIATIONS

- DN: Nominal diameter.
- L/c/d: Liter capita per a day.
- m.a.s.l: Meter above sea level.
- MCM: Million cubic meters.
- MOPIC: Ministry of planning and international cooperation.
- PDO: Pressure dependent outflow.
- P.F: Peak factor.
- JWA: Jijiga water authority.
- S.I: International system.
- UFW: Unaccounted for water.
- WSCs: Water supplies companies.
- L/c/d: Liter per second
- m/s: Meter per second
- MoWR: Ministry of Water Resource
- CSA: Central Statistical Agency
- GWE: German Water Engineering (G W E
- UFW: Unaccounted for water (UFW
- NRW: Non-revenue water (NRW)
- MNF: The minimum night flow (MNF)
- kms/day: Kilometers per day
- DN: Nominal Diameter
- PN: Nominal pressure
- UPVC:
- DCI: Ductile cast Iron pipe
- GI: Galvanized Iron pipe
- EELP: Ethiopian Electric Power Cooperation
- RCC: Reinforced Cement concrete
- TMWD: Theoretical minimum water demand
- DEM: Digital Elevation Model

USEPA:

AWWA:

WHO: World Health Organization

PDO: pressure dependent outflow functions

WWDSE: Water Works Design & Supervision Enterprise

HTU: House Tap users

YTU: Yard Tap users

PTU: Public Tap users

WSSA: Water supply and Sewerage Authority

HH: House Hold

Gpm: Gallon per minuets

1. INTRODUCTION

1.1. General Background

Provisions of safe and adequate water supply and improved sanitation services are necessary components for sustainable development. The estimated water supply service level of Ethiopia in terms of coverage, quantity, quality and reliability is very low. The availability of sanitation facilities is even the worst. This has high negative impact on the economic development of the country and the living conditions/standards of the communities.

The Federal Democratic Republic of Ethiopia, Ministry of Water, Irrigation & Energy (MoWIE) has developed water policy that includes the water supply and sanitation to enhance fast development of water supply for human being and livestock consumption, for industrial and other uses in terms of converge, quantity, reliability and acceptable quality taking the existing and future realities of the country in to consideration. It also emphasizes the necessity of provision of adequate, reliable and clean water supply and sanitation services to enhance the well-being and productivity of the Ethiopian people and to foster its tangible contribution to the economy.

In our region the design of water distribution systems is implemented by using universal design factors without taking into account the effects of local conditions, so that the design parameters should be modified to achieve water requirements.

Jijiga city is the capital of Ethiopian Somali national regional state. Jijiga is located about 630km to the east of Addis Ababa, about 105 km east from the state city of Harar. The geographic coordinates are 9⁰ 20' North and 42⁰ 56' East.

Jijiga city is situated at the foot of Karamara Mountain chain. It is the start of a vast plain continuing to the east for a thousand kilometer to the borders of the country. The altitude of the city ranges between 1720m around Duda Hidi and 1620m around Jijiga health Science College. The city has gentle slope from North-West to South –East.

According to CSA 2007 data, the total population of Jijiga city is estimated to be 125,584 and out of this the males are 66,810 constituting 53.2%, and females are 58,774 constituting 46.8%. In line with this, Jijiga city has 45.4% out of the total population of the Jijiga Woreda's population live in Jijiga city.

The source of water supply system for Jijiga city is ground water. There are about 25 boreholes drilled so far around the city, but out of the total only 22 boreholes are functioning properly supplying only less than 52 l/sec; 8 more were also drilled and connected to the system at Jerer valley about 23km far from the city to the south direction and connected to the system via 3,000m³ Reservoir which is located to the South-East direction along the Asphalt road Jijiga to Degahabour and about 75 l/sec water is being supplied from this Jerer well field.

The old distribution system was designed by German consultancy called German Water Engineering (G.W.E) in 1975. By now as the population number has increased significantly, the supply is not adequate to the dwellers and currently there is a critical shortage of water supply in the city. The public water points and the house taps are usually dry. Water vending is a common practice in the city and a 25 litter container (Jerrycan) costs about 40 birr. There is no perennial stream in the area. There is one dam close to the city but the available water in the dam reservoir has no a treatment facility. Hence it is used only for animals and other uses. In addition to the boreholes, people use other unprotected sources like dug wells and ponds for various uses.

The continuous and repeated deficiency in the performance of the Jijiga City water supply networks became one of the most critical issues in the water supply sector that requires immediate action.

Water distribution systems are designed to adequately satisfy the water requirements for a combination of domestic, commercial, industrial, and firefighting purposes. The system should be capable of meeting the demands placed on it at all times and at satisfactory hydraulic performance. It should enable reliable operation during irregular situations and perform adequately under varying demand loads.

As the information I got from Municipality water Supply service technicians during my site visit, in most areas of the city the distribution systems are suffered from the deficiency of water supply quantities, pipe linkage and deficiency of adequate pressure.

The scarce source of water is a common problem of Jijiga city supply, forcing people to collect water individually, by means of ground or/and roof tanks. These roof tanks satisfy the water demand during its high periods by providing storage space. By tapping water from their own tanks, the consumers there do not rely on the pressure in the distribution system, as long it is sufficient to provide refilling of the tank at certain period of the day. Unlike in continuous supply, this creates smaller range of hourly peak factors allowing fairly stable supply through the distribution pipes. Balancing of the actual demand is therefore done individually for each household, whereby replenishing of the volume will happen somewhere. This way makes the using of the roof storage tanks that are available at the roof of the houses is very efficient for storage water during the non-pumping intervals.

The above-mentioned way of operating the municipal water supply networks will affect the expected performance of the network by affecting the pressure values and the velocities. It also increases pipes breakage rates. The breakage in mains results from oscillating pressures due to providing a large number of homes with a high quantity of water in a short period.

This research is part of studies in which researchers study the performance of water distribution systems. This study is to investigate the state of the existing water distribution systems (Jijiga water distribution system as a case study) and to evaluate the hydraulic performance of the supply network under varying conditions of supply.

1.2. Problem Statement

Jijiga town is one of the towns that have been getting potable water supply system since the majestic regime. Even though distributing the available water and water loss from a utility's distribution system is a growing management problem in Ethiopia, there are few studies conducted on the existing water utilities in the country related to performance evaluation, water loss and coverage.

Jijiga town has water supply and demand related problems. Currently Jijiga town is facing a serious deficit in water supply due to increased population and expanded economic activity in and around the subsystems. Most of existing system network layout is not properly laid, that is obstacles for maintenance, transfer and replacement of old pipes and broken pipe if it is needed. All water supply network pipe line was installed before the existing road access and residential building is constructed as verified by the researcher during site visit. Currently, water distribution lines are found under drainage line, toilets, ditches, and building and in the residential building compound. Due to those problems arise in the hydraulic network performance and water supply coverage get deteriorated as the information obtained from Municipality water service office.

Formerly, Jijiga town water supply system pipe network was designed for residential demand limited on very small area of the town but now the supply coverage area is dramatically expanded with a construction of new small and light industries, commercials, institutions and multiple residential houses and services. Furthermore additional demand load from adjacent boundary Kebeles along the water source line, which were not considered before, when the existing water supply designed, are included at the systems. There is the gap between present water supply and demand.

Weakness and strengths of the system is not identified. As the water lost, the water utility is losing revenue. It is not known where and how much water is lost from existing Water supply system. There are kebeles in the town which are out of the reach of distribution pipes and the town with distribution pipes but without water most of the time. As a result of shortage of water, Jijiga town water utility faced a problem in distributing the available water impartially among the residents. Beside to this poor management of the existing infrastructural asset increases the level of water losses in water supply. In order to assess the status of Jijiga town water supply system hence, this research will identify the gaps between the demand and existing water supply system, the town with distribution pipes but without water most of the time, will evaluate the distribution system performance, assess areas with significant water losses and identify how much water is lost per yearly bases.

Although the Jijiga town water utility distribution system components were built decades ago and are currently in need of attention, issues related to the overall coverage of water supply, system performance and water loss from the utility are not investigated yet. Therefore, assessing the water supply coverage, hydraulics performance and water loss using statistical and water audit methods in order to develop strategies for the future is more urgent than ever. For that reason this study mainly deals with water supply coverage, performance evaluation with loss assessment and developing strategies for the water loss reduction in Jijiga town water utility.

1.3. Objectives of the study

The general objective of this work is to evaluate the supply coverage and to evaluate the hydraulic performance of the water supply networks taking into account the effects of local operating conditions. And suggest a method to better identify and reduce the loss and increase the hydraulic performance of the water supply network

Specific Objectives

- 1 To evaluate the domestic water supply coverage and distribution;
- 2 To evaluate the total loss of water (Unaccounted for water) at City level, to identify the possible causes of water losses and suggest possible solution;
- 3 Model the existing water supply system in order to study the hydraulic parameters in the water distribution system (pressure, velocity), the relations between them and other factors such as the time.
- 4 To assess the town water utility water shortage and leakage management practice, and to recommend the possible improvement measures;

1.4. Main Components of the methodology of the study

The Jijiga water distribution system and representative sectors in the network have been investigated as a case study. Thus, Detailed information and maps of the Jijiga water distribution system that are necessary to carry out the study such as source, existing

population, location and size of reservoirs, location booster station, distribution pipe network, and different data, necessary for the research have been provided by different governmental and Non-governmental organizations like Ministry of Water, Irrigation and Energy, Somali Water, Mineral and Energy, municipality of Jijiga or by Jijiga Water Supply and Sewerage Authority. In line with this the university has wrote a supporting letter to the municipality and other authorities of Jijiga explaining the goals and objectives of the study in order to make them contribute in the research work by feeding available secondary data and get a benefit from the result of the research work.

Apart from the primary information, additional inputs were required for the simulation of the model. The most important was the elevation dataset. Without the elevations, it is not possible to run the hydraulic simulation the elevation will be obtained from the city master plan contour or by overlaying the pipe network on Global Mapper software.

Field measurements, which have been recorded by the Municipality utility service office shall be gathered as secondary data for the analysis to determine the unaccounted for water (UFW) for the whole network.

The next steps involved in naming and arranging the preliminary data and elevation data based on the nodes (with their respective demand), reservoir and pumping station on data base (Microsoft Excel).The existing water supply network has been modeled using a computer program (Water Cad) as in reality (intermittent water 24 system) depending on the existing situation of operating the different parts of the network. The purpose of creating data base for a water supply system is to export and import data elements between the Water CAD model and date base files so as efficiently perform the analysis of the system and produce the required out puts.

Following the establishment of data base for the water supply distribution network, New Project File will be created for the design software. Then connection of data base with the project file will be performed to start the hydraulic analysis of the water supply system. The process of describing and interpreting data base of Microsoft Excel to Water CAD data files is called data base connection. Finally, the synchronization process is conducted for matching the data bases of both Soft wares to commence the hydraulic analysis of the

project.

The next step is connecting the nodes based on existing pipe diameter and analysis of the existing distribution network has been conducted for two scenarios of the peak and minimum demands of the system. The peak hour demand is analyzed to verify that the existing sizes of network pipes are sufficiently provide the minimum required pressure at all demand points. The minimum hour demand is analyzed for evaluation of pipe material and strength of the network.

The existing water supply network has been modeled using a computer program (Water Cad 6.5) as in reality depending on the existing situation of operating the different parts of the network.

The water supply system of Jijiga city has been redesigned as a continuous supply depending on fixed pattern, assuming the availability of water sources, and the using of pressure-reducing valves to reduce the high pressures in the system.

The last step is to evaluate the obtained result on previous step and analyzing the result based on the standard design criteria.

1.5. Study Structure

This research consists of seven chapters including the introduction.

Chapter One (Introduction): this chapter focuses about make a vision about the reasons to make this study. It consisted from: introduction, statement of problem, goals and objectives and Methodology for work.

Chapter Two (Literature Review): covers a general literature reviews published in previous studies for hydraulic modeling networks.

Chapter Three (Jijiga City Water Network): express the components of water network system at Jijiga city. Description of Jijiga city water resources and the state of the existing water distribution systems, also the challenges to be faced the water sector in the Territories

of Jijiga City. It describes the state of the Jijiga water distribution network, theoretical background, existing situation, storage facilities, pipes and materials, valves and regulating devices, tertiary network and ways of delivery to customers.

Chapter Four (Research Methodology): The method how the research was carried out is discussed in detail in this chapter. The methods of data collection and data preparation are also discussed.

Chapter Five (Modeling of Jijiga city water supply distribution network): This chapter discusses in detail the steps taken to construct the model of the existing drinking water distribution system of Jijiga city. It will explain how data is being collected, how the Water Cad model is going to be developed and the way water demand is being assigned to each node and the way how the model is being analyzed and technical recommendation is being forwarded for the problem observed in the water cad model.

In chapter Six, results and analysis of the model shall be explained in detail to select the best option of network modeling the supply system that will lead to a better network performance are stated.

In chapter Seven, logical conclusions and recommendation were given in detail.

2. LITERATURE REVIEW

2.1 Introduction

Several researches have been made to study the behavior of water distribution systems, and to reach an optimal solutions and assumptions in order to improve the hydraulic performance and to increase the water supply coverage within the networks under study.

Moreover, water utilities provide clean water service to local residents of the city and charge the service by the metered water consumption. However, not every drop of water produced reaches customers and generates the revenue for municipalities or water supply services. Instead, a significant portion of drinking water is lost, due to either water dripping away from the distribution pipelines or the unauthorized water usage.

The coming of age of the water infrastructure poses an increasing challenge for utility managers. One of the key issues is to assess the long-term development of network rehabilitation demand. The motivation is to ensure that sufficient funding is raised and appropriately allocated to achieve the foreseen level of service. As a result, the last decade of water infrastructure management has seen increased development, testing, and application of mathematical models in rehabilitation planning and network failure estimation (Scholten, et al, 2013).

In common engineering practice water distribution systems are designed using only heuristics criteria. Determining the optimal configuration and network parameters that can meet required flow and pressure rate are the result of hydraulic and cost-benefit analyses. The probability of system failure and other reliability statistics are very rarely included in such analyses (Dasic, et al., 2004).

The immediate consumers supply without any planned strategy hassled to inefficient operated systems, increasing the energy costs for water supply and distribution. With the actual concerns about sustainable development, the improvement of energy efficiency in Water Supply Systems must be of major importance (Coelho, et al., 2013).

Performance measures and indicators are used to support the managerial approaches to minimize different components of water losses. These concepts and methods have been adopted by countries around the world (Zheng, 2007).

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

In developing countries; many water authorities are facing the challenges in providing adequate water supply to the rapidly growing populations. Thereby, most of the existing water supply systems are unable to meet the various demands of water. Beside to this; infrastructural aging problem, poor management of the existing system components /assets and utilities capacity shortages were increases the level of water losses in the distribution system (Welday, 2005; Jalal, 2008).

Water utilities are facing the high level of water loss in their distribution networks. ‘For many utilities, reducing loss should be the first option to pursue when addressing low service coverage levels and increased demand for piped water supply. But, expanding water distribution networks without addressing water losses will only lead to a cycle of waste and inefficiency’ (Frauendorfer & Liemberger, 2010).

However, there is no simple solution to reduce water losses in the distribution system especially in the developing world, it should be involving improvements not only regard to the water system, but also required a change in attitudes (WUAM, 2013). In addition ‘understanding how leakage are currently performing and collecting relevant data, and turning it into useful information for planning and good information systems’ are essential to water loss reduction polices (Farley, et al., 2008).

The biggest problem with the city water supply network in developing countries is inadequacy of funds to maintain and upgrade the water infrastructure. Due to this most of the city dwellers have difficulty funding construction of new facilities and maintenance of staff. Many times these cities water supply services lack the technical resources that can guide them to optimize and sustainably operate their water distribution systems with scientific knowledge & experience. One other major problem area is that these city water supply services lack sufficient data and records for the proper maintenance of their distribution systems. Lack of technical expertise causes failures and many of these water supply services can only fix problems and they continue to expand the existing systems without considering the reliability of the existing design. These problems lead to non-compliance with the region or Federal Government drinking water quality regulations. Some city service is prone to violate these regulations. Thus, there is a need to evaluate the performance of distribution system of these cities to address the current and future issues related to their water distribution systems.

In general, using a computer model; assessing the hydraulic behaviors such as the water supply coverage of the system and evaluating the performance of existing cities' water distribution network are advantageous. Therefore, 'making hydraulic simulation software, especially from hydraulic point of view using engineering approach is one of the method used for discussion and decision measure on the system, either is the system within level of service based on pressure consideration or not' (Hussni & Zyoud, 2003).

2.2 Need for Hydraulic Modeling

Most small communities do not have very complex networks as compared to cities; however, they have poor data and records regarding their systems. In such cases, when one has to evaluate the hydraulics and the water quality of the distribution systems, it is advantageous to use computer models. Computer models making use of hydraulic simulation software are capable of mimicking the behavior of a real time system and have the capability of predicting the performance of the same system for future 'what if' scenarios (Haestad Methods, 2003). Some rural water districts that have the capability of maintaining and updating real time models, have used hydraulic simulation models in

conjunction with geographic information systems, allowing them to perform criticality studies with greater precision (Zhang, ESRI Users Conference 2009).

This can be cost effective as it will provide decision support in operation and maintenance of their systems.

2.3 Design criteria for Performance Evaluation

The performance of the system is measured based on its ability of the system to deliver good quality water at all the times under suitable set of operating conditions (Coelho, 1997). This performance depends on a number of criteria. Planning of these systems is very important and the factors that need to be considered are as follows:

- Design life of the system
- Appropriate advantages of topographic features to reduce energy costs
- Projected population growth
- Projected industrial and commercial growth
- Water consumption data: average daily consumption, per capita consumption and peak flow factors
- Minimum and maximum acceptable pressures.
- Storage facilities (Swamee, 2008)

Engineering of a good water supply system is very complex. Based on the above criteria, design period can be based on projected growth. Alternatively, for static populations like rural water communities the design period can be based on the life period of the pipes (Swamee, 2008).

The Oklahoma Department of Environmental Quality has issued guidelines for public drinking water systems. As per these guidelines, if a community is being supplied with groundwater, it should have at least adequate water wells with adequate safe yield, or have a standby source which can provide adequate water supply. Also, “if the city is supplied water only through the groundwater resource, then the capacity of the well must

be equal to or greater than the design maximum day demand and the design average day demand, with the largest producing well out of service” (ODEQ, 2009).

All pumping stations will have two pumps (One on duty and the other standby). In case of failure of one pump, the other pump should have a capacity of providing water during the peak periods in the day maintaining optimum pressures. All storage tanks should be able to provide enough storage facility to meet the regular average daily demands satisfying peak hourly periods but most importantly fire flow demands at a key location peak hours (Salvato, 1992).

Generally, the peak hourly flow factors are 3 to 6 times the average daily flows (Haestad Methods, 2003). Also the maximum design variation in the storage levels should not vary more than 10m to maintain the required pressures. In case the distribution system does not provide fire protection, then it should have storage capacity of 24 hours and must be able to maintain a pressure of at least 1.724 bars throughout the distribution system (ODEQ, 2009). As per the Insurance Services Office (ISO), cities having fire class greater than 8 should be able to provide a flow of 56.78 m³/hr peak daily demand and at a pressure of at least 1.379 bars (ISO Mitigation Online, 2009). “Dead ends should be minimized by looping them to the main network system” (ODEQ, 2009). A hydrant or a flushing device should be preferably installed at dead ends so as to not have issues of water contamination due to stagnation (ODEQ, 2009). Main water lines should be at least 150mm in diameter, and the least diameter of the pipe in the system should be 50mm. The design velocities in the pipes can range from 1 to 2 m/s (Salvato, 1992). “Also if the groundwater is subjected to low contamination, then only chlorination shall be used for disinfection, if the coli form count is not more than 50 per 100 ml on an average in one month and if the turbidity of the water is not greater than 5 NTU.” (ODEQ, 2009)

2.4 Basic Principles of Hydraulic Modeling:

In hydraulic simulation modeling a distribution network is considered to be one in which all elements are connected to each other, every element is influenced by its neighbors, and each element is consistent with the condition of all other elements. These conditions

are mainly controlled by two laws: Law of Conservation of Mass and Law of Conservation of Energy. “Thus the total mass of water entering the system should be equal to the total mass of water leaving the system, and the sum of the flows at any given node should be equal to zero. The principle of conservation of energy is mainly dictated by the Bernoulli’s equation, which states that the difference in the energy between any two points should be the same regardless of the path taken” (Haestad Methods, 2003).

A typical network in hydraulic model consists of the following components:

- Nodes linking the pipes
- Pipes
- Storage tanks
- Reservoirs
- Pumps
- Additional appurtenances like valves (Haestad Methods, 2003 ; Ross man, 2000)

The junctions or nodes represent points having particular base demands. Tanks are those points in model, which can have a specific storage capacity that varies with time. Reservoirs in a hydraulic model are assumed to be an infinite source of water (Haestad Methods, 2003; Ross man 2000).

Pumps are energy devices which provide pressure and head to the water. The graph of head vs. flow for a particular pump is called the ‘pump curve’. Figure 2.1 shows a typical pump curve. Generally there are three parameters that define the pump operation; the shut off head, the design point, and the maximum point.

The system curve is an important curve necessary to decide the best operating point of Pump. The pump should be able to overcome the elevations differences, which is dependent on the topography of the system. The head added on the pump to overcome these differences is called the static head. Friction and minor losses also affect the discharge through the pump. “When these losses are added to the static head for different discharge rates, the plot obtained is called system head curve” (Haestad Methods, 2003).

The operating point is considered to that where the system curve intersects the pump curve as shown in Figure 2.2. The other important curve related to the pumps is the pump efficiency curve as shown in Figure 2.3. The point at which the peak efficiency occurs is the best operating point`.

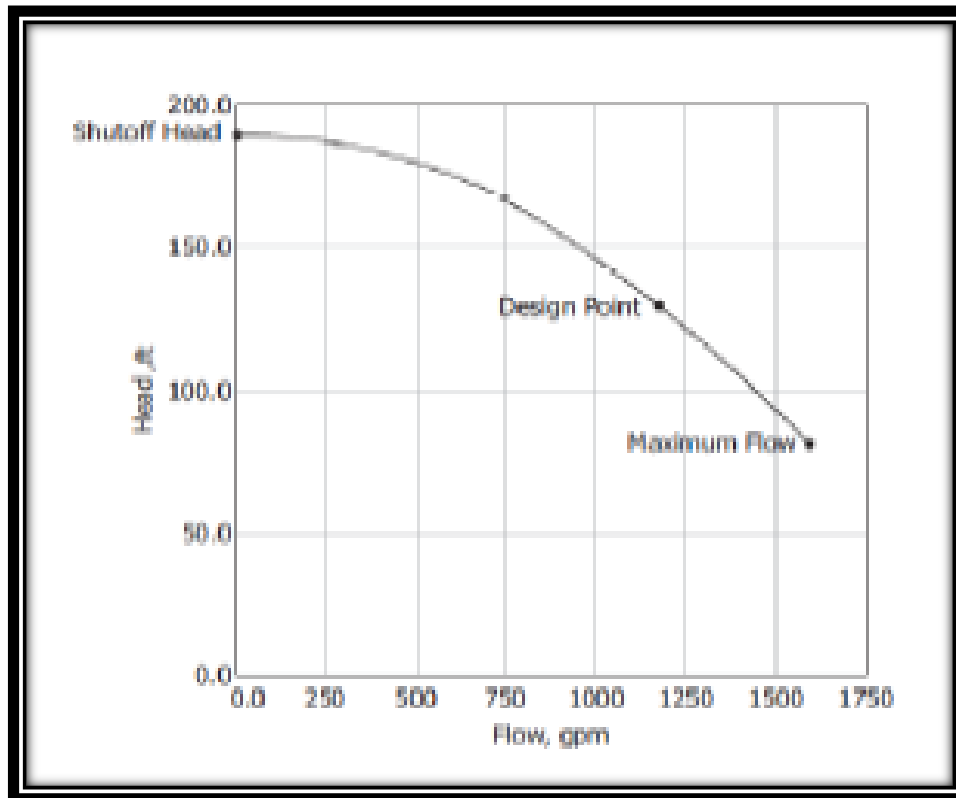


Figure 1 : Pump Curve (Source: Haestad Methods, 2003)

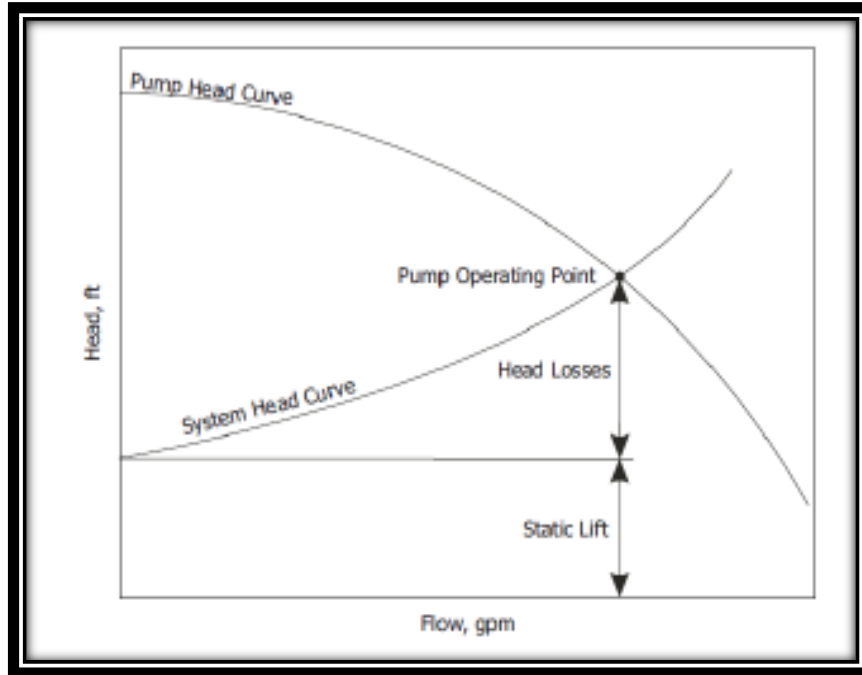


Figure 2 System Curve Vs the Pump curve (Source: Haestad Methods 2003)

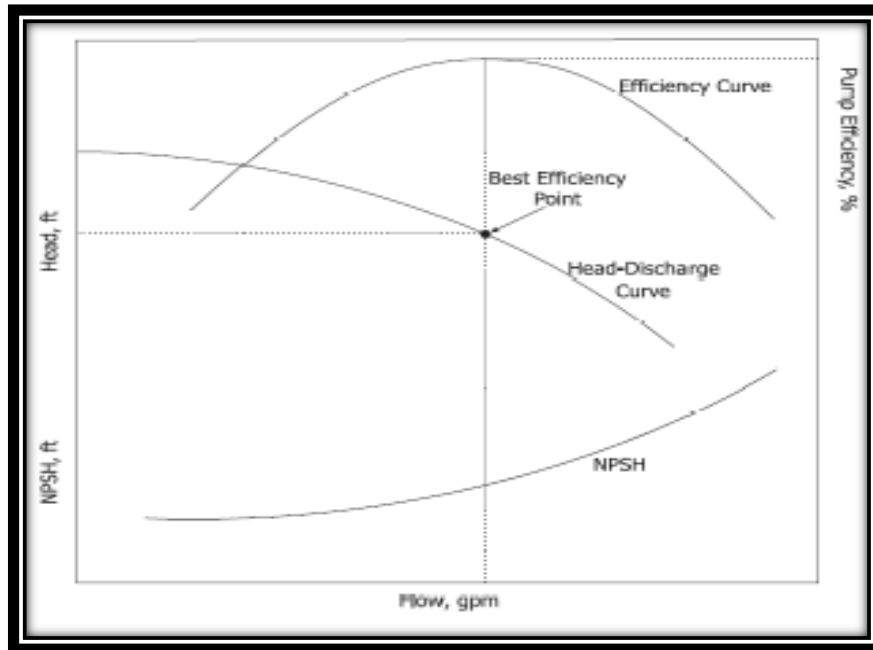


Figure 3 : Pump efficiency curve (Source: Haestad Methods 2003)

In addition to evaluating the hydraulics of the system, the hydraulic simulation models can also evaluate the water quality. “The hydraulic models mainly consider two principles of transport mixing and decay while computing the water quality in the system.

Network hydraulic solutions are utilized to compute water quality.”(Haestad Methods, 2003)”. Water CAD uses the equations developed by Gray man, Ross man and Geldreich (2000) for determining the transport of constituents through the pipe, mixing at the nodes and the tanks and decay of constituents.

2.5 Principles of Distribution Network Hydraulics

In networks of interconnected hydraulic elements, every element is influenced by each of its neighbors; the entire system is interrelated in such a way that the condition of one element must be consistent with the condition of all other elements. Interconnections of hydraulic elements are defined in concepts of conservation of mass and energy. Two basic equations that govern in Water CAD modeling network of these interconnections:

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

2.5.1 Conservation of Mass

The principle of conservation of mass (as shown in Figure 2.4) dictates that the fluid mass entering any pipe will be equal to the mass leaving the pipe (since fluid is typically neither created nor destroyed in hydraulic systems). In network modeling, all outflows are lumped at the nodes or junctions (Walski et al, 2003).

For steady incompressible flow:

Net flow into junction = Use at junction.

Mass in = Mass out

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

-----Eq (2.1)

Where:

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

U = water used at node (L³/T)

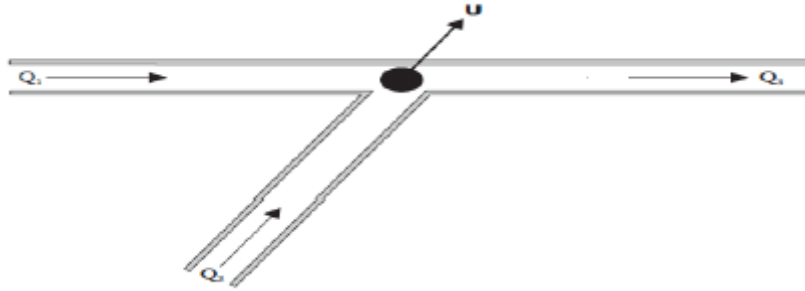


Figure 4 : Forms of energy in water pipes

The conservation of mass equation is applied to all junction nodes and tanks in a network, and one equation is written for each of them.

$$\sum_{\text{pipes}} Q_i - U - \frac{dS}{dt} = 0 \quad \text{----- Eq (2.2)}$$

Where

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

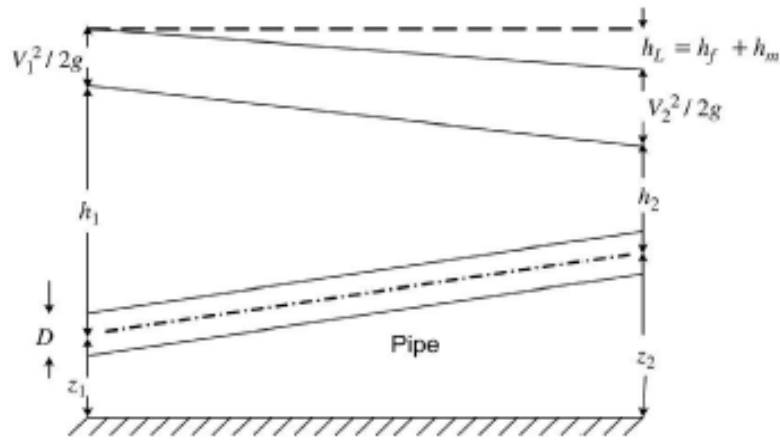
U = water used at node (L³/T)

= change in storage (L³/T)

2.5.2 Conservation of Energy

The principle of conservation of energy dictates that the difference in energy between two points must be the same regardless of the path is taken (Bernoulli, 1738 cited in Walski et. al., 2003). The Energy equation is known as Bernoulli's equation. It consist the pressure head, elevation head, and velocity head. There may be also energy added to the system (such as by a pump), and energy removed from the system (due to friction). The changes in energy are referred to as head gains and head losses.

In hydraulics, energy is converted to energy per unit weight (ft-lb/lb) of water, reported in length units (ft) called “head”. Balancing the energy across any two points in the system, the energy equation will be as follow: Figure 2.5 shows head losses in a pipeline. Source: (Swamee, 2008)



Source: (Swamee, 2008)

Figure 5 : Forms of energy in water pipes

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \sum h_a = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \sum h_f + \sum h_m \quad \text{Eq (2.3)}$$

Where:

P = the pressure (lb/ft²)

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

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

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

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

h_L = the combined head loss (ft or m)

h_f = friction loss(ft,m)

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

h_l = head loss due to pipe friction(h_f+h_m),(ft,m)

h_a = head added by pumps

There are three forms of energy:

Pressure head - p / γ

Velocity head - $V^2 / 2g$

Elevation head – z

2.6 Modeling a system using Water CAD

Water CAD is hydraulic simulation software, distributed by Bentley Systems. Once the spatial model is built, the parameters that need to be defined for each model components include:

- Nods: Elevations and the base demands;
- Pipes: Pipe diameters, lengths and the friction coefficient factors. By default Water CAD considers the pipe material as ductile iron having a Hazen William friction coefficient factor of 130;
- Tanks: Base Elevation, the minimum and maximum levels, 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

After all the parameters required to run the simulation are entered into the model, the successful simulation run provides solution for the following:

- Pressure at every single element in the system
- Flows at every point of time in the system
- Velocities in the pipes
- Levels in the tanks
- Pump cycles
- Water age and constituent concentration.

Additionally it has the capability of performing the analysis of the system for the steady state scenarios and for an extended period of any length. The other capabilities of the software are as follows:

- Evaluate the hydraulics for different demands at a single node with varying time patterns;
- Solve for different frictional head losses using Hazen-William, Darcy-Weisbach or the Chezy-Manning equations;
- “Can determine immediate inefficiencies in the system” (Haestad Methods 2003);
- Determine fire flow capacities for hydrants;
- Model tanks, including those which are not circular;
- Model various valve operations;
- Provides control based operations;
- Perform energy cost calculations;
- Model fire sprinklers, irrigation systems, leakages and pressure dependent demands at any particular node (Haestad Methods 2003);

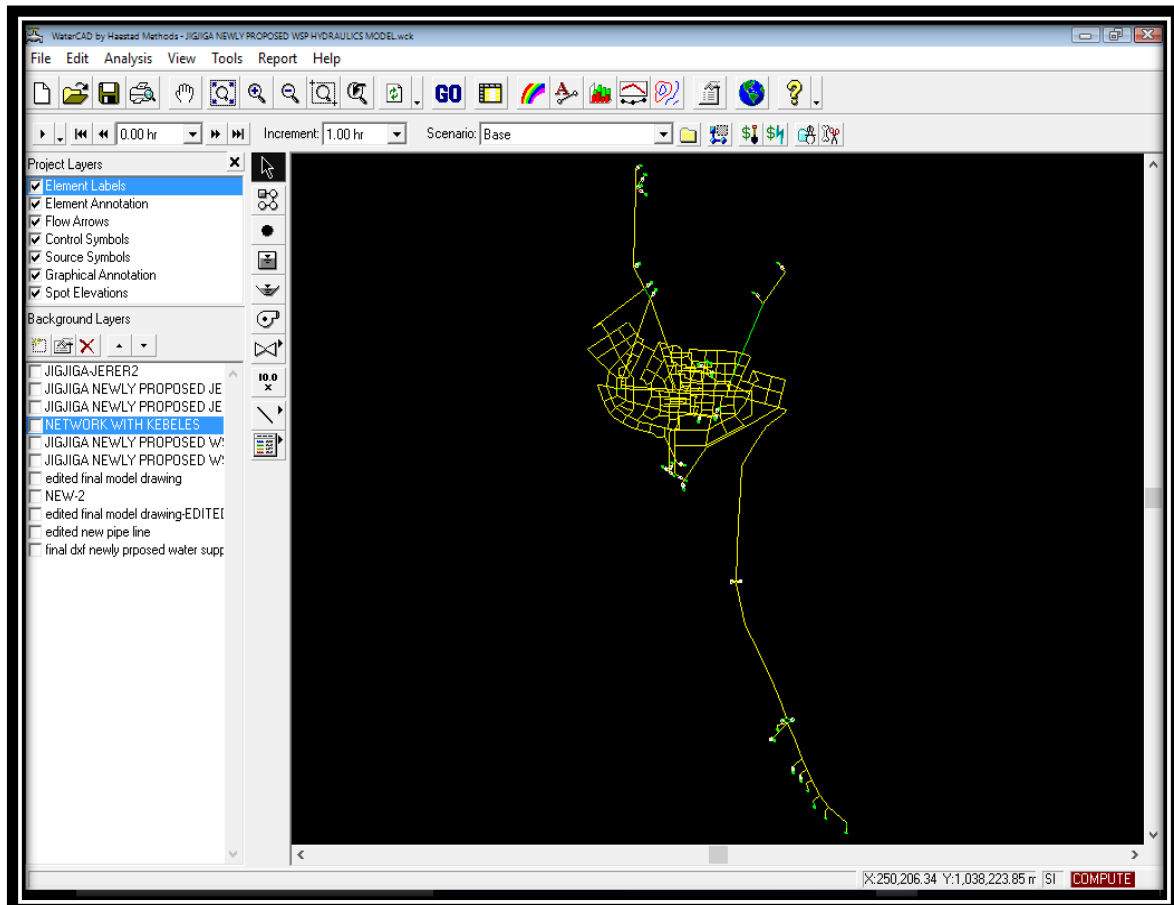


Figure 6 : shows the user interface for Water CAD.

2.6.1 Types of Water Distribution Simulation

Simulation refers to the process of imitating the behavior of one system through the functions another. In our case, the term simulation refers to the process of using a mathematical representation or real system, called a model (Bentley, 2008).

Simulation can be used to predict system responses to under a wide range of conditions without disrupting the actual system, and solutions can be evaluated before time, money, and materials are invested in a real-world project.

There are two most basic types of simulations that a model may perform, depending on what the modeler is trying to observe or predict.

These are:

- Steady state simulation.
- Extended period simulation (EPS).

2.6.1.1 Steady State Simulation

It computes the state of the system (flows, pressures, pump operating attributes, valve position, and so on) assuming that hydraulic demands and boundary conditions do not change with respect to time. The flow chart of steady state simulation is shown in Figure 2.7.

A steady-state simulation provides information regarding the equilibrium flows, pressures, and other variables defining the state of the network for a unique set of hydraulic demands and boundary conditions.

Steady-state models are generally used to analyze specific worst-case conditions such as peak demand times, fire protection usage, and system component failures in which the effects of time are not particularly significant. Source: (Bentley, 2008)

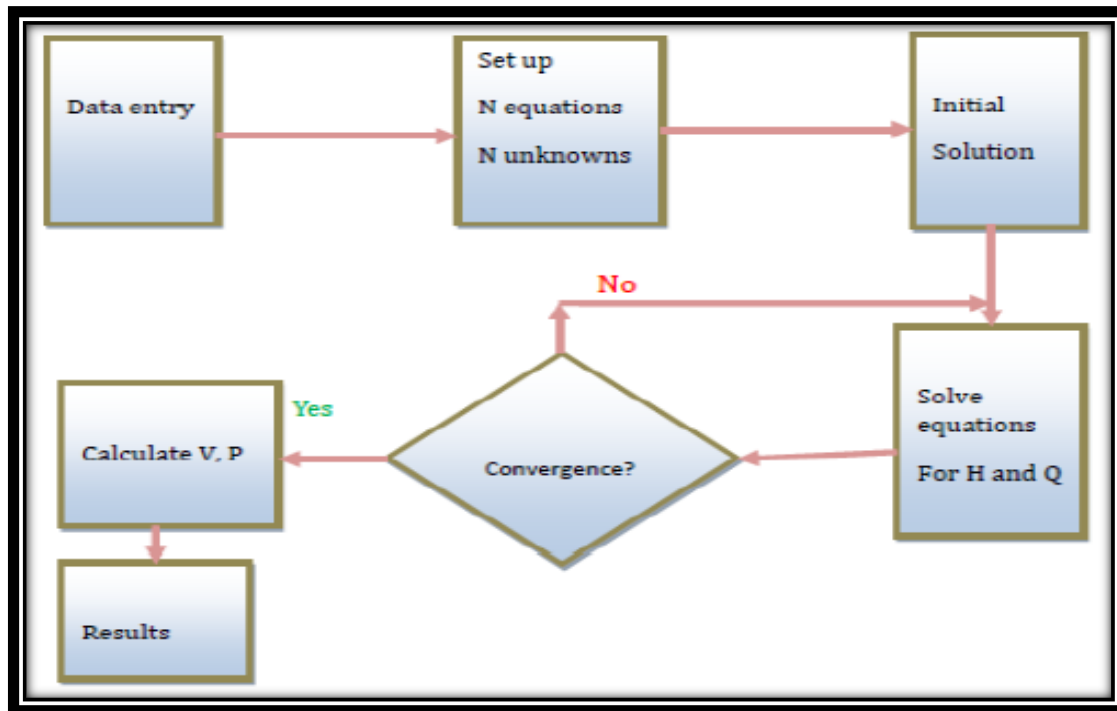


Figure 7 : Flow chart for steady state simulation

2.6.1.2 Extended Period Simulation

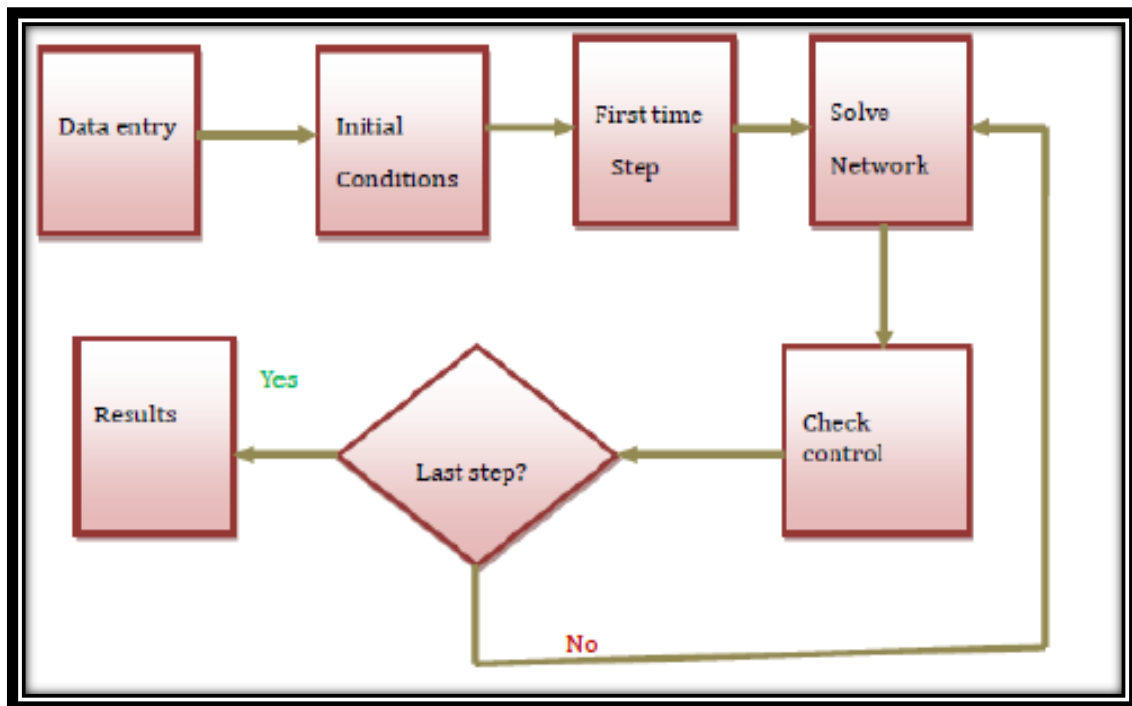
Extended period simulation tracks a system over time, and it is a series of linked steady state runs. The flow chart of extended period simulation is shown in Figure 2.8. The need to run extended period simulation is because the system operations change over time.

- Demands vary over the course of the day.
- Pumps and wells go on and off.
- Valves open and close.
- Tanks fill and draw.
- Water quality

Simulation Duration: An extended-period simulation can be run for any length of time, depending on the purpose of the analysis. The most common simulation duration is typically a multiple of 24 hours, because the most recognizable pattern for demands and operations is a daily one.

Hydraulic Time Step: an important decision when running an extended period simulation is the selection of the hydraulic time step. The time step is the length of time for one steady-state portion of an EPS, and it should be selected such that changes in system hydraulics from one increment to the next are gradual. A time step, too large may cause abrupt hydraulic changes to occur, making it difficult for the model to give good results.

Using an EPS model we can simulate based on the peak, minimum and average day demands.



Source: (Bentley 2008)

Figure 8 : Flow chart for extended period simulation

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2.7 Pressure and Leakage

In many water network systems, even though the total demand and the total loss of water can be known rather easily, information about the possible influence of local pressure upon demand is sadly lacking that as a result creates difficulty to assess and compare the demand and loss of water in its spatial distribution. Pressure distribution system on the one hand contributes to the increase of leakage, when it is more, and on the other

hand when it is low contributes to the shortage of water that as a result causes for unequal distribution of water among residents. To alleviate such problems, some water authorities develop a zoning scheme whereby the complete water distribution network is broken down in to manageable segments that can be easily metered and monitored and analyzed. The leakage from water distribution systems has been shown to be directly proportional to the square root of the distribution system pressure as indicated by the relationship below (Wallingford HR., 2003).

$$\text{Leakage} = \alpha(\text{distribution system pressure})^{1/2} \text{_____} \quad (2.4)$$

Burst rates are also a function of pressure. The strength of the relationship, and the quantification of it, is not as well understood as the relationship between flow rate and pressure.

However, there is still considerable evidence to show that burst frequency is very sensitive to pressure. Evidence shows that the rate of increase of bursts is more than linearly proportional to pressure. Indeed it has even been suggested that there could be a cubic relationship that burst frequency proportional to pressure cubed (Farley and Trow, 2003 cited in Desalegne B. 2005).

In the past the conventional view was that leakage from water distribution systems is relatively insensitive to pressure, as described by the orifice equation:

$$q = C_d A \sqrt{2gh} \text{_____} \quad (2.5)$$

Where,

- q is the leakage flow rate, Cd the discharge coefficient,
- A the orifice area,
- g acceleration due to gravity and
- h the pressure head.

In applying this equation and more general form is used:

$$q = ch^{\alpha} \quad \text{-----} \quad (2.6)$$

Where

- **C** (0.074 L/s/m^{1/2} is the leakage coefficient and =0.5 the leakage exponent (Walski et al, 2006).

Pressure variation in distribution network is caused, among others, by changes of demand of users. The demand usually reaches a peak in the morning when people are at home and preparing their meal and its second peak in the evening. If one compares daily diagram for total demand of the whole system with corresponding data captured at the level of (relatively small) demand management areas one will discover that the first has much smaller amplitude in comparison with the later. The minimum night flow (MNF) is relatively higher and the morning/evening peaks are less prominent (Obradovic, 2000 cited in Desalegne B. 2005).

Frequent starts and stops of pumps, closure and openings of control valves that induce water hammer are also some of the causes to be mentioned for pipe breakage and water loss through leakage. The position of reservoirs also has a great impact on the pressure distribution. ‘Distribution Losses’ is the sum of losses from four different parts of the distribution system; trunk mains, service reservoirs, distribution mains and communication pipes. The combination of these assets in individual companies and supply areas are widely variable, as are the variations of pressure which are known to significantly affect leakage (Lambert and Wallace, 1993 cited in Desalegne B. 2005).

The elevation at which it is desirable to position a service reservoir depends upon both the distance of the reservoir from the distribution area and the elevation of the highest buildings to be supplied. If the distribution area varies widely in elevation it may be necessary to use two or more service reservoirs at different levels, so that the lower

areas do not receive an unduly high pressure. Generally, 45 to 75 meters static pressure is that which best suits the domestic distribution systems. Pressure below 45 meters will be likely to cause trouble in supplying extensive distribution areas; pressure above 90 meters, tend to result in excessive leakage losses (Twort A.C. et al., 1994).

The critical points which would first run dry if pressure is reduced are usually areas located at the highest elevation and excessive pressures can be reduced by adjusting the speed of pumps in areas supplied by pumping, installing a pressure reduction valves (PRV) and dividing the system in to different pressure zones. Pressure control valves are sometimes installed in outlet mains from service reservoirs in order to reduce the pressure to low lying zones, or to limit increases of pressure at night to reduce leakage. Pressure reducing valves (PRVs) throttle automatically to prevent the downstream hydraulic grade from exceeding a set value, and are used in situations where high downstream pressures could cause damage (Walski et al., 2003). Figure 2.5 below illustrates a connection between pressure zones without a PRV; the Hydraulic grade in the upper zone could cause pressures in the lower zone to be high enough to burst pipes or cause relief valves to open Source: (Walski, Chase & Savic, 2003)

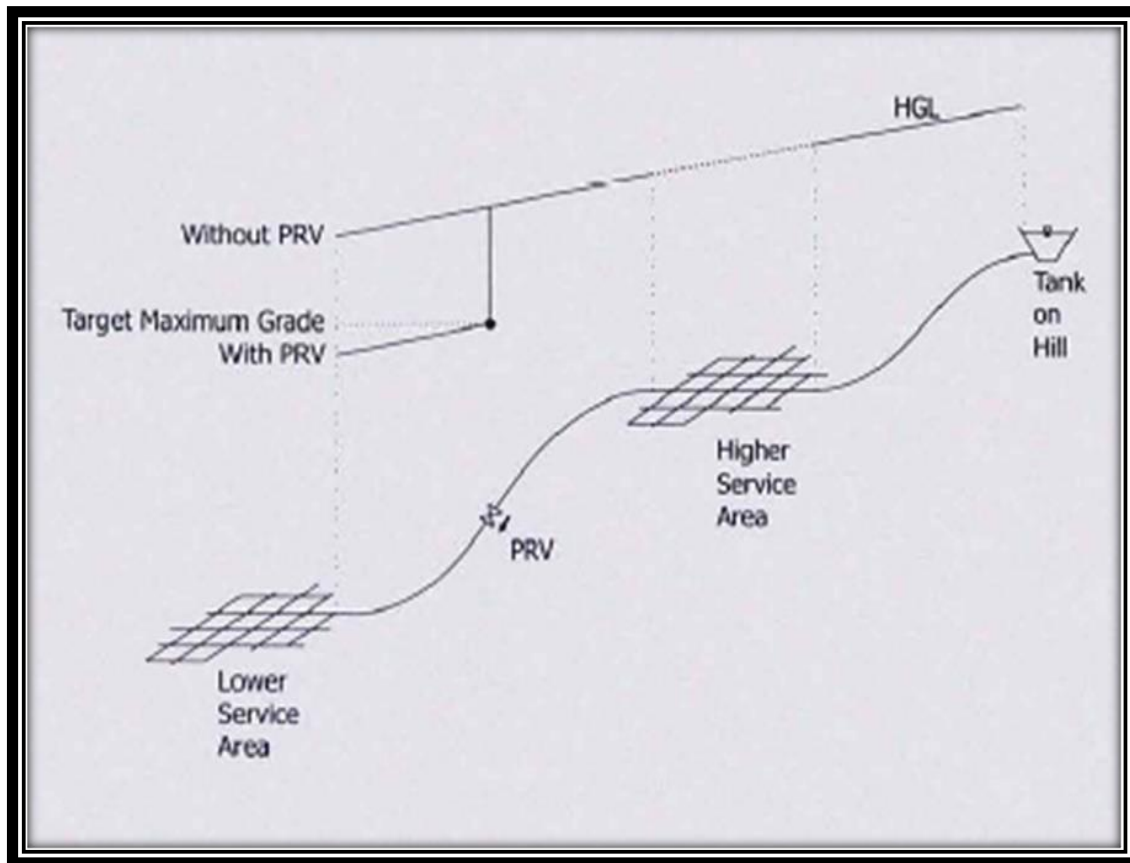


Figure 9: Schematic networks illustrating the use of a pressure reducing valve

In making a decision to install pressure control devices it should be born in mind that if the device fails to operate, which usually happened if the equipment is not properly maintained, then the downstream mains will be subjected to a sudden increase. Reducing pressure on the other hand may make existing leaks more difficult to find, because they make less noise, or do not come up to the surface. Therefore, pressure reduction should be coordinated with leakage detection and repair operations (Farley and Trow, 2003 cited in Desalegne B. 2005).

2.7.1 Negative Pressures

Situations that may give rise to negative pressures should always be avoided. Faeces organisms and culturable human viruses may be present in groundwater adjacent to a pipeline and drawn into a pipe during transient low or negative pressures (Lechevallier et al., 2003 cited in Mosissa 2008). Hydraulic models can be used to identify where, when

and how negative pressures may occur. Preventative measures such as system reinforcement may then be identified and implemented. Until such measures are effective, staff responsible for the daily operation of the network should be informed of these situations and hence where, when and how contamination of the network may occur. Such situations may occur where there are:

- Properties on high ground;
- Remote properties at the end of long lengths of pipe;
- Demands that are greater than the design demand;
- Pipes of inadequate capacity (too small diameter);
- Rough pipes (e.g. corroding iron pipes or pipes with a build-up of sediment);
- Equipment failures (e.g. pumps and valves,).

2.7.2 Pressure Management

Pressure transients and extremely high peak pressures are major causes of failures and leaks in the distribution network. From the results presented, the pressure management approach seems to help maintain average pressures throughout the system, eliminating extreme transients in pressure during peak hours and preventing pipe damage. The district metered area approach can also contribute to pressure management since it can eliminate negative pressures within the network, which can potentially allow contaminants entering the system if leak exist. Adequate installed and maintained pressure reduction valves could provide the distribution network with an easy, cost-effective leak prevention method significantly reducing the risk of leakage (Faraj, 2013). Pressure management is one of the fundamental elements of a well-organized leakage management strategy. It should be an integral part of the strategy because it has a number of benefits such as

- it reduces amount of leakage to help meet water conservation targets
- improves the reliability and continuity of supply by reducing pipe breaks
- reduces pressure fluctuations to achieve more consistent water pressure across the system

- Extends the life of our water supply pipes and assets.

2.8 Water Loss in the Subsystem

Water Losses refer to the total amount of water flowing into the water supply network from a water treatment plant, borehole system or imported bulk total amount of water that consumers (domestic, commercial, industrial and institutions) are authorized to use (the Authorized Consumption) (USAID,2010).

2.8.1 Water losses are categorized as either real or apparent:

Real Losses, also referred to as physical losses, are actual losses of water from the system. When performing financial calculations related to real losses, the water is priced at the cost of production rate since it is not available for a consumer to use and costs only what it takes to produce. Correcting real losses will result in lower operating cost through reduced production requirements and reduced water process chemical and electrical use

Apparent losses, also referred to as commercial losses, occur when water that should be included as revenue generating water appears as a loss due to theft or calculation error. Apparent losses consist of unauthorized consumption, metering calibration errors and data handling errors (EPA, 2004).

Revenue Water is water that is consumed and for which the utility receives payment. Revenue water consumption volume is measured or estimated. Revenue water includes metered and un-metered billed authorized consumption.

Non-Revenue Water (NRW) is water that is not billed and no payment is received. It can be either authorized, unauthorized or result from a water loss. Authorized NRW consists of unbilled metered consumption and unbilled un-metered consumption.

$$\text{NRW} = \text{System Input Volume} - \text{Billed Authorized Consumption} \dots (2.7)$$

Non-revenue water is becoming the standard term replacing unaccounted-for water (UFW) in many water balance calculations and is the term recommended by the International Water Association in preference to UFW. It is a term that can be clearly defined, unlike the unaccounted-for water term, which often represents different components to the various water suppliers (Wagelin et al 2007).

Neither the term “unaccounted-for-water” nor the use of percentages as measures of water loss is sufficient to completely describe the nature and extent of distribution system water loss. Unaccounted-for-water is a term that has been historically used in the United States to quantify water loss from distribution systems. Unaccounted-for-water, expressed as a percentage, is calculated as the amount of water produced by the PWS minus the metered customer use divided by the amount of water produced multiplied by 100, or (EPA, 2009).

The American Water Works Association has identified three major categories of “losses” in a water distribution system. These categories are:

- a. Accounted for losses
- b. Real losses
- c. Apparent losses

Accounted for losses occur at metered locations. Water meters are typically placed at service connections to monitor the amount of water that a billable customer uses and may also be placed on service connections to non-paying customers who put the water to beneficial use. Non-billable customers typically include municipal users and the fire stations. All water that is metered whether billable or un-billable can be identified and quantified by the utility; so that accurate records of water usage can be recorded. All usage of water which is metered, regardless of billable or un-billable, is classified as accounted for losses.

Real losses are the physical losses of water from the distribution system which cannot be tracked by the utility. Typically they occur because the utility did not meter the quantity of water leaving the plant. These losses inflate the water utility’s production costs and

stress water resources since they represent water that is extracted and treated, yet never reaches beneficial use. Examples of this type of loss include leakage, storage overflows and breaks in the water mains.

The third type of water loss, **apparent losses**, is the losses that occur in utility operations due to customer meter inaccuracies, billing system data error, unauthorized consumption and authorized un-metered consumption. This is water which is consumed but not properly measured, accounted or paid for. These losses cost utilities revenue and distort data on customer consumption patterns. Authorized un-metered consumption losses are typically put to beneficial use by the municipality or utility and are commonly used for flushing water mains and firefighting (Brown, 2007).

2.9 Review of Related Works

The following are review of scholarly research conducted on related areas:

Several researches and studies have been made to study the behavior of water distribution systems, and to reach an optimal solutions and assumptions in order to improve the hydraulic performance, cost effective, and to increase the efficiencies of the water supply networks.

The research reviewed for this research is conducted by Mosissa Meressa Gamtessa and titled “Pressure Modeling for Leakage Reduction in Addis Ababa Water Supply System Mains (The case study, Saint Paul and Rufael subsystem)”. The intention of the researcher was to generate a water supply mains model representing the existing states of the city water supply mains pressure in selected sub distribution systems of Saint Paul and Rufael and to evaluate the effect of the obtained pressures on leakage. The researcher attempted to analyze leakage at city level in order to quantify real loss and model pressure mains in selected sub –city. In his findings, he found from leakage analysis part that water leakage in the city is 35.67%. From pressure modeling section, he found excessive pressure at some nodes with pressure of 80m almost all the day, above the recommended maximum for leakage.

The other research titled “water Supply Coverage and Water Loss in Distribution systems with Modeling conducted by **Shimelis Kabeto** (The Case Study of Addis Ababa)”. His intention was to assess the supply coverage and explore the water loss in city water supply distribution system. The researcher attempted to quantify the average water supply per person at city level and determine water loss as leakage at the city level and at the sub system level. In his findings, he found the average water supply coverage of the city as 86.59 liter/person/day and water loss at city level and sub-city level as 39% and 37.56% respectively. The researcher used model to evaluate alternative scenario to improve system performance. The present study is similar to reviewed research for Addis Ababa context in many aspects. The place in which the research conducted, conceptual framework, approach of data collection, method of data analysis and tools used for analysis is almost the same. But the current study is different in its scope. Unlike the above two research, it is not limited to Hydraulic modeling. It includes also hydraulic and water quality modeling, supply and demand gap analysis and water loss at the same time, which was neglected in the previous studies. The fate of water quality constituents in the study water supply distribution system is investigated besides pressure modeling.

3. EXISTING WATER SUPPLY NETWORK

3.1. Description of the Study Area

Jijiga, the capital city of Somali National Regional State of East Ethiopia, is about 630km East from Addis Ababa City and 105km from Harar city of East Hararge Zone of Oromia and Harari Region. The city is astronomically located between 9° 16' 30" to 9° 24' 30" N Latitude and 42° 44' 0" to 42° 51' 0" E Longitude (Fig. 3.1). The altitude of the city ranges between 1720m around Duda-hidi and 1620m around Jijiga health Science College. The city has gentle slope from North-West to South – East.

The city hosts Jijiga University. It lies in temperate climate zone of Ethiopia, it is bounded by the Karamara Mountain in the North-West and South-West, and by the North-East and East and South-East direction the topography is almost flat, lying in the southern direction. The temperature is warm during day and moderate at night. The mean annual precipitation is 657 mm and the monthly average temperature ranges from 18⁰ C in December to 23⁰C in July. The mean monthly wind velocity of Jijiga city ranges b/n 95 to 181kms/day.

Jijiga city is considered one of highest overpopulation city in the region. There are 1,184,330 people in 18.2km² as per the 2015 population data. It is considered one of the poorest regions of water resources. The existing supply of potable water in Jijiga depends on well sources abstracted from the surrounding shallow aquifer (WWDSE, 2008).

The Jijiga city is situated at the foot of Karamara mountain chain. It is the start of a vast plain continuing to the east for a thousand kilometer to the borders of the country. There is no perennial stream in Jijiga area. There are three seasonal streams that pass through or around the city and generally flowing from North-West to South-East. The water bore holes which supply for the cities are concentrated following of these streams.

The city is planned with a regular street pattern providing access to all residential and commercial areas. Most of the residential areas comprise of mud houses. Some of the commercial areas comprise of stone and hollow block buildings. The city comprises of 10 kebeles responsible to the city administration.

The climate of Jijiga city is classified under semiarid (national atlas of Ethiopia) which is characterized by high temperature and low rain fall. The average annual rain fall of Jijiga is about 675mm which occurs from April-May (small rain) and August–September (heavy rain).

The rock types that cover Jijiga include Mesozoic (Adigrat sand stone and Antalo lime stone), sediments, trap series basalts and much recent alluvial deposits.

Based on the recent (2007) census data from CSA of Ethiopia, the city has a population of 125,876 of which 67,128 were males and 58,745 were females. The total household count is about 23,263 with an average of size of 5.4 persons to a household. The 1994 census reported a total population of 56,821. The city has recorded a population growth of 121% in 13 years. Residents of city are engaged in, private business, governmental offices, daily laborer, farming and e.t.c. the dominant economic activity of the city is commercial i.e private business. The climate of the city is subtropical, with a mean annual temperature of 19.5⁰C and annual average rainfall ranging from 150mm to 1000mm. The highest temperature is experienced between November and March and the lowest between July and September.

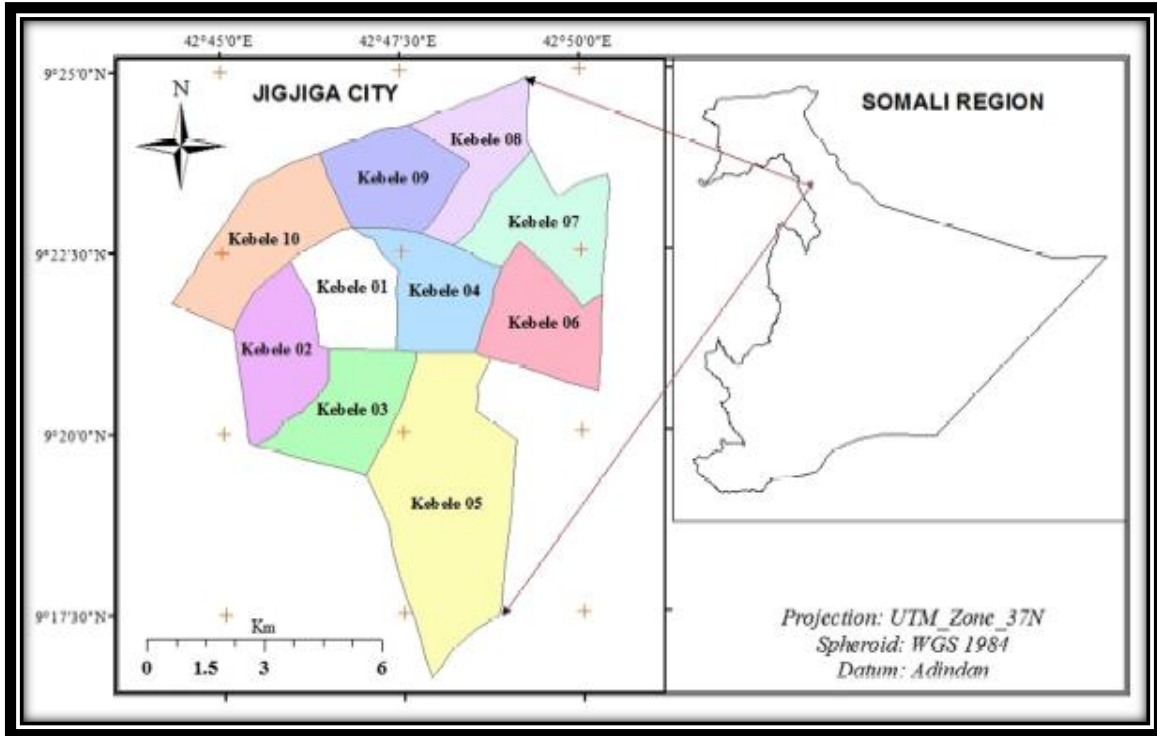


Figure 10 : Location Map of Study Area.

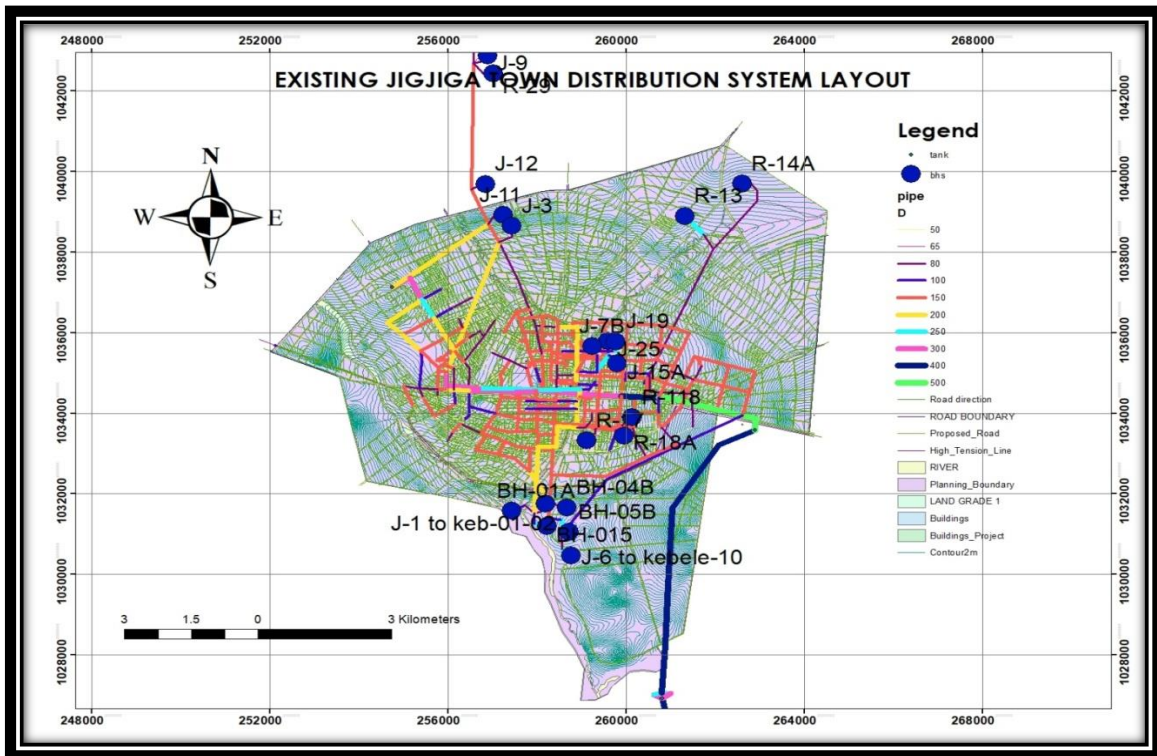


Figure 11 : Jijiga town master plan with the distribution pipe network

3.2 The MAJOR components of the existing system are the following;

EXISTING STRUCTURE TYPE	X-COORDINATE	X-COORDINATE	ELEVATION
25 (22 functional & 3 Non-functional) bore holes of different capacity around the city (1-6l/s)	259,235.74	1,033,369.08	1,651.90
	259,961.01	1,033,462.94	1,644.90
	263,250.58	1,019,431.90	1,444.90
	263,574.16	1,019,105.13	1,438.90
	264,159.87	1,018,054.34	1,446.90
	257,021.60	1,042,416.35	1,685.90
	259,774.67	1,035,772.67	1,652.40
	256,993.18	1,043,212.08	1,683.00
	259,589.15	1,035,778.61	1,652.00
8 Functional bore holes of different capacity at Jerer well field (5-20l/s)	262,052.11	1,021,224.12	1,467.90
	262,614.51	1,020,465.05	1,453.90
	262,758.12	1,018,979.64	1,444.90
	263,172.15	1,018,884.03	1,438.90
	264,018.79	1,018,626.85	1,438.90
	264,260.37	1,018,074.44	1,446.90
	264,951.85	1,017,480.20	1,444.90
	265,498.67	1,017,052.17	1,434.90
350m 3 service reservoir (not functional)	255750.85	1034893.8	1740.60
new reservoirs each having a capacity of 3000m3	262501.05	1033258.27	1788.25
new reservoirs each having a capacity of 1000m3	254660.2	1036967.6	1778.8
Public fountains 17 numbers (9 Functional & 7 Non-Functional.) and cattle troughs			
Newly constructed distribution system and auxiliary works			
Main pump house & two Booster station # 1 at Jerer	262998.97	1021399	
Main pump house & Booster station # 2 at Jerer	260813	1026926	
Collector pipes and two rising mains at Jerer valley			
Pipe distribution network comprising of PVC with sizes ranging DN 50-400 and length of 81,870m & DCI with a diameter of 500mm total length of 2,390 meters			
Rising main line from Jerer Well field to 3,000m3 Reservoir DCI pipe having a length of 17000 meters			
Auxiliary Building, administration building and store and workshop.			

3.3 Existing Water Distribution Network Structure

The water source for the system will be from ground water. There will be two well fields. The first Well field is an existing well field which includes 22 functional boreholes already drilled in and around the city. The other well field is a new well field located about 23km far from the city in the south direction inside Jerer Valley and so far 8 wells were drilled and connected to the system. The estimated production rate of the existing well field which is going to be retained in the future system and currently being pumped direct to the beneficiaries is about 52l/s from the 22 functional wells. As per the proposed plan, the water abstracted from the existing 22 boreholes is planned to be directly pumped to the recently built 1000m³ reservoirs and redistributed to the beneficiaries via the distribution network. On the other hand, the water abstracted from 8 wells of the new well field at Jerer valley shall be pumped to the new 3000m³ reservoirs via two booster stations located along the 23km pressure line and the total discharge expected from this recently built pressure line is about 75l/s. Thus, if the system is operation safely without any defect, the existing system can supply a total of 127 l/s which is very less by 38.65% when it compared with the theoretical average day demand of the system 207l/s required in 2025 & less by 59.8% required in 2035 which is 308l/s. As the yield and water quality of the other existing boreholes are deteriorating from time to time and no more discharge is expected from those old boreholes. Thus, these boreholes will be abandoned or can be used only for animal watering or other similar activities.

3.3 Submersible Pumps

The submersible pumps for the new boreholes will be selected after the exact positions and hydraulic parameters of the new boreholes are known. The capacity of the existing submersible pumps at the existing boreholes which are going to be retained in the future water supply system will be checked for their hydraulic head required to pump water to the new 1000m³ reservoir. If the pumping head is less than the required, they will be replaced by new pumps.

A stand by generator will be installed at each of the well fields to avoid interruption of

water supply during periods of power failure.

3.4 Rising main

There will be two rising mains. Rising main I convey the water abstracted from the existing boreholes named J3, J9, J10, J11, J12 J13 and J20 to the new 1000m³ reservoirs located to the left side of the road to Chinaksen. The second rising main-2 transport the water abstracted from the new boreholes to be drilled at Jerer valley to the new 3000m³ reservoir. Feeder pipes from each boreholes convey water to the collecting pipe which intern convey the collected water to the rising pipe supplying to be delivered to the new service reservoirs Water from the two new reservoirs will flow by gravity to the distribution pipe networks. The design and layout of the feeder pipes, collector pipe and riser pipe for the new well field will be done after the accurate location of the production wells are known. The layout of the existing boreholes which are going to be retained in the future system and the accompanying rising main is shown on the drawing hire under. At each feeder pipes; water meter, check valve, air release valve, and flush outlet provision will be provided.

3.5 Transmission Main

Water from each of the service reservoirs will be conveyed to the distribution system by two transmission mains. The transmission main from the 3000m³ reservoir is a DN500 DCI pipe having a length of 2390m while the transmission main from the 1000m³ reservoir is DN 250 PVC pipe having a length of 1417m. The transmission main from the 3000m³ follow along the road from Degahabor to Jijiga and the transmission main from the 1000m³ reservoir follow along the Chinksen–Jijiga road. Both of the transmission mains are designed for the peak hour demand of year 2035.

3.6 Distribution Network

The distribution pipes are designed to follow the road master plan of the city. Potential future expansion areas have been identified. For expansion areas where the existing master plan doesn't cover, an arbitrary pipe line is designed which is to be modified in the future as per the future master plan to be designed.

The distribution system is designed and built for the peak hour demand of phase II and checked for phase I for pressure and velocity.

The pipes are sized in such a way that;

- The velocity should not be too high causing high head loss or too low preventing the free circulation of water i.e. causing stagnation of water which result in creating good environment for bacterial growth;
- The pressure should not be too high causing higher investment cause or too low creating inconvenience to the consumers of the water.
- The entire pipe should be looped enabling free circulation of water in multi-directional flow.
- The diameters of the pipe should not be less than 50 mm.

All the old distribution pipes have been considered as they were excluded in the newly laid system as they are too old and have lower hydraulic capacity but local plumbers are still using to supply water to local people as the new distribution system is not fully functioning. The tables hire under shows the specifications of the phase I and phase II pipes.

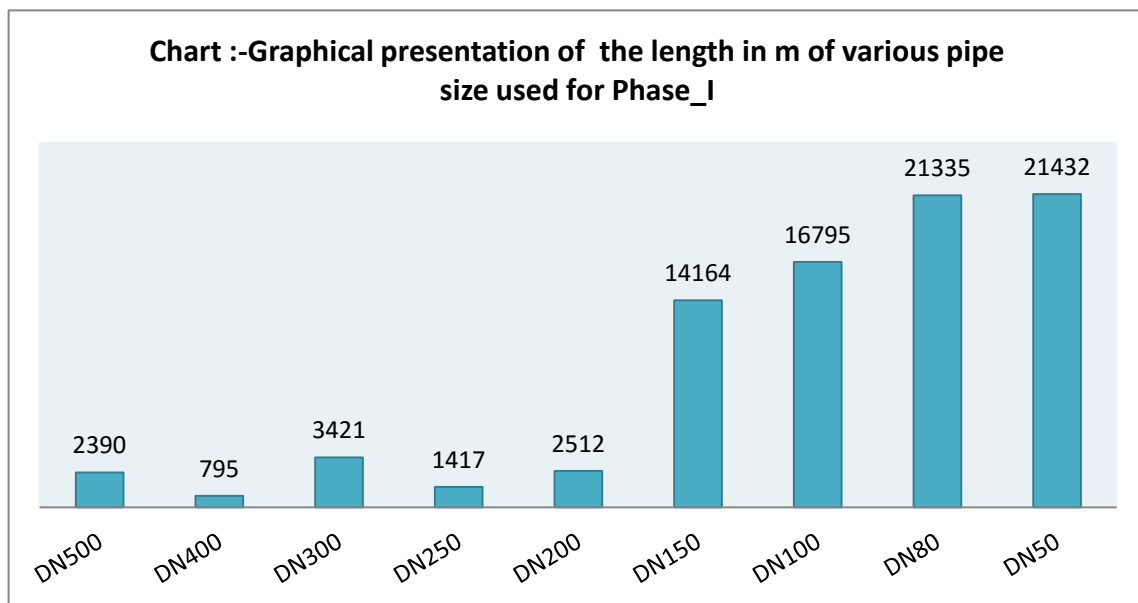


Figure 12 Distribution system of existing water supply of Jijiga city PHASE-1

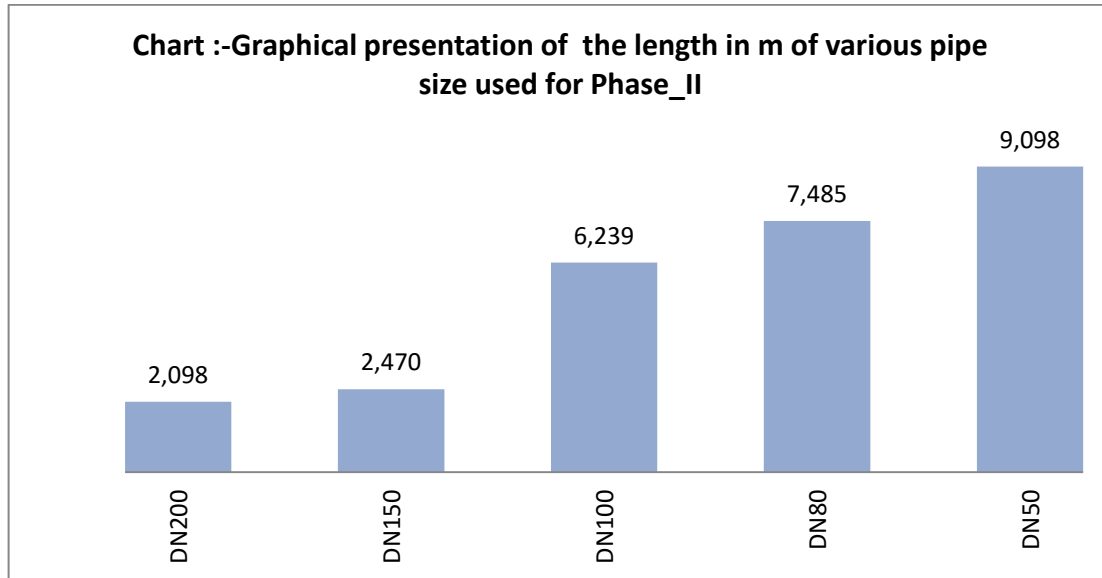


Figure 13 Distribution system of existing water supply of Jijiga city PHASE-II

The system operates by single pressure zone and has a total pipe length of 85,861 m in first phase and an addition pipe length of 27,390m in the second phase. The materials of the pipes will be both uPVC and DCI. All pipes with nominal diameter from DN50 to DN400 are uPVC and above DN400 are DCI pipes. The maximum and minimum diameters of the pipes in the system are 500 and 50mm respectively and the nominal pressure of the pipes to be laid for PVC pipes is PN12.

Flushing devices are provided at low points of the system, surface boxes at each node to accommodate the gate valves and other accessories. The locations of the fire hydrant should not be fixed by now except few were installed at economically important places and at place where the settlement is dense mainly along the main asphalt road.

The distribution system of the very old existing water supply is shown in Figure below.

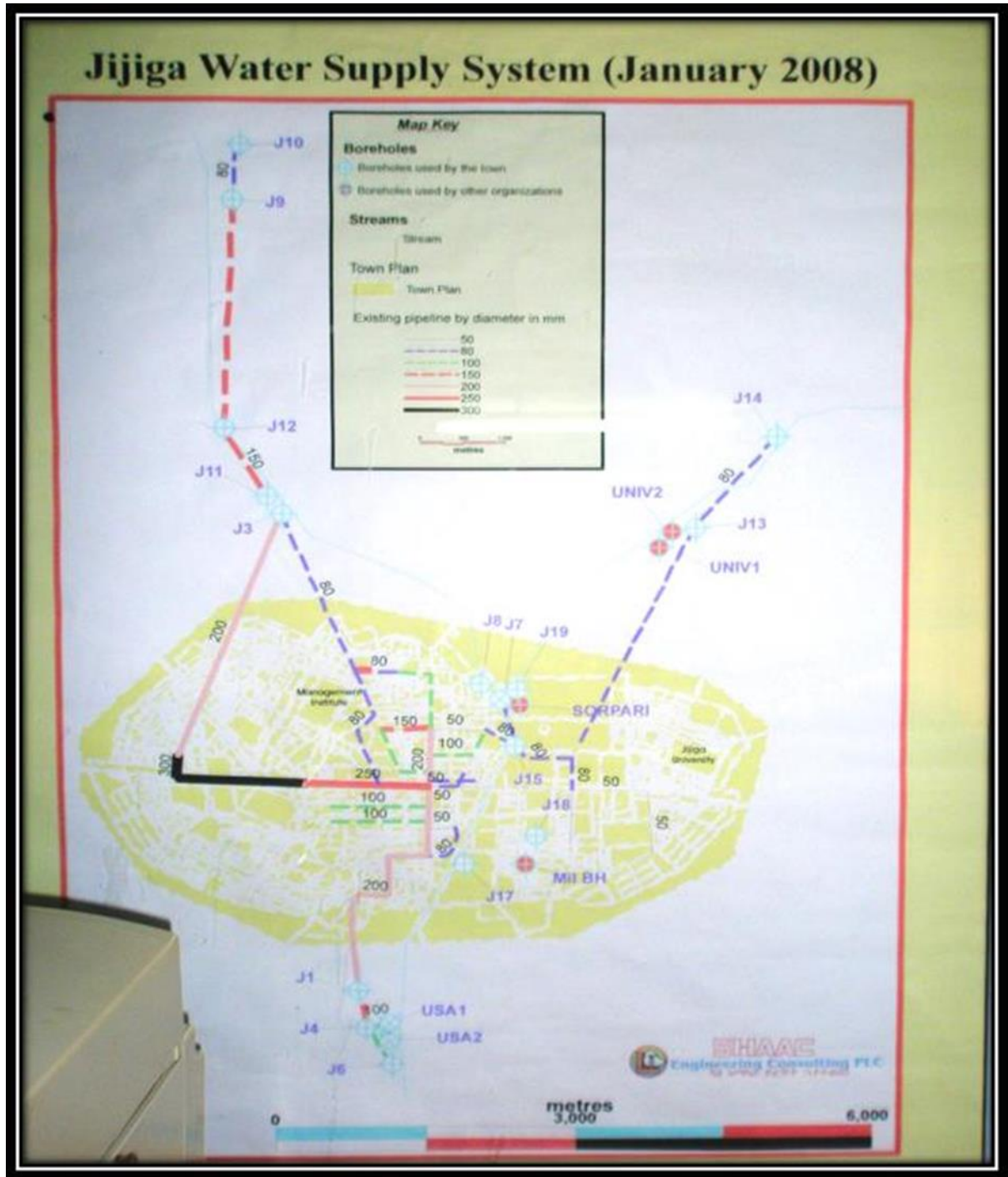


Figure 14 : Distribution system of old & existing water supply on Jijiga city master plan.

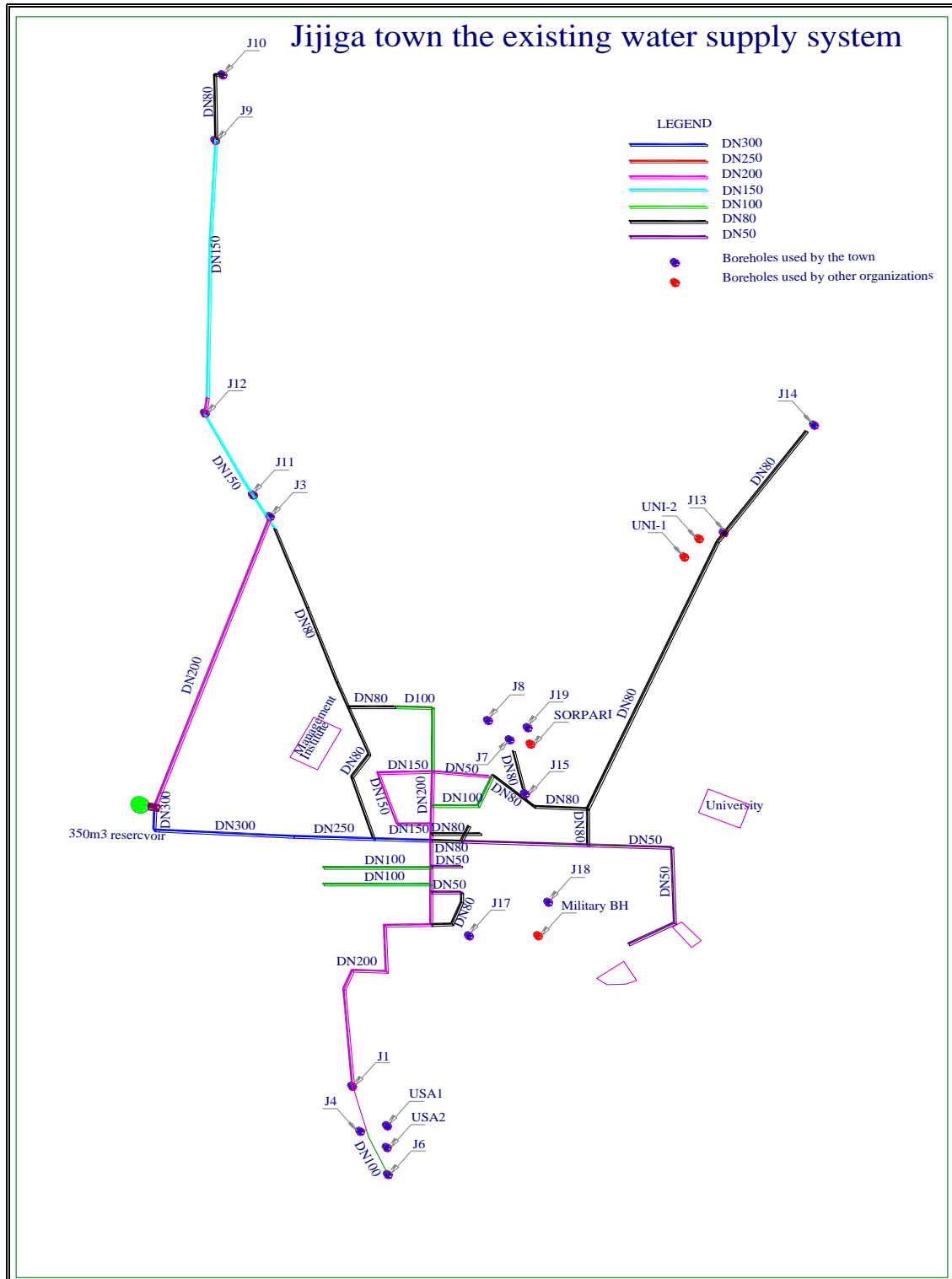


Figure 15 Pipe Distribution Network of existing water supply of Jijiga city

3.7 Public fountains and Cattle troughs

All the existing 17 public fountains are not functional but they will be retained in the future water supply systems of the city with some sort of rehabilitation as the information gathered from City Municipality office.

To estimate the numbers of the additional public taps, it is assumed that 1200 peoples will be served per single public fountain. Taking the public tap users of year 2025 which is 63,528 in number and the number of public tap required for phase I is about 53 in number. Thus, subtracting the existing 17 public taps, it is required to construct 36new public fountains. All the public fountains should be fenced and should be protected from any source of pollution.

During site visit, no Cattle troughs were built in the system, but as the demand for cattle trough is high, adequate number of cattle toughs should be provided at the outskirts of the city.

3.8 Power supply

The source of power for the boreholes will be from the national grid of the Ethiopian Electric Utility (EEU). For power supply to the new well field, separate power supply contract has already been made with EEU. In case of power failure a standby power-generators should be on duty.

3.9 Reservoirs

The main function of storage reservoirs is to provide water to consumer's when facilities are shut down or in the case of urban supplies particularly, to assist the system in meeting peak demand if the source or pumping facilities are incapable of supplying the required capacity.

The existing service reservoir has a capacity of 350 m³ and was constructed in 1968E.C. It is located in the middle of the town at an average elevation of 1737 m.a.s.l. It was made from reinforced concrete and has valve chamber. The design of this reservoir was based

on the assumption that water from the boreholes is directly pumped to the distribution system and the water in excess of consumption would be stored in the service reservoir and used during periods of peak hour demand. However because of the incompatibility of the production and consumption the reservoir is not functioning up to now as per the design. Water is directly pumped to the distribution network without entering to this service reservoir. As observed on site during the field visit and the information obtained from water service bureau, the reservoir is in poor structural condition; too much cracks are observed on the external surface of the wall. This reservoir needs special maintenance to make it part of the system in the future water supply system of the city. The plastering of the external wall is already removed. The pictures here under show the current status of this reservoir. Additionally, the region has built two Concrete reservoirs 1000m³ at North-west direction and 3000m³ RCC Reservoir along the road to Kebribeyah as shown in the table below:

S,N	Volume	Year of construction	ELEVATION	Remark
1	350m ³	1996	1635m	Not Functional
2	1000m ³	2009	1778.8m	Functional
3	3000m ³	2009	1782.2m	Functional

Table 3-1: List of Reservoirs Built in Jijiga

3.10 Water Demand Determination

3.10.1 Population forecasting

The water demand of a particular city is proportionally related with the population to be served. The population of Jijiga city from Ethiopian CSA report, which is carried out in year 2007, was indicated 125,584 and it was used as base population for current estimation. According to CSA, the regional level annual growth rate for urban population (2015) was allocated as 4.11%. Using the above CSA (2007) census data as a base, and applying exponential population forecasting method, the recent (2015) estimated population figure for Jijiga city was presented in table 6.2 below.

$$P = P_0 *(1+r)^n$$

Where:

P = Estimated population figure

P₀ = Base population figure

r = Growth rate and,

n= Number of year

Table 6.2: Jijiga city projected population figure (2010-2035)

Description	Unit	2007	2010	2015	2020	2025	2030	2035
Growth rate	%		4.11	4.11	4	3.8	3.6	3.4
Jijiga Town Urban Population	No	125,584	141,714	173,330	210,883	254,113	303,268	358,450

Source: (CSA, 2007) census

Table 3-2: Projected annual city Population

Therefore, regard to the above table 6.2; the estimated total population figure of Jijiga city was 173,330 during (2015).

3.10.2 Diurnal Curves of Jijiga City Water Supply System for Domestic Demand

Each city has its own unique level of usage that is a function of recent climatic conditions and the time of day. Economic growth also influences demands, but its effect occurs over periods longer than the typical modeling time horizon, and it is accounted for using future demand projections. Figure 6.2 illustrates a typical diurnal curve for a research area. There is relatively low usage at night when most people sleep, increased usage during the early morning hours as people wake up and prepare for the day, decreased usage during the middle of the day, and finally, increased usage again in the early evening as people return home. The following hourly demand variation coefficients have been used in sizing the reservoir.

Reservoirs are provided to balance the hourly fluctuating water demand to be satisfied. The

sizing of the reservoir is done for the maximum day water demand. The following hourly demand variation coefficients have been used in sizing the reservoir.

Hours	Coefficients
0	0.3
1	0.3
2	0.3
3	0.3
4	0.3
5	0.7
6	1.1
7	1.9
8	1.9
9	1.5
10	1.5
11	1.4
12	1.4
13	1.3
14	1.2
15	1.5
16	1.6
17	1.5
18	1.3
19	1
20	0.7
21	0.5
22	0.4
23	0.3

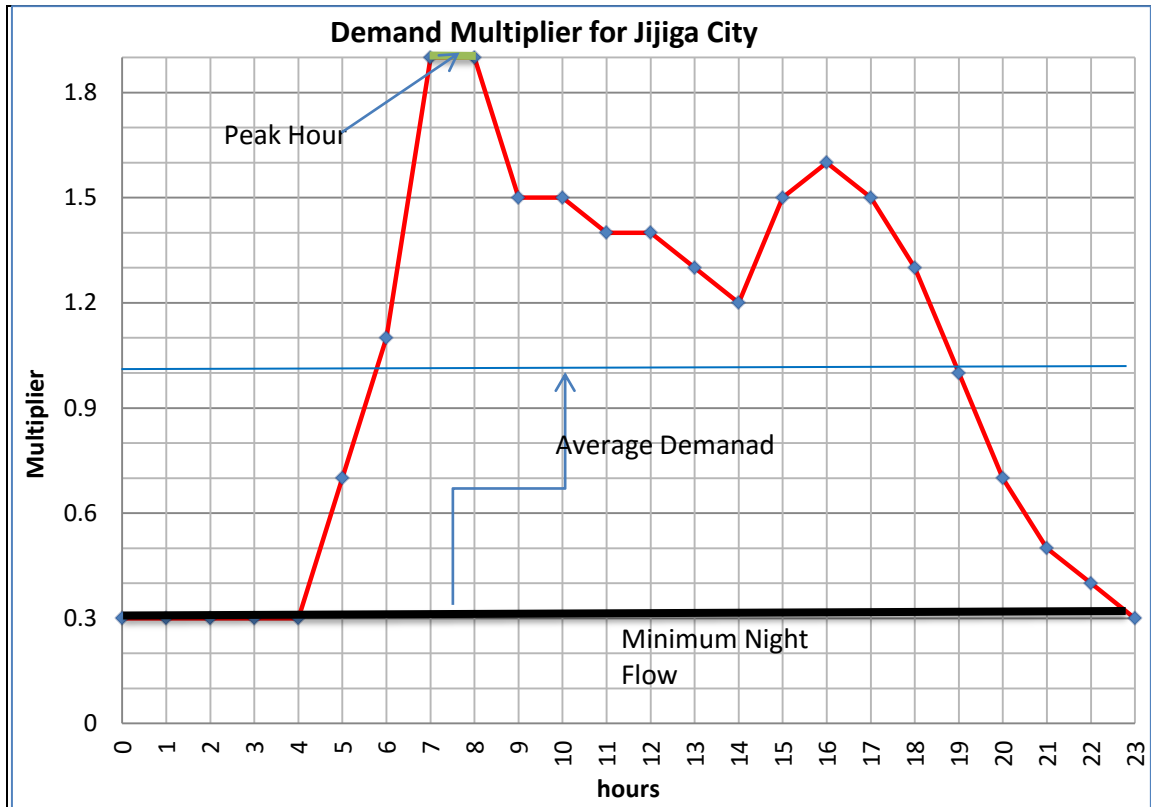


Figure 16 : Variation of domestic water demand during the day

3.11 Current and Future Water demand Analysis

3.11.1 Population Forecasting

The total population of Jijiga city for the base year which is 2015 is estimated to be 173,330 with an average annual growth rate of 4.11% as per the CSA Final result of 2007. This figure has been adopted for this research.

Population According to	Projected population							
	2007	2010	2015	2020	2020	2025	2030	2035
CSA	125,58	141,71	173,33	210,88	254,11	303,2	303,2	141,71
Yearly Growth Rate in (%)	4	4	0	3	3	68	68	4
		4.11	4.11	4	3.8	3.8	3.6	3.4

N.B To estimate the Settlement population five years from now using the recommended growth rate and both figures applying exponential rate function as follows;

$$FP = pp (1 + r)^n \text{ yrs}$$

Where

Fp = Future population

Pp= Present population

R = Rate of population growth (%)

n yrs = number of years

Table 3-3: Projected annual city Population

3.11.2 Domestic Water Demand

Domestic water demand includes water for drinking, for food preparation, washing, cleaning and miscellaneous domestic purposes. The amount of water used for domestic purpose varies depending on the lifestyle, living standard, climate, mode of service and above all on the affordability of the users. The theoretical domestic water demand for different population of any city is estimated for different population categories of domestic consumers. The water supply systems of most cities in Ethiopia have five mode of service in which the populations are served.

- A. House Tap User
- B. Yard Tap User
- C. Neighborhood Tap User
- D. Public Tap User
- E. Traditional source user

Mode of service	Per capital water Demand(l/c/d)
House Tap user	70
Yard Tap user	30
Neighborhood Tap user	40
Public Tap user	25

Table 3-4: **Per capita demand estimate, for stage II, MoWIE, 2006**

But, actually there are people using traditional source users and people buying water from vendors. However, this mode of service is not considered in the analysis as it is not their

exclusive alternative and they are preferring this option as secondary choice to compensate for their short fall of water demand when their primary mode of service are interrupted or is insufficient.

The theoretical domestic water demand for different population of any city is estimated for different categories of domestic consumers. The assumptions are based on the percentage service level for house connections, yard connections and public fountain users previously studied by Water Works Design and Supervision Enterprise (WWDSE) and conducted survey.

3.11.3 Per capita water demands & growth of domestic water demand

The per capita demand initial figures are adopted from the MoWIE design guidelines. The growth rate is also based the demand projection table prepared by MoWIE, 2006. In this regard the stage-II demands are taken considering the rapid economic and population growth the city. The table below shows the initial per capital figure and its growth pattern considered in the design of the system.

The resulting demand using annual growth 5.74 %(urban model, MoWE) is presented below.

Mode of service	2015 (Base Year)	2020	2025	2030	2035
HTU	70	74	78	82	86
YTU	30	32	34	38	42
PTU	25	26	28	29	30.5
NTU	40	42	45	47	50

Table 3-5: Projected Per capita Demand in liter/sec

In projecting the above service levels again the MOWIE recommendations were adapted.

The table below show the projection pattern adopted.

Mode of Service	2010	2015	2020	2025	2030	2035
HC	5	5.67	6.43	7.13	7.85	8.56
YC	21.75	24.63	27.89	30.90	33.97	37.04
YCS	27.80	30.65	33.95	36.95	40.03	43.10
PF	45.45	39.05	31.73	25.02	18.16	11.30

Table 3-6: Mode of Services Projected (Derived from Urban Model, MoWE) ending Year by (%)

In order to assign the corresponding water demand the population has been forecasted with their respective mode of service.

Mode of Service	2010	2015	2020	2025	2030	2035
Total Populations	146,714	184,330	201,005	265,113	314,268	369,450
Jijiga town population	141,714	173,330	210,883	254,113	303,268	358,450
Jijiga University Community	5,000	11,000	11,000	11,000	11,000	11,000
House Connection	7,086	9,828	13,560	18,118	23,791	30,683
Yard Connection	30,823	42,691	58,815	78,513	103,010	132,758
Public tap User	64,409	67,685	58,815	63,588	55,084	40,517
NTU	39,396	53,126	58,815	93,895	121,383	154,492

Table 3-7: The Projected Population by Mode of Service

3.11.4 Projected Per Capita Average Domestic Water Demand

The projected per capita average domestic water demand for a particular year can be obtained by multiplying the per capita water demand in each category of mode of service obtained from table with the corresponding population figure of the respective year obtained from table and summing the result for all demand categories.

For this specific research the water demand of the different patterns were projected to twenty years from the base year. Therefore taking the year 2015 as a base year the end for the projection would be 2035.

This section deals with the water demand projection for the city. Present and future development potentials are considered, along with improved living standards to arrive at the projected water demand.

3.11.4.1 Growth potential

Jijiga city is the capital of the Somali people's regional state, Jijiga zone and Jijiga woreda. It is the center of trade for the region with road network connecting it to Addis Ababa, Harar and Togowajale (eastern border city and trade center).

3.11.4.2 Research Evaluation Horizon

The water supply development for Jijiga has been considered a design period of 20 years for our specific purpose. The water capacity constraints as envisaged from the existing trend were appeared in early 2015. Thus research evaluation horizon considered in between 2015-2035 as design period of the project.

3.11.4.3 Basis for water demand projections

The water demand for the research evaluation horizon considered in between 2015-2035 has been structured to accommodate the following categories; the current not served population and vendor served sections are to benefit from the new development through access to public taps. The population growth rate for both the city and on line beneficiaries has been calculated on medium growth rate variant as pre supposed by CSA and taken from the previous feasibility by Federal Water Works Design and Supervision Study.

3.11.4.4 Climatic and socio-economic grouping

The water requirement is also directly related to the climatic condition and the socio-economic conditions of a particular city. Cities with high average temperature need higher water than those having lower average temperature and cities with higher socioeconomic activities require higher quantity of water than cities with less economic activities. In those cities with higher economic activities and developments, the standard of living will be high

requiring more water for domestic as well as non domestic consumptions. In addition, the religious background also plays a significant role on the water demand.

Thus, as Jijiga is one of the cities in the country with high social, economic and religious values, the per capita water demand of each mode of services have been adjusted to account these values. Both the climatic and socio-economic adjustment factors are applied in estimating the average domestic water demand.

Year	2015	2020	2025	2030	2035
Town Population	167,956	204,344	246,234	293,864	293,864
University Community	11,000	11,000	11,000	11,000	11,000
Total Populations	173,330	210,883	254,113	303,268	358,450
% of population using:					
HTU	6	6	7	8	9
YTU	25	28	31	34	37
PTU	39	32	25	18	11
NTU	31	34	37	40	43
Population by level of service					
HTU	9,828	13,560	18,118	23,791	25,960
YTU	42,691	58,815	78,513	103,010	112,320
PTU	67,685	66,913	63,588	55,084	34,279
NTU	53,126	71,595	93,895	121,383	130,708
Per-capita demand (l/c/d)					
HTU	70	74	78	82	86
YTU	30	32	34	38	42
PTU	25	26	28	29	30.5
NTU	40	42	45	47	50
Demand by mode of service (m³/d)					
HTU	687.9	1003.4	1413.2	1950.9	2232.5
YTU	1280.7	1882.1	2669.4	3914.4	4717.5
PTU	1692.1	1739.7	1780.5	1597.4	1045.5
NTU	2125.0	3007.0	4225.3	5705.0	6535.4
Total domestic demand in (m³/d)	5785.8	7632.2	10088.4	13167.7	14530.9
In (l/s)	67.0	88.3	116.8	152.4	168.2
Adjustment Factors					
Socio-economic adjustment factor	1.1	1.1	1.1	1.1	1.1
Climatic Adjustment factor	1	1	1	1	1
Adjusted Domestic Water Demand in (m³/d)	6364.4	8395.4	11097.2	14484.5	15984.0
In (l/s)	73.66	97.17	128.44	167.64	185.00

Table 3-8: Domestic demand per mode of connection

SUMMARY OF DEMAND					
Demand Categories	2015	2020	2025	2030	2035
Domestic Demand (m ³ /d)	6,959	8,404	12,001	15,379	16,625
Public Demand (m ³ /d)	696	840	1,200	1,538	1,662
Animal demand (m ³ /d)	1,044	1,261	1,800	2,307	2,494
Average day demand (m ³ /d)	8,699	10,505	15,002	19,223	20,781
Loss in distribution system (%) of water supplied	13	16	19	23	28
Water loss in (m ³ /d)	1,131	1,681	2,850	4,421	5,819
Total average day demand (m ³ /d)	9,830	12,186	17,852	23,645	26,599
(l/s)	114	141	207	274	308
Maximum Day Demand (m ³ /d)	13,396	16,072	22,803	29,027	31,171
(l/s)	155	186	264	336	361
Peak hour Demand (m ³ /d)	21,434	25,716	36,484	46,444	49,874
(l/s)	248	298	422	538	577

Table 3-9: Table 6-9: Summary of Water Supply Demand

3. 12 Existing Water Supply System Gap Identified

The existing water supply to Jijiga city water supply system was 4,320m³/day. This water is supplying in the study area at both 24hrs and 12hrs at lower and higher elevation area respectively. Hence the total demand including the UFW in the system is 9,830m³/day for supplying water 24hrs. To fill the gap additional 5,510m³/day amount of water is required to fulfill the supply shortage and demand of Jijiga city water supply system.

S.no	Indicators	Expected Target to be achieved	Current status	Identified Gaps of the existing WS system
1	Water supply coverage	100%	43%	57%
2	Per capita water supply demand	50(l/c/d)	25(l/c/d)	25(l/c/d)
3	2015 demand and supply condition	9830m ³ /day	4,320m ³ /day	(-)5,510m ³ /day
4	Continuity of water supply	24hrs	24-12hrs	12hrs
5	Extent of non revenue water (UFW)	5-20%	37.80%	-17.80%
6	Updating of water line network	100%	70%	30%
7	Fire hydrant (based on calculation)	8	5	3

Table 3-10: The Projected Population by Mode of Service

3.13 Reservoir Capacity Determination (Analytical Method)

Table 3-112: Reservoir Capacity Determination (Analytical Method)year-2025

Year 2025					
Maximum day demand =746.62m ³ /h = 207.39l/s					
Hour	Hourly demand variation factor	Consumption (m ³ /h)	Supply (m ³ /h)	Storage (m ³ /h)	Cumulative storage(m ³)
0	0.3	223.986	746.62	522.634	522.634
1	0.3	223.986	746.62	522.634	1045.268
2	0.3	223.986	746.62	522.634	1567.902
3	0.3	223.986	746.62	522.634	2090.536
4	0.3	223.986	746.62	522.634	2613.17
5	0.7	522.634	746.62	223.986	2837.156
6	1.1	821.282	746.62	-74.662	2165.198
7	1.9	1418.578	746.62	-671.958	1493.24
8	1.7	1269.254	746.62	-522.634	970.606
9	1.5	1119.93	746.62	-373.31	597.296
10	1.5	1119.93	746.62	-373.31	223.986
11	1.4	1045.268	746.62	-298.648	-74.662
12	1.4	1045.268	746.62	-298.648	-373.31
13	1.3	970.606	746.62	-223.986	-597.296
14	1.2	895.944	746.62	-149.324	-746.62
15	1.5	1119.93	746.62	-373.31	-1119.93
16	1.6	1194.592	746.62	-447.972	-1567.902
17	1.5	1119.93	746.62	-373.31	-1941.212
18	1.3	970.606	746.62	-223.986	-2165.198
19	1	746.62	746.62	0	-2165.198
20	0.7	522.634	746.62	223.986	-1941.212
21	0.5	373.31	746.62	373.31	-1567.902
22	0.4	298.648	746.62	447.972	-1119.93
23	0.3	223.986	746.62	522.634	-597.296
Maximum day demand in(m ³ /day)		17919	17919		

Year	Maximum Storage (m ³)	Maximum Deficit (m ³)	Reservoir capacity (m ³)
2025	2837.156	-2165.198	5000.00

From the curve above, the size of the reservoir for phase I is:-

$$\begin{aligned} \text{Capacity} &= \text{Storage} + \text{Deficit} \\ &= 2,837 + 2,165 = 5,000\text{m}^3 \end{aligned}$$

The mass curve shown below which are generated from the daily consumption and supply data's are shown in the figure below.

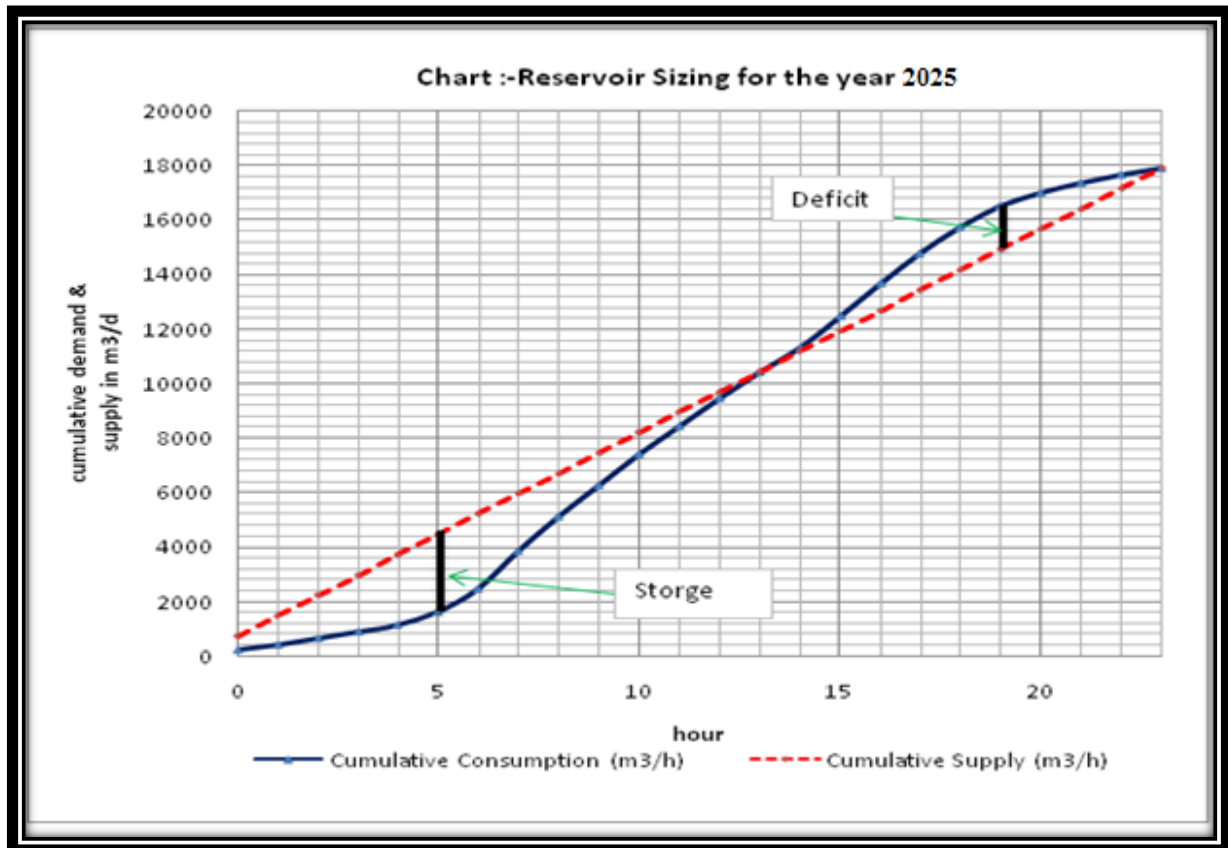


Figure 17 Reservoir sizing for the year 2025

Table 3-13: Reservoir Capacity Determination (Analytical Method)-year 2035

Year 2035					
Maximum day demand =1442.32m³/h=400.64l/s					
Hour	Hourly demand variation factor	Consumption (m³/h)	Supply (m³/h)	Storage (m³/h)	Cumulative storage(m³)
0	0.3	432.696	1442.32	1009.624	806.05
1	0.3	432.696	1442.32	1009.624	1815.674
2	0.3	432.696	1442.32	1009.624	2825.298
3	0.3	432.696	1442.32	1009.624	3834.922
4	0.3	432.696	1442.32	1009.624	4844.546
5	0.7	1009.624	1442.32	432.696	5277.242
6	1.1	1586.552	1442.32	-144.232	5133.01
7	1.9	2740.408	1442.32	-1298.088	3834.922
8	1.7	2451.944	1442.32	-1009.624	2825.298
9	1.5	2163.48	1442.32	-721.16	2104.138
10	1.5	2163.48	1442.32	-721.16	1382.978
11	1.4	2019.248	1442.32	-576.928	806.05
12	1.4	2019.248	1442.32	-576.928	229.122
13	1.3	1875.016	1442.32	-432.696	-203.574
14	1.2	1730.784	1442.32	-288.464	-492.038
15	1.5	2163.48	1442.32	-721.16	-1213.198
16	1.6	2307.712	1442.32	-865.392	-2078.59
17	1.5	2163.48	1442.32	-721.16	-2799.75
18	1.3	1875.016	1442.32	-432.696	-3232.446
19	1	1442.32	1442.32	0	-3232.446
20	0.7	1009.624	1442.32	432.696	-2799.75
21	0.5	721.16	1442.32	721.16	-2078.59
22	0.4	576.928	1442.32	865.392	-1213.198
23	0.3	432.696	1442.32	1009.624	-203.574
Maximum day demand in(m ³ /day)		34616	34616		

Year	Maximum Storage (m³)	Maximum Deficit (m³)	Reservoir capacity (m³)
2035	5133.01	-3232.446	8365.46

The size of the reservoir for phase II is:-

$$\begin{aligned} \text{Capacity} &= \text{Storage} + \text{Deficit} \\ &= 5500 + 2900 = 8400 \text{ m}^3 \end{aligned}$$

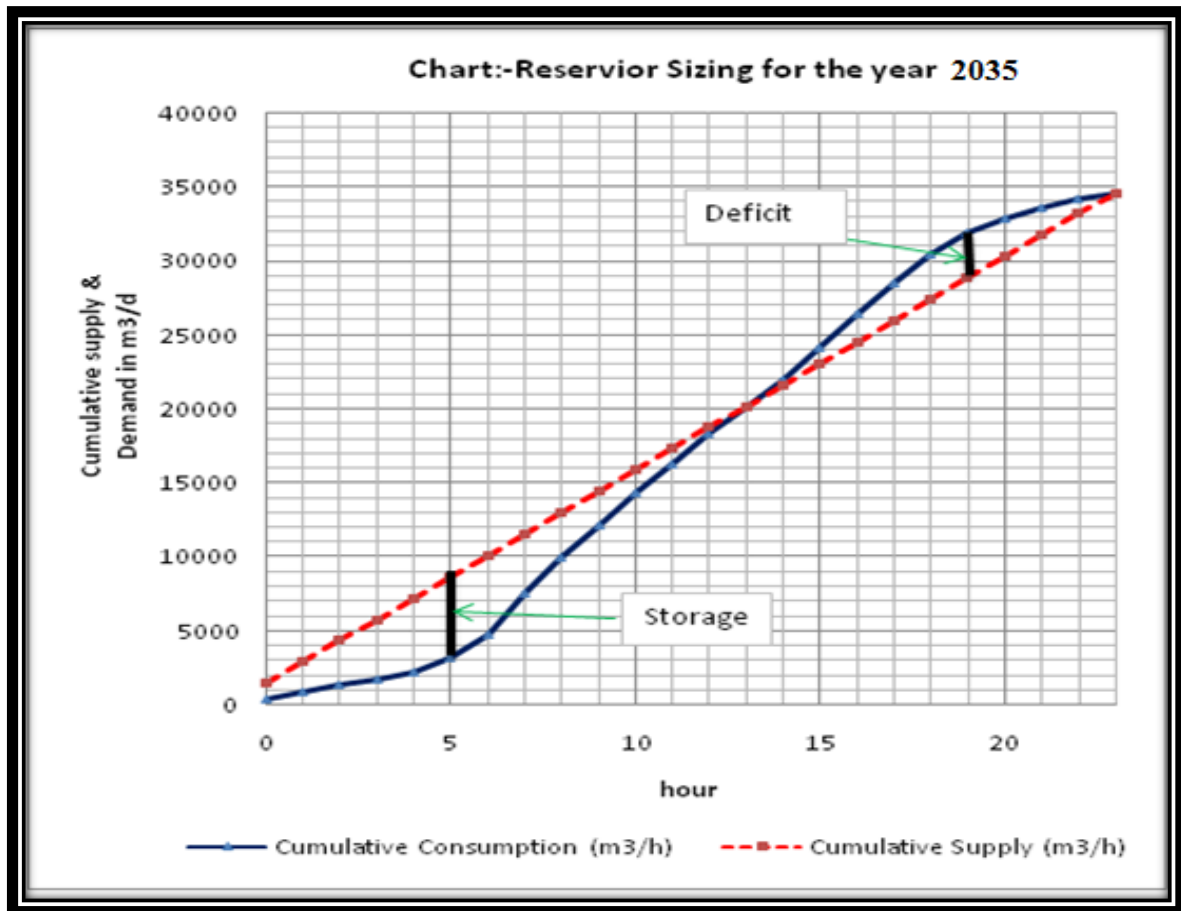


Figure 18 : Reservoir sizing for the year 2035

Thus from the calculations and curves above, it is required to provide 5000 m³ capacity reservoir for phase I and an additional 3500 m³ reservoir for phase II. Two new reservoirs were proposed & designed. The first is 3000m³ reservoir which was constructed along the Jijiga-Degehabur road having floor level of 1758.25masl and the second 1000m³ reservoirs which was built to the right side of the road to Chinaksen has a floor level of 1718.80 masl.

The old existing 350m³ reservoir is integrated in the new system as supposed to be maintained with some rehabilitation work done. The wall of the reservoir has to be chiseled and plastered with rich cement mortar. The internal wall must be painted. Float valve must be provided to automatically close the inflow in case of reservoir filling.

The new reservoirs were constructed from reinforced concrete structure and have circular

shape with flat roof slab. The new 3000m³ reservoir is provided with valve room to accommodate inlet, outlet, and drainpipes and also chlorine tank for chlorine mixture. The valve room is positioned in between the 1st and 2nd phase reservoirs. The construction of the valve room is planned in such a way that it could accommodate both phase pipe installation works.

Float valves were provided at the inlet to each reservoir to shut off the installed pumps in the boreholes to avoid waste of water due to overflow from the reservoir. Water meter is provided on the main transmission line from the 3000m³ and 1000m³ reservoir to record the total flow of water to the distribution network. The reading should be recorded daily so that the data could be utilized for future study in estimating the actual water demand of the city and loss in the distribution network. To inspect the water level in the reservoir, level indicator will be fitted to each reservoir. The compound of the reservoir will be fenced and also a guardhouse is constructed.

3.13 Water Source

Jijiga city is supplied with ground water from a number of boreholes located within the city. There is no perennial stream in the area. There is one dam close to the city but the available water does not justify treatment plant. Hence it is used only for animals and other uses. In addition to the boreholes people use other unprotected sources like dug wells and ponds for various uses.

The supply is not adequate and there is a critical shortage of water supply in the city. The public water points and the house taps are usually dry. Water vending is a common practice in the city and a 25 liter Jerrycan costs about 40 birr.

The quantity of water produced from old boreholes (52 l/s) is only about a quarter of the theoretical average daily demand which is about 207 l/s required in 2025. At present water from the boreholes is pumped directly into the distribution system.

The city gets its water from ground water. The table below shows the different boreholes that are currently serving the city.

S.N	Pipe Type	Year of Construction	Transmission lines	Diameter in(inch)	Yield L/s	Condition
1	GI	1967/68	J1	8inc	0.83	Functional
2	GI	1988	J-3B	6 inc	1.94	Functional
3	GI	1967/68	J4	8inc	1.67	Functional
4	GI	1972	J5	10inc	4.17	Functional
5	GI	1972	J6	10inc	1.94	Functional
6	GI	1989	J7	6inc	2.50	Functional
7	GI	1990	J8	6inc	3.89	Functional
8	GI	1990	J9	10inc	2.78	Functional
9	GI	1990	J10	6inc	1.67	Functional
10	GI	1992	J11	6inc	1.11	Functional
11	GI	1995	J-12(Elyere)	6inc	3.33	Functional
12	GI	1995	J-(Elbayere)	6inc	2.22	Functional
13	GI	1995	J-14	6inc	2.78	Functional
14	GI	1996	USA	6inc	4.17	Functional
15	GI	1997	15	6 inc	1.11	Functional
16	GI	1998	16	6 inc	2.22	Functional
17	GI	1998	17	6 inc	2.22	Functional
18	GI	1998	18	6 inc	2.78	Functional
19	GI	2000	19	6 inc	0.83	Functional
20	GI	2000	20	6 inc	1.94	Functional
21	GI	2000	21	6 inc	2.78	Functional
22	GI	2000	22	6 inc	1.11	Functional
23	GI	2001	23	6 inc	2.22	Functional
24	GI	2001	24	6 inc	1.94	Not-functional
25	GI	2001	25	6 inc	1.11	Not-functional
					52.0l/s	

Table3-112: Boreholes that are currently serving the city

Bore hole Name	Year of construction	Borehole depth in m	Pumping head in m	Dynamic water level in m	Static water level in m	Borehole discharge in l/s	Casing pipe Diameter	Pump capacity in kw	Pump type	Switch board		Operation status
										Capacity (Kw)	Brand	
1	1967/68	62.1	180-220	55	54	0.83	8''	15	Grundfoss	15	Grundfoss	Functional
3B	1988	42	134	35	18	1.94	6''	7.5	Grundfoss	7.5	Grundfoss	Functional
4	1967/68	70	180-220	60	56	1.67	8''	11	Grundfoss	11	Grundfoss	Functional
5	1996	82	134	60	28	4.17	8''	11	Franclin	11	Franclin	Functional
6	1972	70	-	58	53.5	1.94	10''	9.2	Caprary	9.2	Caprary	Functional
7	1989	36	143	28	18	2.50	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
8	1990	36	134	24	19	3.89	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
9	1990	28	-	25	18	2.78	10''	11	Grundfoss	11	Grundfoss	Functional
10	1992	32	-	28	18	1.67	10''	7.5	Plunger	7.5	Plunger	Functional
11	1992	42	134	36	35	1.11	9''	9.2	Grundfoss	9.2	Grundfoss	Functional
12	1995	20	-	18	12	3.33	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
13	1995	20	134	16	6	2.22	8''	9.2	Franclin	9.2	Franclin	Functional
14	1995	36	134	22	6	2.78	6''	11	Grundfoss	11	Grundfoss	Functional
15	1997	90	156	66	45	4.17	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
16	1998	36	156	28	18	1.11	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
17	1998	35	134	27	12	2.22	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
18	1998	32	134	27	12	2.22	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
19	2000	32	137	Not tested	19	2.78	6''	9.2	Grundfoss	9.2	Grundfoss	Functional
20	2000	27	137	Not tested	18	0.83	6''	7.5	Grundfoss	7.5	Grundfoss	Functional
21	2000	20	137	Not	16	1.94	6''	7.5	Grundfoss	7.5	Grundfoss	Functional
22	2000	42	134	Not tested	18	2.78	6 inc	9.2	Grundfoss	9.2	Grundfoss	Functional
23	2001	40	134	Not tested	18	1.11	6 inc	9.2	Grundfoss	9.2	Grundfoss	Functional

(b)

Table 3-113: (a &b) Summarized Data's of The Working Boreholes



Figure 19: Pictures showing current situation of water shortage problem in Jigjiga town

4. RESEARCH METHODOLOGY

4.1 Introduction

Based on the research objectives and questions stated in the introduction chapter the method how the research was carried out is discussed in this chapter. The methods of data collection and data preparation are also discussed in this chapter. Generally the research is divided in to two major parts, to model and analysis the existing Jjiga city water distribution network system and to suggest improved network. Monthly water production and consumption data is used to evaluate the water loss at all levels. After identified the characteristics of water line network, the hydraulic performance parameters is tried to be evaluate using the different desirable criterion that have an impact to the water distribution network in the systems.

4.2 Research Process

The approaches adopted for each of the system components to perform the model are described here below:

- Literature review
- Collection of all the existing water distribution system and other related available data.
- Generate missed data for modeling system
- Built the existing water distribution layout using Auto CAD 2007 tools software for Water CAD model representation.
- Data entered into the built model.
- Check the status of the valves in the model (closed or regulated) considered according to status.
- The model is going to be simulated for both single period and extended period.
- The existing water supply network simulated model will be calibrated by direct field measurement with the sample hydraulic parameters (pressure, velocity, residual chlorine and water age etc.)

- The water supply network model which is simulated using Water CAD also has to be validated using different techniques.
- Run the simulation for the purpose of analysis.

4.3 Data Collection

Prior to the fieldwork, all necessary information prepared by the regional Water Resource Bureau use as a base for the selection of the study area. It is planned to collect secondary data from the City administrative municipality office and the regional Water Mines & Energy Bureau and the other similar offices of the city Water Service Office and the like. Supportive qualitative information was gathered through discussion with local experts of the regional water mines & energy bureau direct concerned different technical staff and departments.

4.3.1 Secondary Data Collection

4.3.1.1 The Study Area Water Line Network

A digital water network for the entire study area including their attribute like the size, age and material of the pipes collected in AutoCAD format. The collected pipe network mainly comprises of main pipes and secondary pipes that covers the major part of the area. The data on the network would be found from two sources within Jijiga branch office and the regional water mines & energy bureau head office.

4.3.1.2 The Study Area Water Reservoirs

In order to evaluate the water supply coverage and the water loss, customers' monthly consumption data has to be collected from Somali Region water mines & energy bureau water consumption bill data preparation section. There are more than 14,109 numbers of customers within the study area. Beside to consumption (meter readings), the data includes information on Woreda and Kebele and unique number and the information on location the water reservoir collect in conjunction with the main water network on the study area. The reservoir's data including their capacity, years of construction and

material of construction also has been collected. The locations of some of the reservoirs are not exactly indicated in the network, and the document found from the planning department indicates only the surrounding where they are located. Some of the reservoirs serve as transfer point to other reservoirs located elsewhere in addition to serving as a distribution to the surrounding areas.

4.3.1.3 Contour of the Study Area

Although a 5 meter interval contour is available before the fieldwork, it has a basic problem like discontinuity in the contour lines and most of the contour lines are missing their elevation values. For this reason, getting other sources were found to be indispensable and that a 20 meter interval of contour with its corresponding digital elevation model (DEM) is found from the planning department of Ethiopia Somali water mines & energy bureau.

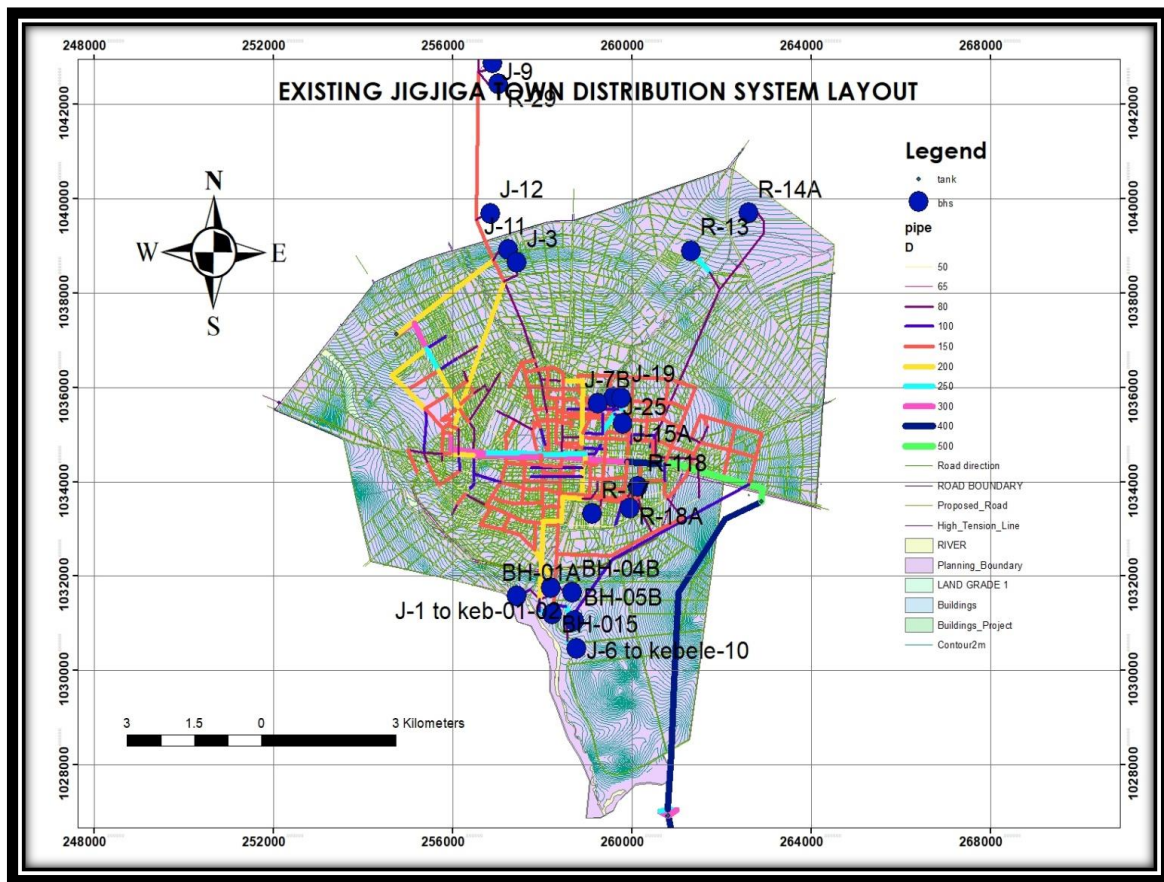


Figure 20: Jijiga town master plan with the distribution pipe network

4.3.1.4 Water Production

According to, the information found during discussion with the Ethiopia Somali water mines & energy bureau experts, no other water sources for Jijiga city distribution network system. As there was no organized data, the water production collected from the Jerer, around the city and Kebele 06 well field to ground water collection tank (GW3) which is the sources to system. Beside to the water production for the entire study area data on monthly water distributed to systems has been collected from water meter installed at the source reservoir outlet.

4.3.1.5 Water Consumption

In order to evaluate the water supply coverage and the water loss, monthly consumption billed data required. There are more than 4109 customer numbers in the system, out of this 3681 is domestic and 413 non-domestic and 15 is stand pipe. These customers within the entire area have been considered to estimate domestic water supply coverage, water loss, and demand and gap analysis purpose.

4.3.1.6 Base Population

Knowing the base population of city alongside with some indications of future growth trends would enable to design a reliable and sustainable water supply system. Adopting non reliable base population figure and formulating non realistic assumption would eventually lead to either an over designed or under designed water supply scheme that doesn't meet the purpose it is designed.

In the design review work, to minimize the risk of over designed or under designed system that results from mistaken assumption of base population figure, population data from various sources like:-the Ethiopian Central Statistical Agency (CSA) and the city's Municipality have been reviewed and compared for their reliability. In forecasting the future population size of the city, the base population figure of 125,584 that are obtained from the 2007 CSA's population and housing census count.

4.3.1.7 Population Growth Rates and Projections

CSA recommends three growth rates for projecting the population sizes of cities in the Somali National Regional States. For projecting the future population sizes of Jijiga city, medium variant growth rate is adopted. In choosing, the medium variant growth rate, the economic and political significance of the city in the region, its future potential for development, availability of infrastructures and land for future development have been considered. The growth rates adopted for the respective years of the design period are shown below.

Table 4-1: Population Growth rate

Year	Growth Rate (%)
2010	4.11
2015	4.11
2020	4.00
2025	3.80
2030	3.60
2035	3.40

The future population size of the city is projected by using a geometric population growth model, which is described by the equation shown here under.

$$P_n = P_o(1 + r)^n$$

Table 4-2: Total Projected Populations

year	Population growth rate	Projected Populations (CSA)	Estimated Jijiga University Community	Total Population
2007		125,584		125,584
2010	4.11	141,714	5,000	146,714
2015	4.11	173,330	11,000	178,330
2020	4.00	210,883	11,000	215,883
2025	3.80	254,113	11,000	259,113
2030	3.60	303,268	11,000	308,268
2035	3.40	358,450	11,000	363,450

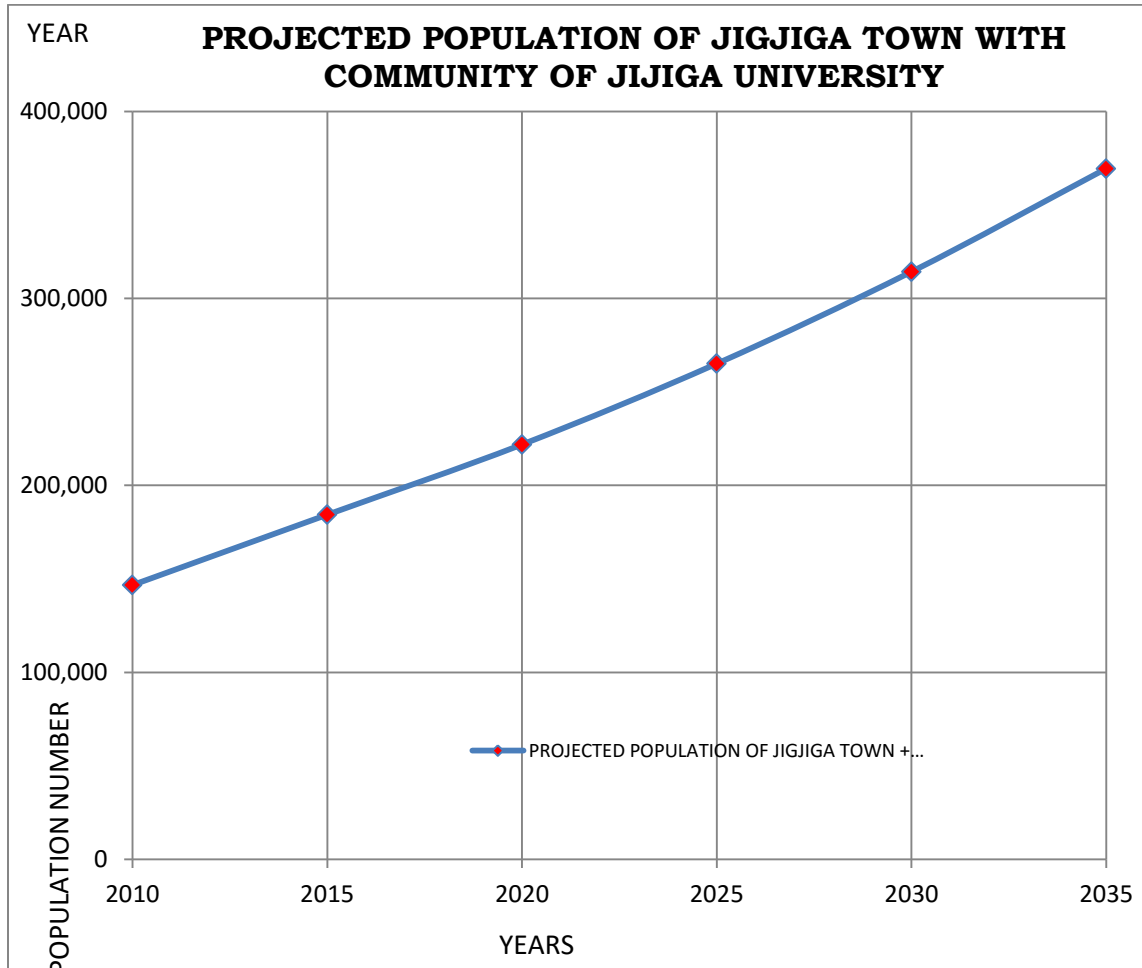


Figure 21 : Jijiga city Total Projected Population

From the table and pictures above it can be seen that the projected population by using the base population figure obtained from the city’s Municipality is nearly 2.89 times to the projection made by using the base population figure obtained from the CSA. The base population figure obtained from the city municipality count is very much exaggerated. Thus, in modeling the water supply system of the city, it is determined to use the population projection made by using the base population figure of the CSA’s as the CSA is an authorized, reliable and a specialized body of the country handling the responsibilities of all aspects of demographic matter.

4.3.2 Primary Data Collection

There are many parameters measured directly to estimate water loss amount and for model calibration and simulation. The amount of water production measure from the main water release tanks which is the head of the subsystem and most parameters also has to be measured directly to the most significant values costumers tap to evaluate nodal pressure and water quality analysis.

4.3.3 Pressure:

- 1) Number of pressure reading 10%-2% of nodes and accuracy of pressure readings ± 2 psi(1.4m)
- 2) Number of flow reading in the pipe 2% of pipes and accuracy of flow readings $\pm 5\%$.
- 3) Water quality number of pressure reading nodes 2% of nodes and accuracy of pressure reading 5%.

4.4 Data Preparation

4.4.1 Water Line Network

The data on study area water network that collects from two sources are in Auto CAD format, one of it from technical department of **the regional water mines & energy bureau** head and Jijiga branch office. Before exporting the Auto CAD format network in to Water CAD reviewing the network in its original format was necessary that Auto CAD software has been installed in order to do so. While the network are reviewed in its original format, the pipe diameter, year of construction (replacement) and its material type is found written as an annotation that makes it difficult to export as it is in to Water CAD. On the other hand a specific code has been assigned as a layer to each annotation. After reviewing which type of code does represent to which description in Auto CAD, the network has been exported to Water CAD.

4.4.2 Domestic Water Supply Coverage

Water supply coverage is usually evaluated based on the quantity, quality, paying capacity of the people, distance, etc., but the intention of this research is not to evaluate all these but related to the quantity of supply and level of connection that are related to the water loss. In this part of the analysis, the number of domestic connections per family and the average daily per capita consumption are used to analyze the domestic water supply coverage for the entire system. Access to water supply may be evaluated using the amount of water consumed and the level of connection. For evaluating the amount of water consumption, the annual water consumption is converted to average daily per capita consumption using the population data of Jijiga city subsystem. The number of domestic connections per family has been also used for analyzing the level of connection as elaborated below.

5. MODELING OF JIJIGA CITY WATER SUPPLY DISTRIBUTION NETWORK

5.1 Introduction:

This chapter discusses in detail the steps taken to construct the model of the existing drinking water distribution system of Jijiga city. The steps were:

- i. Preliminary Data Collection
- ii. Building the model in Water CAD
- iii. Assigning water demands to each node
- iv. Hydraulic Modeling using Water CAD

Each of the following sections will discuss the above steps in detail.

5.2 Data Collection:

The most important step in any research study is data collection. In building the model of the distribution network, the data were first gathered regarding all the distribution system parameters. In line with this, the following data have been needed for implementation the modeling of the system:

- Maps with layout of the existing distribution system.
- Contour maps to determine the elevations of the consumption nodes.
- Capacity and elevation of the central storage reservoirs.
- Modes of operation the system (zoning).
- Sources of water and available quantities of potable water.
- Demand patterns for domestic consumption.
- Commercial, industrial, public consumption.
- The values of the unaccounted for water (UFW).
- Population figures to estimate the consumption at the nodes.
- Field measurements of pressure, flow, roof tanks levels variation.

All above data have been taken from the water department at Jijiga city municipality, or have been carried out by the researcher to make the modeling of the system, as intermittent supply system is able.

A field visit to the city of Jijiga was conducted on the March 2018 & June 2018. The information obtained from Regional Water, Mines & Energy Bureau and Jijiga city water Service office is that the City will expect further industrial or commercial growth in near future. The senior technician in the city Water Service Office said that, there are few houses located at the North-West direction of the city experiences low pressure. These houses are located at a relatively high elevation compared to the main city. The most important information obtained from the Regional Water, Mines & Energy Bureau was that the federal Water works Design & Supervision Enterprise

(WWDSE) did the work of mapping their water assets. Thus, the detailed shape files of the waterlines, reservoirs and the groundwater wells were obtained from WWDSE.

Distribution system Parameter	Information obtained
Water Reservoir type	Groundwater: 25 wells in the north, North-East and south direction of the town. Additionally, 8 wells were also drilled and connected to the system which is located about 23km to the south-east of the main city in Jerer valley. Each well is about 40-150m deep. No adequate information was provided regarding the static water level of the wells.
Pumps stations	Only two new pumping stations were observed along the Jerer transmission line. All wells have single submersible pumps on each well. Rating of Pump of north well have different HP. Rating of the pump on Jerer-south wells also provided with different pumps having different HP.
Storage tank (Standpipes)	<p>Reservoir-1: Located along the main Asphalt Road Jijiga to Gode in South-East direction of the city.</p> <ul style="list-style-type: none"> ☞ Storage capacity: 3,000m³ ☞ Year of construction - 2001 E.C. ☞ Drain pipe 3" GI pipe ☞ Overflow pipe ☞ Material of construction -RCC ☞ Gate valve 3" GI pipe ☞ leakages N/A ☞ Vent pipe ☞ Elevation 1788.25m a.s.l <p>Reservoir-2: Located at boarder the city in North-West direction.</p> <ul style="list-style-type: none"> ☞ Storage capacity: 1,000m³ ☞ Year of construction 2001 E.C. ☞ Drain pipe 3" GI pipe

	<ul style="list-style-type: none"> ☞ Overflow pipe ☞ Material of construction -RCC ☞ Gate valve 3” GI pipe ☞ leakages N/A ☞ Vent pipe ☞ Elevation 1778.80m a.s.l <p>Reservoir-3: Located within the city near the cemetery.</p> <ul style="list-style-type: none"> ☞ Volume 1,000m³ ☞ Year of construction 2001 E.C. ☞ Drain pipe 3” GI pipe ☞ Overflow pipe ☞ Material of construction -RCC ☞ Gate valve 3” GI pipe ☞ leakages N/A ☞ Vent pipe ☞ Elevation 1740.60m a.s.l
<p>Pipelines</p>	<p>Detailed hand drawn maps showing the distribution network classified by line sizes and age were provided by the city.</p>
<p>Hydrants</p>	<p>The location of three fire hydrants are shown transmission line from 3,000m³ Reservoir to main city.</p>
<p>Power supply</p>	<p>Jijiga city gets its 24 hr electric power supply from national grid of the country.</p>

Water consumption and water quality data	Comparing the water quality analysis both current and previous studies with the WHO guidelines values, parameters like sulfate, total hardness and total dissolved solids by far exceeds the maximum permissible limit. Sources of the water had higher content of total dissolved solid leading to salty taste. The water quality of all boreholes is almost the same, though for each hasn't been done. Major contributor to the total salt content of the water are sulfate, chlorine, calcium, sodium and magnesium ions that comprises about 83%, 67% and 79% of the total dissolved salts, respectively.
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Table 5-1: Preliminary Information of the distribution system for Jijiga city

(Source: from Regional Water, Mines & Energy Bureau and Jijiga city water Service office)

Apart from the preliminary information, additional inputs were required for the simulation of the model. The most important was the elevation dataset. Without the elevations, it is not possible to run the hydraulic simulation. Most of the elevation dataset was obtained from actual data collected by the researcher using GPS travelling along the pipe line and the remaining were filled from DEM data of that specific location using ARC Map 10.4. For the elevation data set, files with horizontal resolution of 30 meter and 90 meter are available. For this project, the 90 meter dataset was selected. The second important dataset necessary was the information regarding population of the city in the census 2007 data. This information is required to divide the total population in to reasonable number of nodes and assign base water demands to each node.

5.3 Creating the Model in Water CAD 6.5:

The analysis of the water system under these conditions is performed using (Water CAD) software, which has been developed by the Haestad Methods, and represents a powerful; easy to use that helps in design and analyzes water distribution systems. This package of Water Cad 6.5 software enables the designer to model complex hydraulic situations. The input data needed to perform the analysis by the Water Cad Technique comprise the demand in the nodes, their elevations, pipes

lengths, diameters, materials, reservoirs and their elevations, demand patterns, valves with different types and their control; also if there are pumps in the system, they can be modeled depending on their operating curves.

The population figures, which have been adopted in this model, depend on the statistics of the figures derived from the number of house connections multiplied with the average household size and estimated by 25,700 only can be considered as beneficiaries of the water supply scheme.

Each cluster of houses has been assigned as 150 nodal points for 2025 and 180 nodal points for 2035 and modeled in this Water Cad model as one consumption node, and its consumption was calculated depending on the number of inhabitants in each of them as shown in Annexed table.

This section describes steps involved in building the hydraulic model in Water CAD 6.5. This software offers different ways of modeling the network. The user can physically draw the network if the drawings and the dimensions are available or the user can import files from AutoCAD and Arc Map.

One very good feature that Water CAD offers is the Model Builder. Using this tool one can directly import all the shape files at once. In the Model Builder, one can select the ‘data source type’ as shape files and then click on the browse button. The user then has to browse to the specific location where the shape files are stored and then select all of them. One very important aspect that the user has to consider during modeling is that all the geospatial data files used during modeling should have the same geographic projection. The shape files of the water lines, appurtenances, boreholes, booster stations and the storage facilities were projected with respect to the coordinate system of DEM (Digital Elevation Model) of Jijiga city and nearby areas.

This co-ordinate system was GCS_Adindan_UTM_Zone_37N. Once the shape files are selected the user can preview the attribute tables of each shape file. Next the user needs to specify the co-ordinate unit of the data source. The co-ordinate unit selected was ‘meters’. The check boxes “Create nodes if none found at the end of the pipeline” and “Establish connectivity using spatial data” need to be selected and the tolerance is entered as 1m. This option connects pipe nodes

which are in a range of one meter. The Model Builder gives you an option on whether the data should be imported as a current scenario or new scenario. For this project the option “Current Scenario” was selected. In the next window, the key fields used for object mapping shall be identified.

These are fields that should be identified based on the unique label they possess. Therefore, the fields selected for each shape file are:

- ☞ Nodal points : N-ID
- ☞ Pressure Pipe Lines : PL-ID
- ☞ Distribution pipe Line: DL-ID
- ☞ Borehole : J-ID
- ☞ Pump data : PMP-ID
- ☞ Appurtenances (hydrants): Apprt_ID
- ☞ Storage Reservoirs: Tank_ID
- ☞ Booster Stations: BPS_ID

The Model Builder then executes the build operations evaluating the user defined conditions. Once the model has been built, the user has to edit the network. The Model Builder creates the network but does not physically connect the hydrants to the water lines. This is due to the way in which the geospatial data are created. For this reason the hydrants had to be manually connected to the nodes. Also, once the model is built, all the supply facilities are converted into water tanks, including the reservoirs. The tanks representing the reservoirs need to be physically changed to reservoirs. This is again due to the fact a single shape file was created to represent all the water supply facilities.

5.3.1 Assigning elevations

For this purpose, as the Water Cad 6.5 has no the TREX wizard tool which uses to extracts elevation information from the elevation dataset file by interpolation and the latest version of Water Cad 8.1 can have the TREX wizard tool which uses to extracts elevation information from the elevation dataset file by interpolation. Thus, if the data source type selected was shape file. A shape file in GIS is defined as that which is either a polygon, point or a line file type. The elevation

dataset for Jijiga city that was obtained was a raster file. A raster file in the simplest way can be defined as a digitized file of a photographic image. The raster file cannot be directly used to assign elevations to the nodes. The raster file has to be converted into a point shape file before it can be suitably applied. In Arc MAP, one can convert a raster file to point shape file using the conversion tools. This takes a long time because of very large amount of continuous data that has been digitized into millions of pixels. The shape file also has a size of about 50 MB. After the conversion, in the TREX Wizard, this converted shape file was selected. Since the original units of the data elevation set are in meters, the units of the model were also set to the SI system. The user needs to specify the Z-coordinate as GRID_CODE. Once this is done, the wizard assigns elevations to each node, including the hydrants, the water tanks and the reservoirs. A table showing all the extracted elevations appears once the application is complete and this tabular data having X, y, Z and label-ID shall be exported from Water Cad 8.1 with XL format and be imported in Water Cad 6.5 for Model establishment.

5.3.2 Assigning base water demands to each node:

To assign base demand to each supply node, it is necessary to know the houses around each supply node. It is a multi-step procedure, which is as follows:

In CSA-2007, the total number of houses found in Jijiga city is about 42,769 of which only 25,700 houses were considered as direct beneficiaries of the project and in Arc MAP, the ortho image of 10 Kebeles for the City of Jijiga was opened and the shape file of the distribution network was overlaid on it. The 2007 CSA Census Block shape file was added. The number of houses in each census block were physically counted and roughly assigned to the nearest supply node. An Excel sheet was created for demand allocation. The first column contained all the 150 demand nodes for 2025 and 180 demand nodes for 2035. The second column showed the number of adjoining houses assigned to that node. For the research purpose 2015 was taken as base year, the population of the city is about 173,330 people and 254,000 in 2025. The total number of houses identified was 31,118, giving an average count of 1.5 Rooms per house. In the third column the number of Rooms was converted to the number of people by multiplying an average count of 5.57 peoples per Rooms taking this as by the conversion factor.

Conversion of the number of houses into the amount of water: The amount of water consumed daily by the city is 12,096m³/day or 140lt/sec. Then the fraction of the demand required for those houses around a particular supply node is determined by the following equation.

$$\text{Base Demand for a supply node} = \frac{(\text{Population served by that node}) * 140\text{lt/s}}{(\text{Total Population})}$$

In the same excel sheet all the nodes were thus assigned, base water demand using the above equation. Appendix A shows the calculations for assigning base flow demands to each node. Here, the average per capital demand of the system is computed as 25.1lt/s/p.

5.3.4 Hydraulic modeling in Water CAD

This section describes how all the model parameters, scenarios and alternatives necessary to run the model were set:

5.3.4.1 Setting the elevation for the groundwater well

From the information received from Jijiga Water Bureau, each of their wells was about 20 to 90m deep. The static water level of the wells was unknown. However, The City Water Service technician was interviewed on March-June 30th; 2010EC said that he presumed that the water in the well was found between 10-18m below the surface level. Therefore, for all wells the static water elevation was assumed to be 15m below the ground surface. The ground surface elevation at the location of the North well is 1638.35m. The elevation for the reservoirs was thus set as the difference between this ground surface elevation and 1780m asl.

5.3.4.2 Setting Pump data

The pumps on North well and south well have 10KW to 20KW rating differently. These all are submersible pumps. Since this is the only information available on the pumps, they were assumed to be located at an elevation of 1618m above the mean sea level. This elevation of the pump was also selected based on the information provided by the Water Service Technician, where he assumed that the submersible pump was at least 20-30m deep. The most important parameter

simulating the operation of the pumps is the pump curve.

The information regarding the manufacturers was unknown, therefore suitable pump curves for the flow and the head required were found. Figure 11 shows the series of pump curve used (Flint and Walling, 2009). In Components option, the user defines the Pump Curves. Then the user can create more than one pump curve. Each pump curve has a unique ID. The option of multipoint data curve was selected and all the data points corresponding to the selected pump curve were entered in the table. The graph of the curve can be previewed in the window below the table, as shown in Figure below. Then the pump on the drawing was selected. Double clicking on the object opens the Properties Editor. In the Properties Editor, under the Pump Definition, the user can specify the pump curve by using the scroll bar and selecting the ID of the desired pump curve created. This sets the environment for simulating the pumps.

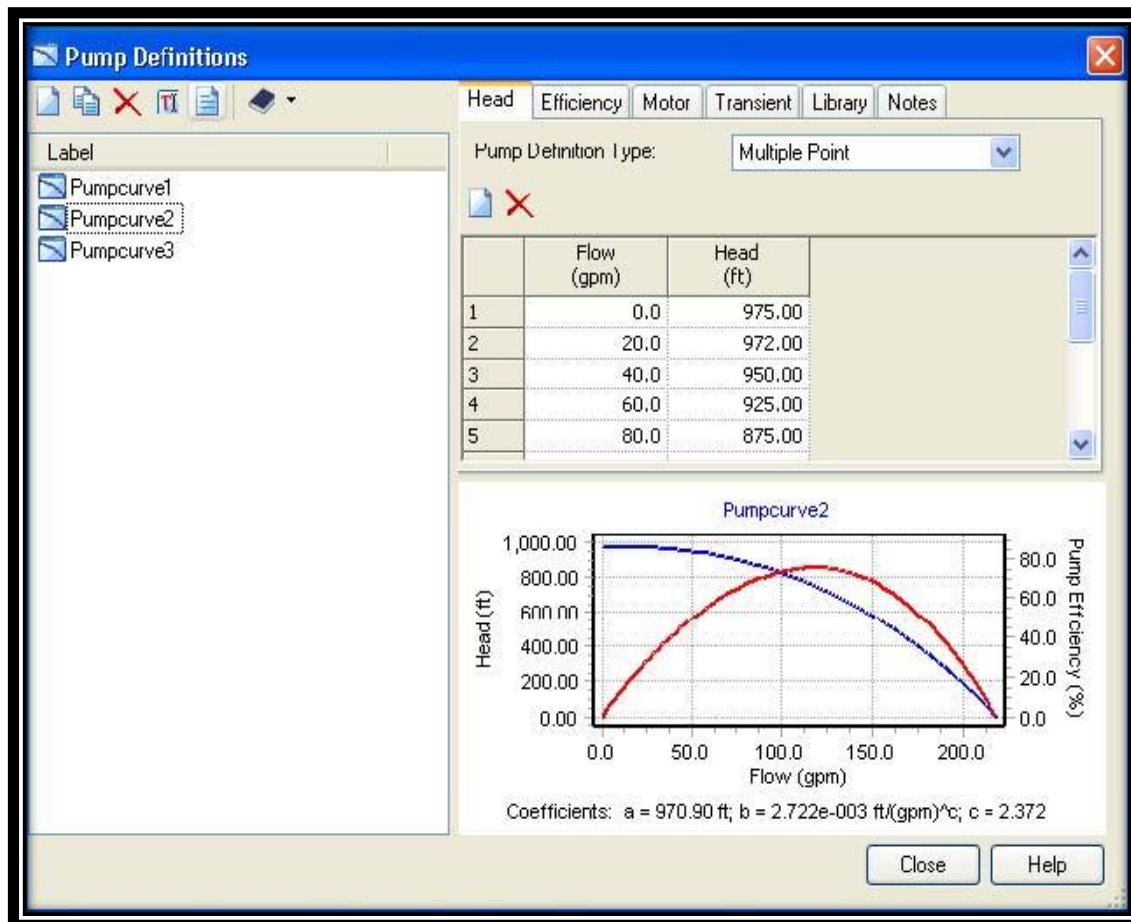


Figure 22 : : Screenshot of the Pump Definition Window.

5.3.4.4 Assigning base demands to each node

Each node was assigned a demand manually. In the Properties Editor of the nodes, under the Demand option, the user can click on the ellipsis (...). Then a window opens which shows demand in (lps) and demand pattern. The value of the base demand was entered under the demand column for all the nodes.

5.3.4.5 Assigning roughness coefficients to pipelines

Hazen-William roughness factors were used to incorporate frictional losses. Water CAD has an engineering library where different friction factors for different pipe materials are stored. In the Properties Editor for pipes one can select the pipe material.

The attribute tables for pipe lines shape file had the information regarding the pipe material. By default, Water CAD considers that the pipeline is new ductile iron pipe. Generally, pipe made of materials such as steel, PVC and asbestos cement do not tend have as much deposition or corrosion as cast iron pipes. The detailed hand drawn maps classified according to the age were provided by the city. These maps were used to adjust the friction factors.

This is summarized in Figure below. Figure 5.2 shows a table of Hazen-William friction factors classified by line sizes and age and degree of attack. Attack on the pipe is defined as the corrosion of the pipe and greater the 'C' factor greater is the smoothness and the carrying capacity of the pipe (Haestad Methods, 2003). This table was used to assign the respective friction factors.

Type of Pipe	C-factor Values for Discrete Pipe Diameters					
	1.0 in. (2.5 cm)	3.0 in. (7.6 cm)	6.0 in. (15.2 cm)	12 in. (30 cm)	24 in. (61 cm)	48 in. (122 cm)
Coated asbestos cement - clean		147	149	150	152	
Uncoated asbestos cement - clean		142	145	147	150	
Spun cement-lined and spun bitumen-lined - clean		147	149	150	152	153
Smooth pipe (including lead, brass, copper, polyethylene, and PVC) - clean	140	147	149	150	152	153
PVC wavy - clean	134	142	145	147	150	150
Concrete - Scobey						
Class 1 - Cs = 0.27; clean		69	79	84	90	95
Class 2 - Cs = 0.31; clean		95	102	106	110	113
Class 3 - Cs = 0.345; clean		109	116	121	125	127
Class 4 - Cs = 0.37; clean		121	125	130	132	134
Best - Cs = 0.40; clean		129	133	138	140	141
Tate relined pipes - clean		109	116	121	125	127
Prestressed concrete pipes - clean				147	150	150

Lambert (1981)

Figure 23 : Table showing the C- factors for different line sizes (Source: Haestad Methods 2003)

5.3.4.6 Assigning demand patterns

The Components tab has an option called 'Patterns' which opens the Pattern Manager window. The user can use this pattern manager to create water usage patterns based on daily, weekly and monthly use. For the maximum hourly demand, a multiplier of 2 was used. Generally, the peak hourly flow is 1.6 times the average daily flow (Haestad Methods, 2003). Also, a study of some city in Ethiopian Somali showed that their peak hourly flow demands were about 1.6 times the average daily flow demand (Salvato, 1992). Thus to test for worst conditions, the factor of 1.6 was selected. The peak hours were considered to be 6:30 am to 9 am in the morning and 4 pm to 8 pm in the evening. A demand pattern for the school was created considering the number of students in the school and then the per capita consumption multiplied by the number of students was assigned to the node providing water to the school. The school was assumed to be open from 8 am to 4 pm

on weekdays and was assigned a pattern of thrice the average residential demands during that period. The school remained closed from July to August, and during those months, demand was considered zero. Fire flow pattern was assigned to all the hydrants. The base demand is 0 lt/s. In case of fire the demand is 16 lt/sec. The pattern was assigned to provide this 16 lt/s at peak hours between 12:30 am and 9 am. In Analysis tab, one can go into the Alternatives options. Under 'Demand Alternatives' option one can assign the specific pattern and the base demand to a nodes.

5.3.4.7 Operating on Rules:

There needs to a set of binding conditions that will control the pump operation. According to the information provided by the city, the pumps are triggered by the automatic level switches in storage tanks. The highest permissible water level in the tank outside the city was 5m and thus the rule written for this tank was: If Tank WT1 level \geq 4.5m, Pump BPMP-1 & BPMP-2 Status = Closed. Since the diameter of these tanks is really large about 3,000m³ it takes a long time to fill these tanks.

Also it was necessary that these tanks remain half filled for maintaining the necessary pressures. Thus, the rule written to trigger the pump on was: If Tank WT2 level \leq 1.5m then Pump BPMP-1 & BPMP-2 Status = Open along Jerer side.

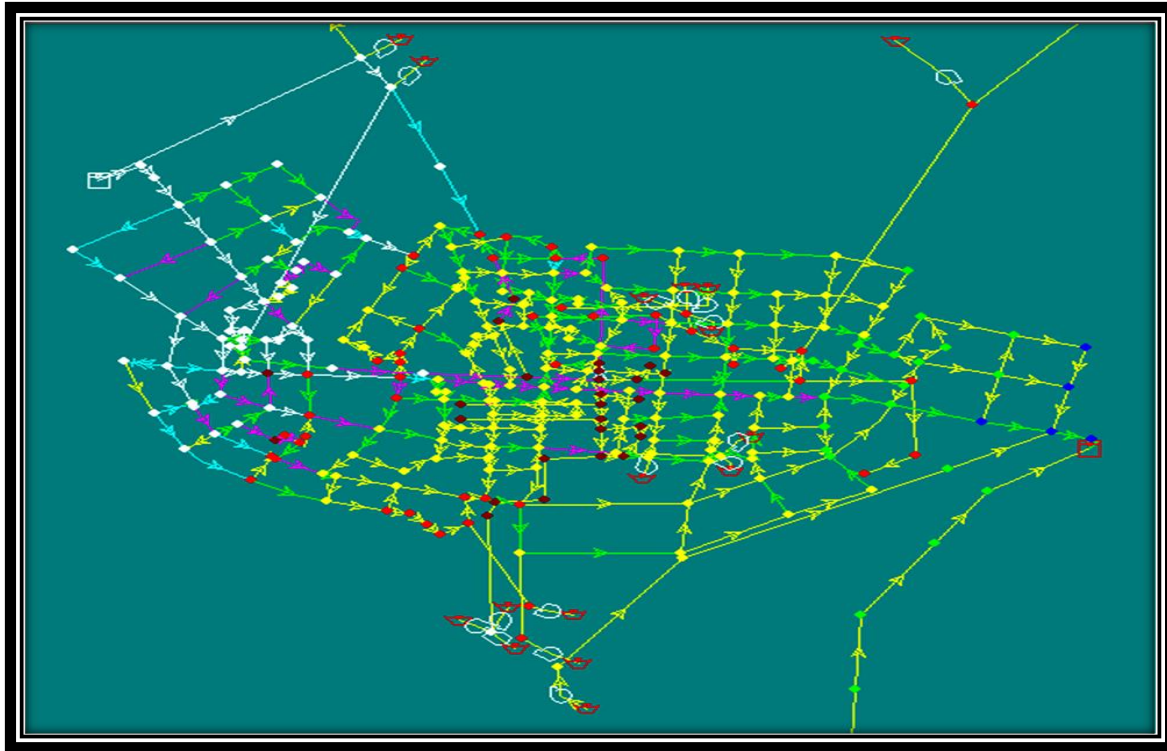


Figure 24 : **Distribution Network of in the city**

5.4 Unaccounted for water (UFW) for Jijiga city

Unaccounted for water is divided into physical, and non-physical water losses. Physical water losses are defined as “that amount of water which is lost without being used due to failures and deficiencies in the distribution facilities.” Non-physical water loss is defined as “the amount of water which is not registered, due to incorrect reading of the measuring instruments installed (measurement errors) and/or absent or inaccurate estimates in the absence of measuring instruments (estimation errors).

The establishment of the (UFW) for Jijiga city is based on some assumptions and measurements carried out by the water Service office at Jijiga city, taking into consideration the number of consumers connected to the water distribution system, recorded data by the metering section, flow measurements and meter readings for sources of water, and for different years.

The calculation of the (UFW) has been carried out and the result is determined to be 37.8% which is too much higher than the allowable range which is in the range of 5-20%.

6. RESULTS AND DISCUSSION

6.1 Evaluation OF Existing Water Supply System & Water Supply Coverage

Introduction

Problems in provision of adequate water supply to the rapidly growing urban population are increasing dramatically. Water demand in the domestic sector of developing cities including Jijiga increases through time that as a result demands for additional water sources and infrastructure. Despite to these, the financial capacity of the city is low to satisfy the growing demand. Financial constraint is one of the major factors for the low water coverage of the water supply but poor management of the existing water supply system also has a great impact for the low coverage. Beside to the overall low supply coverage, supply disparity exists among different localities. Therefore evaluating the entire distribution of the water supply system is important in order to identify the problematic areas and intervene accordingly.

6.1.1 Domestic Water Supply Coverage

Water supply coverage is usually evaluated based on the quantity, quality, paying capacity of the people, distance, etc., but the intention of this research is not to evaluate all these but related to the quantity of supply and level of connection that are related to the imbalance between supply and consumption of water to the city. In this part of the analysis, the number of domestic connections per family and the average daily per capita consumption is used to analyze the domestic water supply coverage for the entire study area. Access to water supply may be evaluated using the amount of water consumed and the level of connection. For evaluating the amount of water consumption, the annual water consumption is converted to average daily per capita consumption using the population data of the city. The number of domestic connections per family has been also used for analyzing the level of connection as elaborated below.

6.1.1.1 Average Daily Per Capita Consumption

The volume of water consumed for domestic purpose has been aggregated to all customers' of the system so as to analyze the distribution of the water coverage in the study area. Evaluating the domestic water supply coverage using volume of consumption may not allow realizing the distribution comparison among the study area (Desalegn, 2005). Per capita consumption in the former study document is considered as 25 liters/capita/day but from the actual data we can estimate by using the Equation (6.1) shall be determined as follows:

$$\begin{aligned} \text{Per capita consumption} \\ (\text{l/person/day}) \end{aligned} = \frac{\text{Annual Consumption in (m}^3\text{) X 1000l/m}^3}{(\text{Number of Population of the City x 365days)} \quad (6.1)$$

Where:

$$\text{Average annual consumption} = 1,024,754\text{m}^3;$$

$$\text{Population of the Town} = 173,330$$

$$\begin{aligned} \text{Thus,} \\ = \frac{1,024,754\text{m}^3 \times 1000\text{Lt/m}^3}{(173,330 \times 365)} \end{aligned}$$

$$\text{Per capita consumption (l/person/day)} = 16.2\text{l/person/day}$$

The average domestic water supply coverage of the town is found to be 16.2 l/capital/day. This average per capita consumption is very low while compared with the country standard used for design purpose (30 to 50 l/capital/day) and even it is lower than that of the minimum standard set by UN-Habitat as a basic need (20 l/capital/day). Out of the all kebeles of the entire town, about 140,000 inhabitants (nearly 80%) are getting water less than this basic service level.

6.1.1.2 Level of Connection per Family

Level of water connection is an important element on the one hand for evaluating the level of water coverage that will be the focus of this section and on the other hand it has a direct impact on

the water loss that will be dealt separately. According to Jijiga city Water Service Office billed data, the total numbers of connections or water meters with in the study area are about 14,466 among those, 13,117 are private household customers, 853 are commercials customers, 445 are Government customers and 51 standing pipe or public tap users.

The total numbers of connections or water meters within the city are about 10,153 households that obtain drinking water from tap inside compound for domestic use. In order to compare the distribution of the water connection among the different sites of the city, the total numbers of connections per city are converted to connection per family using the population data of the city. According to the census of the 2007, average family size of 5.57 is used for calculating the average number of connection per family using the following expression.

$$\begin{aligned}
 \text{Connection per family} &= \frac{\text{Total number of connection by City}}{(\text{Number of Population by City} / \text{Average family size})} & (6.1) \\
 &= \frac{10,153}{(173,330/5.57)} \\
 &= 0.326
 \end{aligned}$$

Like that of the per capital consumption after evaluating for outliers, the average connection per family for the entire town is found to be 0.326. This implies that at average more than 3.05 families or Seventeen persons are sharing one connection or water tap. In other words the average connection per family in house or yard connection of the town is about 32.6%.

6.1.2 Water Balance

Practically ahead of assigning nodal water demand, it is very common to quantify water loss in the water distribution system. The amount of water lost across the network is estimated by doing water balance analysis. The difference between production and water consumption is quantified as total water loss. Water loss in the system is frequently due to either leakage in the system or apparent loss which includes; illegal use of water by

unauthorized person, meter inaccuracy, etc. Table 6.1 below depicts water produced from June 1999 to December 2015 based on available data on hand.

Nominal Present water supply coverage

If the existing water sources are fully exploited, the city water supply coverage will be as follow

I. Water demand

- a) Population (2015) is - 173,330
- b) Domestic per capita demand – 25 l/c/day
- c) Total domestic demand - 4,333.25 m³/d
- d) Non-Domestic Demand(50%) - 2,166.625 m³/d
- e) Total daily demand – 6,499.88m³/d
- f) Unaccounted for water (30%) – 1,949.96 m³/d
- g) Total demand including UFW - 8,449.84 m³/d
- h) Annual demand – 3,084,191.6 m³/year

Existing water production and unaccounted for water

Table 6-1: Recorded Annual water consumption, production and UFW

Year	Water production in m³	Water consumption in m³	Loss in %
1999	437,695	309,600	0.29
2000	606,750	430,820	0.29
2001	733,589	521,025	0.29
*2002	836,033	588,979	0.30

2003	938,477	656,933	0.30
2004	930,800	652,000	0.30
2005	1,018,809	730,000	0.28
2006	1,222,706	870,000	0.29
2007	1,323,870	1,280,000	0.03
2008	1,683,390	1,262,542	0.25
2009	1,851,729	1,343,679	0.27
2010	2,036,901	1,360,800	0.33
*2011	2,048,000	1,392,640	0.32
*2012	2,171,631	1,454,993	0.33
*2013	2,268,708	1,497,347	0.34
*2014	2,368,771	1,539,701	0.35
*2015	2,471,959	1,529,759	0.38

Taking the water production of the year 2015: 3,084,191.6 m³

$$\begin{aligned} \text{Present nominal water supply coverage will be} &= \frac{(\text{Annual Consumption}) * 100}{\text{Annual Production}} \\ &= (1,529,759 / 3,084,191.6) * 100 \\ &\cong \underline{49.6\%} \end{aligned}$$

II. Actual present water supply coverage

Water supply coverage can be defined in the form of either service coverage or connection coverage depending on the availability of data required for the computation. The following steps are recommended in defining water supply coverage in the form of service coverage.

- a. Determined total population of Jijiga city in (2015) is 173,330.
- b. Estimated theoretical minimum water demand (TMWD) in this process we assumed a certain service level for different connection project to satisfy the nutritional and hygienic water requirement at a give community as give in table below.
- c. Determined Actual Consumed Water Amount (ACWA) for Jijiga city is ACWA = 1,529,759m³/ year
- d. Computation of service coverage $SC = \frac{ACWA}{TMWD} * 100\%$

Domestic water demand (l/c/d) for Jijiga city with a population between >80,000 is 40l/c/d

/According to WSDP from one person to total population.

$$= 40 \text{ lt/day per person} * 365 \text{ day/ year} * 173,330$$

$$= 2,530,618 \text{ m}^3 \text{ /year Commercial and institutional and industrial demands}$$

According to the table above

Comm. & inst. Demand = 35% of domestic demand

$$= 885,716.3 \text{ m}^3 \text{ /year}$$

Industrial demand = 10% of domestic demand.

$$= 253,061.8 \text{ m}^3 \text{ /year}$$

There for TMWD = 3,669,395.8 m³/year

$$SC = \frac{ACWA}{TMWD} * 100\%$$

Since

$$ACWA = 1,582,054 \text{ m}^3 \text{ / year. And}$$

$$TMWD = 3,669,395.8 \text{ m}^3 \text{ /year}$$

$$\text{Service coverage (SC)} = \frac{ACWA}{TMWD} * 100\% ; \frac{1,582,054}{3,669,395.8} * 100\%$$

Thus, Service coverage would be **43.11** % which is still less than half.

6.2 Water Loss Analysis

The total water loss has been also evaluated based on percentage of system input volume, length of main and number of connections. Generally, based on the analysis results the total water loss from the system is 939,344.42m³/year and is approximately 38% of the system input volume. This figure is higher compared with the average for developing countries (35%) according to Kingdom et al. (2006). The main reasons for this high loss of water are the present way of water network management with poor maintenance in which the problems are tackled only when there is clear evidence of failure and the insufficient financial resources of the utility.

The loss percentage during the rainy season (July-September) is higher as compared with the long dry season. One of the reasons for this seasonal variation is lack of leak detection activities. As a result in the rainy season losses on the surface can go unnoticed for a long period of time as it is difficult to visually inspect them. However, in the dry season the losses from the system can simply inspected visually as they brought themselves to the surface and actions will be taken to control the losses as a result the loss percentage will be minimized.

Apparent loss

This component of the total water loss volume includes the loss due to unauthorized consumption, customer metering inaccuracies and data handling errors and is aggregated to 247,195.9m³/Year. This loss amount covers 10 % of the total system loss. This result signifies more of the loss in the system as real loss which is mainly caused due to deterioration of the existing distribution system infrastructure.

Unauthorized Consumption

This volume of water includes theft and illegal connections. As there is no any means to determine this quantity of water, its volume is estimated based on the system input volume. Accordingly the unauthorized consumption amounts to 61,798.975m³/Year which is about 2.5% of the system input volume.

Customer Metering Inaccuracies

The total volume of loss due to meter in accuracy in the system is 123,597m³/Year. This apparent loss of water accounts for approximately 5% of the system input volume for the fiscal year and translates to lost revenue of approximately 617,989.75 Ethiopian Birr. Generally, in the case of Jijiga the main reason for this high meter under registration is the deterioration of water meters with age, resulting in inaccurate readings. This is highly influenced by the lack of water meter testing and replacement program and unlimited service year for meters in the distribution system.

Real loss

This category includes the volume of water lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering. In this

specific study the real loss volume is found to be 704,508.32m³/Year. This figure indicates the deterioration of water supply system, water supply management problem and urgent need of a leakage control program.

Unavoidable Annual Real Losses (UARL)

This category represents the allowable volume of real losses from the system, which estimates a volume of leaks that are undetectable or would be uneconomical to repair during the year. This can help to evaluate the feasibility of real loss minimization (provides better understanding of real loss components). Based on the analysis this volume for Jijiga town water utility is 123,597m³/Year.

Potentially recoverable real loss

The recoverable real loss which indicates the amount of real loss that can be recovered through active leakage control strategies/practice is found to be 83,992m³/Year. The figure signifies the need for active leakage control strategies and efficient system management.

Performance indicators Non-Revenue Water

The detailed financial PI for non-revenue water is based on the percentage by value of the water, rather than the percentage by volume (Mutikanga et al., 2010). Accordingly for this case the loss was expressed as percentage by cost of operating system and is found to be 17.4%. This figure shows that the water loss from the distribution system results in 977,498 Birr loss in the fiscal year of the study period.

Apparent loss per service connection

The apparent loss per service connection in Jijiga water utility is 25.2 l/connection/day. Real loss per service connection

The real loss per service connection in Jijiga water utility is 128.14 l/connection/day. This shows that the distribution system of Jijiga water utility is more susceptible for burst and leakage.

Infrastructure leakage index

This PI is a measure of how well a distribution network is managed for the control of real losses, at the current operating pressure (Liemberge & Farey, 2004). Based on the analysis the ILI value for Jijiga town is 1.53.

This ILI value shows that the current annual real losses are assessed as being around 1.5 times as high as the unavoidable annual real loss for the system. In other words options may exist for lowering annual real loss volume to around two third of the current annual real losses, if there are no changes in the current pressure management regime. In practical terms, ILI values close to 1.0 mean that world-class leakage management is ensuring that annual Real Losses are close to the Unavoidable or Technical Minimum value at current operating pressures. However, in the case of Jijiga with aged distribution system and lack of leakage management activities, achieving lower ILI value shows inapplicability of the PI for the town water utility.

Water loss reduction strategies

The ultimate goal of the NRW reduction strategy is to reduce the level of losses to a point where the acceptable level or economic level of losses is reached and maintained (Farley & Liemberger, 2005). Nonetheless, in order to provide an initial reference point for the start of the program, a preliminary target is proposed. This target for the case of Jijiga town is to reduce water losses from the current 38% to around 20 % of the annual system input in targeted year 2035. Based on this study and the existing water supply situations of Jijiga town the following short and long term strategies are outlined in order to improve the existing situation and that help to achieve the target. The areas which are given most focus in the strategy are data collection, record keeping, meters accuracy and pipe and shut valve replacements.

1. The first phase concentrates on collecting accurate data for future needs and improving the efficiency of the water network by renovating shut valves.
2. The second phase aims to control pressure to agreed levels and replace pipes systematically.

The monitoring of the system which is started in the first phase should be maintained during the second phase as well, especially to give beneficial feedback to the managers of the water sector.

6.3 Water Demand Determination

6.3.1 Population forecasting

The water demand of a particular city is proportionally related with the population to be served. The population of Jijiga city from Ethiopian CSA report, which is carried out in year 2007, was indicated 125,584 and it was used as base population for current estimation. According to CSA, the regional level annual growth rate for urban population (2015) was allocated as 4.11%. Using the above CSA (2007) census data as a base, and applying exponential population forecasting method, the recent (2015) estimated population figure for Jijiga city was presented in table 6.2 below.

$$P = P_0 *(1+r)^n$$

Where:

P = Estimated population figure

P₀ = Base population figure

r = Growth rate and,

n= Number of year

Table 6-2: Jijiga city projected population figure (2010-2035)

Description	Unit	2007	2010	2015	2020	2025	2030	2035
Growth rate	%		4.11	4.11	4	3.8	3.6	3.4
Jijiga Town Urban Population	No	125,584	141,714	173,330	210,883	254,113	303,268	358,450

Source: (CSA, 2007) census

Therefore, regard to the above table 6.2; the estimated total population figure of Jijiga city was 173,330 during (2015).

6.3.2 Diurnal Curves of Jijiga City Water Supply System for Domestic Demand

Each city has its own unique level of usage that is a function of recent climatic conditions and the time of day. Economic growth also influences demands, but its effect occurs over

periods longer than the typical modeling time horizon, and it is accounted for using future demand projections. Figure 6.2 illustrates a typical diurnal curve for a research area. There is relatively low usage at night when most people sleep, increased usage during the early morning hours as people wake up and prepare for the day, decreased usage during the middle of the day, and finally, increased usage again in the early evening as people return home. The following hourly demand variation coefficients have been used in sizing the reservoir.

Reservoirs are provided to balance the hourly fluctuating water demand to be satisfied. The sizing of the reservoir is done for the maximum day water demand. The following hourly demand variation coefficients have been used in sizing the reservoir.

Table 6-3: hourly demand variation coefficients

Hours	Coefficients
0	0.3
1	0.3
2	0.3
3	0.3
4	0.3
5	0.7
6	1.1
7	1.9
8	1.9
9	1.5
10	1.5
11	1.4
12	1.4
13	1.3
14	1.2
15	1.5
16	1.6
17	1.5
18	1.3
19	1
20	0.7
21	0.5
22	0.4
23	0.3

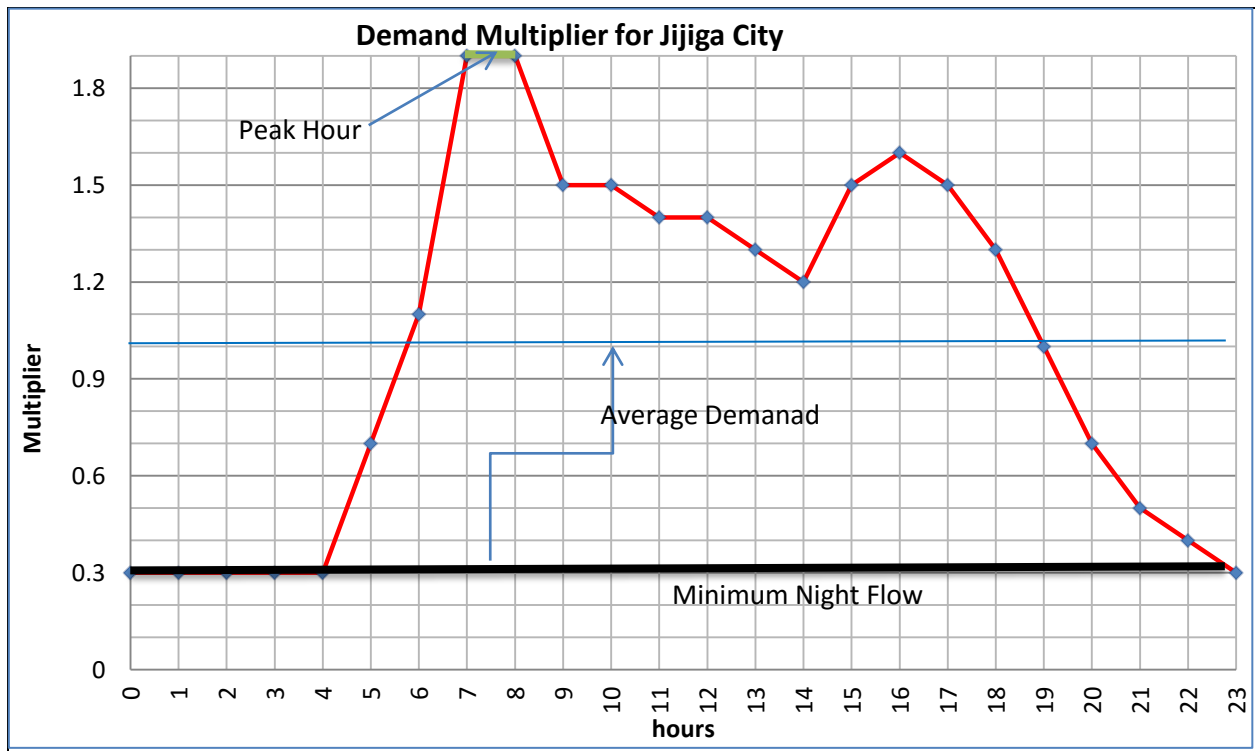


Figure 25 : Variation of domestic water demand during the day

6.4 Current and Future Water demand Analysis

6.4.1 Population Forecasting

The total population of Jijiga city for the base year which is 2015 is estimated to be 173,330 with an average annual growth rate of 4.11% as per the CSA Final result of 2007. This figure has been adopted for this research.

Table 6-4: : Projected annual city Population

Population According to	Projected population							
	2007	2010	2015	2020	2020	2025	2030	2035
CSA	125,584	141,714	173,330	210,883	254,113	303,268	303,268	141,714
Yearly Growth Rate in (%)		4.11	4.11	4	3.8	3.8	3.6	3.4

N.B To estimate the Settlement population five years from now using the recommended growth rate and both figures applying exponential rate function as follows;

$$FP = pp (1 + r)^{n \text{ yrs}}$$

Where

Fp = Future population

Pp= Present population

R = Rate of population growth (%)

n yrs = number of years

6.4.2 Domestic Water Demand

Domestic water demand includes water for drinking, for food preparation, washing, cleaning and miscellaneous domestic purposes. The amount of water used for domestic purpose varies depending on the lifestyle, living standard, climate, mode of service and above all on the affordability of the users. The theoretical domestic water demand for different population of any city is estimated for different population categories of domestic consumers. The water supply systems of most cities in Ethiopia have five mode of service in which the populations are served.

F. House Tap User

G. Yard Tap User

H. Neighborhood Tap User

I. Public Tap User

J. Traditional source user

Mode of service	Per capital water Demand(l/c/d)
House Tap user	70
Yard Tap user	30
Neighborhood Tap user	40
Public Tap user	25

Table 6-5:: Per capita demand estimate, for stage II, MoWIE, 2006

But, actually there are people using traditional source users and people buying water from vendors. However, this mode of service is not considered in the analysis as it is not their exclusive alternative and they are preferring this option as secondary choice to compensate for their short fall

of water demand when their primary mode of service are interrupted or is insufficient.

The theoretical domestic water demand for different population of any city is estimated for different categories of domestic consumers. The assumptions are based on the percentage service level for house connections, yard connections and public fountain users previously studied by Water Works Design and Supervision Enterprise (WWDSE) and conducted survey.

6.4.3 Per capita water demands & growth of domestic water demand

The per capita demand initial figures are adopted from the MoWIE design guidelines. The growth rate is also based the demand projection table prepared by MoWIE, 2006. In this regard the stage-II demands are taken considering the rapid economic and population growth the city. The table below shows the initial per capital figure and its growth pattern considered in the design of the system.

The resulting demand using annual growth 5.74 % (urban model, MoWE) is presented below.

Mode of service	2015 (Base Year)	2020	2025	2030	2035
HTU	70	74	78	82	86
YTU	30	32	34	38	42
PTU	25	26	28	29	30.5
NTU	40	42	45	47	50

Table 6-6: Projected Per capita Demand in liter/sec

In projecting the above service levels again the MOWIE recommendations were adapted. The table below show the projection pattern adopted.

Mode of Service	2010	2015	2020	2025	2030	2035
HC	5	5.67	6.43	7.13	7.85	8.56
YC	21.75	24.63	27.89	30.90	33.97	37.04
YCS	27.80	30.65	33.95	36.95	40.03	43.10
PF	45.45	39.05	31.73	25.02	18.16	11.30

Table 6-7: Mode of Services Projected (Derived from Urban Model, MoWE) ending Year by (%)

In order to assign the corresponding water demand the population has been forecasted with their respective mode of service.

Mode of Service	2010	2015	2020	2025	2030	2035
Total Populations	146,714	184,330	201,005	265,113	314,268	369,450
Jijiga town population	141,714	173,330	210,883	254,113	303,268	358,450
Jijiga University Community	5,000	11,000	11,000	11,000	11,000	11,000
House Connection	7,086	9,828	13,560	18,118	23,791	30,683
Yard Connection	30,823	42,691	58,815	78,513	103,010	132,758
Public tap User	64,409	67,685	58,815	63,588	55,084	40,517
NTU	39,396	53,126	58,815	93,895	121,383	154,492

Table 6-8: The Projected Population by Mode of Service

6.4.4 Projected Per Capita Average Domestic Water Demand

The projected per capita average domestic water demand for a particular year can be obtained by multiplying the per capita water demand in each category of mode of service obtained from table with the corresponding population figure of the respective year obtained from table and summing the result for all demand categories.

For this specific research the water demand of the different patterns were projected to twenty years from the base year. Therefore taking the year 2015 as a base year the end for the projection would be 2035.

This section deals with the water demand projection for the city. Present and future development potentials are considered, along with improved living standards to arrive at the projected water demand.

6.4.4.1 Growth potential

Jijiga city is the capital of the Somali people's regional state, Jijiga zone and Jijiga woreda. It is the center of trade for the region with road network connecting it to Addis Ababa, Harar and Togowajale (eastern border city and trade center).

6.4.4.2 Research Evaluation Horizon

The water supply development for Jijiga has been considered a design period of 20 years for our specific purpose. The water capacity constraints as envisaged from the existing trend were appeared in early 2015. Thus research evaluation horizon considered in between 2015-2035 as design period of the project.

6.4.4.3 Basis for water demand projections

The water demand for the research evaluation horizon considered in between 2015-2035 has been structured to accommodate the following categories; the current not served population and vendor served sections are to benefit from the new development through access to public taps. The population growth rate for both the city and on line beneficiaries has been calculated on medium growth rate variant as pre supposed by CSA and taken from the previous feasibility by Federal Water Works Design and Supervision Study.

6.4.4.4 Climatic and socio-economic grouping

The water requirement is also directly related to the climatic condition and the socioeconomic conditions of a particular city. Cities with high average temperature need higher water than those having lower average temperature and cities with higher socioeconomic activities require higher quantity of water than cities with less economic activities. In those cities with higher economic activities and developments, the standard of living will be high requiring more water for domestic as well as non domestic consumptions. In addition, the religious background also plays a significant role on the water demand.

Thus, as Jijiga is one of the cities in the country with high social, economic and religious values, the per capita water demand of each mode of services have been adjusted to account these values.

Both the climatic and socio-economic adjustment factors are applied in estimating the average domestic water demand.

Year	2015	2020	2025	2030	2035
Town Population	167,956	204,344	246,234	293,864	293,864
University Community	11,000	11,000	11,000	11,000	11,000
Total Populations	173,330	210,883	254,113	303,268	358,450
% of population using:					
HTU	6	6	7	8	9
YTU	25	28	31	34	37
PTU	39	32	25	18	11
NTU	31	34	37	40	43
Population by level of service					
HTU	9,828	13,560	18,118	23,791	25,960
YTU	42,691	58,815	78,513	103,010	112,320
PTU	67,685	66,913	63,588	55,084	34,279
NTU	53,126	71,595	93,895	121,383	130,708
Per-capita demand (l/c/d)					
HTU	70	74	78	82	86
YTU	30	32	34	38	42
PTU	25	26	28	29	30.5
NTU	40	42	45	47	50
Demand by mode of service (m³/d)					
HTU	687.9	1003.4	1413.2	1950.9	2232.5
YTU	1280.7	1882.1	2669.4	3914.4	4717.5
PTU	1692.1	1739.7	1780.5	1597.4	1045.5
NTU	2125.0	3007.0	4225.3	5705.0	6535.4
Total domestic demand in (m³/d)	5785.8	7632.2	10088.4	13167.7	14530.9
In (l/s)	67.0	88.3	116.8	152.4	168.2
Adjustment Factors					
Socio-economic adjustment factor	1.1	1.1	1.1	1.1	1.1
Climatic Adjustment factor	1	1	1	1	1
Adjusted Domestic Water Demand in (m³/d)	6364.4	8395.4	11097.2	14484.5	15984.0
In (l/s)	73.66	97.17	128.44	167.64	185.00

Table 3-9: Domestic demand per mode of connection

SUMMARY OF DEMAND						
Demand Categories		2015	2020	2025	2030	2035
Domestic Demand	(m ³ /d)	6,959	8,404	12,001	15,379	16,625
Public Demand	(m ³ /d)	696	840	1,200	1,538	1,662
Animal demand	(m ³ /d)	1,044	1,261	1,800	2,307	2,494
Average day demand	(m ³ /d)	8,699	10,505	15,002	19,223	20,781
Loss in distribution system (%) of water supplied		13	16	19	23	28
Water loss in	(m ³ /d)	1,131	1,681	2,850	4,421	5,819
Total average day demand	(m ³ /d)	9,830	12,186	17,852	23,645	26,599
	(l/s)	114	141	207	274	308
Maximum Day Demand	(m ³ /d)	13,396	16,072	22,803	29,027	31,171
	(l/s)	155	186	264	336	361
Peak hour Demand	(m ³ /d)	21,434	25,716	36,484	46,444	49,874
	(l/s)	248	298	422	538	577

Table 6-10: Summary of Water Supply Demand

6. 5 Existing Water Supply System Gap Identified

The existing water supply to Jijiga city water supply system was 4,320m³/day. This water is supplying in the study area at both 24hrs and 12hrs at lower and higher elevation area respectively. Hence the total demand including the UFW in the system is 9,830m³/day for supplying water 24hrs. To fill the gap additional 5,510m³/day amount of water is required to fulfill the supply shortage and demand of Jijiga city water supply system.

S.no	Indicators	Expected Target to be achieved	Current status	Identified Gaps of the existing WS system
1	Water supply coverage	100%	43%	57%
2	Per capita water supply demand	50(l/c/d)	25(l/c/d)	25(l/c/d)
3	2015 demand and supply condition	9830m ³ /day	4,320m ³ /day	(-)5,510m ³ /day
4	Continuity of water supply	24hrs	24-12hrs	12hrs
5	Extent of non revenue water (UFW)	5-20%	37.80%	-17.80%
6	Updating of water line network	100%	70%	30%
7	Fire hydrant (based on calculation)	8	5	3

Table 6-11: The Projected Population by Mode of Service

6.6 Reservoir Capacity Determination (Analytical Method)

Table 6-122: Reservoir Capacity Determination (Analytical Method)year-2025

Year 2025					
Maximum day demand =746.62m ³ /h = 207.39l/s					
Hour	Hourly demand variation factor	Consumption (m ³ /h)	Supply (m ³ /h)	Storage (m ³ /h)	Cumulative storage(m ³)
0	0.3	223.986	746.62	522.634	522.634
1	0.3	223.986	746.62	522.634	1045.268
2	0.3	223.986	746.62	522.634	1567.902
3	0.3	223.986	746.62	522.634	2090.536
4	0.3	223.986	746.62	522.634	2613.17
5	0.7	522.634	746.62	223.986	2837.156
6	1.1	821.282	746.62	-74.662	2165.198
7	1.9	1418.578	746.62	-671.958	1493.24
8	1.7	1269.254	746.62	-522.634	970.606
9	1.5	1119.93	746.62	-373.31	597.296
10	1.5	1119.93	746.62	-373.31	223.986
11	1.4	1045.268	746.62	-298.648	-74.662
12	1.4	1045.268	746.62	-298.648	-373.31
13	1.3	970.606	746.62	-223.986	-597.296
14	1.2	895.944	746.62	-149.324	-746.62
15	1.5	1119.93	746.62	-373.31	-1119.93
16	1.6	1194.592	746.62	-447.972	-1567.902
17	1.5	1119.93	746.62	-373.31	-1941.212
18	1.3	970.606	746.62	-223.986	-2165.198
19	1	746.62	746.62	0	-2165.198
20	0.7	522.634	746.62	223.986	-1941.212
21	0.5	373.31	746.62	373.31	-1567.902
22	0.4	298.648	746.62	447.972	-1119.93
23	0.3	223.986	746.62	522.634	-597.296
Maximum day demand in(m ³ /day)		17919	17919		

Year	Maximum Storage (m ³)	Maximum Deficit (m ³)	Reservoir capacity (m ³)
2025	2837.156	-2165.198	5000.00

From the curve above, the size of the reservoir for phase I is:-

$$\begin{aligned} \text{Capacity} &= \text{Storage} + \text{Deficit} \\ &= 2,837 + 2,165 = 5,000\text{m}^3 \end{aligned}$$

The mass curve shown below which are generated from the daily consumption and supply data's are shown in the figure below.

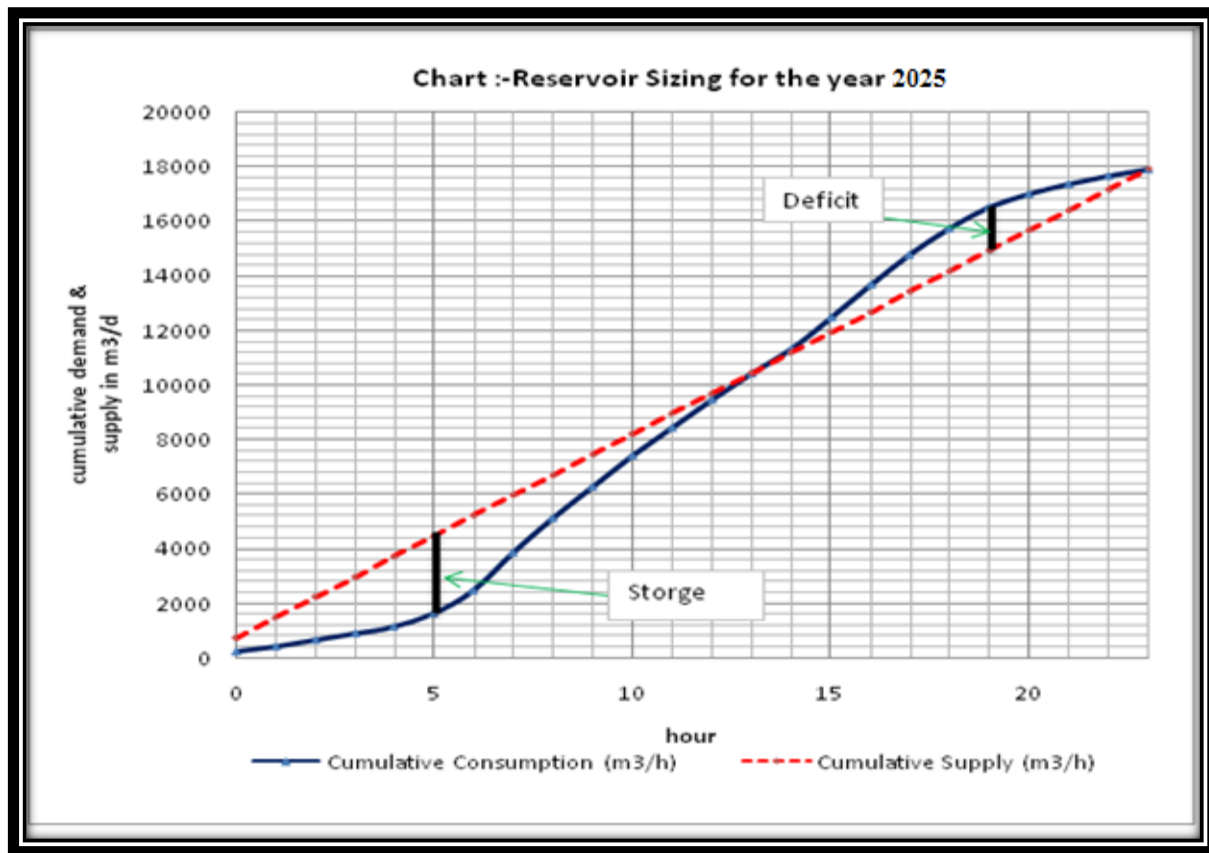


Figure 26 : Reservoir sizing for the year 2025

Table 6-13: Reservoir Capacity Determination (Analytical Method)-year 2035

Year 2035					
Maximum day demand =1442.32m ³ /h=400.64/s					
Hour	Hourly demand variation factor	Consumption (m ³ /h)	Supply (m ³ /h)	Storage (m ³ /h)	Cumulative storage(m ³)
0	0.3	432.696	1442.32	1009.624	806.05
1	0.3	432.696	1442.32	1009.624	1815.674
2	0.3	432.696	1442.32	1009.624	2825.298
3	0.3	432.696	1442.32	1009.624	3834.922
4	0.3	432.696	1442.32	1009.624	4844.546
5	0.7	1009.624	1442.32	432.696	5277.242
6	1.1	1586.552	1442.32	-144.232	5133.01
7	1.9	2740.408	1442.32	-1298.088	3834.922
8	1.7	2451.944	1442.32	-1009.624	2825.298
9	1.5	2163.48	1442.32	-721.16	2104.138
10	1.5	2163.48	1442.32	-721.16	1382.978
11	1.4	2019.248	1442.32	-576.928	806.05
12	1.4	2019.248	1442.32	-576.928	229.122
13	1.3	1875.016	1442.32	-432.696	-203.574
14	1.2	1730.784	1442.32	-288.464	-492.038
15	1.5	2163.48	1442.32	-721.16	-1213.198
16	1.6	2307.712	1442.32	-865.392	-2078.59
17	1.5	2163.48	1442.32	-721.16	-2799.75
18	1.3	1875.016	1442.32	-432.696	-3232.446
19	1	1442.32	1442.32	0	-3232.446
20	0.7	1009.624	1442.32	432.696	-2799.75
21	0.5	721.16	1442.32	721.16	-2078.59
22	0.4	576.928	1442.32	865.392	-1213.198
23	0.3	432.696	1442.32	1009.624	-203.574
Maximum day demand in(m ³ /day)		34616	34616		

Year	Maximum Storage (m ³)	Maximum Deficit (m ³)	Reservoir capacity (m ³)
2035	5133.01	-3232.446	8365.46

The size of the reservoir for phase II is:-

$$\begin{aligned} \text{Capacity} &= \text{Storage} + \text{Deficit} \\ &= 5500 + 2900 = 8400 \text{ m}^3 \end{aligned}$$

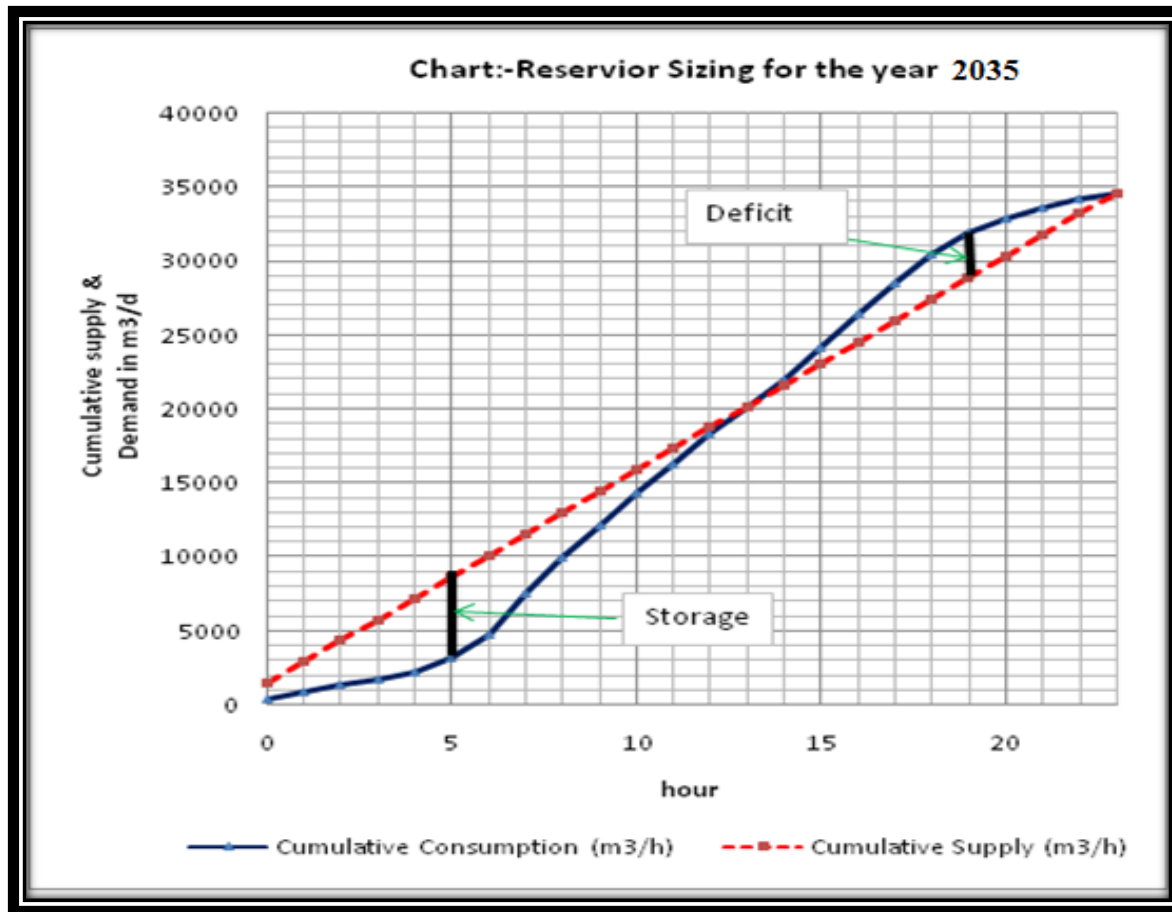


Figure 27 : Reservoir sizing for the year 2035

Thus from the calculations and curves above, it is required to provide 5000 m³ capacity reservoir for phase I and an additional 3500 m³ reservoir for phase II. Two new reservoirs were proposed & designed. The first is 3000m³ reservoir which was constructed along the Jijiga-Degehabur road having floor level of 1758.25masl and the second 1000m³ reservoirs which was built to the right side of the road to Chinaksen has a floor level of 1718.80 masl.

The old existing 350m³ reservoir is integrated in the new system as supposed to be maintained with some rehabilitation work done. The wall of the reservoir has to be chiseled and plastered with rich cement mortar. The internal wall must be painted. Float valve must be provided to automatically close the inflow in case of reservoir filling.

The new reservoirs were constructed from reinforced concrete structure and have circular shape with flat roof slab. The new 3000m³ reservoir is provided with valve room to accommodate inlet, outlet, and drainpipes and also chlorine tank for chlorine mixture. The valve room is positioned in between the 1st and 2nd phase reservoirs. The construction of the valve room is planned in such a way that it could accommodate both phase pipe installation works.

Float valves were provided at the inlet to each reservoir to shut off the installed pumps in the boreholes to avoid waste of water due to overflow from the reservoir. Water meter is provided on the main transmission line from the 3000m³ and 1000m³ reservoir to record the total flow of water to the distribution network. The reading should be recorded daily so that the data could be utilized for future study in estimating the actual water demand of the city and loss in the distribution network. To inspect the water level in the reservoir, level indicator will be fitted to each reservoir. The compound of the reservoir will be fenced and also a guardhouse is constructed.

6.7 Simulation Results

6.7.1. General information of simulation

The aim to conduct the hydraulic performance assessment model is to evaluate and quantify the consequences due to failure events in water distribution systems. The performance assessment by the help of model developed in this thesis mainly consists the hydraulic part only. Regarding component failure and performance measure mathematical models were used to clearly understand the status of the level of service.

In this case, the Water CAD 6.5 software was preferred to perform hydraulic simulation since it is freely available and user friendly, particularly for water supply like the one under the study. The Water CAD 6.5 performs extended period and single snapshot simulation of hydraulic and water quality with in pipe networks. The software tracks the flow in the distribution system, pressure on the node and head of water in the reservoir to understand the reality situation on the ground. For that matter, running a single snapshot simulation was helpful while performing preliminary model calibration. However, it should not work for the assessment of distribution system. Hence, the extended period simulation was exclusively used for entire model calibration and assessment

effort. In most of the cases it uses as a research tool for improving our understanding of the movement and fate of drinking water constituents in the system. The core intention of the research is to understand the hydraulic situation of the component; however, the model can also help assess alternative management strategies for improving water quality in the system. Generally, Water CAD 6.5 contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

- No limit on the size of the network that can be analyzed
- Computes friction head loss, including minor head losses for bends, fittings, etc.
- Models constant or variable speed pumps
- Computes pumping energy and cost models¶ various types of valves including shutoff, check, pressure regulating, and flow control valves
- Allows storage tanks to have any shape (i.e., diameter can vary with height)
- Considers multiple demand categories at nodes, each with its own pattern of time variation
- Models pressure-dependent flow issuing from emitters (sprinkler heads) can base system operation on both simple tank level or timer controls
- And on complex rule-based controls (Rossman, 2000)

For the extended period of simulation, the demand pattern has taken as 1 for 12 hours and 0 for 10 hours because the system is totally open point discharge throughout the service time and closed for the given 10 hours of time.

6.7.2. System Maps development

In building system model, it is typically useful to draw system map for the water distribution system because it illustrates a wide variety of valuable characteristics. System maps may include information such as:

- Pipe alignment, connectivity, material, diameter, and so on
- The locations of other system components, such as tanks and valves

- Pressure zone boundaries
- Elevations
- Miscellaneous notes or references for tank characteristics
- Background information, such as the locations of roadways, streams, planning zones, and so on
- Other utilities

For this study system map was done by the data collected from the site. It is as built system map the map on the design has big variation on arrangement and positioning compared to the existing.

6.7.3 Steady-state Analysis

The model has been performed 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 software simulates Steady-State hydraulic calculation based on mass and energy conservation equations principle. Refer appendix-A-2 & A-3 for the results.

6.7.4 Extended Period Simulation

The system conditions have been computed over twenty-four hours with a specified time increment of three hour and starting model run time at 12:00 PM. The software simulates non-steady-State hydraulic calculation based on mass and energy conservation principle.

The model can be simulated for every three-hour time setup in the twenty- four hour duration. However, for the analysis the peak and minimum hours, demand has been simulated to identify the current problems of the system and then to redesign the model based on the design criteria of the water distribution system, parameters like pressure and velocity.

The attached results of the system performed run from:

- 1. 12:00 PM – 4:00 AM for the minimum hour consumption.**
- 2. 7:00 AM – 8:00 AM for the peak hour consumption.**

6.8 Summary of the Simulation Result

6.8.1 Pressure

Pressure in water distribution system has to be maintained optimum; as to efficiently make water available to each demand category including at instances of fire fighting (high withdrawal period) and as to reduce leakage as well as pipe breakage across the system. The former one is frequently achieved in setting minimum pressure to be maintained at each junction. The later one is achieved differently in setting allowable pressure to be maintained in the system.

According to (Swamee et al 2008) the minimum design nodal pressures are prescribed to discharge flows onto the properties. The general consideration is that the water should reach up to the stories of low rise buildings in sufficient quality and pressure, considering fire fighting requirement. In the case of high rise building, booster pumps are installed in the water supply system to furnish for the pressure head requirements. With these considerations, various codes recommended minimum ranging from 8m to 20m for residential areas.

Similarly, (Johnson et al 2009) recommend;

1. Minimum pressures at **peak hour demand**: sufficient to serve the highest supply point in the network. Typically mains pressures of not less than 15m to 20m would be required to serve buildings up to three stories high. Higher pressures may be necessary in some areas where there are significant numbers of dwellings exceeding three-storey height; but high rise buildings are normally required to have their own booster supply.
2. Maximum static pressure during low demand periods: typically at night should be as low as practicable to minimize leakage. For flat areas a maximum static pressure in the ranges 30m to 45m is desirable. The maximum pressure in mains is considered not to exceed 80m to limit leakage and stresses on pipes (Mosissa, 2008).

For city of Jijiga, the city water supply service is using operating pressures which ranges from 0.60 Bar to 11.27 Bar: However, there was no defined maximum and minimum pressure ranges set by the office. Therefore, literature based recommendation for optimum operating pressure was used to assess system hydraulic performance. With regard to current simulation, result for pressure at average day demand is summarized in Table 6.11 and Fig.6.6 shown in detail.

Table 6-13: Distribution of actual node pressure at average day demand

Pressure (Bar)	Nodes (number)	Percentage (%)
>8 Bar	18	8.61
7-8bar	39	18.66
6-7bar	44	21.05
5-6bar	34	16.27
4-5bar	24	11.48
3-4bar	33	15.79
2-3bar	13	6.22
<2Bar	4	1.91
Total	209	100

As depicted in Table 6.11, shows that 1.91% of nodes are failed to satisfy desirable minimum pressure during the average day demand situation and this is almost negligible. But, on the other hand 8.61% of nodes exceed maximum allowable pressure of 80m. While 89.47% of nodes are in the permissible pressure ranges of minimum 20m and maximum 80m. From the above table results 10.53% should be improved to be under the minimum pressure criteria in the water supply system.

Legend

- Black-pipe
- Cyan 1Bar
- Red 2Bar
- Green 4Bar
- Yellow 6Bar
- Blue 8Bar

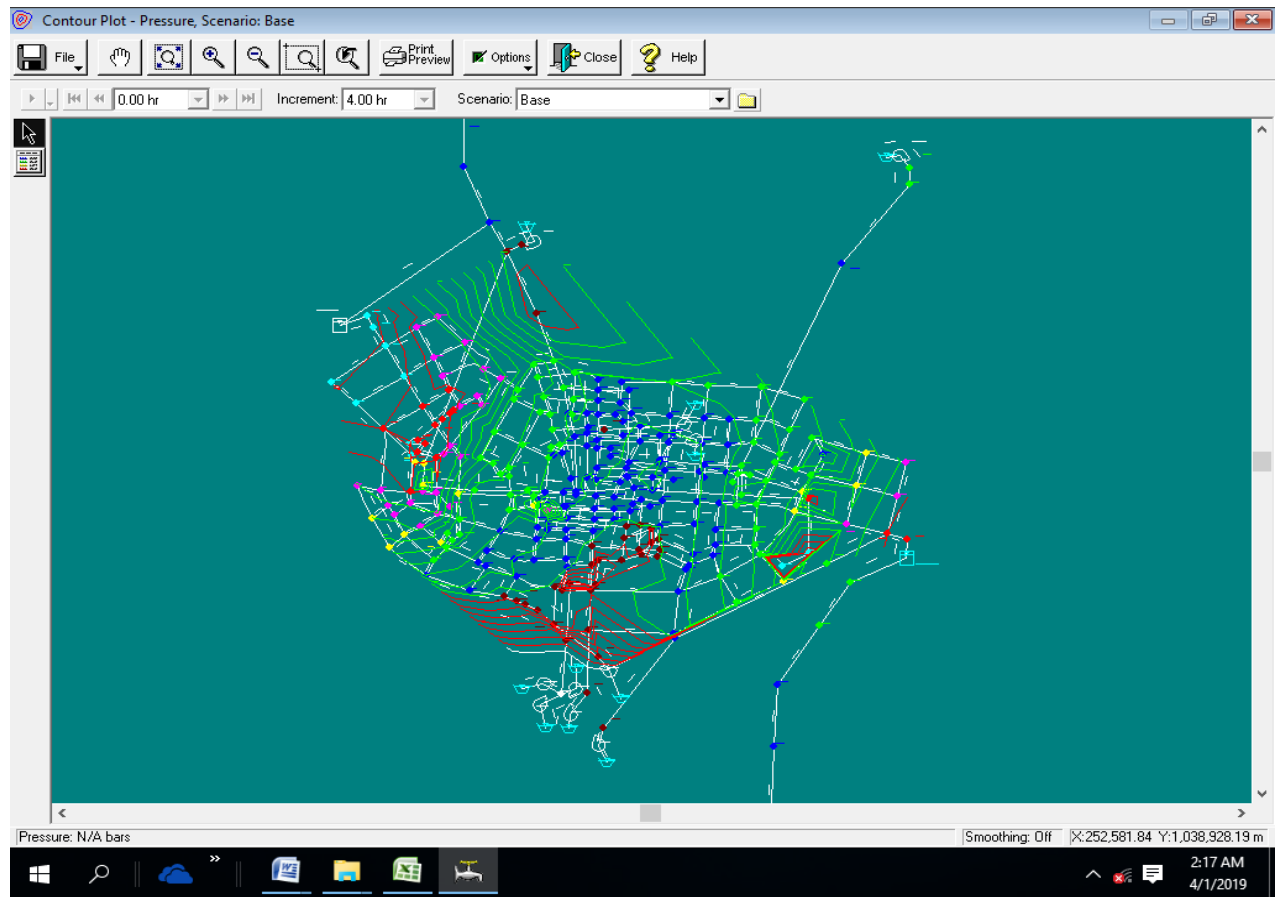


Figure 28 : shows actual node pressure contour at average day demand consumption hour

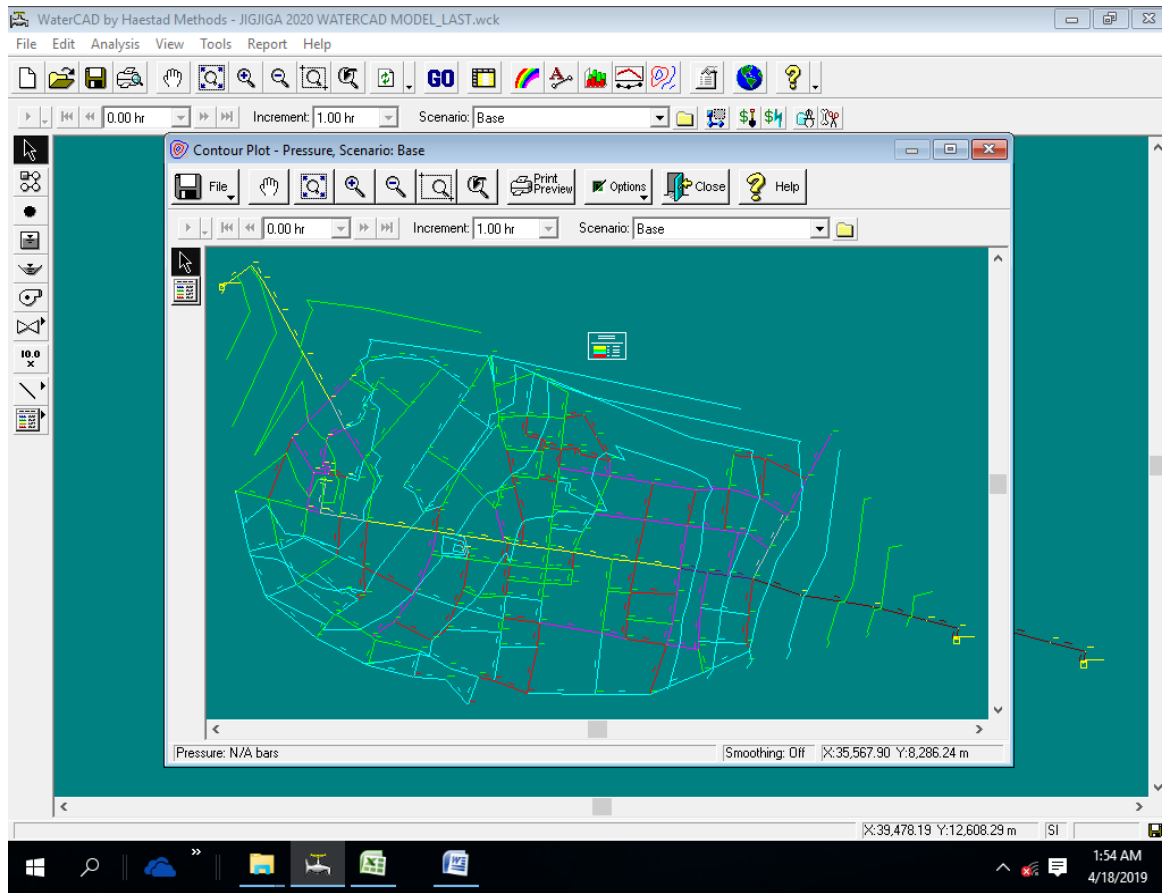


Figure 29 : shows actual node pressure contour at average day demand consumption hour

Figure 6.6 Shows actual node pressure contour at average day demand consumption hour. With regard to current simulation of actual water distribution condition at peak hour demands as shown below in both tabular and figure and the results for pressure at peak flow is summarized in Table 6.12 and Figure 6.7 and detailed in Appendix A-II, pressure on this peak hour is the most important for design and improving and expansion of existing system, updating and installation of new water supply distribution schemes.

Table 6-14: Distribution of actual node pressure at **peak hour flow**

Pressure (Bar)	Nodes (number)	Percentage (%)
>8 Bar	0	0
7-8bar	9	4.31
6-7bar	21	10.05
5-6bar	35	16.75
4-5bar	37	17.70
3-4bar	25	11.96
2-3bar	40	19.14
<2Bar	42	20.10
Total	209	100

As depicted in Table 6.12, 20.10% of nodes are below the minimum desirable pressures (20m) during peak hour demand. There are no nodes exceeded to maximum allowable pressures of 80m. While 80.90% of nodes are in the permissible pressure ranges of minimum 20m and maximum 80m pressure. Estimating pressure distribution at the peak hour demand is the governing parameters for the purposes of design and improving the existing water distribution network next to minimum consumption hour demand type. At this peak hour level the water consumption demand expected to more over all the hour demands. Demand is peak especially at morning and early evening for domestic water consumption or residential use. Therefore from the above Table 6.12 pressure which less than the minimum pressure must be improved for the purpose of to demand and water quality problems in the study area.

Legend

- Black-pipe line
- Green 1Bar
- Red 2 Bar
- Blue 4 Bar
- Yellow 6Bar
- Magenta 8 Bar

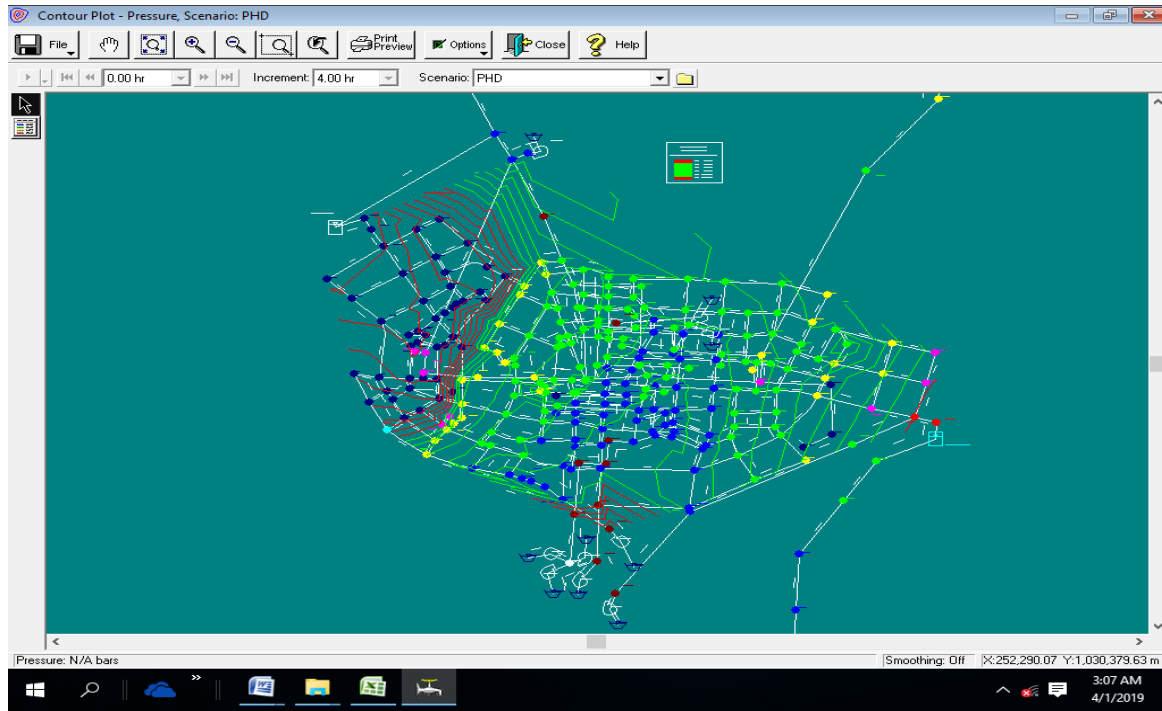


Figure 30 : shows pressure distribution contour map during peak hour flow.

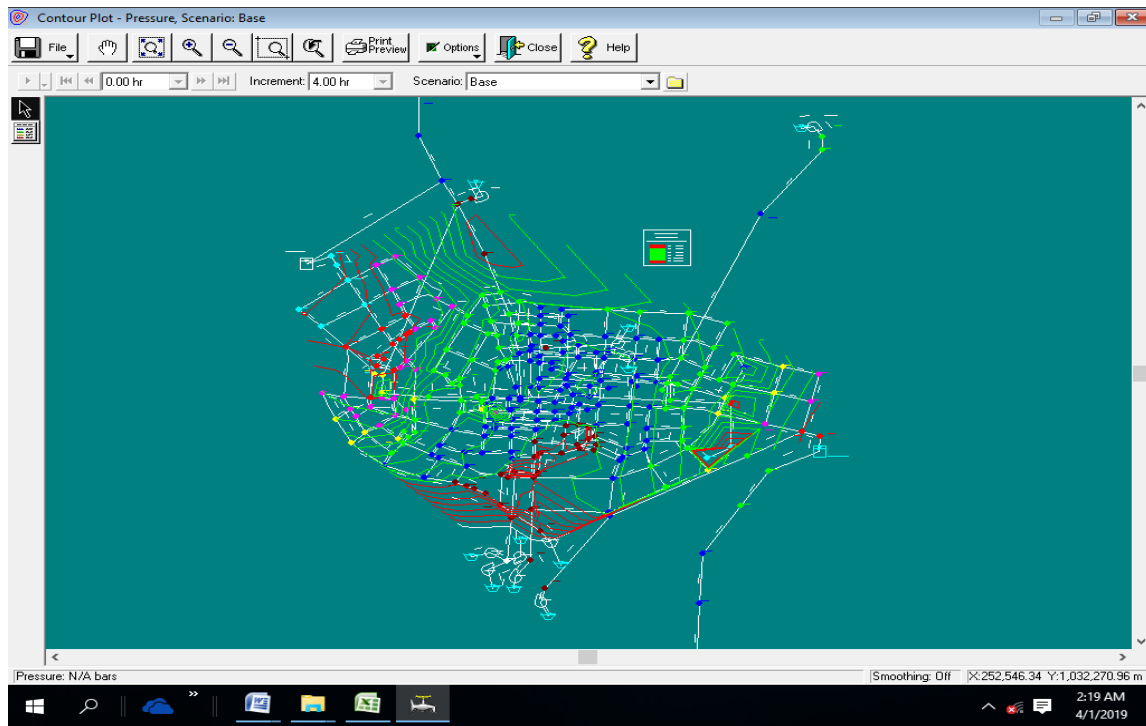


Figure 31 : shows pressure distribution contour map during peak hour flow.

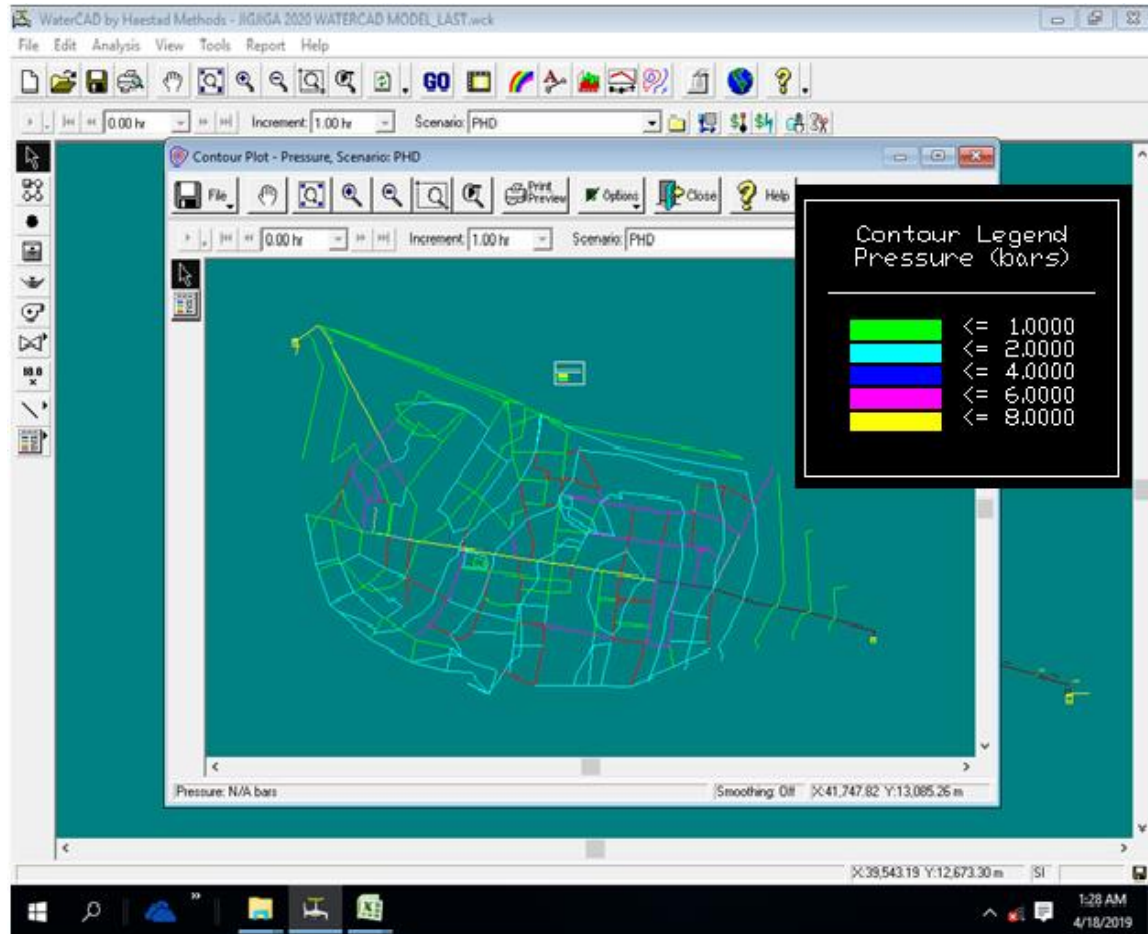


Figure 32 : shows actual node pressure contour at Peak demand consumption hour

As shown in the figure above, nodes located at the green color marked area which is more covered the downstream part of the system with lower elevation, are susceptible to lower pressure (negative pressure) due to under pipe diameter size. There are some reasons that are why the negative pressure is occurred in the water supply distribution system might be as result of the following:

- Properties on high ground; elevations difference remote properties at the end of long lengths of pipe; downstream side demands that are greater than the design demand; negative Q demand pipes of inadequate capacity (too small diameter); pipe size rough pipes (e.g. corroding iron pipes or pipes with a build-up of sediment);

- Equipment failures (e.g. pumps and valves).

In contrary minimum pressures are also observed mainly nodes situated near to tanks. In few instances nodes positioned in middle of network are susceptible to low pressure. Whereas majority of nodes located in relative perfect loop receive optimum pressure which does not violet minimum or maximum allowable pressure range. On the other hand, at night time maximum pressure, maximum water residence time (water age in the pipe) and minimum velocity and leakage rate are expected to be high because at this time no water flow occurred at the distribution. The actual node pressure simulation distribution as shown below Table 6.13 and Figure 6.8 in detail.

Table 6-15: Distribution of actual node pressure at minimum consumption hour

Pressure (Bar)	Nodes (number)	Percentage (%)
>8 Bar	87	41.63
7-8bar	41	19.62
6-7bar	26	12.44
5-6bar	25	11.96
4-5bar	17	8.13
3-4bar	7	3.35
2-3bar	3	1.44
<2Bar	3	1.44
Total	209	100

During low flow typically at mid-night distribution system of case study is marked by excessive pressure. As portrayed in Table 6 .13, Figure 6.8 and detailed in appendix A-II, 41.63% of nodes are liable to extremely high pressure. This figure is extremely high. 1.44% Minimum pressure is also observed during low consumption period. Only 56.93% of nodes are received water of optimum pressure at low consumption hour. As compared to at peak hour Table 6.13, shows about 23.97% nodes with permissible pressure due to excessive demand.

Node pressure at the minimum consumption hour, is very important rather than others two peak and average water demand because, leakage and water quality is deter rioted very high in the system during this low consumption hour. Due to above reasons new and

existing water supply distribution systems often time are designed by taking considerations it as the base parameters. For this study, improving the existing water supply system has been done at both peak and low consumption hour level because minimum and maximum pressures are found than average demand.

Legend P(m)

- Black-pipe line
- Yellow ≤ 5 Bar
- Green 6Bar
- Blue 7Bar
- Red 8Bar
- Magenta 9Bar
- Cyan 10Bar

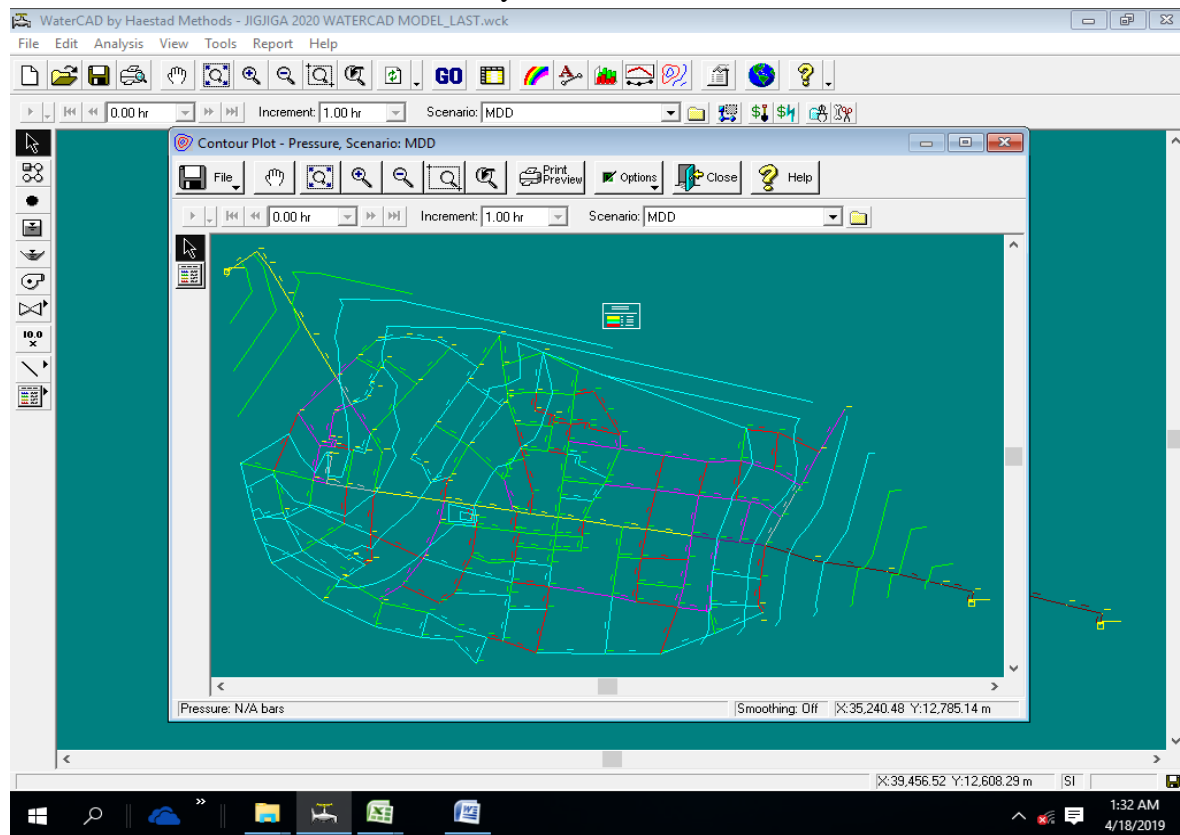


Figure 33 : Shows actual node pressure contour map at minimum consumption hour

6.8.2. Velocity Distribution in Actual Pipe

Velocity of water flow in a pipe is also one of the important parameters in hydraulic

modeling performance evaluation of the efficiency of water supply distribution and transmission line. Velocity distribution is also varying with demand pattern changes. At the peak hour demand the values are different as compare to minimum consumption hour. The water supply system network velocity during peak hour demand is summarized in the Table 6.14 below.

Table 6-16: Distribution of actual pipe velocity at peak hour demand

Velocity (m/s)	Pipe (number)	Percentage (%)
≥ 2.5	4	1.26
2-2.5	6	1.89
1.5-2	21	6.62
1-1.5	82	25.87
0.3-1	181	57.10
0.1-0.3	16	5.05
0.05-0.1	5	1.58
≤ 0.05	2	0.63
Total	317	100.00

As depicted in Table 6.14, during the peak hour demand situations about 1.26% of pipes are failed to satisfy the permissible velocity or maximum velocity in distribution and transmission line ($>2.5\text{m/s}$), in addition to that, 0.63% of pipes also below the minimum velocity at residential tap 0.05 m/s . While, only 98.11% of pipes are in the permissible velocity ranges. Improving or upgrading the existing water supply distribution is also considering and checking the velocity minimum and maximum limit based criteria. For this study velocity is considered as criteria during resizing the pipe diameter. Velocity has also a great impact on water quality as turbidity and the like. Carried out Modeling is helpful in pinpointing the cause of hydraulic efficiency problems. In general the study area of water distribution system has the following major problems with respect to hydraulic network modeling as mentioned below:

- Undersized service pipe diameter
- Oversized service pipe diameter

- Low pressure
- High pressure
- High velocity
- Low velocity

Undersized pipes can usually be found by looking for pipes with high velocities. Increasing the diameter of the pipe in the model should result in a corresponding decrease in velocity and increase in pressure.

No fixed rule exists regarding the maximum velocity in a main (although some utilities do have guidelines). The optimal velocity in pumped lines can range from 1 to 3 m/s, depending on the relative size of the peak and average flow rates (Desalegn, 2005). When checking designs for permissible velocities some engineers use 1.5 m/s as a maximum, other use 2.4 m/s, and yet still others use 3.1 m/s. Consistent low pressure problem is due to trying to serve customers at too high an elevation for that pressure zone. High pressures are usually caused by serving customers at too low an elevation for the pressure zone. Usually, high pressures are easiest to evaluate with model runs at low demands. This range corresponds to minimum night time demands for a typical system. If the engineer feels that pressures are too high, the usual solution is to establish a new pressure zone for the lower elevation using PRVs.

7. Conclusion and Recommendations

7.1 Conclusions:

This study has attempted to evaluate and update the local situation with respect to the water supply coverage and water loss in Jijiga water supply system. The study has also proposed appropriate strategies and techniques for the reduction and control of non-revenue water.

This research has generated several significant results. Pressure and flow velocity and nodal discharges were modeled to provide deeper understanding of the current situation of water distribution network system. Subsequently valuable suggestions were drawn based on finding to improve the situation. However, more comprehensive and detailed understanding, future works are suggested to focus on:

- More local studies are recommended. This is to understand how the water systems perform under the local conditions of operation and management.
- Impacts of various development activities on performance of water distribution system.

In this water supply system, inadequate operation of water distributing components, weak management system and absence of inspection largely contribute to inefficient hydraulic performance which as a result create poor level of service to the satisfaction of user community. In this study, some of the fundamental performance challenges identified and taken as cases to be considered on the system are: -

- Insufficient availability of water on some of water points, uneven distribution
- Evaluation indicated that acceptable minimum and maximum pressures have not been met. During the service hour of the system, parts of the distribution receive water with low pressure and under some circumstances on some of points water is not observed because of the pressure and velocity in the distribution system is contradicting to the permissible minimum requirement.
- Despite the low water supply coverage, the total water loss in the focused area is up to 39.1% of the total system input volume. This is the main issue that Jijiga water supply system is presently struggling with. Because of this most of the customers are not satisfied

in the level of service of the system.

- Malfunctioning of taps and valves, frequent disconnection of joint is observed.
- Poor workmanship and lack of supervision on the construction brought the pipe type and dimension installed different with recommended type and size on some portion of the system.
- Poor management, absence of inspection and O&M

Therefore, about the satisfaction level of service, the system was observed in poor performance which deliver fluctuating amount of water to various demand categories within the user community.

7.2 Recommendations

Based on the findings, the following recommendation are made

- Above all resource conservation must be given priority to guarantee future consumption, hence the system must be maintained to be closed system, which means all taps and gate valves should be replaced.
- Pressure sustaining valves or controlling valves must be installed between two successive junctions on the distribution system in the model to control the occurrences of variation of pressure. These valves start closing and opening either automatically or manually to avoid fluctuation of pressure by maintaining minimum required pressure.
- In addition to the above technical recommendation it is also good the think on establish asset management plan specially to control the water loss.
- The system age is 18 years, the pipes are not deteriorated except the disconnection of joints, breakage of valves and taps so with some improvement on reservoir capacity to 450m³, change on the pipe diameter and installation of pressure reducing valve the future demand can be covered and the design period could also be extended to 25 year.
- The system is large system which can be run by water service so, it requires establishment of utility or satellite water office in central part of the user community.
- Expansion should be based on the careful study with the help of models build for the existing system on the ground.
- To alleviate question of information on the system there must be as built drawing of lay

out which helps to be guide the maintenance crew rather going to field to check the pipe size and arrangement.

- In the system, it was observed that a masonry reservoir constructed for income generating by using irrigation. This reservoir has created challenge on water points because it breaks the pressure for the water points located downstream. So, it must be looped to the original pipe and provide water for the reservoir like other water points. These by far modify the flow rate of water points in the downstream.
 - Water point installed on the transmission main, which is similarly feed with water at the same time with the reservoir. So, to reduce loss both in head and flow it is better to put tanker considering the population in that area so, it is possible to loop and close the pipe and reduced loss by directing water to the main reservoir.
 - Establish chlorine injection system on the reservoir.
 - Finally, concerned government organization or other stakeholder should frequently follow up the system and should be pay enough attention and put forward dimensions on water loss management

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Jijiga City Water Supply Project						
Table: - A-1 Nodal Demand Calculation for Phase II (2025)						
Node Name	Adjoining Nodes	Pipe Arm Length	Pipe arm Share to Node	Demand per Pipe Length in l/s/m	Nodal Demand in l/s	Cumulative Nodal Demand in l/s
N188	N173A	269.48	134.74	0.0024	0.323	1.146
	N187	361.05	180.53	0.0024	0.433	
	N199	324.13	162.07	0.0024	0.389	
N187	N188	361.05	180.53	0.0024	0.433	1.132
	N174	211.16	105.58	0.0024	0.253	
	N186	370.80	185.40	0.0024	0.445	
N173	N173A	105.85	52.93	0.0024	0.127	0.869
	N172	148.29	74.15	0.0024	0.178	
	N174	470.19	235.10	0.0024	0.564	
N173A	N173	105.85	52.925	0.0024	0.127	0.450
	N188	269.48	134.74	0.0024	0.323	
N174	N187	211.16	105.58	0.0024	0.253	1.152
	N173	470.19	235.10	0.0024	0.564	
	N175	278.88	139.44	0.0024	0.335	
N175	N174	278.88	139.44	0.0024	0.335	1.124
	N176	371.82	185.91	0.0024	0.446	
	N165	285.80	142.90	0.0024	0.343	
N176	N175	371.82	185.91	0.0024	0.446	1.480
	N186	507.90	253.95	0.0024	0.609	
	N178	353.54	176.77	0.0024	0.424	
N164	N165	268.11	134.06	0.0024	0.322	1.305
	N155	501.00	250.50	0.0024	0.601	
	N163	317.99	159.00	0.0024	0.382	
N165	N164	268.11	134.06	0.0024	0.322	1.790
	N175	285.80	142.90	0.0024	0.343	
	N154	474.28	237.14	0.0024	0.569	
	N166	463.30	231.65	0.0024	0.556	
N172	N173	148.29	74.145	0.0024	0.178	1.181
	N171	434.24	217.12	0.0024	0.521	
	N166	401.72	200.86	0.0024	0.482	
N166	N172	401.72	200.86	0.0024	0.482	2.042
	N168	384.46	192.23	0.0024	0.461	
	N167	452.32	226.16	0.0024	0.543	
	N165	463.34	231.67	0.0024	0.556	

N186	N187	370.80	185.4	0.0024	0.445	1.424
	N176	507.90	253.95	0.0024	0.609	
	N185	308.04	154.02	0.0024	0.370	
N185	N186	308.04	154.02	0.0024	0.370	1.074
	N184	84.78	42.39	0.0024	0.102	
	N178	502.45	251.23	0.0024	0.603	
N179	N178	79.66	39.83	0.0024	0.096	0.806
	N180	249.07	124.54	0.0024	0.299	
	N162	342.80	171.40	0.0024	0.411	
N178	N179	79.66	39.83	0.0024	0.096	1.123
	N185	502.45	251.23	0.0024	0.603	
	N176	353.54	176.77	0.0024	0.424	
N163	N164	317.99	159.00	0.0024	0.382	1.222
	N156	480.22	240.11	0.0024	0.576	
	N162	220.20	110.10	0.0024	0.264	
N162	N161	33.91	16.96	0.0024	0.041	0.716
	N179	342.80	171.40	0.0024	0.411	
	N163	220.20	110.10	0.0024	0.264	
N157	N151	253.74	126.87	0.0024	0.304	1.072
	N156	204.26	102.13	0.0024	0.245	
	N161	434.98	217.49	0.0024	0.522	
N151	N157	253.74	126.87	0.0024	0.304	1.399
	N121	463.61	231.81	0.0024	0.556	
	N152	448.17	224.09	0.0024	0.538	
N156	N157	204.25	102.13	0.0024	0.245	1.163
	N163	480.22	240.11	0.0024	0.576	
	N155	284.83	142.42	0.0024	0.342	
N155	N156	284.83	142.42	0.0024	0.342	1.619
	N152	242.07	121.04	0.0024	0.290	
	N164	501.00	250.50	0.0024	0.601	
	N154	321.31	160.66	0.0024	0.386	1.248
N152	N155	242.07	121.04	0.0024	0.290	
	N153	349.38	174.69	0.0024	0.419	
	N151	448.17	224.09	0.0024	0.538	1.825
N154	N165	474.28	237.14	0.0024	0.569	
	N167	455.98	227.99	0.0024	0.547	
	N153	269.15	134.58	0.0024	0.323	1.237
	N155	321.32	160.66	0.0024	0.386	
N153	N154	269.15	134.58	0.0024	0.323	
	N152	349.38	174.69	0.0024	0.419	1.237
	N111	412.64	206.32	0.0024	0.495	

N167	N154	455.98	227.99	0.0024	0.547	2.243
	N166	452.32	226.16	0.0024	0.543	
	N109	560.45	280.23	0.0024	0.673	
	N169	400.31	200.16	0.0024	0.480	
N109	N167	560.45	280.23	0.0024	0.673	1.552
	N110	220.57	110.29	0.0024	0.265	
	N105	83.60	41.80	0.0024	0.100	
	N108	428.88	214.44	0.0024	0.515	
N103	N104	155.80	77.90	0.0024	0.187	0.945
	BN102	338.06	169.03	0.0024	0.406	
	N307	293.66	146.83	0.0024	0.352	
N104	N103	155.80	77.90	0.0024	0.187	1.825
	N98	547.00	273.50	0.0024	0.656	
	N169	469.83	234.92	0.0024	0.564	
	N105	348.12	174.06	0.0024	0.418	
N101	N100	353.87	176.94	0.0024	0.425	0.710
	BN102	52.92	26.46	0.0024	0.064	
	N97	185.27	92.64	0.0024	0.222	
N97	N101	185.27	92.64	0.0024	0.222	1.131
	N96	352.42	176.21	0.0024	0.423	
	N91	201.26	100.63	0.0024	0.242	
	N98	203.57	101.79	0.0024	0.244	
N100	N307	261.11	130.56	0.0024	0.313	0.970
	N101	353.86	176.93	0.0024	0.425	
	N96	193.19	96.60	0.0024	0.232	
N96	N100	193.19	96.60	0.0024	0.232	1.398
	N97	352.41	176.21	0.0024	0.423	
	N93	400.61	200.31	0.0024	0.481	
	BN95	218.66	109.33	0.0024	0.262	
N94	BN95	440.06	220.03	0.0024	0.528	1.648
	N93	471.89	235.95	0.0024	0.566	
	N67	461.55	230.78	0.0024	0.554	
N93	N94	471.89	235.95	0.0024	0.566	2.031
	N96	400.61	200.31	0.0024	0.481	
	N81	314.46	157.23	0.0024	0.377	
	N91	505.53	252.77	0.0024	0.607	
N91	N93	505.53	252.77	0.0024	0.607	0.909
	N97	201.26	100.63	0.0024	0.242	
	N90	50.98	25.49	0.0024	0.061	
N90	N80	386.33	193.17	0.0024	0.464	0.866
	N91	50.98	25.49	0.0024	0.061	

	N89	284.36	142.18	0.0024	0.341	
N80	N90	386.32	193.16	0.0024	0.464	
	N79	125.97	62.99	0.0024	0.151	
	N69	295.69	147.85	0.0024	0.355	0.970
N79	N80	125.97	62.99	0.0024	0.151	
	N70	400.53	200.27	0.0024	0.481	
	N77	158.26	79.13	0.0024	0.190	0.822
N77	N78	105.11	52.56	0.0024	0.126	
	N79	158.26	79.13	0.0024	0.190	
	N89	284.33	142.17	0.0024	0.341	0.657
N78	N77	105.11	52.56	0.0024	0.126	
	N88A	80.57	40.29	0.0024	0.097	
	N75	376.34	188.17	0.0024	0.452	0.674
N88A	N78	80.57	40.29	0.0024	0.097	
	N88	225.09	112.55	0.0024	0.270	
	N83A	319.15	159.58	0.0024	0.383	0.750
N89	N77	284.33	142.17	0.0024	0.341	
	N88	191.52	95.76	0.0024	0.230	
	N99	206.34	103.17	0.0024	0.248	
	N90	284.37	142.19	0.0024	0.341	1.160
N99	N89	206.33	103.17	0.0024	0.248	
	N98	140.47	70.24	0.0024	0.169	
	N108	298.18	149.09	0.0024	0.358	
	N105	590.29	295.15	0.0024	0.708	1.482
N98	N97	203.57	101.79	0.0024	0.244	
	N99	140.47	70.24	0.0024	0.169	
	N104	547.00	273.50	0.0024	0.656	1.069
N88	N88A	225.09	112.55	0.0024	0.270	
	N89	191.52	95.76	0.0024	0.230	
	N87	302.52	151.26	0.0024	0.363	0.863
N108	N109	428.89	214.45	0.0024	0.515	
	N99	298.18	149.09	0.0024	0.358	
	N112	192.50	96.25	0.0024	0.231	1.103
N84	N83A	256.66	128.33	0.0024	0.308	
	N75	121.08	60.54	0.0024	0.145	
	N85	240.10	120.05	0.0024	0.288	0.741
N83	N83A	16.44	8.22	0.0024	0.020	
	N87	106.65	53.33	0.0024	0.128	
	N86	222.15	111.08	0.0024	0.267	0.414
N83A	N83	16.44	8.22	0.0024	0.020	
	N84	256.67	128.34	0.0024	0.308	0.711

	N88A	319.15	159.58	0.0024	0.383	
N87	N83	106.65	53.33	0.0024	0.128	0.717
	N88	302.52	151.26	0.0024	0.363	
	N112	188.67	94.34	0.0024	0.226	
N85	N85A	39.25	19.63	0.0024	0.047	0.839
	N84	240.10	120.05	0.0024	0.288	
	N137	420.12	210.06	0.0024	0.504	
N85A	N85	39.25	19.63	0.0024	0.047	0.490
	N86	149.53	74.77	0.0024	0.179	
	N136A	219.60	109.80	0.0024	0.264	
N86	N85A	149.53	74.77	0.0024	0.179	0.795
	N83	222.14	111.07	0.0024	0.267	
	N113	291.08	145.54	0.0024	0.349	
N112	N87	188.67	94.34	0.0024	0.226	1.141
	N110	345.01	172.51	0.0024	0.414	
	N108	192.50	96.25	0.0024	0.231	
	N113	224.97	112.49	0.0024	0.270	1.191
N113	N112	224.97	112.49	0.0024	0.270	
	N114	203.57	101.79	0.0024	0.244	
	N86	291.09	145.55	0.0024	0.349	0.965
	N111	272.64	136.32	0.0024	0.327	
N110	N112	345.00	172.50	0.0024	0.414	
	N109	220.57	110.29	0.0024	0.265	1.226
	N111	238.27	119.14	0.0024	0.286	
N105	N109	83.60	41.80	0.0024	0.100	
	N99	590.29	295.15	0.0024	0.708	1.323
	N104	348.12	174.06	0.0024	0.418	
N111	N113	272.65	136.33	0.0024	0.327	
	N110	238.27	119.14	0.0024	0.286	0.745
	N153	412.65	206.33	0.0024	0.495	
	N117	178.89	89.45	0.0024	0.215	
N117	N111	178.89	89.45	0.0024	0.215	1.248
	N114	284.19	142.10	0.0024	0.341	
	N118	157.35	78.68	0.0024	0.189	
N114	N117	284.19	142.10	0.0024	0.341	1.223
	N136	390.62	195.31	0.0024	0.469	
	N113	203.57	101.79	0.0024	0.244	
	N115	161.72	80.86	0.0024	0.194	1.223
N115	N114	161.72	80.86	0.0024	0.194	
	N132	177.39	88.70	0.0024	0.213	
	N118	288.64	144.32	0.0024	0.346	

	N134	391.55	195.78	0.0024	0.470	
N118	N115	288.64	144.32	0.0024	0.346	1.139
	N117	157.35	78.68	0.0024	0.189	
	N121	503.53	251.77	0.0024	0.604	
N132	N115	177.39	88.70	0.0024	0.213	0.963
	N130	386.85	193.43	0.0024	0.464	
	N122	238.16	119.08	0.0024	0.286	
N121	N118	503.53	251.77	0.0024	0.604	1.424
	N151	463.60	231.80	0.0024	0.556	
	N122	219.59	109.80	0.0024	0.264	
N122	N121	219.59	109.80	0.0024	0.264	1.166
	N132	238.16	119.08	0.0024	0.286	
	N129	386.54	193.27	0.0024	0.464	
	N123	127.46	63.73	0.0024	0.153	
N123	N122	127.46	63.73	0.0024	0.153	0.786
	N124	135.86	67.93	0.0024	0.163	
	N128	391.55	195.78	0.0024	0.470	
N124	N123	135.86	67.93	0.0024	0.163	1.099
	N127	392.57	196.29	0.0024	0.471	
	N125	387.64	193.82	0.0024	0.465	
N125	N124	387.64	193.82	0.0024	0.465	2.463
	N126	391.00	195.50	0.0024	0.469	
	N158	1273.76	636.88	0.0024	1.529	
N126	N125	391.00	195.50	0.0024	0.469	1.118
	N127	361.70	180.85	0.0024	0.434	
	N144	178.94	89.47	0.0024	0.215	
N129	N122	386.54	193.27	0.0024	0.464	1.533
	N130	228.36	114.18	0.0024	0.274	
	N141	519.59	259.80	0.0024	0.624	
	N128	143.32	71.66	0.0024	0.172	
N128	N129	143.32	71.66	0.0024	0.172	1.394
	N127	157.24	78.62	0.0024	0.189	
	N123	391.55	195.78	0.0024	0.470	
	N142	469.83	234.92	0.0024	0.564	
N127	N128	157.24	78.62	0.0024	0.189	1.094
	N126	361.70	180.85	0.0024	0.434	
	N124	392.57	196.29	0.0024	0.471	
N144	N126	178.94	89.47	0.0024	0.215	1.817
	BN143	323.16	161.58	0.0024	0.388	
	N146	1012.16	506.08	0.0024	1.215	
N145			0.00	0.0024	0.000	

N147	BN143	358.14	179.07	0.0024	0.430	1.394
	N146	299.23	149.62	0.0024	0.359	
	N22	504.69	252.35	0.0024	0.606	
N148	N142	297.02	148.51	0.0024	0.356	0.903
	N24	455.67	227.84	0.0024	0.547	
N142	N148	297.02	148.51	0.0024	0.356	1.217
	N141	247.22	123.61	0.0024	0.297	
	N128	469.83	234.92	0.0024	0.564	
N141	N142	247.22	123.61	0.0024	0.297	1.690
	N129	519.59	259.80	0.0024	0.624	
	N27	460.14	230.07	0.0024	0.552	
	N140	181.27	90.64	0.0024	0.218	
N130	N129	228.36	114.18	0.0024	0.274	1.523
	N134	177.63	88.82	0.0024	0.213	
	N132	386.85	193.43	0.0024	0.464	
	N140	476.64	238.32	0.0024	0.572	
N134	N130	177.63	88.82	0.0024	0.213	1.429
	N136	168.06	84.03	0.0024	0.202	
	N115	391.55	195.78	0.0024	0.470	
	N139	453.31	226.66	0.0024	0.544	
N139	N134	453.31	226.66	0.0024	0.544	1.472
	N28	433.82	216.91	0.0024	0.521	
	N138	178.08	89.04	0.0024	0.214	
	N140	161.06	80.53	0.0024	0.193	
N136	N134	168.07	84.04	0.0024	0.202	0.727
	N136A	47.15	23.58	0.0024	0.057	
	N114	390.62	195.31	0.0024	0.469	
N136A	N136	47.15	23.58	0.0024	0.057	0.803
	N138	402.51	201.26	0.0024	0.483	
	N85A	219.60	109.80	0.0024	0.264	
N138	N136A	402.51	201.26	0.0024	0.483	1.705
	N29	388.37	194.19	0.0024	0.466	
	N139	178.07	89.04	0.0024	0.214	
	N137	451.68	225.84	0.0024	0.542	
N140	N130	476.64	238.32	0.0024	0.572	0.983
	N141	181.27	90.64	0.0024	0.218	
	N139	161.06	80.53	0.0024	0.193	
N24	N148	455.67	227.84	0.0024	0.547	1.938
	N27	374.10	187.05	0.0024	0.449	
	N23	293.28	146.64	0.0024	0.352	
	N15	491.84	245.92	0.0024	0.590	

N27	N24	374.10	187.05	0.0024	0.449	2.035
	N141	460.14	230.07	0.0024	0.552	
	N18	610.40	305.20	0.0024	0.732	
	N28	251.00	125.50	0.0024	0.301	
N28	N27	251.00	125.50	0.0024	0.301	1.037
	N139	433.82	216.91	0.0024	0.521	
	N29	179.52	89.76	0.0024	0.215	
N29	N28	179.52	89.76	0.0024	0.215	0.982
	N30A	250.71	125.36	0.0024	0.301	
	N138	388.37	194.19	0.0024	0.466	
N30A	N29	250.71	125.36	0.0024	0.301	
	N73	274.13	137.07	0.0024	0.329	1.900
	N119	739.93	369.97	0.0024	0.888	
	N137	318.80	159.40	0.0024	0.383	
N37	N20	420.06	210.03	0.0024	0.504	
	N38	201.63	100.82	0.0024	0.242	1.130
	N36	319.76	159.88	0.0024	0.384	
N75	N84	121.08	60.54	0.0024	0.145	
	N71	541.09	270.55	0.0024	0.649	1.246
	N78	376.34	188.17	0.0024	0.452	
N73	N71	406.22	203.11	0.0024	0.487	
	N30A	274.10	137.05	0.0024	0.329	2.049
	N55	1027.30	513.65	0.0024	1.233	
N71	N75	541.09	270.55	0.0024	0.649	
	N70	162.13	81.07	0.0024	0.195	
	N55	414.25	207.13	0.0024	0.497	1.828
	N73	406.22	203.11	0.0024	0.487	
N70	N71	162.13	81.07	0.0024	0.195	
	N79	400.54	200.27	0.0024	0.481	1.179
	N168	419.60	209.80	0.0024	0.504	
N55	N71	414.25	207.13	0.0024	0.497	
	N73	1027.30	513.65	0.0024	1.233	2.431
	N65	583.90	291.95	0.0024	0.701	
N68	N69	84.28	42.14	0.0024	0.101	
	N65	450.01	225.01	0.0024	0.540	1.145
	N70	419.59	209.80	0.0024	0.504	
N69	N68	84.28	42.14	0.0024	0.101	
	N81	58.27	29.14	0.0024	0.070	0.526
	N80	295.69	147.85	0.0024	0.355	
N81	N69	58.27	29.14	0.0024	0.070	
	N93	314.45	157.23	0.0024	0.377	0.835

	N67	323.44	161.72	0.0024	0.388	
N67	N81	323.44	161.72	0.0024	0.388	
	N94	461.55	230.78	0.0024	0.554	
	N64	765.82	382.91	0.0024	0.919	1.861
N64	N67	765.82	382.91	0.0024	0.919	
	N63	365.66	182.83	0.0024	0.439	
	N65	196.28	98.14	0.0024	0.236	1.593
N65	N64	196.28	98.14	0.0024	0.236	
	N68	450.01	225.01	0.0024	0.540	
	N55	583.91	291.96	0.0024	0.701	1.476
N63	N64	365.66	182.83	0.0024	0.439	
	N62	155.13	77.57	0.0024	0.186	
	N57	530.55	265.28	0.0024	0.637	1.262
N57	N63	530.55	265.28	0.0024	0.637	
	N58	209.00	104.50	0.0024	0.251	
	N36	739.80	369.90	0.0024	0.888	1.775
N42	N43	422.92	211.46	0.0024	0.508	
	N38	151.38	75.69	0.0024	0.182	
	N10	401.98	200.99	0.0024	0.482	1.172
N38	N42	151.38	75.69	0.0024	0.182	
	N37	201.63	100.82	0.0024	0.242	
	N45	652.77	326.39	0.0024	0.783	1.207
N36	N45	376.14	188.07	0.0024	0.451	
	N37	319.76	159.88	0.0024	0.384	
	N57	739.80	369.90	0.0024	0.888	
	N19	696.94	348.47	0.0024	0.836	2.559
N32A			0.00	0.0024	0.000	
N137	N85	420.12	210.06	0.0024	0.504	
	N30A	318.80	159.40	0.0024	0.383	
	N138	451.68	225.84	0.0024	0.542	1.429
N35			0.00	0.0024	0.000	
N19	N36	696.94	348.47	0.0024	0.836	
	N30A	739.93	369.97	0.0024	0.888	
	N20	294.44	147.22	0.0024	0.353	
	N118	477.44	238.72	0.0024	0.573	2.651
N20	N19	294.44	147.22	0.0024	0.353	
	N8	418.32	209.16	0.0024	0.502	
	N20A	212.32	106.16	0.0024	0.255	1.110
N10	N20A	148.57	74.29	0.0024	0.178	
	N6	431.15	215.58	0.0024	0.517	
	N42	401.98	200.99	0.0024	0.482	1.527

	N9	290.54	145.27	0.0024	0.349	
N20A	N10	148.57	74.29	0.0024	0.178	
	N20	212.32	106.16	0.0024	0.255	0.433
N6	B1	355.55	177.78	0.0024	0.427	
	N43	691.05	345.53	0.0024	0.829	
	N11	475.19	237.60	0.0024	0.570	
	N10	431.15	215.58	0.0024	0.517	2.344
N9	N10	290.54	145.27	0.0024	0.349	
	N5	285.32	142.66	0.0024	0.342	
	N8	421.67	210.84	0.0024	0.506	1.197
N5	N9	285.32	142.66	0.0024	0.342	
	N11	67.05	33.53	0.0024	0.080	
	N4	406.37	203.19	0.0024	0.488	0.910
N8	N20	418.32	209.16	0.0024	0.502	
	N9	421.67	210.84	0.0024	0.506	
	N18	301.73	150.87	0.0024	0.362	
	N7	299.09	149.55	0.0024	0.359	1.729
N18	N19	477.44	238.72	0.0024	0.573	
	N15	359.85	179.93	0.0024	0.432	
	N8	301.73	150.87	0.0024	0.362	
	N27	610.40	305.20	0.0024	0.732	2.099
N7	N8	299.09	149.55	0.0024	0.359	
	N4	232.00	116.00	0.0024	0.278	
	N15	579.30	289.65	0.0024	0.695	1.332
N13	N12	321.06	160.53	0.0024	0.385	
	N4	513.76	256.88	0.0024	0.617	
	N14	17.30	8.65	0.0024	0.021	1.023
N62	N63	155.13	77.57	0.0024	0.186	
	B59A	636.50	318.25	0.0024	0.764	
	N58	546.94	273.47	0.0024	0.656	1.606
N50	N49	266.50	133.25	0.0024	0.320	
	N45	562.20	281.10	0.0024	0.675	
	N58	344.32	172.16	0.0024	0.413	1.408
N58	N50	344.32	172.16	0.0024	0.413	
	N57	209.00	104.50	0.0024	0.251	
	N62	546.94	273.47	0.0024	0.656	1.320
N49	N50	266.50	133.25	0.0024	0.320	
	B59A	280.29	140.15	0.0024	0.336	
	N44	314.12	157.06	0.0024	0.377	1.033
B59A	N49	280.29	140.14	0.0024	0.336	
	N62	636.50	318.25	0.0024	0.764	1.100

N45	N50	562.20	281.10	0.0024	0.675	
	N44	351.58	175.79	0.0024	0.422	
	N38	652.77	326.39	0.0024	0.783	
	N36	376.14	188.07	0.0024	0.451	2.331
N44	N45	351.57	175.79	0.0024	0.422	
	N49	314.12	157.06	0.0024	0.377	
	N43	567.72	283.86	0.0024	0.681	1.480
N43	N44	567.72	283.86	0.0024	0.681	
	N42	422.93	211.47	0.0024	0.508	
	N6	691.05	345.53	0.0024	0.829	2.018
B1			0.00	0.0024	0.000	
N11	N5	67.05	33.53	0.0024	0.080	
	N6	475.19	237.60	0.0024	0.570	
	N2	315.55	157.78	0.0024	0.379	1.029
N2	N11	315.55	157.78	0.0024	0.379	
	B1	643.98	321.99	0.0024	0.773	
	N3	516.99	258.50	0.0024	0.620	1.772
N3	N2	516.99	258.50	0.0024	0.620	
	N4	352.92	176.46	0.0024	0.424	
	N12	690.58	345.29	0.0024	0.829	1.873
N4	N3	352.92	176.46	0.0024	0.424	
	N5	406.37	203.19	0.0024	0.488	
	N13	513.76	256.88	0.0024	0.617	
	N7	231.99	116.00	0.0024	0.278	1.806
N15	N14	293.53	146.77	0.0024	0.352	
	N7	579.30	289.65	0.0024	0.695	
	N18	359.85	179.93	0.0024	0.432	
	N24	491.84	245.92	0.0024	0.590	2.069
N14	N13	17.30	8.65	0.0024	0.021	
	N15	293.53	146.77	0.0024	0.352	
	N23	453.06	226.53	0.0024	0.544	0.917
N12	N13	321.05	160.53	0.0024	0.385	
	N21	632.71	316.36	0.0024	0.759	
	N3	690.58	345.29	0.0024	0.829	1.973
N146	N21	498.32	249.16	0.0024	0.598	
	N147	299.23	149.62	0.0024	0.359	
	N144	1012.16	506.08	0.0024	1.215	2.172
N22	N147	504.69	252.35	0.0024	0.606	
	N23	33.46	16.73	0.0024	0.040	
	N21	289.16	144.58	0.0024	0.347	0.993
N21	N146	498.32	249.16	0.0024	0.598	1.704

	N22	289.16	144.58	0.0024	0.347	
	N12	632.71	316.36	0.0024	0.759	
N23	N22	33.46	16.73	0.0024	0.040	
	N24	293.28	146.64	0.0024	0.352	
	N14	453.06	226.53	0.0024	0.544	0.936
N198	N199	89.67	44.84	0.0024	0.108	
	N195	315.74	157.87	0.0024	0.379	
	N197	453.18	226.59	0.0024	0.544	1.030
N197	N198	453.18	226.59	0.0024	0.544	
	N196	486.51	243.26	0.0024	0.584	
	N300	502.44	251.22	0.0024	0.603	1.731
N196	N197	486.51	243.26	0.0024	0.584	
	N195	419.19	209.60	0.0024	0.503	
	B170	349.03	174.52	0.0024	0.419	1.506
N195	N196	419.19	209.60	0.0024	0.503	
	N198	315.74	157.87	0.0024	0.379	
	N171	372.52	186.26	0.0024	0.447	1.329
N171	N195	372.52	186.26	0.0024	0.447	
	N172	434.24	217.12	0.0024	0.521	
	B170	365.61	182.81	0.0024	0.439	
	N168	344.32	172.16	0.0024	0.413	1.820
B170	N196	349.03	174.52	0.0024	0.419	
	N171	365.61	182.81	0.0024	0.439	0.858
N168	N171	344.32	172.16	0.0024	0.413	
	N169	473.09	236.55	0.0024	0.568	
	N166	384.46	192.23	0.0024	0.461	1.442
N169	N168	473.09	236.55	0.0024	0.568	
	N104	469.83	234.92	0.0024	0.564	
	N167	400.31	200.16	0.0024	0.480	1.612
N158	N125	1273.76	636.88	0.0024	1.529	
	N161	525.98	262.99	0.0024	0.631	
	N180	624.46	312.23	0.0024	0.749	2.909
N161	N162	33.91	16.96	0.0024	0.041	
	N157	434.98	217.49	0.0024	0.522	
	N158	525.98	262.99	0.0024	0.631	1.194
N184	N185	84.80	42.40	0.0024	0.102	
	N180	551.52	275.76	0.0024	0.662	
	N205	1114.99	557.50	0.0024	1.338	2.102
N180	N184	551.52	275.76	0.0024	0.662	
	N179	249.07	124.54	0.0024	0.299	
	N158	624.46	312.23	0.0024	0.749	1.710

N199	N198	89.67	44.84	0.0024	0.108	
	N188	324.13	162.07	0.0024	0.389	0.497
N300	N197	502.44	251.22	0.0024	0.603	
	plus university			0.0024	8.178	8.781
		sum	83,258.98			208.000

Jijiga City Water Supply Project

Table: - A-2 Nodal Demand Calculation for Phase II (2035)

Node Name	Adjoining Nodes	Pipe Arm Length	Pipe arm Share to Node	Demand per Pipe Length in l/s/m	Nodal Demand in l/s	Cumulative Nodal Demand in l/s
N188	N173A	269.48	134.74	0.00271911	0.3664	2.03
	N187	361.05	180.525	0.00271911	0.4909	
	N199	324.13	162.065	0.00271911	0.4407	
N187	N204	541.7	270.85	0.00271911	0.7365	2.05
	N188	361.05	180.525	0.00271911	0.4909	
	N174	211.16	105.58	0.00271911	0.2871	
	N186	370.8	185.4	0.00271911	0.5041	
N173	N205	564.64	282.32	0.00271911	0.7677	0.98
	N173A	105.85	52.925	0.00271911	0.1439	
	N172	148.29	74.145	0.00271911	0.2016	
N173A	N174	470.19	235.095	0.00271911	0.6392	0.12
	N173	105.85	52.925	0.00271911	0.1439	
N174	N188	269.48	134.74	0.00271911	0.3664	1.31
	N187	211.16	105.58	0.00271911	0.2871	
	N173	470.19	235.095	0.00271911	0.6392	
N175	N175	278.88	139.44	0.00271911	0.3792	1.27
	N174	278.88	139.44	0.00271911	0.3792	
	N176	371.82	185.91	0.00271911	0.5055	
N176	N165	285.8	142.9	0.00271911	0.3886	1.68
	N175	371.82	185.91	0.00271911	0.5055	
	N186	507.9	253.95	0.00271911	0.6905	
N164	N178	353.54	176.77	0.00271911	0.4807	1.48
	N165	268.11	134.055	0.00271911	0.3645	
	N155	501	250.5	0.00271911	0.6811	
N165	N163	317.99	158.995	0.00271911	0.4323	2.03
	N164	268.11	134.055	0.00271911	0.3645	
	N175	285.8	142.9	0.00271911	0.3886	
	N154	474.28	237.14	0.00271911	0.6448	
N172	N166	463.3	231.65	0.00271911	0.6299	1.34
	N173	148.29	74.145	0.00271911	0.2016	
	N171	434.24	217.12	0.00271911	0.5904	
N166	N166	401.72	200.86	0.00271911	0.5462	2.31
	N172	401.72	200.86	0.00271911	0.5462	
	N168	384.46	192.23	0.00271911	0.5227	
	N167	452.32	226.16	0.00271911	0.6150	

	N165	463.34	231.67	0.00271911	0.6299	
N186	N187	370.8	185.4	0.00271911	0.5041	
	N176	507.9	253.95	0.00271911	0.6905	
	N185	308.04	154.02	0.00271911	0.4188	1.61
N185	N186	308.04	154.02	0.00271911	0.4188	
	N184	84.78	42.39	0.00271911	0.1153	
	N178	502.45	251.225	0.00271911	0.6831	1.22
N179	N178	79.66	39.83	0.00271911	0.1083	
	N180	249.07	124.535	0.00271911	0.3386	
	N162	342.8	171.4	0.00271911	0.4661	0.91
N178	N179	79.66	39.83	0.00271911	0.1083	
	N185	502.45	251.225	0.00271911	0.6831	
	N176	353.54	176.77	0.00271911	0.4807	1.27
N163	N164	317.99	158.995	0.00271911	0.4323	
	N156	480.22	240.11	0.00271911	0.6529	
	N162	220.2	110.1	0.00271911	0.2994	1.38
N162	N161	33.91	16.955	0.00271911	0.0461	
	N179	342.8	171.4	0.00271911	0.4661	
	N163	220.2	110.1	0.00271911	0.2994	0.81
N157	N151	253.74	126.87	0.00271911	0.3450	
	N156	204.26	102.13	0.00271911	0.2777	
	N161	434.98	217.49	0.00271911	0.5914	1.21
N151	N157	253.74	126.87	0.00271911	0.3450	
	N121	463.61	231.805	0.00271911	0.6303	
	N152	448.17	224.085	0.00271911	0.6093	1.58
N156	N157	204.25	102.125	0.00271911	0.2777	
	N163	480.22	240.11	0.00271911	0.6529	
	N155	284.83	142.415	0.00271911	0.3872	1.32
N155	N156	284.83	142.415	0.00271911	0.3872	
	N152	242.07	121.035	0.00271911	0.3291	
	N164	501	250.5	0.00271911	0.6811	
	N154	321.31	160.655	0.00271911	0.4368	1.83
N152	N155	242.07	121.035	0.00271911	0.3291	
	N153	349.38	174.69	0.00271911	0.4750	
	N151	448.17	224.085	0.00271911	0.6093	1.41
N154	N165	474.28	237.14	0.00271911	0.6448	
	N167	455.98	227.99	0.00271911	0.6199	
	N153	269.15	134.575	0.00271911	0.3659	
	N155	321.32	160.66	0.00271911	0.4369	2.07
N153	N154	269.15	134.575	0.00271911	0.3659	
	N152	349.38	174.69	0.00271911	0.4750	1.40

	N111	412.64	206.32	0.00271911	0.5610	
N167	N154	455.98	227.99	0.00271911	0.6199	
	N166	452.32	226.16	0.00271911	0.6150	
	N109	560.45	280.225	0.00271911	0.7620	
	N169	400.31	200.155	0.00271911	0.5442	2.54
N109	N167	560.45	280.225	0.00271911	0.7620	
	N110	220.57	110.285	0.00271911	0.2999	
	N105	83.6	41.8	0.00271911	0.1137	
	N108	428.88	214.44	0.00271911	0.5831	1.76
N103	N104	155.8	77.9	0.00271911	0.2118	
	BN102	338.06	169.03	0.00271911	0.4596	
	N307	293.66	146.83	0.00271911	0.3992	1.07
N104	N103	155.8	77.9	0.00271911	0.2118	
	N98	547	273.5	0.00271911	0.7437	
	N169	469.83	234.915	0.00271911	0.6388	
	N105	348.12	174.06	0.00271911	0.4733	2.07
N101	N100	353.87	176.935	0.00271911	0.4811	
	BN102	52.92	26.46	0.00271911	0.0719	
	N97	185.27	92.635	0.00271911	0.2519	0.80
N97	N101	185.27	92.635	0.00271911	0.2519	
	N96	352.42	176.21	0.00271911	0.4791	
	N91	201.26	100.63	0.00271911	0.2736	
	N98	203.57	101.785	0.00271911	0.2768	1.28
N100	N307	261.11	130.555	0.00271911	0.3550	
	N101	353.86	176.93	0.00271911	0.4811	
	N96	193.19	96.595	0.00271911	0.2627	
	N305	1186.89	593.445	0.00271911	1.6136	2.71
N96	N100	193.19	96.595	0.00271911	0.2627	
	N97	352.41	176.205	0.00271911	0.4791	
	N93	400.61	200.305	0.00271911	0.5447	
	BN95	218.66	109.33	0.00271911	0.2973	1.58
N94	BN95	440.06	220.03	0.00271911	0.5983	
	N93	471.89	235.945	0.00271911	0.6416	
	N67	461.55	230.775	0.00271911	0.6275	1.87
N93	N94	471.89	235.945	0.00271911	0.6416	
	N96	400.61	200.305	0.00271911	0.5447	
	N81	314.46	157.23	0.00271911	0.4275	
	N91	505.53	252.765	0.00271911	0.6873	2.30
N91	N93	505.53	252.765	0.00271911	0.6873	
	N97	201.26	100.63	0.00271911	0.2736	
	N90	50.98	25.49	0.00271911	0.0693	1.03

N90	N80	386.33	193.165	0.00271911	0.5252	
	N91	50.98	25.49	0.00271911	0.0693	
	N89	284.36	142.18	0.00271911	0.3866	0.98
N80	N90	386.32	193.16	0.00271911	0.5252	
	N79	125.97	62.985	0.00271911	0.1713	
	N69	295.69	147.845	0.00271911	0.4020	1.10
N79	N80	125.97	62.985	0.00271911	0.1713	
	N70	400.53	200.265	0.00271911	0.5445	
	N77	158.26	79.13	0.00271911	0.2152	0.93
N77	N78	105.11	52.555	0.00271911	0.1429	
	N79	158.26	79.13	0.00271911	0.2152	
	N89	284.33	142.165	0.00271911	0.3866	0.74
N78	N77	105.11	52.555	0.00271911	0.1429	
	N88A	80.57	40.285	0.00271911	0.1095	
	N75	376.34	188.17	0.00271911	0.5117	0.76
N88A	N78	80.57	40.285	0.00271911	0.1095	
	N88	225.09	112.545	0.00271911	0.3060	
	N83A	319.15	159.575	0.00271911	0.4339	0.85
N89	N77	284.33	142.165	0.00271911	0.3866	
	N88	191.52	95.76	0.00271911	0.2604	
	N99	206.34	103.17	0.00271911	0.2805	
	N90	284.37	142.185	0.00271911	0.3866	1.31
N99	N89	206.33	103.165	0.00271911	0.2805	
	N98	140.47	70.235	0.00271911	0.1910	
	N108	298.18	149.09	0.00271911	0.4054	
	N105	590.29	295.145	0.00271911	0.8025	1.68
N98	N97	203.57	101.785	0.00271911	0.2768	
	N99	140.47	70.235	0.00271911	0.1910	
	N104	547	273.5	0.00271911	0.7437	1.21
N88	N88A	225.09	112.545	0.00271911	0.3060	
	N89	191.52	95.76	0.00271911	0.2604	
	N87	302.52	151.26	0.00271911	0.4113	0.98
N108	N109	428.89	214.445	0.00271911	0.5831	
	N99	298.18	149.09	0.00271911	0.4054	
	N112	192.5	96.25	0.00271911	0.2617	1.25
N84	N83A	256.66	128.33	0.00271911	0.3489	
	N75	121.08	60.54	0.00271911	0.1646	
	N85	240.1	120.05	0.00271911	0.3264	0.84
N83	N83A	16.44	8.22	0.00271911	0.0224	
	N87	106.65	53.325	0.00271911	0.1450	
	N86	222.15	111.075	0.00271911	0.3020	0.47

N83A	N83	16.44	8.22	0.00271911	0.0224	
	N84	256.67	128.335	0.00271911	0.3490	
	N88A	319.15	159.575	0.00271911	0.4339	0.81
N87	N83	106.65	53.325	0.00271911	0.1450	
	N88	302.52	151.26	0.00271911	0.4113	
	N112	188.67	94.335	0.00271911	0.2565	0.81
N85	N85A	39.25	19.625	0.00271911	0.0534	
	N84	240.1	120.05	0.00271911	0.3264	
	N137	420.12	210.06	0.00271911	0.5712	0.95
N85A	N85	39.25	19.625	0.00271911	0.0534	
	N86	149.53	74.765	0.00271911	0.2033	
	N136A	219.6	109.8	0.00271911	0.2986	0.56
N86	N85A	149.53	74.765	0.00271911	0.2033	
	N83	222.14	111.07	0.00271911	0.3020	
	N113	291.08	145.54	0.00271911	0.3957	0.90
N112	N87	188.67	94.335	0.00271911	0.2565	
	N110	345.01	172.505	0.00271911	0.4691	
	N108	192.5	96.25	0.00271911	0.2617	
	N113	224.97	112.485	0.00271911	0.3059	1.29
N113	N112	224.97	112.485	0.00271911	0.3059	
	N114	203.57	101.785	0.00271911	0.2768	
	N86	291.09	145.545	0.00271911	0.3958	
	N111	272.64	136.32	0.00271911	0.3707	1.35
N110	N112	345	172.5	0.00271911	0.4690	
	N109	220.57	110.285	0.00271911	0.2999	
	N111	238.27	119.135	0.00271911	0.3239	1.09
N105	N109	83.6	41.8	0.00271911	0.1137	
	N99	590.29	295.145	0.00271911	0.8025	
	N104	348.12	174.06	0.00271911	0.4733	1.39
N111	N113	272.65	136.325	0.00271911	0.3707	
	N110	238.27	119.135	0.00271911	0.3239	
	N153	412.65	206.325	0.00271911	0.5610	
	N117	178.89	89.445	0.00271911	0.2432	1.50
N117	N111	178.89	89.445	0.00271911	0.2432	
	N114	284.19	142.095	0.00271911	0.3864	
	N118	157.35	78.675	0.00271911	0.2139	0.84
N114	N117	284.19	142.095	0.00271911	0.3864	
	N136	390.62	195.31	0.00271911	0.5311	
	N113	203.57	101.785	0.00271911	0.2768	
	N115	161.72	80.86	0.00271911	0.2199	1.41
N115	N114	161.72	80.86	0.00271911	0.2199	1.39

	N132	177.39	88.695	0.00271911	0.2412	
	N118	288.64	144.32	0.00271911	0.3924	
	N134	391.55	195.775	0.00271911	0.5323	
N118	N115	288.64	144.32	0.00271911	0.3924	
	N117	157.35	78.675	0.00271911	0.2139	
	N121	503.53	251.765	0.00271911	0.6846	1.29
N132	N115	177.39	88.695	0.00271911	0.2412	
	N130	386.85	193.425	0.00271911	0.5259	
	N122	238.16	119.08	0.00271911	0.3238	1.09
N121	N118	503.53	251.765	0.00271911	0.6846	
	N151	463.6	231.8	0.00271911	0.6303	
	N122	219.59	109.795	0.00271911	0.2985	1.61
N122	N121	219.59	109.795	0.00271911	0.2985	
	N132	238.16	119.08	0.00271911	0.3238	
	N129	386.54	193.27	0.00271911	0.5255	
	N123	127.46	63.73	0.00271911	0.1733	1.32
N123	N122	127.46	63.73	0.00271911	0.1733	
	N124	135.86	67.93	0.00271911	0.1847	
	N128	391.55	195.775	0.00271911	0.5323	0.89
N124	N123	135.86	67.93	0.00271911	0.1847	
	N127	392.57	196.285	0.00271911	0.5337	
	N125	387.64	193.82	0.00271911	0.5270	1.25
N125	N124	387.64	193.82	0.00271911	0.5270	
	N126	391	195.5	0.00271911	0.5316	
	N158	1273.76	636.88	0.00271911	1.7317	
	N317	664.78	332.39	0.00271911	0.9038	3.69
N126	N125	391	195.5	0.00271911	0.5316	
	N127	361.7	180.85	0.00271911	0.4918	
	N144	178.94	89.47	0.00271911	0.2433	1.27
N129	N122	386.54	193.27	0.00271911	0.5255	
	N130	228.36	114.18	0.00271911	0.3105	
	N141	519.59	259.795	0.00271911	0.7064	
	N128	143.32	71.66	0.00271911	0.1949	1.74
N128	N129	143.32	71.66	0.00271911	0.1949	
	N127	157.24	78.62	0.00271911	0.2138	
	N123	391.55	195.775	0.00271911	0.5323	
	N142	469.83	234.915	0.00271911	0.6388	1.58
N127	N128	157.24	78.62	0.00271911	0.2138	
	N126	361.7	180.85	0.00271911	0.4918	
	N124	392.57	196.285	0.00271911	0.5337	1.24
N144	N126	178.94	89.47	0.00271911	0.2433	2.06

	BN143	323.16	161.58	0.00271911	0.4394	
	N146	1012.16	506.08	0.00271911	1.3761	
N145			0	0.00271911	0.0000	
N147	BN143	358.14	179.07	0.00271911	0.4869	
	N146	299.23	149.615	0.00271911	0.4068	
	N22	504.69	252.345	0.00271911	0.6862	1.58
N148	N142	297.02	148.51	0.00271911	0.4038	
	N24	455.67	227.835	0.00271911	0.6195	1.02
N142	N148	297.02	148.51	0.00271911	0.4038	
	N141	247.22	123.61	0.00271911	0.3361	
	N128	469.83	234.915	0.00271911	0.6388	1.38
N141	N142	247.22	123.61	0.00271911	0.3361	
	N129	519.59	259.795	0.00271911	0.7064	
	N27	460.14	230.07	0.00271911	0.6256	
	N140	181.27	90.635	0.00271911	0.2464	1.91
N130	N129	228.36	114.18	0.00271911	0.3105	
	N134	177.63	88.815	0.00271911	0.2415	
	N132	386.85	193.425	0.00271911	0.5259	
	N140	476.64	238.32	0.00271911	0.6480	1.73
N134	N130	177.63	88.815	0.00271911	0.2415	
	N136	168.06	84.03	0.00271911	0.2285	
	N115	391.55	195.775	0.00271911	0.5323	
	N139	453.31	226.655	0.00271911	0.6163	1.62
N139	N134	453.31	226.655	0.00271911	0.6163	
	N28	433.82	216.91	0.00271911	0.5898	
	N138	178.08	89.04	0.00271911	0.2421	
	N140	161.06	80.53	0.00271911	0.2190	1.67
N136	N134	168.07	84.035	0.00271911	0.2285	
	N136A	47.15	23.575	0.00271911	0.0641	
	N114	390.62	195.31	0.00271911	0.5311	0.82
N136A	N136	47.15	23.575	0.00271911	0.0641	
	N138	402.51	201.255	0.00271911	0.5472	
	N85A	219.6	109.8	0.00271911	0.2986	0.91
N138	N136A	402.51	201.255	0.00271911	0.5472	
	N29	388.37	194.185	0.00271911	0.5280	
	N139	178.07	89.035	0.00271911	0.2421	
	N137	451.68	225.84	0.00271911	0.6141	1.93
N140	N130	476.64	238.32	0.00271911	0.6480	
	N141	181.27	90.635	0.00271911	0.2464	
	N139	161.06	80.53	0.00271911	0.2190	1.53
N24	N148	455.67	227.835	0.00271911	0.6195	2.20

	N27	374.1	187.05	0.00271911	0.5086	
	N23	293.28	146.64	0.00271911	0.3987	
	N15	491.84	245.92	0.00271911	0.6687	
N27	N24	374.1	187.05	0.00271911	0.5086	
	N141	460.14	230.07	0.00271911	0.6256	
	N18	610.4	305.2	0.00271911	0.8299	
	N28	251	125.5	0.00271911	0.3412	2.31
N28	N27	251	125.5	0.00271911	0.3412	
	N139	433.82	216.91	0.00271911	0.5898	
	N29	179.52	89.76	0.00271911	0.2441	1.11
N29	N28	179.52	89.76	0.00271911	0.2441	
	N30A	250.71	125.355	0.00271911	0.3409	
	N138	388.37	194.185	0.00271911	0.5280	1.72
N30A	N29	250.71	125.355	0.00271911	0.3409	
	N73	274.13	137.065	0.00271911	0.3727	
	N119	739.93	369.965	0.00271911	1.0060	
	N137	318.8	159.4	0.00271911	0.4334	2.15
N37	N20	420.06	210.03	0.00271911	0.5711	
	N38	201.63	100.815	0.00271911	0.2741	
	N36	319.76	159.88	0.00271911	0.4347	1.41
N75	N84	121.08	60.54	0.00271911	0.1646	
	N71	541.09	270.545	0.00271911	0.7356	
	N78	376.34	188.17	0.00271911	0.5117	2.32
N73	N71	406.22	203.11	0.00271911	0.5523	
	N30A	274.1	137.05	0.00271911	0.3727	
	N55	1027.3	513.65	0.00271911	1.3967	1.52
N71	N75	541.09	270.545	0.00271911	0.7356	
	N70	162.13	81.065	0.00271911	0.2204	
	N55	414.25	207.125	0.00271911	0.5632	
	N73	406.22	203.11	0.00271911	0.5523	2.07
N70	N71	162.13	81.065	0.00271911	0.2204	
	N79	400.54	200.27	0.00271911	0.5446	
	N168	419.6	209.8	0.00271911	0.5705	2.75
N55	N71	414.25	207.125	0.00271911	0.5632	
	N73	1027.3	513.65	0.00271911	1.3967	
	N65	583.9	291.95	0.00271911	0.7938	1.30
N68	N69	84.28	42.14	0.00271911	0.1146	
	N65	450.01	225.005	0.00271911	0.6118	
	N70	419.59	209.795	0.00271911	0.5705	1.30
N69	N68	84.28	42.14	0.00271911	0.1146	
	N81	58.27	29.135	0.00271911	0.0792	0.60

	N80	295.69	147.845	0.00271911	0.4020	
N81	N69	58.27	29.135	0.00271911	0.0792	
	N93	314.45	157.225	0.00271911	0.4275	
	N67	323.44	161.72	0.00271911	0.4397	0.95
N67	N81	323.44	161.72	0.00271911	0.4397	
	N94	461.55	230.775	0.00271911	0.6275	
	N64	765.82	382.91	0.00271911	1.0412	2.11
N64	N67	765.82	382.91	0.00271911	1.0412	
	N63	365.66	182.83	0.00271911	0.4971	
	N65	196.28	98.14	0.00271911	0.2669	1.81
N65	N64	196.28	98.14	0.00271911	0.2669	
	N68	450.01	225.005	0.00271911	0.6118	
	N55	583.91	291.955	0.00271911	0.7939	1.67
N63	N64	365.66	182.83	0.00271911	0.4971	
	N62	155.13	77.565	0.00271911	0.2109	
	N57	530.55	265.275	0.00271911	0.7213	1.43
N57	N63	530.55	265.275	0.00271911	0.7213	
	N58	209	104.5	0.00271911	0.2841	
	N36	739.8	369.9	0.00271911	1.0058	2.01
N42	N43	422.92	211.46	0.00271911	0.5750	
	N38	151.38	75.69	0.00271911	0.2058	
	N10	401.98	200.99	0.00271911	0.5465	1.33
N38	N42	151.38	75.69	0.00271911	0.2058	
	N37	201.63	100.815	0.00271911	0.2741	
	N45	652.77	326.385	0.00271911	0.8875	1.37
N36	N45	376.14	188.07	0.00271911	0.5114	
	N37	319.76	159.88	0.00271911	0.4347	
	N57	739.8	369.9	0.00271911	1.0058	
	N19	696.94	348.47	0.00271911	0.9475	2.90
N32A			0	0.00271911	0.0000	
N137	N85	420.12	210.06	0.00271911	0.5712	
	N30A	318.8	159.4	0.00271911	0.4334	
	N138	451.68	225.84	0.00271911	0.6141	1.62
N35			0	0.00271911	0.0000	
N19	N36	696.94	348.47	0.00271911	0.9475	
	N30A	739.93	369.965	0.00271911	1.0060	
	N20	294.44	147.22	0.00271911	0.4003	
	N118	477.44	238.72	0.00271911	0.6491	3.00
N20	N19	294.44	147.22	0.00271911	0.4003	
	N8	418.32	209.16	0.00271911	0.5687	
	N20A	212.32	106.16	0.00271911	0.2887	1.26

N10	N20A	148.57	74.285	0.00271911	0.2020	
	N6	431.15	215.575	0.00271911	0.5862	
	N42	401.98	200.99	0.00271911	0.5465	
	N9	290.54	145.27	0.00271911	0.3950	1.73
N20A	N10	148.57	74.285	0.00271911	0.2020	
	N20	212.32	106.16	0.00271911	0.2887	0.49
N6	B1	355.55	177.775	0.00271911	0.4834	
	N43	691.05	345.525	0.00271911	0.9395	
	N11	475.19	237.595	0.00271911	0.6460	
	N10	431.15	215.575	0.00271911	0.5862	2.66
N9	N10	290.54	145.27	0.00271911	0.3950	
	N5	285.32	142.66	0.00271911	0.3879	
	N8	421.67	210.835	0.00271911	0.5733	1.36
N5	N9	285.32	142.66	0.00271911	0.3879	
	N11	67.05	33.525	0.00271911	0.0912	
	N4	406.37	203.185	0.00271911	0.5525	1.03
N8	N20	418.32	209.16	0.00271911	0.5687	
	N9	421.67	210.835	0.00271911	0.5733	
	N18	301.73	150.865	0.00271911	0.4102	
	N7	299.09	149.545	0.00271911	0.4066	1.96
N18	N19	477.44	238.72	0.00271911	0.6491	
	N15	359.85	179.925	0.00271911	0.4892	
	N8	301.73	150.865	0.00271911	0.4102	
	N27	610.4	305.2	0.00271911	0.8299	2.38
N7	N8	299.09	149.545	0.00271911	0.4066	
	N4	232	116	0.00271911	0.3154	
	N15	579.3	289.65	0.00271911	0.7876	1.51
N13	N12	321.06	160.53	0.00271911	0.4365	
	N4	513.76	256.88	0.00271911	0.6985	
	N14	17.3	8.65	0.00271911	0.0235	1.16
N62	N63	155.13	77.565	0.00271911	0.2109	
	B59A	636.5	318.25	0.00271911	0.8654	
	N58	546.94	273.47	0.00271911	0.7436	
	N325	708.89	354.445	0.00271911	0.9638	2.78
N50	N49	266.5	133.25	0.00271911	0.3623	
	N45	562.2	281.1	0.00271911	0.7643	
	N58	344.32	172.16	0.00271911	0.4681	1.59
N58	N50	344.32	172.16	0.00271911	0.4681	
	N57	209	104.5	0.00271911	0.2841	
	N62	546.94	273.47	0.00271911	0.7436	1.50
N49	N50	266.5	133.25	0.00271911	0.3623	1.17

	B59A	280.29	140.145	0.00271911	0.3811	
	N44	314.12	157.06	0.00271911	0.4271	
B59A	N49	280.288	140.144	0.00271911	0.3811	
	N62	636.502	318.251	0.00271911	0.8654	
	N323	381.8641	190.93205	0.00271911	0.5192	1.77
N45	N50	562.2	281.1	0.00271911	0.7643	
	N44	351.58	175.79	0.00271911	0.4780	
	N38	652.77	326.385	0.00271911	0.8875	
	N36	376.14	188.07	0.00271911	0.5114	2.64
N44	N45	351.57	175.785	0.00271911	0.4780	
	N49	314.12	157.06	0.00271911	0.4271	
	N43	567.72	283.86	0.00271911	0.7718	
	N320	505.66	252.83	0.00271911	0.6875	2.36
N43	N44	567.72	283.86	0.00271911	0.7718	
	N42	422.93	211.465	0.00271911	0.5750	
	N6	691.05	345.525	0.00271911	0.9395	
	N319	651.45	325.725	0.00271911	0.8857	3.17
B1			0	0.00271911	0.0000	
N11	N5	67.05	33.525	0.00271911	0.0912	
	N6	475.19	237.595	0.00271911	0.6460	
	N2	315.55	157.775	0.00271911	0.4290	1.17
N2	N11	315.55	157.775	0.00271911	0.4290	
	B1	643.98	321.99	0.00271911	0.8755	
	N3	516.99	258.495	0.00271911	0.7029	2.01
N3	N2	516.99	258.495	0.00271911	0.7029	
	N4	352.92	176.46	0.00271911	0.4798	
	N12	690.58	345.29	0.00271911	0.9389	2.12
N4	N3	352.92	176.46	0.00271911	0.4798	
	N5	406.37	203.185	0.00271911	0.5525	
	N13	513.76	256.88	0.00271911	0.6985	
	N7	231.99	115.995	0.00271911	0.3154	2.05
N15	N14	293.53	146.765	0.00271911	0.3991	
	N7	579.3	289.65	0.00271911	0.7876	
	N18	359.85	179.925	0.00271911	0.4892	
	N24	491.84	245.92	0.00271911	0.6687	2.34
N14	N13	17.3	8.65	0.00271911	0.0235	
	N15	293.53	146.765	0.00271911	0.3991	
	N23	453.06	226.53	0.00271911	0.6160	1.04
N12	N13	321.05	160.525	0.00271911	0.4365	
	N21	632.71	316.355	0.00271911	0.8602	
	N3	690.58	345.29	0.00271911	0.9389	2.24

N146	N21	498.32	249.16	0.00271911	0.6775	
	N147	299.23	149.615	0.00271911	0.4068	
	N144	1012.16	506.08	0.00271911	1.3761	2.46
N22	N147	504.69	252.345	0.00271911	0.6862	
	N23	33.46	16.73	0.00271911	0.0455	
	N21	289.16	144.58	0.00271911	0.3931	1.12
N21	N146	498.32	249.16	0.00271911	0.6775	
	N22	289.16	144.58	0.00271911	0.3931	
	N12	632.71	316.355	0.00271911	0.8602	1.93
N23	N22	33.46	16.73	0.00271911	0.0455	
	N24	293.28	146.64	0.00271911	0.3987	
	N14	453.06	226.53	0.00271911	0.6160	1.06
N198	N199	89.67	44.835	0.00271911	0.1219	
	N195	315.74	157.87	0.00271911	0.4293	
	N197	453.18	226.59	0.00271911	0.6161	1.17
N197	N198	453.18	226.59	0.00271911	0.6161	
	N196	486.51	243.255	0.00271911	0.6614	
	N300	502.44	251.22	0.00271911	0.6831	
	N201	240.91	120.455	0.00271911	0.3275	2.29
N196	N197	486.51	243.255	0.00271911	0.6614	
	N195	419.19	209.595	0.00271911	0.5699	
	B170	349.03	174.515	0.00271911	0.4745	
	N301	497.59	248.795	0.00271911	0.6765	2.38
N195	N196	419.19	209.595	0.00271911	0.5699	
	N198	315.74	157.87	0.00271911	0.4293	
	N171	372.52	186.26	0.00271911	0.5065	1.51
N171	N195	372.52	186.26	0.00271911	0.5065	
	N172	434.24	217.12	0.00271911	0.5904	
	B170	365.61	182.805	0.00271911	0.4971	
	N168	344.32	172.16	0.00271911	0.4681	2.06
B170	N196	349.03	174.515	0.00271911	0.4745	
	N171	365.61	182.805	0.00271911	0.4971	
	N303	332.67	166.335	0.00271911	0.4523	1.42
N168	N171	344.32	172.16	0.00271911	0.4681	
	N169	473.09	236.545	0.00271911	0.6432	
	N166	384.46	192.23	0.00271911	0.5227	
	N303	416.9	208.45	0.00271911	0.5668	2.20
N169	N168	473.09	236.545	0.00271911	0.6432	
	N104	469.83	234.915	0.00271911	0.6388	
	N167	400.31	200.155	0.00271911	0.5442	
	N304	401	200.5	0.00271911	0.5452	2.37

N158	N125	1273.76	636.88	0.00271911	1.7317	
	N161	525.98	262.99	0.00271911	0.7151	
	N180	624.46	312.23	0.00271911	0.8490	
	N316	654.64	327.32	0.00271911	0.8900	4.19
N161	N162	33.91	16.955	0.00271911	0.0461	
	N157	434.98	217.49	0.00271911	0.5914	
	N158	525.98	262.99	0.00271911	0.7151	1.35
N184	N185	84.8	42.4	0.00271911	0.1153	
	N180	551.52	275.76	0.00271911	0.7498	
	N205	1114.99	557.495	0.00271911	1.5159	
	N314	503.86	251.93	0.00271911	0.6850	3.07
N180	N184	551.52	275.76	0.00271911	0.7498	
	N179	249.07	124.535	0.00271911	0.3386	
	N158	624.46	312.23	0.00271911	0.8490	
	N315	524.43	262.215	0.00271911	0.7130	2.65
N199	N198	89.67	44.835	0.00271911	0.1219	
	N188	324.13	162.065	0.00271911	0.4407	
	N200	315.34	157.67	0.00271911	0.4287	0.99
N201	N308	766.753	383.3765	0.00271911	1.0424	
	N203	699.3269	349.66345	0.00271911	0.9508	
	N197	240.914	120.457	0.00271911	0.3275	2.32
N205	N184	1114.9914	557.4957	0.00271911	1.5159	
	N187	564.6395	282.31975	0.00271911	0.7677	
	N312	750.064	375.032	0.00271911	1.0198	3.30
N203	N204	312.5965	156.29825	0.00271911	0.4250	
	N313	631.4147	315.70735	0.00271911	0.8584	
	N200	199.7925	99.89625	0.00271911	0.2716	
	N201	699.3269	349.66345	0.00271911	0.9508	2.51
N200	N199	315.341	157.6705	0.00271911	0.4287	
	N203	199.792	99.896	0.00271911	0.2716	
	N201	475.6043	237.80215	0.00271911	0.6466	1.35
N204	N203	312.596	156.298	0.00271911	0.4250	
	N188	541.7041	270.85205	0.00271911	0.7365	
	N205	285.977	142.9885	0.00271911	0.3888	1.55
N300	N197	502.443	251.2215	0.00271911	0.6831	
	N301	664.71	332.355	0.00271911	0.9037	
	plus univesity			0.00271911	0.0000	1.59
N301	N300	664.71	332.355	0.00271911	0.9037	
	N302	676.167	338.0835	0.00271911	0.9193	
	N196	497.593	248.7965	0.00271911	0.6765	2.50
N302	N301	676.1	338.05	0.00271911	0.9192	2.17

	N303	500.199	250.0995	0.00271911	0.6800	
	N305	421.625	210.8125	0.00271911	0.5732	
N303	N302	500.1991	250.09955	0.00271911	0.6800	
	N168	416.9	208.45	0.00271911	0.5668	
	B170	332.67	166.335	0.00271911	0.4523	
	N304	450.327	225.1635	0.00271911	0.6122	2.31
N304	N303	450.327	225.1635	0.00271911	0.6122	
	N307	699.44	349.72	0.00271911	0.9509	
	N169	401.004	200.502	0.00271911	0.5452	
	N305	501.829	250.9145	0.00271911	0.6823	2.79
N305	N304	501.829	250.9145	0.00271911	0.6823	
	N302	421.6259	210.81295	0.00271911	0.5732	
	N100	1186.8865	593.44325	0.00271911	1.6136	2.87
N306			0	0.00271911	0.0000	
N307	N304	699.44	349.72	0.00271911	0.9509	
	N100	261.115	130.5575	0.00271911	0.3550	
	N103	293.662	146.831	0.00271911	0.3992	1.71
N308	N201	766.75	383.375	0.00271911	1.0424	
	N309	600.007	300.0035	0.00271911	0.8157	
	N313	519.99	259.995	0.00271911	0.7070	2.57
N309	N308	600.007	300.0035	0.00271911	0.8157	
	N310	519.993	259.9965	0.00271911	0.7070	1.52
N310	N309	519.993	259.9965	0.00271911	0.7070	
	N313	600	300	0.00271911	0.8157	
	N311	586.8346	293.4173	0.00271911	0.7978	2.32
N311	N310	586.8346	293.4173	0.00271911	0.7978	
	N312	600.007	300.0035	0.00271911	0.8157	1.61
N312	N311	600.007	300.0035	0.00271911	0.8157	
	N313	586.834	293.417	0.00271911	0.7978	
	N205	750.064	375.032	0.00271911	1.0198	2.63
N313	N203	631.41	315.705	0.00271911	0.8584	
	N310	600	300	0.00271911	0.8157	
	N308	519.99	259.995	0.00271911	0.7070	
	N312	586.834	293.417	0.00271911	0.7978	3.18
N314	N184	503.861	251.9305	0.00271911	0.6850	
	N315	698.481	349.2405	0.00271911	0.9496	1.63
N315	N314	698.481	349.2405	0.00271911	0.9496	
	N180	524.43	262.215	0.00271911	0.7130	
	N316	874.16	437.08	0.00271911	1.1885	2.85
N316	N315	874.16	437.08	0.00271911	1.1885	
	N158	654.638	327.319	0.00271911	0.8900	3.82

	N317	1283.7409	641.87045	0.00271911	1.7453	
N317	N316	1283.7409	641.87045	0.00271911	1.7453	
	N125	664.7782	332.3891	0.00271911	0.9038	2.65
N318	N319	517.342	258.671	0.00271911	0.7034	
	N321	567.2217	283.61085	0.00271911	0.7712	1.47
N319	N318	517.342	258.671	0.00271911	0.7034	
	N320	545.384	272.692	0.00271911	0.7415	
	N43	651.45	325.725	0.00271911	0.8857	2.33
N320	N319	545.384	272.692	0.00271911	0.7415	
	N323	588.266	294.133	0.00271911	0.7998	
	N321	532.9861	266.49305	0.00271911	0.7246	
	N44	505.664	252.832	0.00271911	0.6875	2.95
N321	N320	532.9861	266.49305	0.00271911	0.7246	
	N322	602.579	301.2895	0.00271911	0.8192	
	N318	567.2217	283.61085	0.00271911	0.7712	2.32
N322	N321	602.579	301.2895	0.00271911	0.8192	
	N324	543.11	271.555	0.00271911	0.7384	
	N323	550.0283	275.01415	0.00271911	0.7478	2.31
N323	N322	550.0283	275.01415	0.00271911	0.7478	
	B59A	381.86	190.93	0.00271911	0.5192	
	N320	588.26	294.13	0.00271911	0.7998	
	N325	548.893	274.4465	0.00271911	0.7463	2.81
N324	N322	543.11	271.555	0.00271911	0.7384	
	N325	564.66	282.33	0.00271911	0.7677	1.51
N325	N324	564.66	282.33	0.00271911	0.7677	
	N323	548.89	274.445	0.00271911	0.7462	
	N62	708.8997	354.44985	0.00271911	0.9638	2.48
		sum	113272.5953		308.0006465	308.8

Jijiga Water Supply Design Review

Table: - A-3 Node result during Base Demand Scenario for 2025

S.N	Label	X (m)	Y (m)	Elevation (m)	Calculated Hydraulic Grade (m)	Pressure (bars)	Demand (Calculated) (l/s)
1	N317	258300.0	1032622.2	1679.0	1621.75	0.01	5.71
2	N315	260369.6	1032898.4	1712.1	1712.18	0.01	6.14
3	N309	262892.5	1035023.7	1765.2	1769.53	0.43	3.28
4	N316	259580.6	1032515.4	1693.4	1698.48	0.49	8.24
5	B205	262946.7	1033856.1	1782.0	1787.35	0.52	0.00
6	N314	260990.1	1033199.7	1733.2	1738.55	0.53	3.53
7	B1	255235.1	1035295.7	1741.0	1747.83	0.67	0.00
8	B20A	256181.5	1035363.5	1746.0	1753.41	0.73	0.00
9	N20	256324.3	1034623.8	1735.9	1743.75	0.77	1.82
10	B37A	257146.6	1035275.3	1736.3	1744.25	0.78	0.00
11	N35	257024.9	1035363.3	1735.0	1743.21	0.80	0.00
12	N42	256066.2	1035505.8	1749.0	1760.45	1.12	1.92
13	N38	256413.7	1035451.7	1746.2	1757.91	1.15	1.97
14	N310	262757.1	1034513.4	1768.8	1781.05	1.20	5.02
15	N311	262615.9	1033943.3	1772.9	1785.51	1.23	0.00
16	N37	256343.8	1035035.9	1740.1	1752.96	1.26	1.84
17	B40	256139.4	1035618.2	1747.8	1761.31	1.32	0.00
18	N66	257956.0	1036724.4	1725.0	1738.54	1.33	3.05
19	N324	256680.0	1037784.1	1726.4	1740.29	1.36	3.25
20	B137A	257647.3	1034691.3	1736.0	1750.07	1.38	0.00
21	N39	256219.4	1035487.8	1746.2	1760.54	1.40	0.00
22	B39	256233.5	1035554.8	1746.2	1760.83	1.43	0.00
23	N65	257616.0	1036205.4	1721.5	1736.79	1.50	2.41
24	N67	257998.8	1036398.3	1725.0	1740.61	1.52	1.87

25	N20A	256144.6	1035079.7	1737.0	1753.41	1.61	0.72
26	N305	259879.7	1036272.5	1707.7	1724.24	1.62	6.20
27	N64	257765.4	1036473.0	1720.5	1737.11	1.63	2.61
28	N10	255996.4	1035115.3	1738.2	1754.88	1.63	2.48
29	B41	256200.8	1035853.0	1745.5	1762.33	1.64	0.00
30	N55	257283.0	1035726.1	1723.2	1740.15	1.66	3.97
31	N8	256324.3	1034622.5	1726.7	1743.74	1.67	2.82
32	N321	255713.0	1037167.5	1756.7	1773.95	1.69	0.00
33	N43	255838.5	1035852.0	1747.5	1765.04	1.72	3.30
34	B326	255517.7	1037515.5	1762.8	1780.31	1.72	0.00
35	N32A	256630.7	1034983.7	1734.0	1752.31	1.79	0.00
36	N318	255239.5	1036858.4	1752.0	1771.09	1.87	3.17
37	B-37A	256530.3	1035415.5	1740.0	1759.15	1.87	0.00
38	B327	255396.8	1037668.4	1763.9	1783.42	1.91	0.00
39	N308	262311.5	1035168.4	1745.9	1765.56	1.92	5.53
40	N319	255518.3	1036420.0	1749.0	1768.9	1.94	5.04
41	N62	257177.4	1036728.9	1727.0	1747.11	1.97	2.64
42	N7	256081.8	1034452.1	1720.0	1740.27	1.99	2.18
43	N44	256225.8	1036260.5	1744.4	1765.06	2.02	2.41
44	N325	256950.3	1037276.5	1726.6	1747.29	2.03	5.35
45	N2	255370.4	1034674.2	1716.4	1737.44	2.06	2.89
46	B59B	256955.8	1036706.4	1732.0	1753.16	2.07	0.00
47	N320	255978.1	1036702.7	1749.0	1770.28	2.08	0.00
48	N9	255956.1	1034824.0	1729.4	1750.73	2.09	1.95
49	N11	255663.0	1034772.2	1725.4	1746.88	2.11	1.69
50	N45	256392.7	1035951.0	1741.7	1763.24	2.11	3.81
51	B46	256580.2	1036173.6	1738.8	1760.79	2.15	0.00
52	N6	255574.9	1035215.6	1731.6	1753.53	2.15	3.84
53	N59	256755.9	1036451.1	1735.2	1757.94	2.23	0.00
54	N14	256306.8	1033999.5	1712.1	1734.9	2.23	1.48
55	N50	256681.9	1036340.4	1736.4	1759.48	2.26	2.30

56	N49	256458.8	1036477.1	1740.5	1764.09	2.31	1.69
57	N19	256630.7	1034983.2	1728.6	1752.17	2.31	4.33
58	B47	256624.1	1036144.0	1737.5	1761.14	2.31	0.00
59	B48	256543.6	1036017.2	1738.2	1762.14	2.34	0.00
60	N57	257079.7	1036198.3	1729.2	1753.18	2.35	5.04
61	B34	257223.3	1035095.5	1721.6	1745.59	2.35	0.00
62	N-32A	256720.5	1035423.3	1734.0	1758.24	2.37	0.00
63	N63	257428.8	1036593.6	1723.2	1747.56	2.38	2.07
64	N36	256595.5	1035637.6	1736.6	1761.52	2.44	4.17
65	N18	256596.6	1034511.4	1720.0	1745.05	2.45	3.43
66	N313	262182.5	1034671.7	1749.6	1774.65	2.46	6.86
67	N5	255702.7	1034689.2	1720.2	1745.73	2.49	1.48
68	B59A	256661.8	1036674.4	1735.2	1761.2	2.55	1.79
69	B17	256335.5	1034200.7	1715.2	1741.71	2.59	0.00
70	N4	255878.0	1034329.3	1712.2	1738.75	2.60	2.94
71	N323	256487.4	1037002.3	1732.5	1759.11	2.60	6.07
72	N13	256279.8	1034014.7	1708.0	1734.64	2.61	1.66
73	B16	256450.8	1034354.7	1715.8	1742.48	2.61	0.00
74	B16A	256591.2	1034218.2	1716.0	1743.64	2.71	0.00
75	N71	257628.1	1035495.1	1715.5	1743.32	2.72	6.12
76	N201	261559.7	1035358.9	1734.4	1763.21	2.82	7.14
77	N68	257968.8	1035941.9	1714.6	1743.49	2.83	0.00
78	N312	262036.9	1034096.4	1753.7	1782.61	2.83	0.00
79	N81	258035.2	1036080.1	1713.8	1743.55	2.91	1.36
80	N69	258043.5	1035958.8	1713.4	1743.62	2.95	0.84
81	N3	255559.0	1034197.0	1702.6	1732.92	2.97	3.07
82	N15	256539.3	1034170.7	1712.7	1743.3	3.00	3.38
83	N300	261589.8	1035893.1	1725.7	1757.42	3.10	22.17
84	N73	257433.4	1035154.3	1715.3	1747.09	3.11	3.35
85	N12	256088.2	1033753.1	1698.5	1733.08	3.38	3.23
86	N301	260970.3	1036141.5	1717.8	1752.63	3.41	5.40

87	N80	258116.1	1035734.4	1710.9	1746.07	3.44	2.25
88	N322	256225.2	1037495.4	1733.0	1768.45	3.47	4.97
89	N147	257196.6	1033635.2	1695.0	1730.82	3.51	2.28
90	N22	256709.8	1033735.1	1700.6	1736.58	3.53	1.61
91	B74	257396.4	1035053.4	1712.0	1748.22	3.54	0.00
92	N202	261789.2	1035060.4	1730.2	1766.44	3.55	5.40
93	N93	258351.3	1036102.6	1709.0	1745.68	3.59	3.33
94	N94	258412.6	1036528.6	1706.9	1743.58	3.59	2.69
95	N27	257153.6	1034241.5	1706.2	1743.12	3.61	5.04
96	N30A	257367.6	1034876.1	1712.9	1750.12	3.64	3.10
97	N29	257328.3	1034631.7	1709.9	1747.4	3.67	1.61
98	N24	256926.0	1033933.6	1702.9	1740.43	3.67	3.17
99	N23	256689.0	1033771.0	1701.2	1738.85	3.69	1.54
100	B92	258332.5	1035886.8	1708.2	1746.47	3.74	0.00
101	N302	260298.7	1036214.4	1709.2	1748.34	3.83	4.68
102	N306	258985.1	1036388.4	1703.0	1742.19	3.84	0.00
103	N197	261318.8	1035425.9	1722.0	1762.46	3.96	2.84
104	N200	261388.1	1034921.3	1727.4	1767.99	3.97	5.02
105	N21	256650.7	1033460.2	1692.6	1733.42	3.99	2.79
106	N144	257819.9	1033356.9	1683.7	1724.47	3.99	2.97
107	N77	258179.6	1035455.3	1706.8	1747.7	4.00	1.74
108	B91A	258545.8	1035938.6	1705.7	1747.27	4.07	0.00
109	B76	258029.6	1035299.9	1707.8	1749.71	4.10	0.00
110	N91	258518.1	1035788.0	1705.7	1747.83	4.12	1.48
111	N90	258493.5	1035709.6	1705.5	1747.81	4.14	1.41
112	B95	258774.4	1036325.4	1703.0	1745.85	4.20	0.00
113	N78	258205.9	1035359.3	1705.6	1748.53	4.20	1.10
114	N96	258747.4	1036065.1	1704.0	1747.27	4.24	2.28
115	N137	257683.7	1034829.8	1707.3	1751.36	4.31	2.33
116	N75	258004.1	1035117.6	1706.8	1750.9	4.31	2.05
117	N89	258463.4	1035439.0	1703.8	1748.02	4.32	3.30

118	N205	261269.5	1034215.3	1734.4	1779.06	4.37	0.00
119	B137B	257721.5	1034666.8	1704.6	1749.36	4.38	0.00
120	N138	257708.4	1034587.1	1703.6	1748.64	4.40	3.23
121	N204	261447.4	1034533.2	1732.0	1777.33	4.44	3.35
122	N97	258709.2	1035746.3	1703.8	1749.44	4.47	1.84
123	B145A	257713.4	1033067.9	1678.5	1724.6	4.51	0.00
124	N146	257133.0	1033349.0	1678.5	1724.89	4.54	3.56
125	N196	260890.1	1035646.4	1714.2	1760.6	4.55	2.46
126	N140	257655.7	1034262.6	1699.3	1746.21	4.59	4.02
127	N203	261560.3	1034826.8	1725.1	1772.08	4.59	2.92
128	B82	258037.1	1035200.2	1706.5	1750.34	4.29	0.00
129	N99	258668.1	1035408.5	1701.7	1748.81	4.61	2.43
130	N304	259768.3	1035782.6	1704.1	1751.24	4.62	6.02
131	N100	258950.5	1036098.0	1700.3	1748	4.67	1.59
132	N141	257581.6	1034096.2	1697.7	1745.45	4.67	2.76
133	N307	259080.3	1035869.0	1701.8	1750.14	4.73	0.00
134	N98	258683.7	1035543.2	1702.9	1751.47	4.76	1.74
135	N148	257259.6	1033711.0	1693.0	1741.87	4.78	0.00
136	N101	258899.6	1035757.4	1701.2	1750.13	4.79	1.15
137	B107	258802.2	1035392.6	1700.2	1749.6	4.84	0.00
138	B102	258896.8	1035685.6	1701.1	1750.53	4.84	0.00
139	N198	261127.0	1035058.3	1718.6	1768.17	4.86	1.69
140	N142	257482.3	1033848.7	1694.7	1744.64	4.89	2.00
141	N303	260224.5	1035723.4	1705.5	1755.52	4.89	4.99
142	N199	261082.5	1034971.1	1718.6	1769.31	4.96	0.82
143	B130	257853.7	1034181.3	1696.0	1746.75	4.97	0.00
144	N85	258042.8	1034789.6	1700.9	1751.71	4.98	1.36
145	N136	258156.4	1034536.5	1697.8	1748.95	5.01	1.31
146	N85A	258131.8	1034769.1	1700.3	1751.87	5.05	0.79
147	N184	260722.8	1033637.8	1722.5	1774.08	5.05	3.53
148	B-	257474.1	1033324.0	1673.0	1724.75	5.06	0.00

	146B						
149	B105	258785.1	1035280.4	1699.7	1751.57	5.08	0.00
150	N108	258628.9	1035111.0	1699.3	1751.67	5.12	1.79
151	N-136A	258043.7	1034562.6	1697.6	1750.05	5.13	0.00
152	N195	260858.9	1035228.0	1712.1	1764.6	5.14	2.18
153	N83	258308.4	1034963.9	1697.6	1750.13	5.14	2.97
154	B170	260548.1	1035684.3	1706.6	1759.44	5.17	0.00
155	N134	258133.3	1034376.8	1694.8	1747.99	5.20	2.33
156	N188	260925.1	1034703.3	1720.2	1773.43	5.21	1.87
157	N185	260643.2	1033761.1	1720.7	1773.98	5.22	1.77
158	N112	258601.3	1034916.4	1697.6	1751.6	5.28	1.87
159	N186	260699.0	1034011.1	1720.7	1775.02	5.32	2.33
160	N86	258286.3	1034742.5	1697.8	1752.22	5.33	1.18
161	B143	257512.5	1033451.2	1672.9	1727.44	5.34	0.00
162	N127	258053.2	1033668.3	1686.3	1741.39	5.39	1.79
163	N130	258115.7	1034190.8	1692.2	1747.41	5.40	2.48
164	N129	258085.9	1033963.6	1690.1	1746.7	5.54	2.51
165	N126	257990.5	1033306.5	1680.6	1737.42	5.56	1.82
166	N180	260223.3	1033402.2	1708.7	1765.62	5.57	2.79
167	N128	258070.9	1033826.4	1688.2	1745.2	5.58	2.28
168	N103	259226.3	1035614.6	1695.1	1752.37	5.60	1.54
169	N187	260752.7	1034381.3	1720.0	1777.28	5.61	1.84
170	N113	258572.7	1034698.4	1695.4	1753.08	5.65	1.95
171	N104	259226.7	1035463.9	1694.2	1752.97	5.76	3.00
172	N114	258542.5	1034493.0	1692.0	1750.8	5.76	2.05
173	N171	260501.1	1035321.0	1703.9	1763	5.78	2.97
174	N173A	260709.4	1034850.4	1713.2	1772.79	5.83	0.20
175	N125	258339.3	1033177.5	1679.0	1738.73	5.85	4.02
176	N110	258945.7	1034871.5	1694.3	1754.08	5.85	1.59
177	N115	258522.1	1034335.2	1689.3	1750.17	5.96	2.00

178	N132	258498.3	1034155.2	1688.6	1749.63	5.98	1.56
179	N111	258845.3	1034661.9	1692.8	1754.08	6.00	2.18
180	N179	260171.0	1033645.8	1707.1	1768.51	6.01	1.31
181	N124	258447.9	1033659.7	1682.5	1744.02	6.02	3.07
182	N173	260600.0	1034874.8	1710.7	1772.52	6.06	1.43
183	N172	260452.0	1034894.2	1708.3	1770.41	6.08	1.92
184	N174	260498.6	1034411.4	1713.5	1775.72	6.09	1.89
185	N178	260173.6	1033727.3	1706.4	1769.06	6.13	1.84
186	N117	258828.3	1034481.9	1689.5	1752.19	6.14	1.23
187	N168	260155.0	1035322.2	1697.8	1760.79	6.16	2.36
188	N169	259684.7	1035391.3	1694.7	1757.77	6.17	2.64
189	N105	259087.5	1035131.5	1694.1	1757.41	6.20	2.00
190	N118	258812.4	1034322.9	1686.9	1750.91	6.27	1.87
191	N158	259647.7	1033171.9	1695.8	1760.24	6.31	4.76
192	N176	260200.2	1034081.8	1706.9	1771.56	6.33	2.41
193	N122	258472.0	1033916.0	1684.4	1749.78	6.40	4.22
194	N109	259049.7	1035062.3	1694.2	1759.7	6.42	2.53
195	N175	260268.5	1034452.2	1707.5	1774.56	6.57	1.84
196	N163	259889.5	1033909.9	1698.7	1767.96	6.78	2.00
197	N162	259828.2	1033693.9	1697.7	1767.4	6.82	3.12
198	N167	259607.1	1035000.7	1692.7	1763.5	6.93	3.66
199	N151	259143.3	1033807.3	1685.8	1756.84	6.95	2.28
200	N166	260052.4	1034938.1	1697.5	1768.53	6.95	3.33
201	N164	259942.8	1034223.6	1698.1	1769.9	7.03	2.12
202	N157	259394.8	1033750.2	1686.8	1758.92	7.06	1.74
203	N125B	259064.7	1033171.5	1679.0	1753.52	7.30	0.00
204	N156	259412.6	1033957.0	1688.0	1762.62	7.31	1.89
205	N165	259982.5	1034481.9	1697.9	1773.43	7.39	2.92
206	N152	259205.1	1034254.2	1687.8	1764.22	7.48	2.05
207	N155	259447.8	1034236.0	1688.9	1765.49	7.49	2.64
208	N154	259505.3	1034554.7	1689.3	1767.56	7.66	3.00

209	N153	259255.0	1034594.7	1689.7	1768	7.66	2.02
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Jijiga Water Supply Design Review

Table: - A-4 Node result during Base Demand Scenario for 2025

S.N	Label	X (m)	Y (m)	Elevation (m)	Demand (Calculated) (l/s)	Calculated Hydraulic Grade (m)	Pressure (bars)
1	B205	262946.72	1033856.14	1776.02	0	1783.46	0.73
2	N311	262615.90	1033943.28	1772.94	0	1783.08	0.99
3	B327	255396.77	1037668.37	1763.93	0	1790.76	2.63
4	B326	255517.66	1037515.45	1762.77	0	1789.91	2.66
5	N312	262036.90	1034096.41	1753.68	0	1782.39	2.81
6	B20A	256181.48	1035363.47	1746.00	0	1776.10	2.95
7	N42	256066.21	1035505.77	1748.99	1.15	1779.58	2.99
8	B321	255712.99	1037167.48	1756.66	0	1788.30	3.10
9	B40	256139.39	1035618.17	1747.82	0	1780.52	3.20
10	N43	255838.51	1035851.98	1747.51	1.98	1780.51	3.23
11	N38	256413.69	1035451.66	1746.17	1.18	1779.89	3.30
12	B39	256233.46	1035554.77	1746.19	0	1780.21	3.33
13	B1	255235.12	1035295.70	1741.00	0	1776.42	3.47
14	B41	256200.78	1035852.97	1745.54	0	1781.84	3.55
15	B320	255978.06	1036702.74	1749.03	0	1786.11	3.63
16	N10	255996.36	1035115.28	1738.21	1.49	1776.85	3.78
17	B137A	257647.28	1034691.29	1736.00	0	1775.04	3.82
18	20A	256144.59	1035079.67	1737.00	0	1776.10	3.83
19	N20A	35480.02	10068.81	1737.00	0.43	1776.10	3.83
20	N37	256343.83	1035035.93	1740.12	1.1	1779.33	3.84
21	N44	256225.79	1036260.54	1744.44	1.44	1784.03	3.87
22	N20	256324.31	1034623.81	1735.91	1.09	1775.85	3.91
23	N45	256392.67	1035951.02	1741.68	2.29	1782.78	4.02
24	N49	256458.77	1036477.05	1740.52	1.01	1783.66	4.22

25	B46	256580.22	1036173.58	1738.84	0	1782.42	4.27
26	B48	256543.63	1036017.17	1738.24	0	1781.97	4.28
27	B37A	257146.58	1035275.25	1736.25	0	1780.21	4.30
28	B47	256624.10	1036143.98	1737.50	0	1782.08	4.36
29	N50	256681.89	1036340.37	1736.44	1.38	1781.54	4.41
30	N6	255574.85	1035215.58	1731.57	2.3	1776.71	4.42
31	N36	256595.46	1035637.58	1736.56	2.5	1781.90	4.44
32	N66	257956.00	1036724.43	1725.00	1.83	1770.52	4.45
33	N32A	256630.69	1034983.67	1734.00	0	1779.64	4.47
34	N67	257998.76	1036398.32	1725.03	1.12	1771.23	4.52
35	N9	255956.12	1034823.96	1729.36	1.17	1775.59	4.52
36	N19	256630.73	1034983.21	1728.58	2.59	1775.60	4.60
37	N205	261269.52	1034215.29	1734.42	0	1781.51	4.61
38	N8	256324.26	1034622.48	1726.71	1.69	1774.12	4.64
39	B59A	256661.80	1036674.38	1735.18	1.07	1782.76	4.66
40	N35	257024.90	1035363.33	1724.69	0	1772.61	4.69
41	N55	257283.04	1035726.08	1723.15	2.38	1771.34	4.72
42	N59	256755.89	1036451.06	1732.00	0	1780.83	4.78
43	N11	255662.96	1034772.20	1725.35	1.01	1774.26	4.79
44	N65	257616.01	1036205.44	1721.49	1.44	1770.44	4.79
45	N62	257177.37	1036728.89	1726.97	1.58	1775.95	4.79
46	N57	257079.70	1036198.30	1729.16	3.02	1778.63	4.84
47	N300	261589.83	1035893.05	1725.72	13.28	1775.29	4.85
48	N64	257765.36	1036473.00	1720.48	1.56	1770.51	4.90
49	B59B	256955.75	1036706.40	1729.00	0	1779.57	4.95
50	B34	257223.30	1035095.47	1721.56	0	1773.01	5.04
51	N7	256081.76	1034452.05	1719.97	1.3	1772.35	5.13
52	N63	257428.76	1036593.64	1723.20	1.24	1776.00	5.17
53	N18	256596.58	1034511.41	1719.98	2.06	1773.25	5.21
54	N5	255702.72	1034689.19	1720.24	0.89	1773.95	5.26
55	N2	255370.38	1034674.18	1716.36	1.73	1771.31	5.38

56	N197	261318.81	1035425.90	1721.95	1.7	1777.12	5.40
57	B33	256720.48	1035423.28	1717.78	0	1773.60	5.46
58	N184	260722.77	1033637.81	1722.47	2.12	1778.41	5.48
59	B16A	256591.22	1034218.20	1716.00	0	1772.70	5.55
60	B16	256450.77	1034354.72	1715.77	0	1772.49	5.55
61	N71	257628.08	1035495.13	1715.50	3.67	1772.42	5.57
62	B17	256335.49	1034200.70	1715.24	0	1772.47	5.60
63	N68	257968.76	1035941.89	1714.56	0	1771.99	5.62
64	N185	260643.16	1033761.14	1720.67	1.06	1778.51	5.66
65	N81	258035.16	1036080.13	1713.81	0.81	1772.06	5.70
66	N14	256306.81	1033999.48	1712.10	0.89	1770.67	5.73
67	N186	260699.03	1034011.05	1720.65	1.4	1779.22	5.73
68	N69	258043.45	1035958.78	1713.43	0.51	1772.09	5.74
69	N73	257433.36	1035154.27	1715.28	2.01	1774.19	5.77
70	N188	260925.07	1034703.34	1720.16	1.12	1779.58	5.82
71	N4	255878.02	1034329.29	1712.18	1.76	1771.67	5.82
72	N15	256539.29	1034170.67	1712.68	2.02	1772.54	5.86
73	N198	261126.96	1035058.26	1718.55	1.01	1778.54	5.87
74	B74	257396.37	1035053.44	1714.42	0	1774.58	5.89
75	N199	261082.51	1034971.07	1718.63	0.49	1778.79	5.89
76	N187	260752.69	1034381.28	1720.00	1.1	1780.89	5.96
77	N80	258116.07	1035734.42	1710.94	1.35	1773.04	6.08
78	N30A	257367.55	1034876.05	1712.94	1.86	1775.56	6.13
79	N13	256279.75	1034014.69	1707.95	1	1770.58	6.13
80	N196	260890.09	1035646.35	1714.16	1.47	1777.45	6.19
81	N93	258351.34	1036102.62	1709.01	1.99	1772.45	6.21
82	B92	258332.50	1035886.75	1708.24	0	1772.73	6.31
83	N94	258412.58	1036528.60	1706.91	1.61	1771.45	6.32
84	N29	257328.33	1034631.72	1709.91	0.97	1774.55	6.33
85	N195	260858.85	1035228.02	1712.13	1.3	1777.93	6.44
86	N173A	260709.42	1034850.36	1713.21	0.12	1779.49	6.49

87	N77	258179.58	1035455.29	1706.82	1.04	1773.60	6.54
88	N174	260498.60	1034411.35	1713.46	1.13	1780.36	6.55
89	B76	258029.62	1035299.92	1707.83	0	1774.73	6.55
90	N27	257153.56	1034241.46	1706.21	3.02	1773.14	6.55
91	N3	255559.00	1034196.99	1702.58	1.84	1769.72	6.57
92	B91A	258545.81	1035938.59	1705.69	0	1773.01	6.59
93	N91	258518.09	1035788.02	1705.72	0.89	1773.10	6.59
94	N90	258493.51	1035709.59	1705.48	0.84	1773.10	6.62
95	N137	257683.72	1034829.84	1707.30	1.4	1775.61	6.69
96	N78	258205.91	1035359.26	1705.58	0.66	1774.09	6.70
97	N75	258004.14	1035117.62	1706.83	1.23	1775.37	6.71
98	N173	260600.03	1034874.84	1710.65	0.86	1779.45	6.73
99	N96	258747.35	1036065.12	1703.96	1.36	1772.85	6.74
100	N180	260223.28	1033402.15	1708.71	1.67	1777.88	6.77
101	B95	258774.44	1036325.38	1702.97	0	1772.30	6.78
102	N24	256925.97	1033933.62	1702.90	1.9	1772.31	6.79
103	N89	258463.38	1035439.01	1703.84	1.98	1773.46	6.81
104	N97	258709.21	1035746.31	1703.81	1.1	1773.48	6.82
105	B137B	257721.47	1034666.81	1704.61	0	1774.75	6.86
106	B82	258037.12	1035200.18	1704.77	0	1775.08	6.88
107	N22	256709.81	1033735.07	1700.56	0.97	1770.99	6.89
108	N23	256688.98	1033770.96	1701.16	0.92	1771.83	6.92
109	N172	260451.98	1034894.22	1708.27	1.15	1778.99	6.92
110	N138	257708.43	1034587.05	1703.63	1.93	1774.47	6.93
111	B170	260548.11	1035684.29	1706.60	0	1777.50	6.94
112	N98	258683.67	1035543.21	1702.85	1.04	1774.00	6.96
113	N179	260170.96	1033645.77	1707.10	0.78	1778.30	6.97
114	N12	256088.23	1033753.11	1698.52	1.93	1769.90	6.99
115	B106	258785.10	1035280.36	1699.70	0	1771.57	7.03
116	N307	259080.25	1035868.95	1701.79	0	1773.71	7.04
117	N99	258668.07	1035408.52	1701.73	1.46	1773.70	7.04

118	N178	260173.58	1033727.34	1706.43	1.1	1778.43	7.05
119	N176	260200.24	1034081.78	1706.85	1.44	1779.09	7.07
120	B107	258802.16	1035392.63	1700.17	0	1772.54	7.08
121	N101	258899.59	1035757.36	1701.24	0.69	1773.69	7.09
122	N175	260268.48	1034452.21	1707.46	1.1	1779.97	7.10
123	B102	258896.75	1035685.56	1701.08	0	1773.78	7.12
124	N100	258950.50	1036098.04	1700.32	0.95	1773.11	7.12
125	N171	260501.14	1035320.95	1703.92	1.78	1777.66	7.22
126	N140	257655.68	1034262.59	1699.28	2.41	1773.20	7.23
127	N147	257196.64	1033635.16	1694.99	1.36	1769.65	7.31
128	N105	259087.53	1035131.52	1694.10	1.2	1768.79	7.31
129	N85	258042.84	1034789.62	1700.87	0.81	1775.75	7.33
130	N141	257581.56	1034096.18	1697.73	1.66	1772.73	7.34
131	N85A	258131.78	1034769.11	1700.26	0.48	1775.78	7.39
132	N108	258628.91	1035111.02	1699.30	1.07	1775.29	7.44
133	N148	257259.56	1033710.96	1695.65	0.89	1772.33	7.50
134	N136	258156.43	1034536.45	1697.75	0.78	1774.62	7.52
135	N83	258308.42	1034963.92	1697.60	1.78	1774.92	7.57
136	N21	256650.70	1033460.24	1692.64	1.67	1770.01	7.57
137	B130	257853.72	1034181.31	1696.00	0	1773.48	7.58
138	N142	257482.26	1033848.66	1694.65	1.2	1772.40	7.61
139	N135	258043.70	1034562.62	1696.88	0.71	1774.87	7.63
140	N112	258601.31	1034916.44	1697.63	1.12	1775.64	7.63
141	N86	258286.25	1034742.51	1697.78	0.71	1775.91	7.65
142	N103	259226.27	1035614.56	1695.13	0.92	1774.37	7.75
143	N168	260154.98	1035322.23	1697.84	1.41	1777.25	7.77
144	N134	258133.30	1034376.80	1694.81	1.4	1774.22	7.77
145	N163	259889.52	1033909.90	1698.69	1.2	1778.14	7.78
146	N162	259828.20	1033693.88	1697.69	1.87	1778.02	7.86
147	N104	259226.74	1035463.89	1694.16	1.79	1774.56	7.87
148	N164	259942.78	1034223.59	1698.09	1.27	1778.61	7.88

149	B143	257512.49	1033451.16	1688.87	0	1769.65	7.91
150	N113	258572.66	1034698.41	1695.36	1.17	1776.24	7.92
151	N166	260052.43	1034938.10	1697.48	1.99	1778.55	7.93
152	N158	259647.66	1033171.89	1695.79	2.85	1777.04	7.95
153	N169	259684.67	1035391.29	1694.69	1.58	1776.18	7.98
154	B146B	257474.12	1033323.98	1687.09	0	1768.68	7.99
155	N130	258115.67	1034190.84	1692.21	1.49	1773.84	7.99
156	N165	259982.47	1034481.93	1697.92	1.75	1779.58	7.99
157	N110	258945.72	1034871.47	1694.29	0.95	1776.48	8.04
158	N109	259049.65	1035062.32	1694.15	1.52	1776.75	8.08
159	N129	258085.91	1033963.61	1690.10	1.5	1772.73	8.09
160	N114	258542.46	1034493.00	1691.95	1.23	1775.12	8.14
161	N111	258845.34	1034661.88	1692.77	1.3	1776.67	8.21
162	N128	258070.91	1033826.35	1688.22	1.36	1772.28	8.23
163	N127	258053.23	1033668.25	1686.31	1.07	1770.91	8.28
164	N167	259607.14	1035000.68	1692.67	2.19	1777.43	8.30
165	N115	258522.08	1034335.17	1689.32	1.2	1774.55	8.34
166	N132	258498.27	1034155.18	1688.56	0.94	1774.15	8.38
167	N144	257819.86	1033356.87	1683.66	1.78	1769.65	8.42
168	N117	258828.29	1034481.90	1689.49	0.74	1775.75	8.44
169	N153	259254.95	1034594.69	1689.69	1.21	1777.53	8.60
170	N118	258812.41	1034322.87	1686.85	1.12	1775.06	8.63
171	N155	259447.82	1034235.95	1688.94	1.58	1777.35	8.65
172	N156	259412.59	1033957.02	1687.95	1.13	1776.58	8.67
173	N154	259505.26	1034554.74	1689.30	1.79	1778.12	8.69
174	N157	259394.76	1033750.16	1686.75	1.04	1775.62	8.70
175	N122	258472.04	1033915.98	1684.41	2.53	1773.36	8.71
176	N145	257713.36	1033067.89	1680.24	0	1769.20	8.71
177	N152	259205.06	1034254.18	1687.77	1.23	1776.82	8.71
178	N124	258447.94	1033659.74	1682.48	1.84	1771.66	8.73
179	N126	257990.49	1033306.50	1680.58	1.09	1769.82	8.73

180	N151	259143.28	1033807.30	1685.83	1.36	1775.09	8.74
181	N146	257133.02	1033349.01	1678.49	2.13	1768.18	8.78
182	N125	258339.30	1033177.46	1678.98	2.41	1770.30	8.94
183	N125B	259064.66	1033171.49	1682.35	0	1774.82	9.05

Jigjiga Water Supply Design Review**Table: - A-5 Pipe result during Base Consumption Scenario for 2025**

S.N	From Node	To Node	Length	Diameter	Discharge	Velocity	Friction loss	Gradient
			m	mm	l/s	m/s	m	m/km
99	B20A	20A	50.29	200	0.00	0.00	0.00	0.00
100	B20A	N20A	302.06	200	0.00	0.00	0.00	0.00
101	N129	N141	519.38	50	0.02	0.01	0.00	0.00
97	B143	N144	322.78	50	0.03	0.01	0.00	0.01
98	N147	B143	357.53	50	0.03	0.01	0.00	0.01
102	N66	N64	429.16	80	0.14	0.03	0.01	0.02
94	N91	N90	52.12	100	0.20	0.03	0.00	0.01
114	N148	N24	452.63	100	0.40	0.05	0.02	0.04
103	N21	N12	629.72	50	0.15	0.08	0.11	0.17
104	N185	N178	503.53	50	0.15	0.08	0.09	0.18
96	N128	N142	585.52	50	0.16	0.08	0.12	0.20
105	N12	N3	689.76	50	0.18	0.09	0.18	0.26
116	N90	N80	390.75	80	0.44	0.09	0.05	0.14
95	N176	N186	506.88	50	0.19	0.10	0.13	0.27
106	N63	N62	158.5	50	0.21	0.11	0.05	0.34
107	B17	N7	373.08	50	0.21	0.11	0.13	0.34
108	N15	B16	153.92	50	0.21	0.11	0.05	0.34
109	B16	B17	48.77	50	0.21	0.11	0.02	0.34
110	N64	N65	195.68	50	0.22	0.11	0.07	0.37
120	N29	N138	387.1	80	0.57	0.11	0.08	0.22
80	N196	B170	347.47	100	0.84	0.11	0.05	0.15
140	N18	N27	610.82	100	0.89	0.11	0.10	0.17
232	N19	N30A	741.27	300	7.82	0.11	0.04	0.06
111	N151	N125B	638.25	50	0.24	0.12	0.27	0.42
130	N10	N6	431.6	80	0.72	0.14	0.14	0.33
112	N71	N68	573.02	50	0.32	0.16	0.43	0.74
135	N69	N81	70.41	80	0.78	0.16	0.03	0.39

136	N69	N81	70.41	80	0.78	0.16	0.03	0.39
152	N142	N148	195.68	100	1.29	0.16	0.06	0.33
93	N130	N132	386.79	50	0.34	0.17	0.31	0.80
81	B170	N171	366.37	80	0.84	0.17	0.16	0.44
113	N27	N141	459.03	50	0.36	0.18	0.42	0.91
139	N94	N67	438.61	80	0.89	0.18	0.22	0.49
79	N89	N77	283.77	80	0.91	0.18	0.15	0.51
92	N180	N184	556.56	50	0.37	0.19	0.54	0.97
18	N30A	N137	318.82	300	14.09	0.20	0.05	0.17
91	N68	N69	85.34	50	0.42	0.21	0.10	1.19
115	N109	N110	220.37	50	0.42	0.21	0.27	1.21
206	N173A	N173	105.46	150	3.74	0.21	0.03	0.33
208	N188	N173A	271.58	150	3.87	0.22	0.09	0.35
90	N158	N180	623.93	50	0.45	0.23	0.84	1.34
76	N110	N111	238.05	80	1.15	0.23	0.19	0.78
147	N6	B1	354.18	80	1.16	0.23	0.28	0.80
149	N115	N134	391.67	80	1.18	0.23	0.32	0.82
87	N146	B146B	342.29	50	0.46	0.24	0.50	1.45
88	B146B	N145	356.01	50	0.46	0.24	0.52	1.45
89	N145	N144	312.72	50	0.46	0.24	0.45	1.45
117	N55	N65	583.69	50	0.48	0.24	0.90	1.54
68	N197	N196	484.94	100	1.90	0.24	0.33	0.68
72	N138	N135	402.64	80	1.31	0.26	0.40	1.00
153	N96	N93	401.12	80	1.31	0.26	0.40	1.00
118	N124	N127	393.19	50	0.54	0.27	0.75	1.92
39	N162	N163	220.68	150	4.81	0.27	0.12	0.52
119	N4	N13	510.54	50	0.57	0.29	1.09	2.14
156	N93	N81	314.55	80	1.45	0.29	0.38	1.21
64	N144	N126	178.61	100	2.27	0.29	0.17	0.94
17	N137	N85	419.71	300	20.34	0.29	0.14	0.34
86	B48	B47	50.9	50	0.58	0.30	0.11	2.22

121	N45	B46	161.85	50	0.58	0.30	0.36	2.22
122	B48	N50	195.38	50	0.58	0.30	0.43	2.22
123	B46	B47	151.79	50	0.58	0.30	0.34	2.22
124	N93	N94	450.19	50	0.58	0.30	1.00	2.22
157	N89	N90	285.6	80	1.48	0.30	0.36	1.27
71	N136	N114	387.71	80	1.49	0.30	0.49	1.28
125	N110	N112	345.34	50	0.61	0.31	0.84	2.44
69	B130	N130	266.4	80	1.53	0.31	0.36	1.35
70	N140	B130	206.04	80	1.53	0.31	0.28	1.35
61	N184	N185	89.61	100	2.49	0.32	0.10	1.11
177	N101	N97	187.15	100	2.49	0.32	0.21	1.11
59	N196	N195	420.62	100	2.54	0.32	0.48	1.15
182	N99	N89	206.35	100	2.55	0.32	0.24	1.16
30	N171	N195	372.16	150	5.78	0.33	0.27	0.73
83	N35	B34	140.51	50	0.67	0.34	0.40	2.83
84	B33	N73	211.84	50	0.67	0.34	0.60	2.83
85	B34	B33	208.18	50	0.67	0.34	0.59	2.83
126	N35	N55	450.19	50	0.67	0.34	1.27	2.83
184	N141	N142	263.65	100	2.65	0.34	0.33	1.25
57	N126	N125	377.65	100	2.67	0.34	0.48	1.27
56	N96	N100	201.78	100	2.71	0.34	0.26	1.30
127	N8	N18	300.23	50	0.68	0.35	0.88	2.93
128	N127	N126	361.8	50	0.69	0.35	1.09	3.00
159	N179	N180	249.02	80	1.74	0.35	0.43	1.71
160	N112	N108	199.95	80	1.77	0.35	0.35	1.75
53	B92	B91A	213.66	100	2.72	0.35	0.28	1.31
54	B91A	N91	67.67	100	2.72	0.35	0.09	1.31
185	B92	N93	213.97	100	2.72	0.35	0.28	1.31
227	N179	N162	342.29	150	6.12	0.35	0.28	0.82
129	N2	N3	515.42	50	0.70	0.36	1.59	3.09
161	N118	N115	289.26	80	1.79	0.36	0.52	1.79

131	N132	N122	235.61	50	0.73	0.37	0.79	3.35
162	N97	N96	322.17	80	1.88	0.37	0.63	1.97
243	N20	N19	293.52	200	11.68	0.37	0.25	0.87
132	N68	N65	449.28	50	0.74	0.38	1.55	3.45
133	N9	N8	420.93	50	0.74	0.38	1.46	3.48
163	N96	B95	270.36	80	1.92	0.38	0.55	2.03
164	B95	N94	418.19	80	1.92	0.38	0.85	2.03
67	N152	N153	345.95	80	1.93	0.38	0.71	2.06
52	N167	N154	450.49	100	2.96	0.38	0.69	1.53
134	N21	N146	497.74	50	0.76	0.39	1.82	3.66
165	N67	N66	332.23	80	1.97	0.39	0.71	2.14
166	N13	N12	317.91	80	1.97	0.39	0.68	2.14
66	N99	N98	139.9	80	1.98	0.39	0.30	2.16
190	N122	N129	387.71	100	3.05	0.39	0.63	1.62
228	N104	N98	547.42	150	6.94	0.39	0.56	1.03
82	N125B	N158	578.51	50	0.78	0.40	2.21	3.83
167	N155	N152	242.32	80	2.00	0.40	0.53	2.20
168	N115	N132	180.44	80	2.00	0.40	0.40	2.20
65	N114	N117	284.38	80	2.02	0.40	0.64	2.24
194	B102	N101	53.04	100	3.18	0.40	0.09	1.75
195	N103	B102	335.89	100	3.18	0.40	0.59	1.75
28	N75	N85	356.62	150	7.04	0.40	0.38	1.06
15	N85	N85A	43.89	300	28.19	0.40	0.03	0.61
196	N162	N158	559	100	3.19	0.41	0.99	1.76
229	N172	N166	401.12	150	7.16	0.41	0.44	1.09
49	N15	B16A	81.99	100	3.29	0.42	0.15	1.87
201	N18	B16A	293.52	100	3.29	0.42	0.55	1.87
230	N44	N49	313.94	150	7.45	0.42	0.37	1.18
231	N171	N168	344.12	150	7.47	0.42	0.41	1.18
202	N77	N80	283.77	100	3.39	0.43	0.56	1.97
48	N91	N97	192.94	100	3.41	0.43	0.39	2.00

27	N109	N167	559	150	7.60	0.43	0.68	1.22
169	N71	N55	414.83	80	2.19	0.44	1.08	2.60
170	N81	N67	318.52	80	2.20	0.44	0.84	2.62
171	N23	N14	431.29	80	2.23	0.44	1.16	2.69
47	N78	N83	407.82	100	3.47	0.44	0.84	2.05
26	N103	N104	155.14	150	7.75	0.44	0.20	1.27
249	N20A	N20	210.62	200	13.71	0.44	0.25	1.17
137	N11	N5	66.45	50	0.88	0.45	0.31	4.72
138	N130	N129	228.6	50	0.89	0.45	1.11	4.85
172	N22	N147	494.69	80	2.24	0.45	1.34	2.72
173	N113	N112	217.63	80	2.27	0.45	0.61	2.79
141	N147	N146	293.83	50	0.90	0.46	1.46	4.98
174	N7	N4	231.04	80	2.33	0.46	0.67	2.92
204	N134	N130	176.78	100	3.58	0.46	0.38	2.18
45	N307	N103	290.17	100	3.66	0.47	0.66	2.27
46	N100	N307	264.87	100	3.66	0.47	0.60	2.27
44	N185	N186	306.93	100	3.70	0.47	0.71	2.31
63	N13	N14	30.18	80	2.39	0.48	0.09	3.07
175	N129	N128	143.26	80	2.43	0.48	0.45	3.14
205	N154	N155	325.53	100	3.74	0.48	0.77	2.37
207	N136	N134	164.59	100	3.79	0.48	0.40	2.43
25	N163	N164	316.69	150	8.47	0.48	0.47	1.49
14	N85A	N86	148.13	300	33.77	0.48	0.13	0.86
142	N4	N3	352.35	50	0.96	0.49	1.96	5.55
143	N5	N4	405.99	50	0.96	0.49	2.28	5.61
176	N49	B59A	282.24	80	2.44	0.49	0.90	3.18
62	N156	N163	479.45	80	2.47	0.49	1.56	3.26
178	N80	N69	288.65	80	2.49	0.49	0.95	3.29
43	N155	N164	499.26	100	3.88	0.49	1.26	2.53
233	N178	N179	79.25	150	8.64	0.49	0.12	1.55
144	N9	N5	285.29	50	0.98	0.50	1.64	5.75

60	N108	N109	428.55	80	2.53	0.50	1.46	3.41
209	N98	N97	201.78	100	3.91	0.50	0.52	2.57
42	N141	N140	183.18	100	3.93	0.50	0.47	2.59
179	N75	B82	84.43	80	2.54	0.51	0.29	3.43
180	B82	B76	102.41	80	2.54	0.51	0.35	3.43
181	B76	N78	188.98	80	2.54	0.51	0.65	3.43
58	N21	N22	278.28	80	2.58	0.51	0.98	3.54
183	N114	N115	161.24	80	2.59	0.51	0.57	3.55
211	N155	N156	284.07	100	4.03	0.51	0.77	2.72
234	N24	N23	292.61	150	8.94	0.51	0.48	1.65
78	N125	N125B	725.42	50	1.02	0.52	4.53	6.24
41	N125	N124	494.08	100	4.06	0.52	1.36	2.75
212	N38	N37	201.17	100	4.10	0.52	0.56	2.80
145	N15	N14	282.85	50	1.05	0.54	1.87	6.62
55	N151	N152	448.06	80	2.71	0.54	1.73	3.85
235	N176	N178	353.87	150	9.60	0.54	0.67	1.88
24	N195	N198	322.17	150	9.62	0.54	0.61	1.89
216	N172	N171	433.12	100	4.31	0.55	1.33	3.08
217	N167	N169	400.81	100	4.33	0.55	1.24	3.11
23	N173	N174	470	150	9.73	0.55	0.91	1.93
77	N37	B37A	121.31	50	1.11	0.56	0.88	7.27
146	N36	B37A	232.56	50	1.11	0.56	1.69	7.27
22	N42	N38	152.1	150	9.95	0.56	0.31	2.01
13	N86	N113	288.95	300	39.72	0.56	0.34	1.16
186	N10	N9	289.86	80	2.89	0.57	1.26	4.34
187	N73	N71	405.08	80	2.90	0.58	1.78	4.39
188	N117	N118	157.58	80	2.91	0.58	0.69	4.40
189	N36	N57	739.75	80	2.91	0.58	3.27	4.42
40	N168	N166	384.35	100	4.54	0.58	1.30	3.39
236	N157	N151	253.9	150	10.19	0.58	0.53	2.10
148	B1	N2	645.87	50	1.16	0.59	5.11	7.91

237	N43	N42	423.06	150	10.43	0.59	0.93	2.19
238	N27	N24	377.65	150	10.44	0.59	0.83	2.20
21	N166	N165	460.25	150	10.54	0.60	1.03	2.24
239	N168	N169	472.14	150	10.60	0.60	1.07	2.26
73	B106	B107	115.52	50	1.20	0.61	0.97	8.38
74	N105	B106	332.23	50	1.20	0.61	2.79	8.38
75	B107	N99	138.07	50	1.20	0.61	1.16	8.38
191	N135	N136	50.6	80	3.09	0.61	0.25	4.91
218	N138	N140	336.8	100	4.80	0.61	1.27	3.76
240	N45	N36	375.21	150	10.81	0.61	0.88	2.34
241	N175	N176	372.16	150	10.85	0.61	0.88	2.36
150	N128	N127	157.58	50	1.22	0.62	1.37	8.71
192	N57	N63	530.96	80	3.10	0.62	2.63	4.94
51	N104	N109	432.51	80	3.13	0.62	2.18	5.05
36	N138	B137B	74.07	100	4.86	0.62	0.28	3.84
37	B137B	B137A	75.9	100	4.86	0.62	0.29	3.84
38	B137A	N137	148.13	100	4.86	0.62	0.57	3.84
193	N6	N11	475.49	80	3.16	0.63	2.44	5.14
242	N166	N167	451.41	150	11.17	0.63	1.12	2.49
197	N59	N57	417.88	80	3.20	0.64	2.20	5.26
198	N50	N59	134.42	80	3.20	0.64	0.71	5.26
199	N108	N99	297.79	80	3.23	0.64	1.59	5.33
219	N20	N8	420.62	100	5.04	0.64	1.73	4.11
20	N122	N151	681.84	150	11.29	0.64	1.73	2.54
151	N11	N2	314.86	50	1.27	0.65	2.95	9.38
50	N114	N113	204.22	80	3.28	0.65	1.13	5.51
200	N75	N71	538.89	80	3.28	0.65	2.96	5.49
35	N135	N85A	216.41	100	5.10	0.65	0.91	4.20
12	N113	N111	272.8	300	46.44	0.66	0.42	1.55
34	N83	N86	222.2	100	5.24	0.67	0.98	4.42
33	N186	N187	372.47	100	5.28	0.67	1.67	4.48

203	N8	N7	299.01	80	3.42	0.68	1.78	5.95
220	N78	N77	105.46	100	5.35	0.68	0.48	4.58
221	N156	N157	206.04	100	5.37	0.68	0.95	4.62
154	B59B	N62	337.11	50	1.37	0.70	3.62	10.74
155	B59A	B59B	297.18	50	1.37	0.70	3.19	10.74
222	N19	N18	477.32	100	5.56	0.71	2.35	4.93
31	B74	N30A	197.51	100	5.58	0.71	0.98	4.96
32	N73	B74	77.11	100	5.58	0.71	0.38	4.96
244	N173	N172	148.13	150	12.62	0.71	0.46	3.12
223	N111	N117	178.61	100	5.66	0.72	0.91	5.10
245	N29	N27	430.99	150	12.93	0.73	1.41	3.27
8	N165	N175	284.99	400	92.10	0.73	0.39	1.36
246	N198	N197	425.81	150	13.08	0.74	1.42	3.34
225	N162	N157	441.35	100	5.86	0.75	2.40	5.44
226	N43	N6	690.68	100	5.90	0.75	3.81	5.51
247	N197	N300	533.1	150	13.28	0.75	1.83	3.43
16	N198	N199	102.41	200	23.71	0.75	0.25	2.47
248	N169	N104	467.56	150	13.35	0.76	1.62	3.47
19	N164	N165	269.75	150	13.62	0.77	0.97	3.60
258	N188	N199	307.54	200	24.20	0.77	0.79	2.57
11	N111	N153	413	300	54.55	0.77	0.86	2.09
1	B205	RES- 3,000M3	119.79	500	150.50	0.77	0.14	1.14
2	N205	N312	777.24	500	150.50	0.77	0.88	1.14
3	N312	N311	600.15	500	150.50	0.77	0.68	1.14
4	N311	B205	341.07	500	150.50	0.77	0.39	1.14
5	N187	N205	539.19	500	150.50	0.77	0.61	1.14
210	N49	N50	267.31	80	4.00	0.80	2.12	7.94
250	N10	N20A	148.74	150	14.14	0.80	0.75	5.02
213	N37	N20	416.97	80	4.10	0.82	3.47	8.33
29	N124	N122	262.43	100	6.44	0.82	1.70	6.47

251	N30A	N29	249.94	150	14.47	0.82	1.01	4.02
10	N153	N154	254.2	300	57.70	0.82	0.59	2.32
7	N175	N174	229.21	400	104.06	0.83	0.39	1.70
158	N63	N64	364.54	50	1.64	0.84	5.49	15.07
214	N36	N32A	250.24	80	4.29	0.85	2.26	9.04
215	N32A	N19	446.84	80	4.29	0.85	4.04	9.04
252	N45	B41	211.53	150	15.23	0.86	0.94	4.42
253	B41	B40	299.62	150	15.23	0.86	1.32	4.42
254	B39	N38	71.63	150	15.23	0.86	0.32	4.42
255	B40	B39	70.71	150	15.23	0.86	0.31	4.42
6	N174	N187	261.52	400	114.93	0.91	0.54	2.05
259	N44	N45	350.22	200	28.91	0.92	1.25	3.57
260	N187	N188	361.49	200	29.19	0.93	1.31	3.63
9	N154	N165	488.29	300	66.19	0.94	1.46	2.99
256	N44	N43	565.71	150	18.31	1.04	3.52	6.22
257	N42	N10	402.03	150	19.23	1.09	2.74	6.81
261	B327	B326	205.44	250	56.12	1.14	0.84	4.11
262	B326	B321	391.97	250	56.12	1.14	1.61	4.11
263	B321	B320	533.1	250	56.12	1.14	2.19	4.11
264	RES- 1000M3	B327	387.1	250	56.12	1.14	1.59	4.11
265	B320	N44	506.88	250	56.12	1.14	2.08	4.11
224	N23	N22	53.34	80	5.79	1.15	0.84	15.76

Annex 1 A-6 PIPE BASE-2025

PIPE BASE-2025

S.N	From Node	To Node	Length	Diameter	Discharge	Velocity	Friction loss	Gradient
			m	mm	l/s	m/s	m	m/km
99	B20A	20A	50.29	200	0.00	0.00	0.00	0.00
100	B20A	N20A	302.06	200	0.00	0.00	0.00	0.00
97	N91	N90	52.12	100	0.08	0.01	0.00	0.00
98	N128	N142	585.52	50	0.08	0.04	0.03	0.05
179	N19	N30A	741.27	300	4.01	0.06	0.01	0.02
95	N147	B143	357.53	50	0.18	0.09	0.09	0.24
96	B143	N144	322.78	50	0.18	0.09	0.08	0.24
113	N66	N64	429.16	80	0.59	0.12	0.10	0.23
124	N148	N24	452.63	100	0.97	0.12	0.09	0.19
101	N64	N65	195.68	50	0.25	0.13	0.09	0.48
114	N29	N138	387.10	80	0.65	0.13	0.11	0.27
102	N129	N141	519.38	50	0.27	0.14	0.28	0.55
132	N18	N27	610.82	100	1.13	0.14	0.16	0.26
103	N185	N178	503.53	50	0.31	0.16	0.35	0.69
104	N21	N12	629.72	50	0.32	0.16	0.46	0.73
80	N196	B170	347.47	100	1.24	0.16	0.11	0.31
94	N176	N186	506.88	50	0.35	0.18	0.44	0.88
105	N151	N125B	638.25	50	0.37	0.19	0.60	0.93
119	N90	N80	390.75	80	0.93	0.19	0.21	0.53
106	N12	N3	689.76	50	0.42	0.21	0.82	1.19
107	N71	N68	573.02	50	0.44	0.22	0.75	1.31
108	B16	B17	48.77	50	0.45	0.23	0.07	1.39
109	N15	B16	153.92	50	0.45	0.23	0.21	1.39
110	B17	N7	373.08	50	0.45	0.23	0.52	1.39
82	N89	N77	283.77	80	1.16	0.23	0.23	0.81
111	N63	N62	158.50	50	0.46	0.24	0.23	1.44
81	B170	N171	366.37	80	1.24	0.25	0.33	0.91

135	N69	N81	70.41	80	1.24	0.25	0.06	0.91
136	N69	N81	70.41	80	1.24	0.25	0.06	0.91
112	N27	N141	459.03	50	0.51	0.26	0.79	1.73
93	N130	N132	386.79	50	0.59	0.30	0.88	2.27
157	N142	N148	195.68	100	2.39	0.30	0.20	1.04
92	N180	N184	556.56	50	0.63	0.32	1.42	2.55
144	N94	N67	438.61	80	1.61	0.32	0.65	1.48
77	N110	N111	238.05	80	1.63	0.32	0.36	1.51
147	N6	B1	354.18	80	1.79	0.36	0.63	1.79
229	N20	N19	293.52	200	11.44	0.36	0.25	0.84
91	N158	N180	623.93	50	0.73	0.37	2.10	3.37
68	N197	N196	484.94	100	2.94	0.37	0.74	1.52
213	N173A	N173	105.46	150	6.47	0.37	0.10	0.90
216	N188	N173A	271.58	150	6.67	0.38	0.26	0.96
88	N146	B146B	342.29	50	0.76	0.39	1.25	3.66
89	N145	N144	312.72	50	0.76	0.39	1.14	3.66
90	B146B	N145	356.01	50	0.76	0.39	1.30	3.66
115	N55	N65	583.69	50	0.79	0.40	2.28	3.90
150	N10	N6	431.60	80	1.99	0.40	0.94	2.17
151	N115	N134	391.67	80	2.02	0.40	0.88	2.25
87	N68	N69	85.34	50	0.82	0.42	0.36	4.18
116	N4	N13	510.54	50	0.84	0.43	2.21	4.33
39	N162	N163	220.68	150	7.66	0.43	0.27	1.24
18	N30A	N137	318.82	300	30.63	0.43	0.23	0.72
155	N96	N93	401.12	80	2.22	0.44	1.07	2.66
117	N109	N110	220.37	50	0.90	0.46	1.08	4.91
118	N124	N127	393.19	50	0.90	0.46	1.94	4.94
72	N138	N135	402.64	80	2.29	0.46	1.14	2.82
156	N89	N90	285.60	80	2.37	0.47	0.86	3.00
64	N144	N126	178.61	100	3.79	0.48	0.43	2.42
86	B48	B47	50.90	50	0.95	0.49	0.28	5.50

120	N45	B46	161.85	50	0.95	0.49	0.89	5.50
121	B46	B47	151.79	50	0.95	0.49	0.84	5.50
122	B48	N50	195.38	50	0.95	0.49	1.07	5.50
123	N8	N18	300.23	50	0.95	0.49	1.66	5.52
125	N93	N94	450.19	50	0.98	0.50	2.58	5.74
158	N93	N81	314.55	80	2.51	0.50	1.06	3.36
126	N2	N3	515.42	50	0.99	0.51	3.06	5.93
127	N110	N112	345.34	50	1.01	0.51	2.10	6.09
71	N136	N114	387.71	80	2.54	0.51	1.33	3.43
69	B130	N130	266.40	80	2.58	0.51	0.94	3.52
70	N140	B130	206.04	80	2.58	0.51	0.73	3.52
159	N112	N108	199.95	80	2.59	0.51	0.71	3.54
62	N184	N185	89.61	100	4.02	0.51	0.24	2.70
239	N20A	N20	210.62	200	15.99	0.51	0.33	1.55
128	N9	N8	420.93	50	1.02	0.52	2.64	6.28
61	N196	N195	420.62	100	4.05	0.52	1.16	2.75
183	N101	N97	187.15	100	4.18	0.53	0.54	2.90
83	N35	B34	140.51	50	1.06	0.54	0.94	6.66
84	B33	N73	211.84	50	1.06	0.54	1.41	6.66
85	B34	B33	208.18	50	1.06	0.54	1.39	6.66
129	N35	N55	450.19	50	1.06	0.54	3.00	6.66
130	N132	N122	235.61	50	1.07	0.55	1.62	6.86
160	N179	N180	249.02	80	2.78	0.55	1.01	4.04
30	N171	N195	372.16	150	9.70	0.55	0.71	1.92
131	N127	N126	361.80	50	1.11	0.56	2.62	7.25
184	N99	N89	206.35	100	4.37	0.56	0.65	3.15
185	N141	N142	263.65	100	4.39	0.56	0.84	3.18
56	N126	N125	377.65	100	4.42	0.56	1.22	3.23
54	B91A	N91	67.67	100	4.46	0.57	0.22	3.28
55	B92	B91A	213.66	100	4.46	0.57	0.70	3.28
186	B92	N93	213.97	100	4.46	0.57	0.70	3.28

16	N137	N85	419.71	300	40.55	0.57	0.51	1.21
53	N96	N100	201.78	100	4.52	0.58	0.68	3.36
52	N167	N154	450.49	100	4.54	0.58	1.52	3.38
228	N179	N162	342.29	150	10.22	0.58	0.72	2.11
161	N118	N115	289.26	80	2.95	0.59	1.30	4.51
67	N152	N153	345.95	80	2.97	0.59	1.58	4.57
133	N21	N146	497.74	50	1.19	0.61	4.14	8.32
162	N97	N96	322.17	80	3.09	0.61	1.59	4.93
134	N11	N5	66.45	50	1.23	0.62	0.58	8.77
163	N115	N132	180.44	80	3.16	0.63	0.93	5.14
164	N13	N12	317.91	80	3.19	0.63	1.66	5.22
28	N75	N85	356.62	150	11.10	0.63	0.88	2.46
137	N68	N65	449.28	50	1.26	0.64	4.15	9.24
165	N96	B95	270.36	80	3.22	0.64	1.43	5.30
166	B95	N94	418.19	80	3.22	0.64	2.22	5.30
196	N162	N158	559.00	100	5.14	0.65	2.38	4.27
230	N44	N49	313.94	150	11.51	0.65	0.83	2.63
231	N104	N98	547.42	150	11.60	0.66	1.46	2.67
79	N125B	N158	578.51	50	1.31	0.67	5.73	9.91
66	N114	N117	284.38	80	3.37	0.67	1.65	5.79
167	N113	N112	217.63	80	3.37	0.67	1.26	5.78
168	N155	N152	242.32	80	3.38	0.67	1.41	5.82
200	B102	N101	53.04	100	5.28	0.67	0.24	4.48
201	N103	B102	335.89	100	5.28	0.67	1.51	4.48
202	N122	N129	387.71	100	5.33	0.68	1.76	4.55
203	N77	N80	283.77	100	5.34	0.68	1.30	4.57
48	N15	B16A	81.99	100	5.37	0.68	0.38	4.63
49	N78	N83	407.82	100	5.37	0.68	1.88	4.62
204	N18	B16A	293.52	100	5.37	0.68	1.36	4.63
232	N172	N166	401.12	150	12.09	0.68	1.16	2.88
65	N99	N98	139.90	80	3.44	0.69	0.84	6.02

169	N22	N147	494.69	80	3.46	0.69	3.01	6.08
138	N130	N129	228.60	50	1.38	0.70	2.50	10.94
170	N67	N66	332.23	80	3.51	0.70	2.07	6.24
171	N71	N55	414.83	80	3.54	0.70	2.63	6.33
139	N5	N4	405.99	50	1.39	0.71	4.48	11.04
208	N38	N37	201.17	100	5.55	0.71	0.99	4.91
233	N171	N168	344.12	150	12.60	0.71	1.07	3.11
27	N109	N167	559.00	150	12.73	0.72	1.77	3.17
26	N103	N104	155.14	150	12.80	0.72	0.50	3.20
172	N81	N67	318.52	80	3.69	0.73	2.18	6.84
173	N23	N14	431.29	80	3.69	0.73	2.95	6.84
209	N134	N130	176.78	100	5.75	0.73	0.93	5.24
140	N147	N146	293.83	50	1.45	0.74	3.54	12.04
47	N91	N97	192.94	100	5.80	0.74	1.03	5.33
78	N37	B37A	121.31	50	1.48	0.75	1.51	12.44
141	N36	B37A	232.56	50	1.48	0.75	2.89	12.43
174	N49	B59A	282.24	80	3.78	0.75	2.02	7.16
210	N154	N155	325.53	100	5.90	0.75	1.79	5.51
15	N85	N85A	43.89	300	52.95	0.75	0.09	1.98
175	N7	N4	231.04	80	3.81	0.76	1.67	7.24
211	N136	N134	164.59	100	5.96	0.76	0.92	5.60
25	N42	N38	152.10	150	13.37	0.76	0.53	3.48
176	B76	N78	188.98	80	3.85	0.77	1.40	7.42
177	N75	B82	84.43	80	3.85	0.77	0.63	7.42
178	B82	B76	102.41	80	3.85	0.77	0.76	7.42
46	N185	N186	306.93	100	6.02	0.77	1.75	5.71
44	N307	N103	290.17	100	6.05	0.77	1.67	5.76
45	N100	N307	264.87	100	6.05	0.77	1.52	5.76
142	N4	N3	352.35	50	1.54	0.78	4.69	13.30
24	N163	N164	316.69	150	13.71	0.78	1.15	3.64
63	N13	N14	30.18	80	3.95	0.79	0.23	7.75

234	N43	N42	423.06	150	13.99	0.79	1.60	3.78
180	N129	N128	143.26	80	4.03	0.80	1.15	8.05
43	N141	N140	183.18	100	6.25	0.80	1.12	6.13
143	N9	N5	285.29	50	1.59	0.81	4.03	14.12
235	N178	N179	79.25	150	14.25	0.81	0.31	3.91
236	N24	N23	292.61	150	14.36	0.81	1.16	3.96
181	N80	N69	288.65	80	4.11	0.82	2.41	8.35
60	N156	N163	479.45	80	4.13	0.82	4.04	8.42
182	N114	N115	161.24	80	4.15	0.83	1.37	8.51
59	N21	N22	278.28	80	4.19	0.83	2.40	8.64
214	N98	N97	201.78	100	6.48	0.83	1.32	6.55
42	N155	N164	499.26	100	6.52	0.83	3.31	6.63
215	N155	N156	284.07	100	6.52	0.83	1.88	6.62
41	N125	N124	494.08	100	6.60	0.84	3.35	6.78
76	N125	N125B	725.42	50	1.67	0.85	11.34	15.63
145	N15	N14	282.85	50	1.68	0.86	4.45	15.73
58	N108	N109	428.55	80	4.30	0.86	3.89	9.08
57	N151	N152	448.06	80	4.39	0.87	4.22	9.43
14	N85A	N86	148.13	300	61.79	0.87	0.39	2.64
237	N45	N36	375.21	150	15.63	0.88	1.74	4.64
187	N10	N9	289.86	80	4.47	0.89	2.83	9.77
217	N167	N169	400.81	100	6.99	0.89	3.02	7.54
218	N172	N171	433.12	100	6.99	0.89	3.27	7.54
238	N176	N178	353.87	150	15.70	0.89	1.66	4.68
23	N173	N174	470.00	150	15.83	0.90	2.23	4.75
22	N195	N198	322.17	150	15.84	0.90	1.53	4.75
146	B1	N2	645.87	50	1.79	0.91	11.40	17.65
188	N73	N71	405.08	80	4.56	0.91	4.11	10.14
189	N36	N57	739.75	80	4.60	0.91	7.61	10.29
190	N57	N63	530.96	80	4.61	0.92	5.50	10.35
191	N135	N136	50.60	80	4.67	0.93	0.54	10.57

240	N27	N24	377.65	150	16.43	0.93	1.92	5.09
192	N117	N118	157.58	80	4.74	0.94	1.71	10.87
40	N168	N166	384.35	100	7.36	0.94	3.18	8.28
241	N10	N20A	148.74	150	16.68	0.94	1.01	6.82
193	N6	N11	475.49	80	4.82	0.96	5.34	11.23
194	N59	N57	417.88	80	4.85	0.96	4.74	11.35
195	N50	N59	134.42	80	4.85	0.96	1.53	11.35
219	N138	N140	336.80	100	7.53	0.96	2.91	8.64
242	N157	N151	253.90	150	16.91	0.96	1.36	5.37
73	B106	B107	115.52	50	1.91	0.97	2.31	20.02
74	N105	B106	332.23	50	1.91	0.97	6.65	20.02
75	B107	N99	138.07	50	1.91	0.97	2.76	20.02
21	N166	N165	460.25	150	17.15	0.97	2.53	5.51
148	N128	N127	157.58	50	1.92	0.98	3.19	20.22
36	B137A	N137	148.13	100	7.68	0.98	1.33	8.98
37	B137B	B137A	75.90	100	7.68	0.98	0.68	8.98
38	N138	B137B	74.07	100	7.68	0.98	0.66	8.98
243	N175	N176	372.16	150	17.66	1.00	2.16	5.81
244	N168	N169	472.14	150	17.70	1.00	2.76	5.84
149	N11	N2	314.86	50	1.98	1.01	6.69	21.26
51	N104	N109	432.51	80	5.10	1.01	5.39	12.46
13	N86	N113	288.95	300	71.14	1.01	0.99	3.42
197	N108	N99	297.79	80	5.17	1.03	3.80	12.77
220	N20	N8	420.62	100	8.07	1.03	4.13	9.83
35	N135	N85A	216.41	100	8.08	1.03	2.13	9.86
221	N78	N77	105.46	100	8.17	1.04	1.06	10.05
152	B59A	B59B	297.18	50	2.07	1.05	6.85	23.04
153	B59B	N62	337.11	50	2.07	1.05	7.77	23.05
198	N37	N20	416.97	80	5.26	1.05	5.51	13.20
199	N75	N71	538.89	80	5.28	1.05	7.16	13.28
50	N114	N113	204.22	80	5.29	1.05	2.72	13.31

34	N83	N86	222.20	100	8.22	1.05	2.26	10.16
222	N43	N6	690.68	100	8.31	1.06	7.16	10.36
245	N166	N167	451.41	150	18.69	1.06	2.92	6.46
20	N122	N151	681.84	150	18.75	1.06	4.43	6.50
205	N8	N7	299.01	80	5.44	1.08	4.20	14.03
154	N63	N64	364.54	50	2.16	1.10	9.17	25.15
206	N32A	N19	446.84	80	5.55	1.10	6.51	14.56
207	N36	N32A	250.24	80	5.55	1.10	3.64	14.56
33	N186	N187	372.47	100	8.61	1.10	4.12	11.07
31	B74	N30A	197.51	100	8.83	1.12	2.30	11.62
32	N73	B74	77.11	100	8.83	1.12	0.90	11.62
223	N156	N157	206.04	100	8.83	1.12	2.39	11.61
224	N19	N18	477.32	100	8.83	1.12	5.54	11.62
12	N113	N111	272.80	300	81.66	1.16	1.20	4.42
246	N29	N27	430.99	150	20.65	1.17	3.35	7.77
226	N111	N117	178.61	100	9.29	1.18	2.28	12.75
247	B41	B40	299.62	150	20.81	1.18	2.36	7.88
248	B40	B39	70.71	150	20.81	1.18	0.56	7.88
249	B39	N38	71.63	150	20.81	1.18	0.56	7.88
250	N45	B41	211.53	150	20.81	1.18	1.67	7.88
251	N173	N172	148.13	150	20.93	1.18	1.18	7.96
252	N198	N197	425.81	150	21.03	1.19	3.42	8.04
253	N197	N300	533.10	150	21.25	1.20	4.37	8.19
212	N49	N50	267.31	80	6.11	1.21	4.65	17.38
17	N198	N199	102.41	200	38.49	1.23	0.62	6.06
8	N165	N175	284.99	400	155.09	1.23	1.02	3.57
227	N162	N157	441.35	100	9.75	1.24	6.16	13.95
254	N169	N104	467.56	150	22.16	1.25	4.14	8.86
258	N188	N199	307.54	200	39.27	1.25	1.94	6.29
19	N164	N165	269.75	150	22.27	1.26	2.41	8.93
1	N312	N311	600.15	500	250.27	1.27	1.75	2.92

2	N311	B205	341.07	500	250.27	1.27	1.00	2.92
3	B205	RES- 3,000M3	119.79	500	250.27	1.27	0.35	2.92
4	N205	N312	777.24	500	250.27	1.27	2.27	2.92
5	N187	N205	539.19	500	250.27	1.27	1.57	2.92
255	N30A	N29	249.94	150	22.84	1.29	2.34	9.37
259	N44	N45	350.22	200	41.05	1.31	2.39	6.83
29	N124	N122	262.43	100	10.45	1.33	4.16	15.85
11	N111	N153	413.00	300	94.66	1.34	2.40	5.81
7	N175	N174	229.21	400	174.52	1.39	1.02	4.44
10	N153	N154	254.20	300	99.57	1.41	1.62	6.38
256	N44	N43	565.71	150	25.46	1.44	6.48	11.45
257	N42	N10	402.03	150	25.52	1.44	4.62	11.50
260	N187	N188	361.49	200	47.73	1.52	3.26	9.03
6	N174	N187	261.52	400	192.17	1.53	1.39	5.31
9	N154	N165	488.29	300	112.88	1.60	3.93	8.04
261	B327	B326	205.44	250	80.32	1.64	1.64	7.99
262	B326	B321	391.97	250	80.32	1.64	3.13	7.99
263	B321	B320	533.10	250	80.32	1.64	4.26	7.99
264	RES- 1000M3	B327	387.10	250	80.32	1.64	3.09	7.99
265	B320	N44	506.88	250	80.32	1.64	4.05	7.99
225	N23	N22	53.34	80	9.19	1.83	1.98	37.10

LOCATION OF EXISTING WATER SUPPLY STRUCTURES IN JIJIGA CITY			
X-Coordinate	Y-Coordinate	Elevation (M)	Lable
258679.17	1033812.28	1636.957	Flushing Point
258553.83	1033147.66	1631.556	Flushing Point
258719.95	1034594.99	1646.196	Flushing Point
255087.05	1035313.30	1694.706	Flushing Point
256014.56	1033674.21	1671.527	Flushing Point
257778.96	1036631.00	1655.753	Flushing Point
256687.88	1034943.88	1676.349	Flushing Point
257016.58	1034886.41	1669.974	Fire Hydrant _1
258293.53	1034674.20	1650.407	Fire Hydrant _2
259416.20	1034490.75	1641.672	Fire Hydrant _3
261300.16	1035670.19	1680.685	Fire Hydrant _4
258262.22	1034072.34	1645.742	Fire Hydrant _5
258187.70	1034322.27	1649.284	Fire Hydrant _6
257581.44	1034560.47	1657.979	Fire Hydrant _7
256235.99	1035891.30	1686.391	Fire Hydrant _8
262538.91	1033389.52	1745.829	3,000m3 Reservoir
255977.19	1035280.55	1693.595	350m3 Reservoir
254925.19	1037368.94	1703.938	1000m3 Reservoir
263057.00	1021402.00	1592.534	Booster Station # 1
260812.00	1026953.00	1648.476	Booster Station # 2
257,720.22	1,031,575.44	1,575.90	BORE HOLE-1A
258,127.49	1,031,739.59	1,575.90	BORE HOLE-1
257,439.34	1,038,635.47	1,644.90	BORE HOLE-3
258,664.38	1,031,648.74	1,575.90	BORE HOLE-4
258,705.06	1,031,035.34	1,565.90	BORE HOLE-5
258,773.45	1,030,460.97	1,575.90	BORE HOLE-6
259,248.32	1,035,648.91	1,649.00	BORE HOLE-7B
256,803.31	1,042,784.45	1,684.90	BORE HOLE-9
256,800.62	1,043,557.78	1,681.90	BORE HOLE-10
257,244.27	1,038,905.74	1,650.30	BORE HOLE-11
256,718.00	1,039,663.60	1,672.20	BORE HOLE-12
261,323.67	1,038,887.31	1,673.90	BORE HOLE-13
262,605.27	1,039,690.34	1,699.90	BORE HOLE-14
259,806.38	1,035,223.19	1,650.40	BOREHOLE-15A
258,185.49	1,031,219.05	1,565.90	BORE HOLE-15

LOCATION OF EXISTING WATER SUPPLY STRUCTURES IN JIJIGA CITY			
X-Coordinate	Y-Coordinate	Elevation (M)	Lable
259,235.74	1,033,369.08	1,651.90	BORE HOLE-17
259,961.01	1,033,462.94	1,644.90	BOREHOLE-18A
263,250.58	1,019,431.90	1,444.90	BORE HOLE-03
263,574.16	1,019,105.13	1,438.90	BORE HOLE-04
264,159.87	1,018,054.34	1,446.90	BORE HOLE-05
257,021.60	1,042,416.35	1,685.90	BORE HOLE-29
259,774.67	1,035,772.67	1,652.40	BORE HOLE-19
256,993.18	1,043,212.08	1,683.00	BORE HOLE-20
259,589.15	1,035,778.61	1,652.00	BORE HOLE-25
262,052.11	1,021,224.12	1,467.90	JERER-BH-1
262,614.51	1,020,465.05	1,453.90	JERER-BH-2
262,758.12	1,018,979.64	1,444.90	JERER-BH-3
263,172.15	1,018,884.03	1,438.90	JERER-BH-4
264,018.79	1,018,626.85	1,438.90	JERER-BH-5
264,260.37	1,018,074.44	1,446.90	JERER-BH-6
264,951.85	1,017,480.20	1,444.90	JERER-BH-7
265,498.67	1,017,052.17	1,434.90	JERER-BH-8