Water Distribution Network Analysis Using Epanet

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Abstract- *Water is the most essential thing on this Earth for the survival of living species. Ever increasing demands for public water supply all over the world is pressurizing the augmentation of existing water supply systems and also demanding new supply systems and trends. The network system must be modelled, analyzed, and its performance is evaluated under the various physical and hydraulic parameters or conditions. This process is called as "Simulation". EPANET is a computer program that performs extended period simulation of hydraulic and water quality behaviour within pressurized pipe networks. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps.*

Keywords*:* water supply, water demand, Google images and elevations, distribution analysis, EPANET

CHAPTER-1

INTRODUCTION

1.1 The importance of water:

Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth. Apart from drinking it to survive, people have many other uses for water. These include: Cooking, Washing their bodies, Washing clothes, Washing cooking and eating utensils; such as saucepans, crockery and cutlery, Keeping houses and communities clean, Recreation; such as swimming pools, Keeping plants alive in gardens and parks

Water is also essential for the healthy growth of farm crops and farm stock and is used in the manufacture of many products. It is most important that the water which people drink and use for other purposes is clean water. This means that the water must be free of germs and chemicals and must be clear (not cloudy).Water that is safe for drinking is called potable water. Disease-causing germs and chemicals can find their way into water supplies. When this happens the water becomes polluted or contaminated and when people drink it or come in contact with it in other ways they can become very sick.

Water that is not safe to drink is said to be non-potable. Throughout history there have been many occasions when hundreds of thousands of people have died because disease-causing germs have been spread through a community by a polluted water supply. One of the reasons this happens less frequently now is that people in many countries make sure drinking water supplies are potable. Water supplies are routinely checked for germs and chemicals which can pollute water. If the water is not safe to drink it is treated. All the action taken to make sure that drinking water is potable is called water treatment.

1.2 Sources of water

There are many ways in which we can collect water. The main sources are discussed below.

1.2.1 Surface water:

This is water which falls to the ground as rain or hail. This water is collected from a special area called a catchment. The catchment feeds water into a holding area via rivers, streams and creeks. The water is then stored in a natural or artificial (manmade) barrier called a dam or reservoir. Dams are usually placed at the lower end of a valley. Catchment areas are usually far away from towns or cities to lessen the chance of the water being polluted. There are laws which control human activities, such as farming and recreation in catchment areas and on dams to make sure that water supplies are kept potable.

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and sub-surface seepage. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss.

1.2.2 Artesian bores:

Sometimes when a bore is sunk into a low lying area the water gushes out of the hole under its own pressure. This water is under pressure because it is part of an underground body of water much of which is at a higher level than the bore opening. This kind of bore is called an artesian bore. A water supply taken directly from a bore or well is often called **groundwater.**

1.3 Distribution system

Distribution system is a network of pipelines that distribute water to the consumers. They are designed to adequately satisfy the water requirement for a combination of: Domestic, Commercial, Industrial and Firefighting purposes.

1.3.1 Layouts of Distribution Network

The distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads. There are, in general, four different types of pipe networks; any one of which either singly or in combinations, can be used for a particular place. They are:

1.3.1.1 Dead End System:

It is suitable for old towns and cities having no definite pattern of roads. Example shown in figure-1

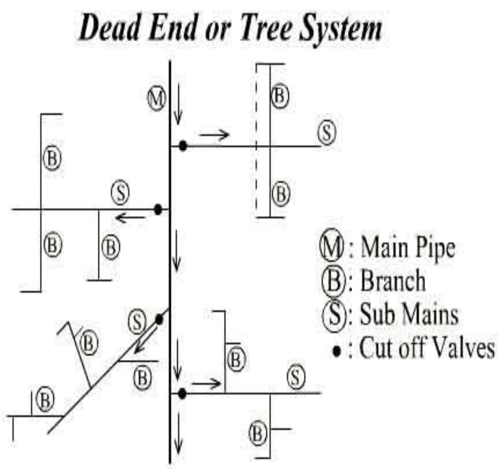


Figure 1 Dead End or Tree System

Advantages: Relatively cheap, and determination of discharges and pressure easier due to less number of valves.

Disadvantages: Due to many dead ends, stagnation of water occurs in pipes.

1.3.1.2 Grid Iron System:

It is suitable for cities with rectangular layout, where the water mains and branches are laid in rectangles. Example shown in figure-2.

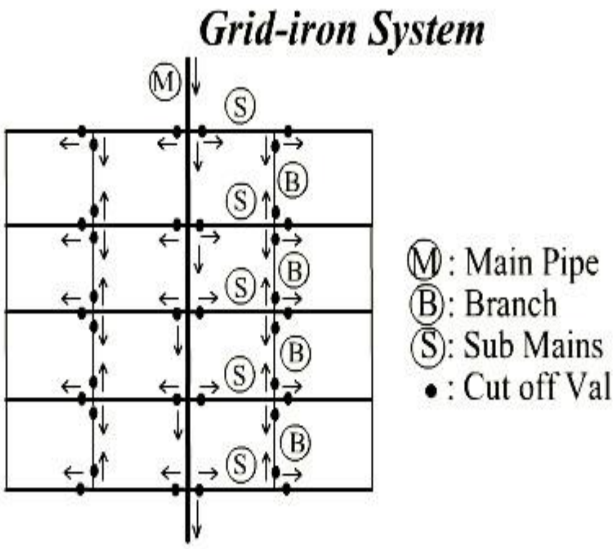


Figure 2 Grid-Iron System

Advantages: Water is kept in good circulation due to the absence of dead ends.and In the cases of a breakdown in some section, water is available from some other direction.

Disadvantages: Exact calculation of sizes of pipes is not possible due to provision of valves on all branches.

1.3.1.3 Ring System:

The supply main is laid all along the peripheral roads and submains branch out from the mains. Thus, this system also follows the grid iron system with the flow pattern similar in character to that of dead end system. So, determination of the size of pipes is easy. Example shown in figure-3

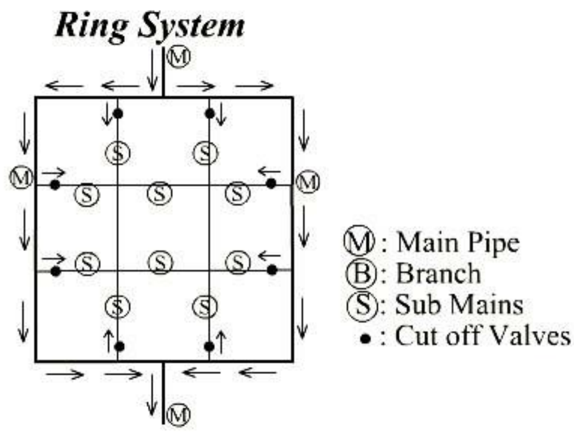


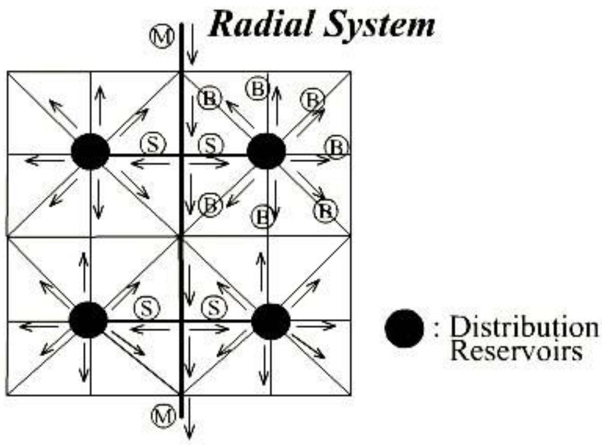
Figure 3 Ring System

Advantages: Water can be supplied to any point from at least two directions.

1.3.1.4 Radial System:

The area is divided into different zones. The water is pumped into the distribution reservoir kept in the middle of each zone and the supply pipes are laid radially ending towards the periphery. Example shown in figure-4

Advantages: It gives quick service and



Calculation of pipe sizes is easy.

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1.4 Population forecasting

1.4.1 Arithmetical Increase method

Arithmetical Increase method is suitable for large and old city with considerable development. If it is used for small, average or comparatively new cities, it will give lower population estimate than actual value. In this method the average increase in population per decade is calculated from the past census reports. This increase is added to the present population to find out the populationof the next decade. Thus, it is assumed that the population is increasing at constant rate. Hence,

$$dP/dt = C$$

i.e., rate of change of population with respect to time is constant.

Therefore, Population after nth decade will be

$$Pn = P + n.C \quad (1)$$

Where, Pnis the population after 'n' decades and 'P' is present population

1.4.2 Geometrical increase method (or geometrical progression method)

In this method the percentage increase in population from decade to decade is assumed to remain constant. Geometric mean increase is used to find out the future increment in population. Since this method gives higher values and hence should be applied for a new industrial town at the beginning of development for only few decades. The population at the end of nth decade 'Pn' can be estimated as:

$$Pn = P (1+ IG/100)n$$

Where, IG = geometric mean (%)

P = Present population

N = no. of decades.

1.4.3 Incremental increase method

This method is modification of arithmetical increase method and itis suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method the increase in increment is considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase. Hence, population after nth decade is

$$Pn = P + n.X + \{n (n+1)/2\}.Y$$

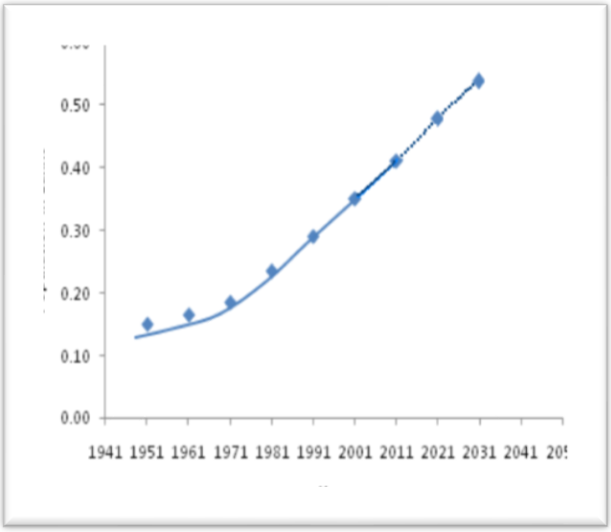
(3)

Where, Pn = Population after nth decade

X = Average increase Y = Incremental increase

1.4.4 Graphical method

In this method, the populations' of last few decades are correctly plotted to a suitable scale on graph (Graph-1). The population curve is smoothly extended for getting future population. This extension should be done carefully and it requires proper experience and judgment. The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition.



Graph 1 Graphical method of population forecasting

1.4.5 Decreasing Rate of Growth Method

In this method, the average decrease in the percentage increase is worked out, and is then subtracted from the latest percentage increase to get the percentage increase of next decade

1.4.6 Simple Graphical Method

In this method, a graph is plotted from the available data, between time and population. The curve is then smoothly extended upto the desired year. This method gives very approximate results and should be used along with other forecasting methods.

1.4.7 Comparative Graphical Method

In this method, the cities having conditions and characteristics similar to the city whose future population is to be estimated are selected. It is then assumed that the city under consideration will develop, as the selected similar cities have developed in the past.

1.4.8 Ratio Method

In this method, the local population and the country's population for the last four to five decades is obtained from the census records. The ratios of the local population to national population are then worked out for these decades. A graph is then plotted between time and these ratios, and extended upto the design period to extrapolate the ratio corresponding to future design year. This ratio is then multiplied by the expected national population at the end of the design period, so as to obtain the required city's future population.

Drawbacks: Depends on accuracy of national population estimate.Does not consider the abnormal or special conditions which can lead to population shifts from one city to another.

1.5 Methods

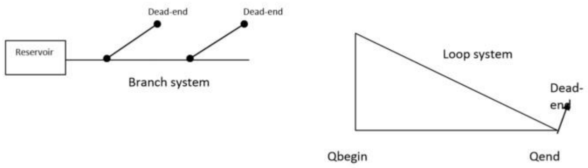
i. Dead-end method

ii. Hardy-Cross method

iii. Equivalent pipe method

1.5.1 Dead-End Method:

Determine the locations of "dead-ends" providing that water will be distributed in the shortest way. At the dead-end points there will be no flow distribution. Figure-5 showing dead end method.



1.6 Factors affecting per capita demand:

a. Size of the city: Per capita demand for big cities is generally large as compared to that for smaller towns as big cities have sewered houses.

b. Presence of industries.

c. Climatic conditions.

d. Habits of people and their economic status.

e.Quality of water: If water is aesthetically $ medically safe, the consumption will increase as people will not resort to private wells, etc.

f. Pressure in the distribution system.

g. Efficiency of water works administration: Leaks in water mains and services; and unauthorised use of water can be kept to a minimum by surveys.

h. Cost of water.

i. Policy of metering and charging method: Water tax is charged in two different ways: on the basis of meter reading and on the basis of certain fixed monthly rate.

CHAPTER-2

LITERATURE REVIEW

2.1. General

The history of water distribution network analysis from medieval period to modern time has been concisely documented by Walski (2006). In the article published by American Water Works Association (AWWA) he chronicled the development of water distribution systems and analysis methods from wood pipes to the modern piping materials; from crude rule of thumb analysis to lengthy long-hand iterative Hardy Cross method to modern computer aided design.

Water distribution networks are designed and constructed to convey treated water from the water treatment plant to the end users. Today, water is taken for granted by the consumers. It is expected that clean water in the right quantity will be available by just turning the tap. It took a large number of incremental advances in science and technology to make modern water distribution systems as reliable and inexpensive as they are today (Walski, 2006). While this may be so for the developed countries, the same cannot be said of developing countries where the majority of the population does not have access to clean water due to inadequate supply and distribution system (Adeniran and Bamiro, 2010).

According to Anil (2004), it is necessary to plan and construct suitable water supply schemes including well designed distribution network in order to ensure the availability of sufficient quantity of good quality of water to the various section of the community in accordance with their demand and requirements. Vasan and Simonovic (2010) suggested the simulation of the water distribution network system by modelling, analysing, and its performance evaluation through scenario investigation of the physical and hydraulic parameters.

CHAPTER-3

STUDY AREA

3.1 Location

Study area of saraswathi nagar and metroland is located in Medchal town shown in figure-3 at 17.6297°N 78.4814°E. It has an average elevation of 577 meters (1896 feet). Medchal (Town of Glory), formerly called as Medi (fig) Chelama (spring), but later came to known as Medchal, this place once resort for Nizams who constructed beautiful mansion here, there is famous temples in Medchal Sri Sri Sri GadiMaisamma temple and Ramalingeshwara temple at height of 61 metres on hillock, this temple believed to be constructed by Kakatiyas, and mosque built in the village during Quli Qutub Shah time. And Medchal also famous for saint Jaffer sahab who served the people not only to the Medchal people but to all, former chief justice and president justice Hidayatullah visited to him. Recently government of Telangana state is planning to make the Medchal as municipality.

Figure 4 Location of Study Area Saraswathi nagar and metroland

3.2 Commercial area

MediCiti Institute of Medical Sciences is located at Ghanpur village in Medchal mandal. Mediciti Hospital is attached to this institution. Shantha Biotechnics (P) Ltd., is located at Athvelly village in Medchal mandal. Ultra Tile (P) Limited is located in Kistapur, Medchal mandal.

3.3 Public transport

There is a railway station in Medchal under South Central Railway, Indian Railways.

CHAPTER-4

METHODOLOGY

4.1 Data collection

In order to carry out the analysis and simulation for the study area (ie. Saraswathi nagar and Metroland area) collected the population data of 2001 year. The population in study area are in the year 2001 is 2832 and also the Surveying data layout of network lengths with junction node elevations collected in the AutoCADD format from the Telangana State Rural water Supply Department. In the figure-7 showing the lanes, junction node IDs and node elevations.

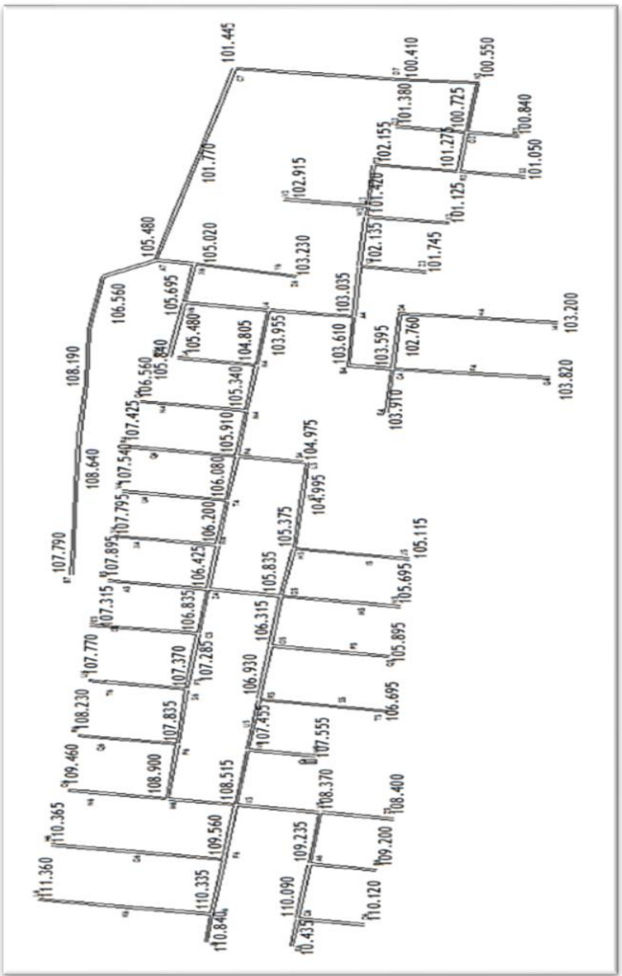
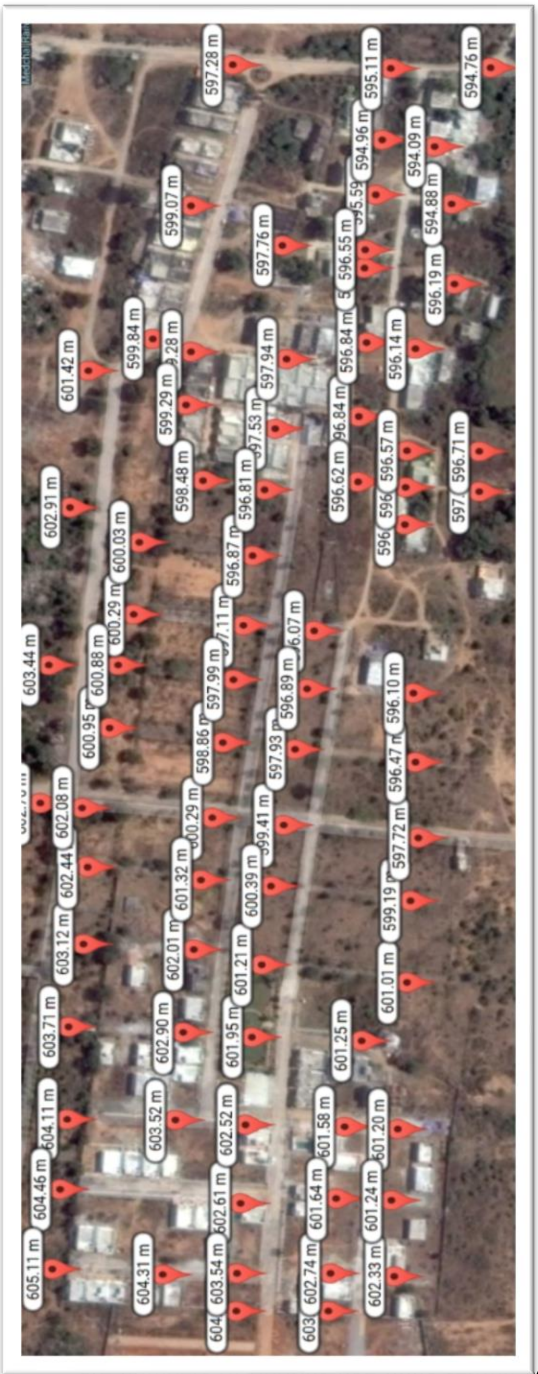


Figure 5 Surveying layout

To get the study area image of google map is taken by the screen shot option available in conputer keyboard. The process is simple to take snapshot. while taking the google image it is necessary to adjust the screen such that the required area to be snapped, later press the printscreen button on keyboard. Then launch the paint application from Windows, go to programs, acessories and sellect paint and launch then paste the snapped image by using shortcut key Ctrl+V or go to edit menu and sellect option paste, now the snapped image will be on screen, now crop the image or edit as per the requirement. The snapped goole map image shown in figure-8 taken with above mentioned snapshot procedure.

Figure 6 Image from google map

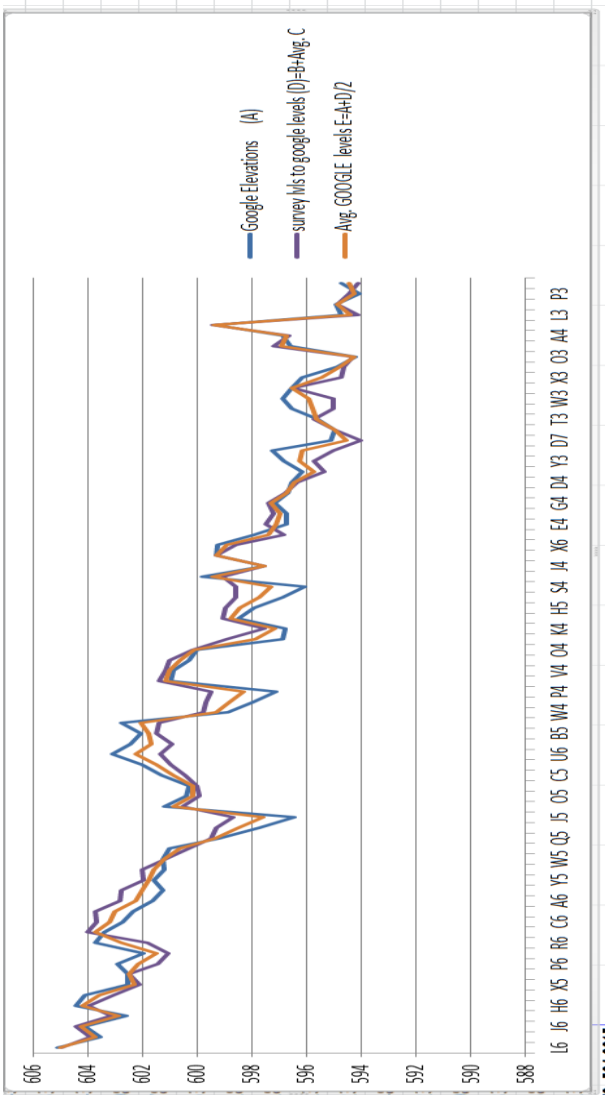
Altitudes are noted and pinned in google map from the website www.altitude.nu in this website there



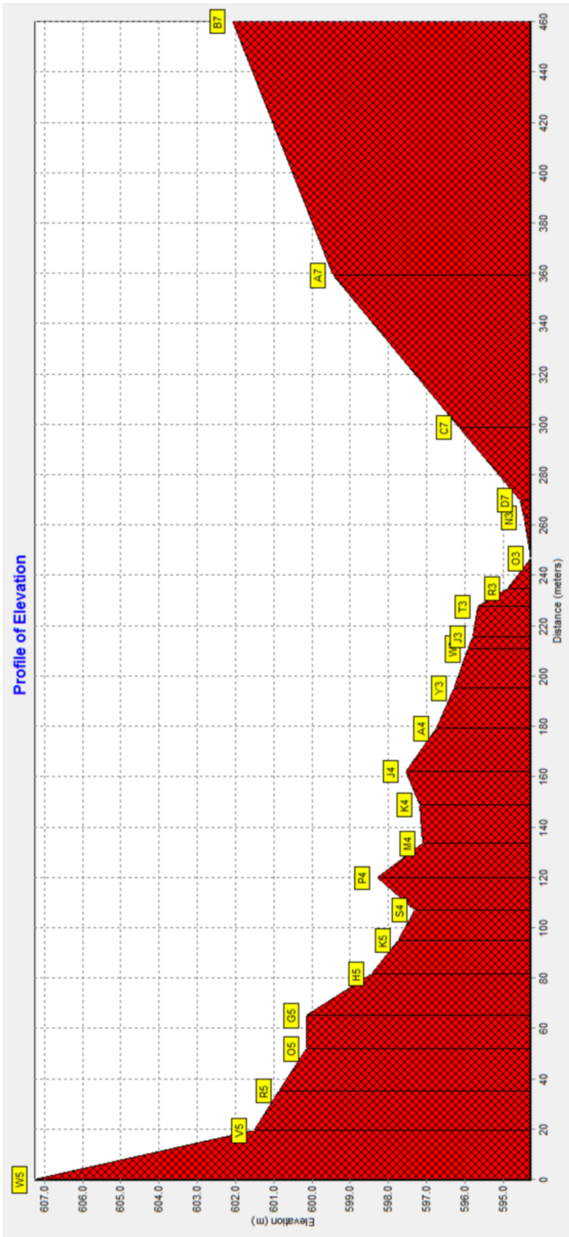
are numbers of options like units setting Meters or Feets, map or satillete views, show position or hide positions options, clear and save option. Scroll and zoom option. Altitudes will be displayed while clicking directly on map. Altitudes of the study are shown in figure-9 are done by mentioned as above.

Figure 7 Image showing Altitudes pinned in Google map

4.1 Elevation Comparison Comparision of traditional survey elavations which collected from telangana state rural water supply department and from google earth. In Graph-2 showing that the google elevations line (A), traditional surveying elevations line (D), and the Average elevation line (A+D)/2.Graph-3 showing elevation profile along the pipeline.



Graph 2 Elevations comparison



Graph 3 Profile of elevation along shown Drawing network

Collected google snapshot image imported in EPANET from Viewmenu-Backdrop-load-browse the image already taken from the google map saved as a bmp file.

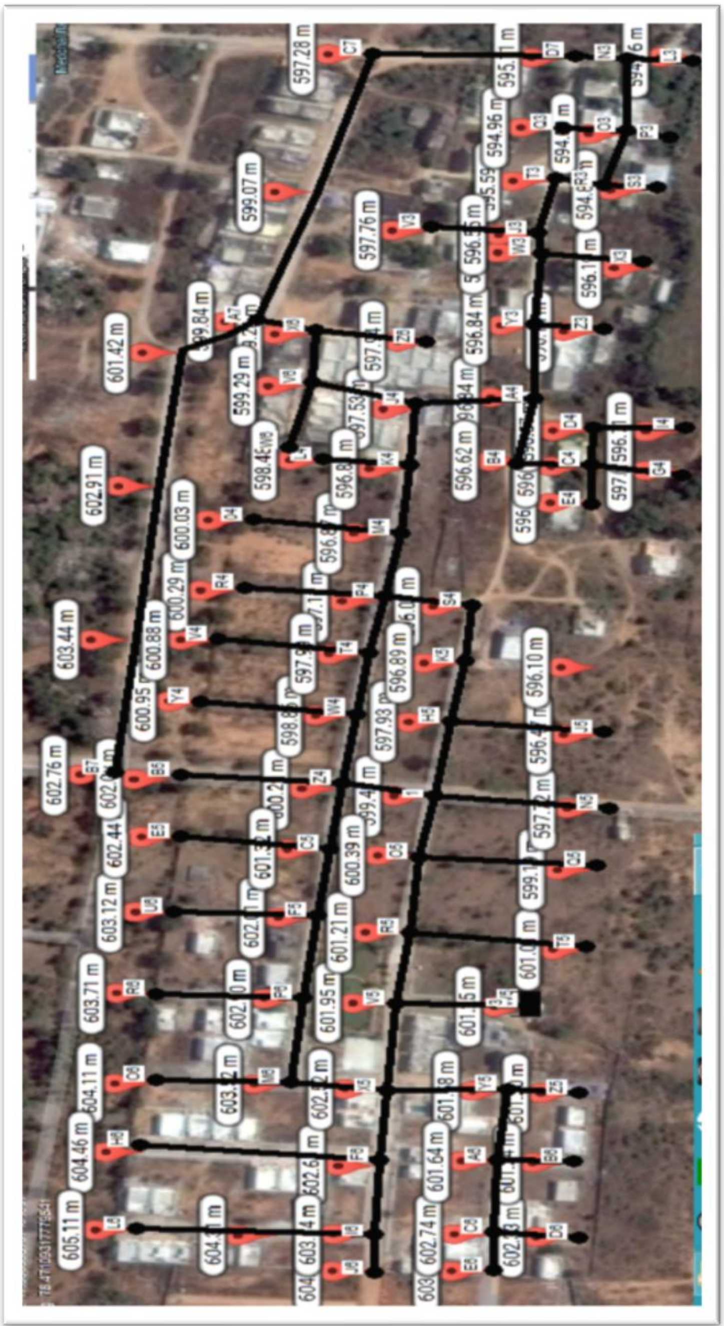


Figure 8 Pipeline network drawing

Scaling of background map done by taking any two known points of network and their distance as a reference. Then measure the actual distance in EPANET by placing two junction nodes on the background image, then actual distance by existing distance multiplied by value 10000 as a coordinate value. To enter the scale value in EPANET program there is a option Dimensions in Viewmenu, then Enter the calculated value in X- coordinate and Y-coordinate upright.

Placing of junction nodes at each of road intersections or water distribution network junctions of proposed pipe line. Each node atomatically gets default node IDs. To change the node ID as per the network or to edit double click on the junction node then edit the junction IDs for the study area junction node IDs as shown in figure-11.

To enter the elevations at each and every node the procedure is same like the editing junction node IDs,double click on the juction ID enter the elevation value in elevation box. For the study area elevation at each juntion is shown in figure-12.

After completing the juntion nodes connect all the junctions nodes with pipe link. For connecting the pipe link atleast two juntion node would be their, for connecting the link select the option Add Pipe on the standard toolbar, then click first junction node and other junction node.

Assigning Distribution Network Parameters after the skeletonization of the network on EPANET platform, the next step was to assign network parameters. The networks parameters include: pipe lengths, pipe diameters, roughness coefficients (Hazen-Williams or Darcy-Welsbach), These are basic network parameters on which future simulation will be based depending on the flow to be simulated. The figure-9 & figure-10 shows the Nodes IDs and Node elevations.

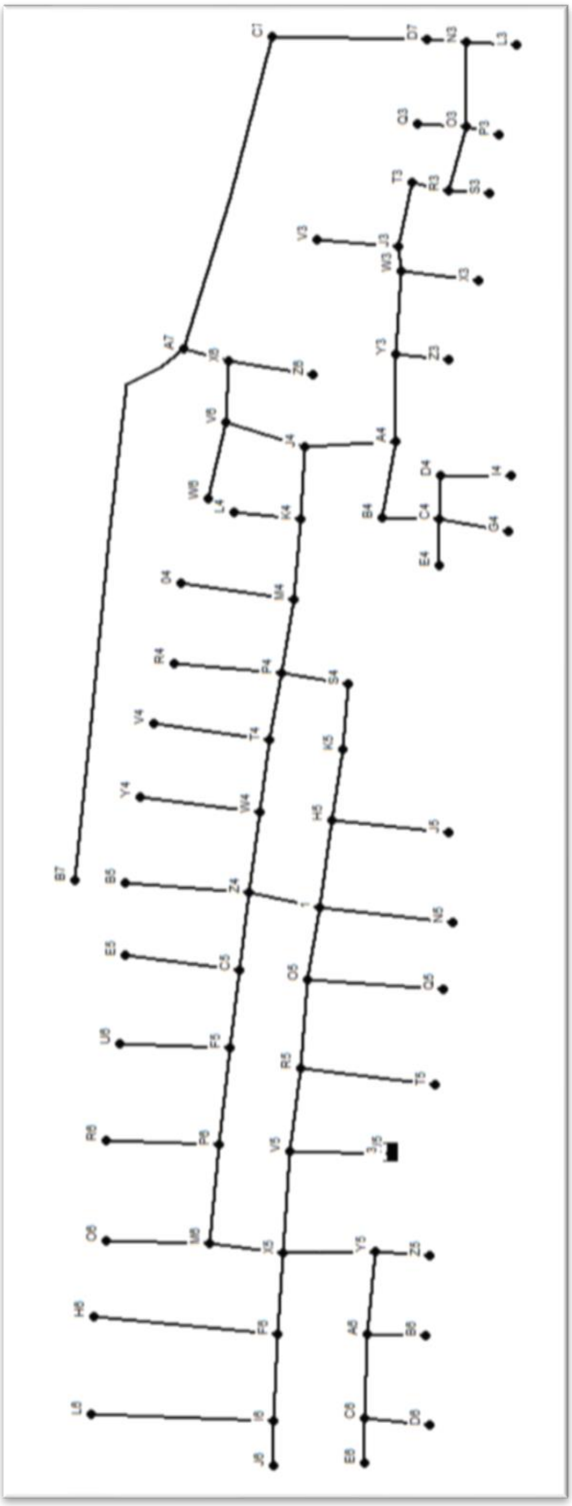


Figure 9 Junction node IDS

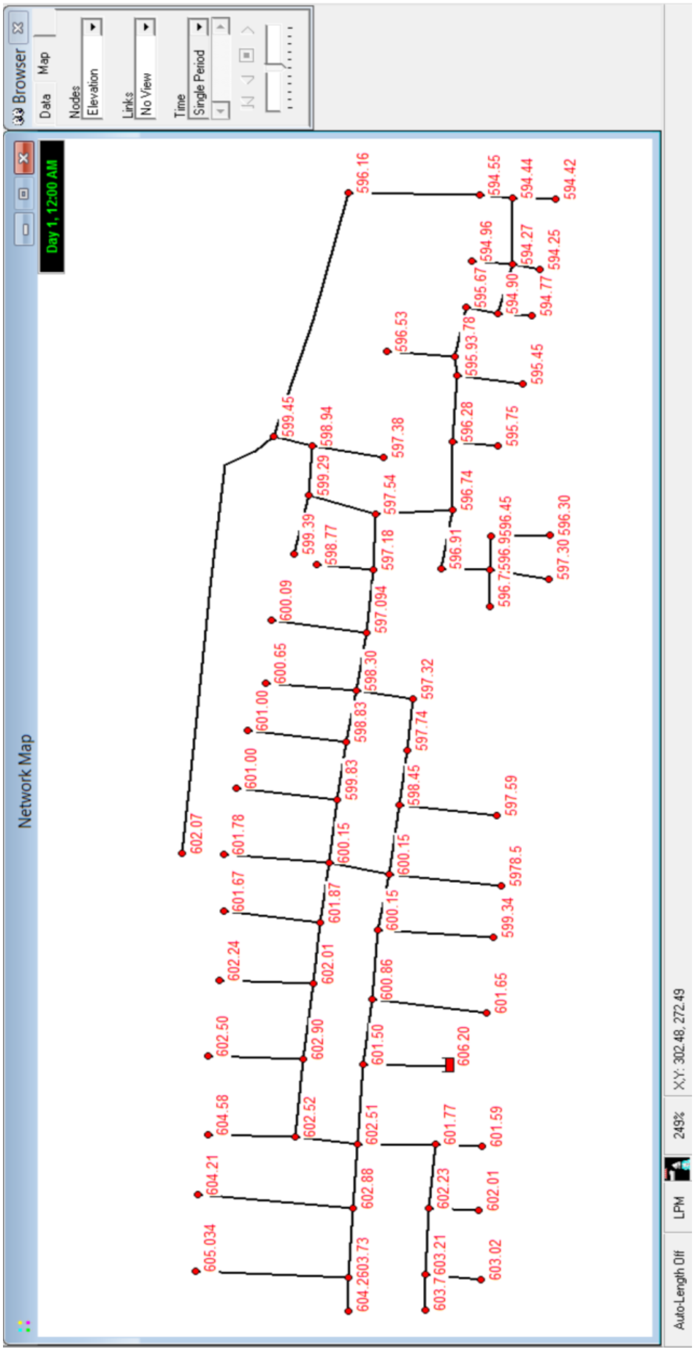


Figure 10 Node Elevations

4.2 Population forecast and nodal demand calculation

Arithmetical Increase method is suitable for large and old city with considerable development. If it is used for small, average or comparatively new cities, it will give lower population estimate than actual value. In this method the average increase in population per decade is calculated from the past census reports. This increase is added to the present population to find out the populationof the next decade. Thus, it is assumed that the population is increasing at constant rate. Hence,

dP/dt = C i.e., rate of change of population with respect to time is constant.

Therefore, Population after nth decade will be Pn= P + n.C
(1)

Where, Pnis the population after 'n' decades and 'P' is present population

In order to estimate the demand at each node, the population for each node is used to multiply the per capita demand of the node. The daily demand is further translated into liters per Minute (LPM) for consistency with EPANET specifications.

4.3 Water Demand:

A special aspect of the model building process is the determination of nodal demands. A survey of numerous users spread all over the network was carried out and using an average household occupancy of six, and a daily per capita water consumption of 40l, their demand was concentrated into a limited number of pipe junctions in order to make the network presentation suitable for a computer model. The starting point is the calculation of the average demand. This yields the demand of a certain area, which has to be converted into demand at a point (pipe junctions). The next step is the conversion procedure based on the following assumptions: An even distribution of consumer s and the border between the supply areas of two nodes connected by a pipe is at half of their distance.

4.4 EPANET software

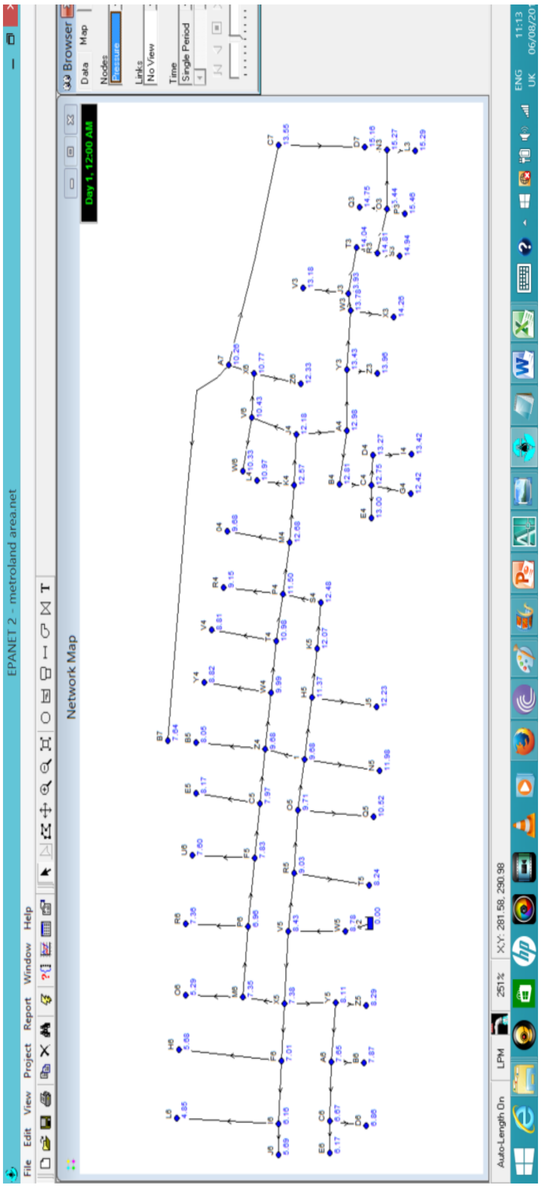
EPANET is a computer program that performs extended period simulation of hydraulic and water quality behaviour within pressurized pipe networks. A network consists of pipes,nodes (pipe junctions), pumps, valves and storage tanks or reservoirs.

EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

EPANET was developed by the water supply and water resources division (formerly the drinking water research division) of the U.S Environmental protection agency's national risk management research laboratory. It is public domain software that may be freely copied and distributed.

EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. Sampling program design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment are some examples.

EPANET can help assess alternative management strategies for improving water quality throughout a system.Running under windows, EPANET provides an integrated environment for editingnnetwork input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.



CHAPTER-5

ANALYSIS AND RESULTS

5.1 Population forecast and demand calculation

The Population forecasting and the demand calculation, the population data collected from the Telangana state rural water supply department and the table-8 showing the calculations of population forecast and demand estimation.The ultimate demand is the ultimate year population multiplied by per capita demand and divided by 10^6. Discharge in liters per minute is ultimate demand multiplied by 10^6 and divided by 24x60. Discharge per running meter is discharge divided by total length of the pipeline. Demand factor is Demand per running meter length divided by 2.

Figure 11 Nodal Demand

5.2 Network Input Data

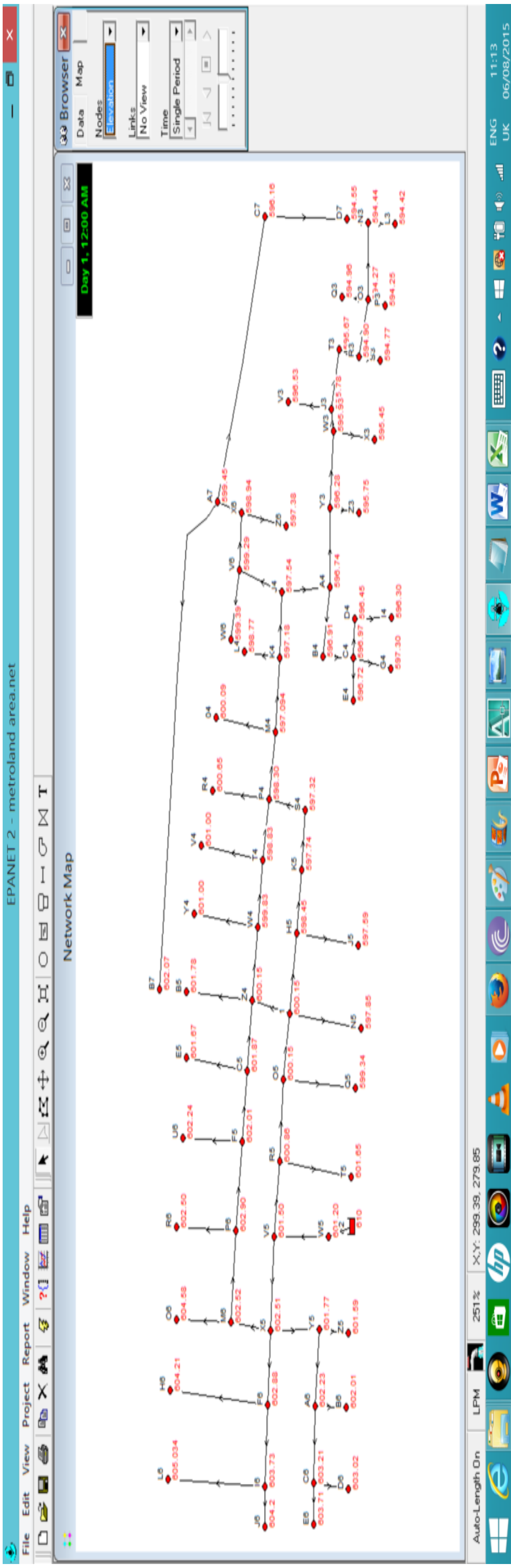
In order to analyze the Water distribution network using EPANET following input data files are needed:

Junction Report: Junctions are points in the network where links join together and where water enters or leaves the network. The basic input data required for junctions are, 1.Elevation above some reference (usually mean sea level) 2.Water demand (rate of withdrawal from the network), 3.Initial water quality. The output results computed for junctions at all time periods of a simulation are. 1. Hydraulic head (internal energy per unit weight of fluid), 2. Pressure. 3.Water quality.

Junctions can also: Have their demand vary with time, multiple categories of demands assigned to them, Have negative demands indicating that water is entering the network be water quality sources where constituents enter the network, Contain emitters (or sprinklers) which make the outflow rate depend on the pressure.

5.3 Elevations comparison and error correction

In table-10 third column google elevations taken from the google maps mentioned(A), Forth column traditional surveying elevations collected



from the Telangana state rural water supply department mentioned (B), the difference between A and B is C, the average of all values in C column gives the value for converting the surveying elevations. The values in column (E) are the average of elevations in Column (A) and column (D). Finally values of (E) are taken for the analysis of the water distribution network in EPANET. Final elevations are entered in EPANET Shown in figure 17 and pipe diameters shown in figure-18.

Figure 12 Node Elevations

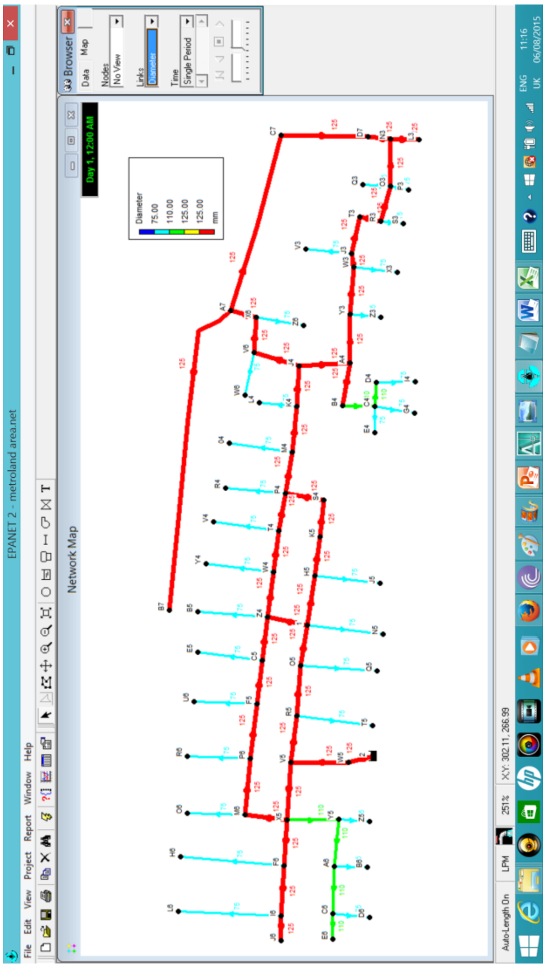
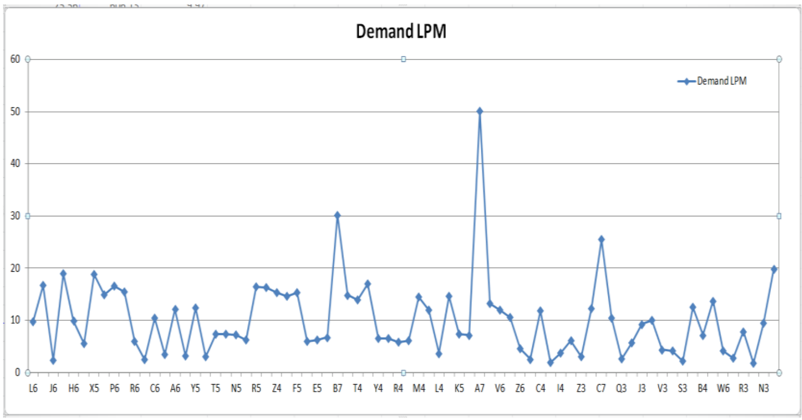
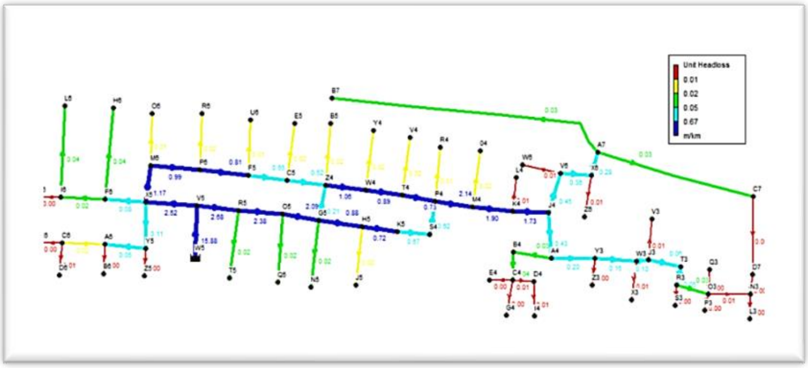


Figure 13 Pipe diameters



Graph 4 Demand in Litres per minute



Graph 5 Pressure at nodes

5.4 Results

Nodal data generated in EPANET from the report menu, then select the option tables, table selection wizard window will be opens, in this window selecting type network node and click on OK, then select data to clipboard or file option from the edit menu select copy to option to get data values in MS-Excel. In table 11 is the generated network nodal report. This tabulated data is useful to study the network system.

CHAPTER-6

CONCLUSIONS

In this study, it is observed that in water distribution network the highest elevation is 605.034m at junction node ID L6. The lowest elevation is 594.259m at junction node ID P3. The difference in Google elevations and traditional survey elevations it is observed the average error of 0.0001m Level. With the comparison of elevations and average value of error it is observed that instead of doing traditional surveying on field, taking google elevations and google map is a time saving and economical in cost.

Estimation of population forecasting population for the ultimate year 2038, in the year

2001 the population is 2832, In the prospective year 2023 the population is 4550 and the ultimate year 2038 the population is 6250. Per capita Demand of water is 175 liters per capita per day, and the ultimate demand found that 1.09 million liters per Day. Discharge for this network is found that 759.55 liters per minute. The total length of the water distribution network is 4353 meters, and the demand per meter length 0.174 liters per minute. Demand factor observed in this study is 0.087.

This study simulation for reliability analysis of water distribution systems using EPANET 2.0, taking into account the hydraulic considerations such as pressure, head, velocity etc...

Maximum Nodal demand observed for this study area water distribution network is 50.08 liters per minute at Junction node number A7 and Minimum Nodal demand of 1.74 liters per minute at junction node number P3. Nodal demand less than 10 litres per minute found at the following node junction, they are L6, O6, H6 ,J6, E6, D6, R6, U6, B6, B5, E5, T5, Z5, V4, Y4, R4, W6, Q5, L4, N5, K5, Z6, G4, J5, S4, B4, E4, V3, D4, I4, J3, Z3, T3, X3, Q3, R3, S3, N3, L3, P3. Nodal demand less than 20 litres per minute found at the following node junction, they are I6, P6, F6, M6, X5, A6, F5, C5, Y5, V5, R5, Z4, G5, O5, W4, V6, T4, H5, P4, J4, K4, C4, M4, A4, Y3, O3.

The maximum Nodal pressure observed in this network is 11.88 meters at junction node number P3 and Minimum Nodal pressure observed in this network is 1.74 meters at junction node number L6.

The results of the simulations are checked using hydraulic equations. This showed that the results are correct and can be used for modeling water supply system. This study would help the water supply engineers in saving time as it this process is fast, less tedious, easy to incorporates the changes etc., under one umbrella.

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