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RESEARCH ARTICLE

DESIGN OF WATER DISTRIBUTION SYSTEM USINGEPANET

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Abstract

In order to fulfil the water demand of the continuously growing population, it is essential to provide the sufficient and uniform quantity of water through thedesigned network of pipes. For this purpose the details provided by the **IPH** (IRRIGATION AND PUBLIC HEALTHE DEPARTMENT) department, Indora Himachal Pradesh have been followed. The general features of the area like information about the main water source, population of the area, demand of water, requirement of the pumps, distribution network and water tanks are essential for effiecient design of water distribution system. According to the government of Himachal Pradesh the per capita consumption of water by an Individual person is 70litres per day and design has been made accordingly. This work highlights the process carried out on design of water supply system for an area named **KATHGARH** with the help of all this information the design of the water supply scheme for the area with the help of software **"EPANET".**Thisdesign of the water supply scheme for proper supply of water is efficient to meet the daily requirement of water in this area.

INTRODUCTION

In order to fulfill the water demand of the continuouslygrowing population we need to provide the sufficient and uniform quantity of water through the designed network of pipes is known as water supply. Infrastructure for the collection, transmission, treatment, storage, distribution of water for homes, commercial establishments, industry, and irrigation, as well as for such public needs as fire fighting and street flushing. Water supply systems must also meet requirements for public, commercial, and industrial activities.In all cases, the water must fulfill both quality and quantity requirements. A plan of water supply system for the Kathgarh (Indora) area of Himachal Pradesh has been made based on the information provided by the **IPH** (IRRIGATION AND PUBLIC HEALTHE DEPARTMENT) department, Indora Himachal Pradesh and using EPANET software.

NEED OF WATER SUPPLY

Human life, as with all animal and plant life on the planet, is dependent upon water. Not only do we need water to grow our food, generate our power and run our industries, but we need it as a basic part of our daily lives - our bodies need to ingest water every day to continue functioning. "Basic needs of about 70litres per person per day". It includes the need for water to maintain a basic standard of personal and domestic hygiene sufficient to maintain health.The effects of inadequate water supply causes disease, time and energy expended in daily collection, high unit costs, etc. provision of basic daily water needs is yet to be regarded by many countries as a human right.

EPANET

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior 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 is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. EPANET can help assess alternative management strategies for improving water quality throughout a system. These can include:

(i) altering source utilization within multiple source systems,
(ii) altering pumping and tank filling/emptying schedules,
(iii) use of satellite treatment, such as re-chlorination at storage tanks,
(iv) Targeted pipe cleaning and replacement.

DESCRIPTION OF AREA

The area for which we are designing the water distribution system is Village Kathgarh. The population of the area is 990 (source IPH, personal comm..). The distribution system designed here is tree system or dead end system. By the use of EPANET that is by filling the data into it about number of nodes, demand, elevation, tanks and pipes we design the respective distribution system. The number of nodes designed here are 36 and 2 overhead water tanks and these all are shown in figure1 below

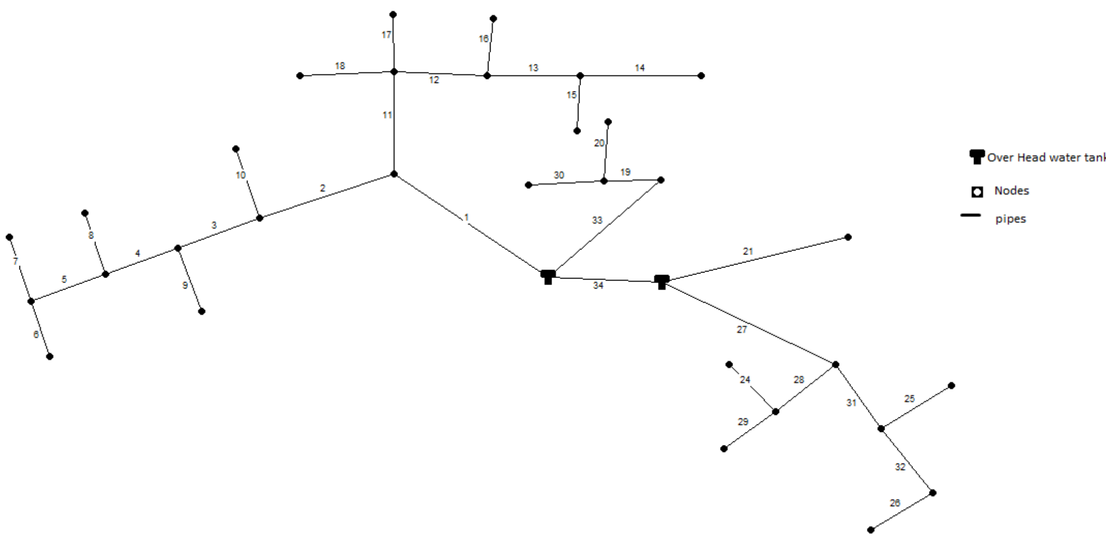


Fig 1.WATER DISTRIBUTION SYSTEM IN KATHGARH

POPULATION DETERMINATION:

Determination of population is one of the most important factors in planning, if the project has to serve the community for a certain design period. Normally, a design period of 20 to 40 years is selected. What will be the population at the end of design period is the basic question. This can be achieved by using various methods for population.

ARITHMETICAL INCREASE METHOD

This is the simplest method of population forecast, though it generally gives lower results. In this method the increase in population from decade to decade is assumed constant. Mathematically, this hypothesis may be expressed as

$$\frac{dP}{dT} = K$$

Where $\frac{dP}{dT}$ $is$the rate of change of population, K is a constant.

From the census data of past 3 to 4 decades, the increase in population for each decade is found, and form that an average increment is found. For each successive future decade, this average increment is added. The future population Pn after n decades is thus given by

$$Pn = P + nI$$

Where Pn = future population at end of n decades

P = Present population

I = Average increment for a decade

GEOMETRICAL INCREASE METHOD OR UNIFORM PERCENTAGE GROWTH METHOD

In this method, it is assumed that the percentage increase in population fromdecade to decade is constant. From the population data of previous three or fourdecades, the percentage increase in the population is found and its average isfound. If Ig is the average percentage increase per decade, or rg is the increase per decade expressed as ratio, the population Pn after n decades is given by

$$P^n= P(1+\frac{Ig}{100})^n=P(1+r_g)^n$$

Let P be the present population and P1 be the population after one decade.

Then,

$$P1 = P +\frac{Ig}{100} = (1 +\frac{1}{100})1$$

Hence,

$$P_n= P(1+\frac{Ig}{100})n$$

This method gives higher result since the percent increase never remains constant but, instead decreases when the growth of the city reaches to saturation.

INCREMENTAL INCREASE METHOD

This method combines both the arithmetic average method and the geometrical average method. From the census data for the past several decades, the actual increase in each decade is found. Then increment in each decade is found. Population in next decade is found by adding to the present population the average increase plus the average incremental increase per decade. The process is repeated for the second future decade, and so on. And it is expressed as:

$$Pn = P + nI + n\ (n + 1)/2$$

Where, P = present population

I = average increase per decade

r = incremental increase

n = number of decades

Let P be the present population. The population P1 after one decade will be

$$P1 = P + I + Ir$$

WATER DEMAND:

TABLE 1: WATER REQUIREMENTS FOR DOMESTIC PURPOSES

S.No.	Description	Amount Of Water In Liters Per Head
1	Bathing	55
2	Washing of clothes	20
3	Flushing	30
4	Washing the house	10
5	Washing the utensils	10
6	Cooking	5
7	Drinking	5
	Total	**135**

TABLE 2: CONSUMPTION OF WATER FOR DOMESTIC ANIMALS AND LIVE – STOCKS

S.No.	Animals	Water Consumption(Lt)
1	Cow & Buffalo	40 to 60
2	Horse	40 to 50
3	Dog	8 to 12
4	Sheep & goat	5 to 10

WATER SYSTEM LOSSES

Losses from a water distribution system consists of Leakage and over – flow from service reservoirs, Leakage from main and service pipe connections, Leakage and losses on customer premises when they get un – metered house hold supply, Under – registration of supply meters and large leakage or wastage from public tabs. In the case of well maintained and fully metered water distribution system, the losses may hardly exceed 20% of the total consumption. In a system where supply is partly metered and partly – metered the losses may be up to 50% of the total supply.

DESIGN:

METHODS OF DISTRIBUTION:

Three methods or systems are outlined below:

(i) Gravity system
(ii) Pumping system
(iii) Combined gravity and pumping system

LAYOUT OF DISTRIBUTION NETWORKS

There are four principal methods of layout for distribution systems:

(i) Dead end or tree system
(ii) Gridiron system
(iii) Circular or ring system
(iv) Radial system

STEPS IN DESIGNING WATER DISTRIBUTION NETWORKS

(i) Conducting topographic surveys and preparation of maps.
(ii) Preparation of tentative layout.
(iv) Computation of discharges in pipelines.
(iv)Calculation of pipe diameters.
(v) Computation of pressures in the pipelines.
(vi) Determination and positioning of appurtenances

SURVEYS AND MAPS

The strip of land lying between the source of water supply and the distribution area is surveyed to obtain the levels for fixing up the alignment of the rising main. This main will carry treated water to the distribution reservoir(s) located in the distribution area. The distribution area is also surveyed and detailed maps of are prepared showing the positions of roads, streets, lanes, residential areas, commercial locality, industrial areas, gardens etc. A topographical map of the area is prepared to locate the high and low areas. The cross section of streets, roads, lanes, etc. is prepared, showing the position of existing underground service lines like electric and telephone lines, sewer lines, existing water supply lines (if any), etc.

TENTATIVE LAYOUT

A tentative layout of the distribution line is then marked, showing the location of the treatment plant(s), distribution mains, distribution and balancing reservoirs, valves, hydrants, etc. The whole area is divided into various distribution districts. The density of population (average number of people per hectare area) is also marked. The length of pipelines should be kept as short as possible.

DISCHARGE IN PIPELINES

Based on the density of the population, type of distribution district (residential, commercial etc) and fire fighting and other requirements, the discharge required from each pipeline is calculated. The fire hydrants are placed at 50 to 100m intervals on straight runs, and on street junctions. The size of the distribution pipes are fixed such that a minimum necessary pressure head is maintained at all points, carrying peak hourly flow through them. The pipes should be designed for a discharge ranging from 2.25 to 3 times the average rate of supply. For populations over 50,000, the distribution mains should have a capacity of 225% of average rate of supply, while for population below 5000; the distribution pipes should have a capacity of 300% for the average rate of supply. The flow required for firefighting should be added to this maximum flow, to get the total flow. The pipes should be able to carry this total flow without excessive pressure drops.

CALCULATION OF PIPE DIAMETERS

Once the design discharge is known, pipe diameters are assumed in a way that the velocities of flow in pipes remain between 0.6 to 3 m/s. smaller velocity is assumed for pipes of smaller diameter and larger velocity for pipes of larger diameter. The loss of head in the pipes is then calculated using Hazen Williams formula (or monogram) as:

$$V = 0.849 \times C \times R \times 0.63S \times 0.54$$

Where:

V = mean velocity of flow in pipe (m/s)
R = hydraulic radius (mean depth) in m
S = hydraulic gradient
C = coefficient of roughness of pipe

In terms of diameter D of the pipe, the above formula reduces to:

$$V = 0.354\ C \times D \times 0.63S \times 0.54$$

Where, D is the diameter of the pipe in meters. Expressed in terms of head loss hf and the length L of the pipe, the Hazen Williams formula takes the following
form:

$$\mathrm{h}f = 6.843(D \times 1.167) \times VC \times 1.852$$

The discharge Q (m3/s) is given by:

$$Q = 0.278C \times D \times 2.63S \times 0.54$$

APPURTENANCES

Listed below are accessories that may be fitted to the distribution systems for various purposes.

(i) Sluice valves or gate valves
(ii) Air valves
(iii) Reflux valves
(iv) Relief valves
(v) Altitude valves, and scour valves

LAYING OF DISTRIBUTION NETWORKS

Minimum trench depth should be 15+ D+30+ ≥145 cm for heavy and normal traffic and 15+D+30+≥115 cm for other cases, where D is the external diameter of the pipe in cm, 15cm is the bedding thickness, 30cm is the compacted overburden thickness and the remaining is the backfilled compacted thickness.

Minimum depth of filling on the pipes should not be less than 0.8 m, and referable one meter, to protect them from traffic loads to prevent the effects of climatic changes on water, in the pipe, making it unpalatable.

For distribution network sizes ranging from 7.5 cm up to 25 cm, the minimum and maximum width of the trench should be 45 cm and 80 cm respectively.

RESULTS AND DISCUSSIONS

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior 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 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. These can include:

- altering source utilization within multiple source systems,
- altering pumping and tank filling/emptying schedules,
- use of satellite treatment, such as re-chlorination at storage tanks,

argeted pipe cleaning and replacement. Running under Windows, EPANET provides an integrated environment for editing network 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.

With the help of various data collected from the IPH deptt about the nodes, joints, junctions, discharge, diameters of pipes we have prepared excel sheet as given below:

TABLE 3.DETAILS OF KATHGARH AREA

Junction Id	Elevation	Demand (Lpm)
4	129.1	21.14
5	127.9	9.58
6	123.1	8.65
7	126.9	7.38
8	127	4.13
9	124.1	2.24
10	123.1	1.85
11	124.1	1.60
12	125.7	1.94
13	125.9	1.94
14	126.7	11.5
15	126.5	6.75
16	125.9	4.81
17	124.1	2.23
18	123.9	2.57
19	123.9	1.94
20	122.1	2.57
21	124.2	2.23
22	124.3	3.35
23	119.5	1.65
24	118.2	22.60
25	117.9	3.84
26	117.1	1.94
27	117.1	1.94
28	116.75	2.57
29	113.2	1.26
30	112.9	3.84
31	111.6	3.84
32	112.3	1.94
33	112.9	2.57
34	112.4	2.57
35	109.15	1.26
36	168.2	1.26

TABLE 4.PIPES DESCRIPTION

Node 1	Node 2	Length	Diameter	Roughness
4	5	200	65	100
5	6	150	50	100
6	7	150	50	100
7	8	105	40	100
8	9	80	32	100
9	10	90	20	100
9	11	80	20	100
8	12	100	20	100
7	13	90	20	100
6	14	100	32	100
5	15	100	40	100
15	16	100	40	100
16	17	100	32	100
17	18	100	25	100
18	19	90	25	100
16	20	100	25	100
15	21	60	25	100
15	22	100	25	100
23	24	100	25	100
24	26	70	25	100
27	28	200	65	100
29	30	100	50	100
30	31	100	25	100
30	32	100	25	100
33	34	100	25	100
35	36	100	20	100
27	29	1320	50	100
29	30	100	20	100
30	31	200	20	100
24	25	200	25	100
29	33	1250	50	100
33	35	1100	40	100
4	23	1133	50	100

Description of Graphs

By the use of EPANET various relation are being found between elevation, velocities, flow, pressure, head, demand, contours, etc. these relations can be understood by studying the graphs plotted

1. Pressure Velocity Distribution

This is the graph between pressure and velocity which shows the variation of velocity in different pipes with respect to the pressure provided to the particular pipe line. . The different values of pressure and velocity are also given in the figure 1.

2. Contour Plot Demand

This map shows the contour of different levels according to the demand at different locations in litres per meter. This is differentiated by different colours as shown in figure .2 .

3. Contour Plot Elevation

This map shows the contour levels according to the elevation of pipe lines at different levels which is also differentiated with the help of different colours as shown in figure 3.

4. Contour Plot Pressure

This map also shows the contour levels of different pressures at different nodes with the help of colours.as shown in figure 4.

5. Demand Flow Graph

This is the graph between demand rate and flow at all nodes.

6. Demand at Node 7

This is the graph between demand and time interval. This shows up and down graph. That is firstly the graph goes increases and then decreases and again so on as shown in figure 12.

7. Demand and Unit Head Loss

This is the graph between demand rate and amount of head loss at each nodes as shown in figure 8.

8. Pressure-Flow Distribution

This graph between pressure and flow shows variation in pressure and velocities by different colours as shown n figure 5.

9. Elevation-Diameter Distribution

This graph shows variation in elevation and diameter by different colours as shown in figure 6.

10. Demand-Flow Distribution

This graph shows variation in demand of water and flow distribution in figure

11. Pressure-Velocity Distribution

This graph shows variations in pressure and velocity distribution through different values allotted by different colours as shown in figure 10.

12. Pressure Graph for Node 5

This graph shows the variation in pressure in node 5 during different time intervals. Water is supplied for 8 hours a day. This is shown in figure 11.

13. System Flow Balance

This graph is shown in figure .13

14. Pressure Graph for Node 29

The pressure at node number 29 with respect to time in shown in figure 14

15. Pressure Graph for Node 15

The pressure graph for node number 5 is shown in figure 15.

All the figures explaining above are shown below:

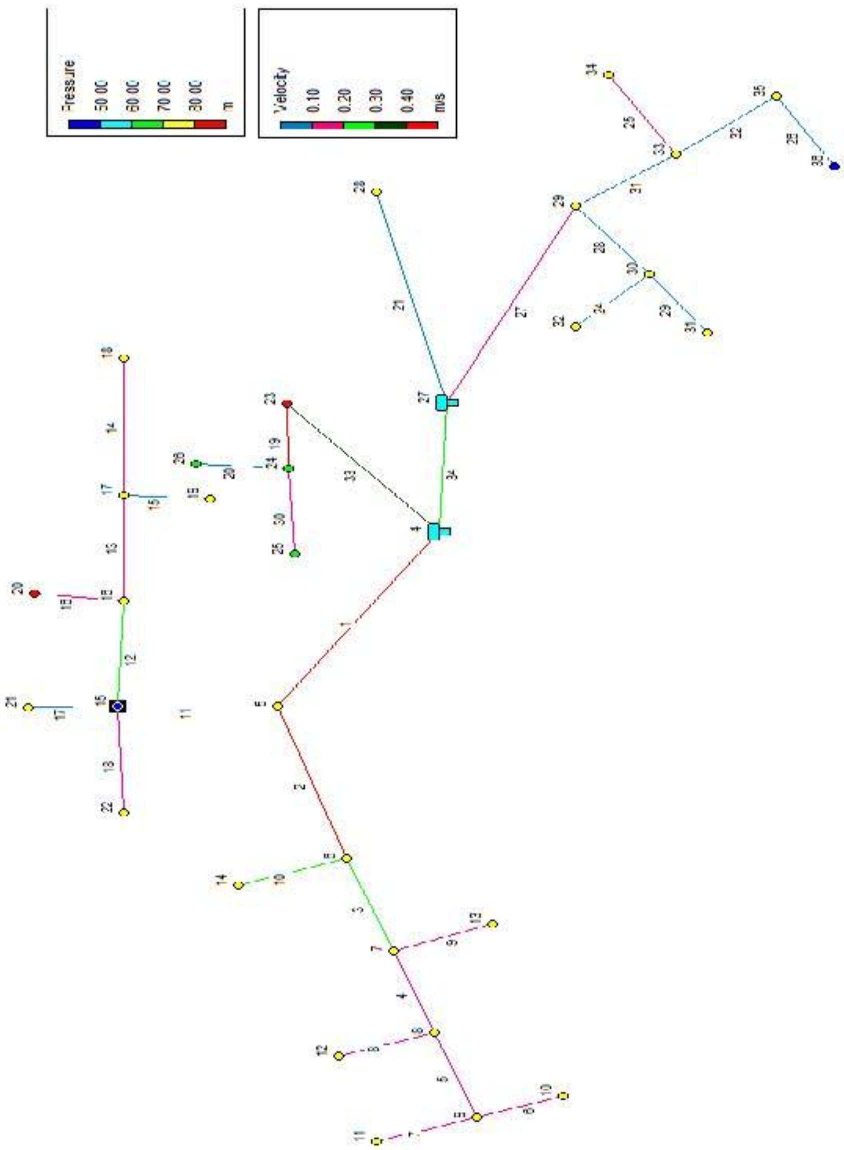


FIG 2. PRESSURE VS VELOCITY DISTRIBUTION

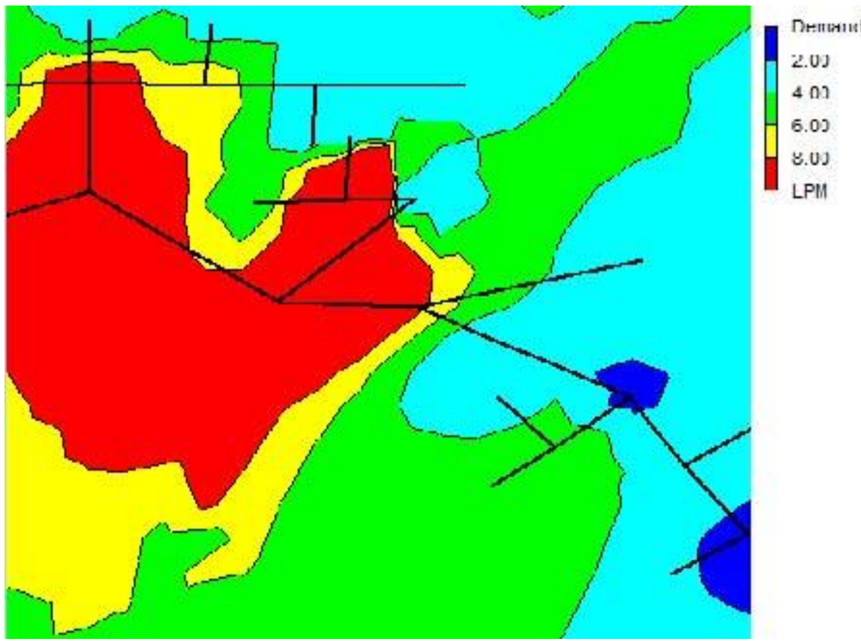


FIG 3. CONTOUR PLOT OF DEMAND

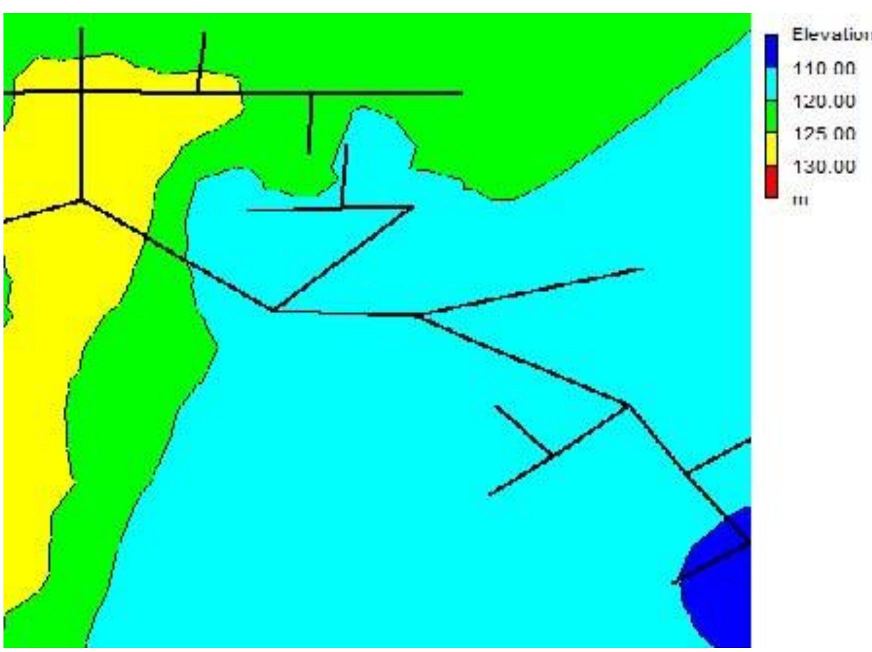


FIG 4 CONTOUR OF ELEVATION

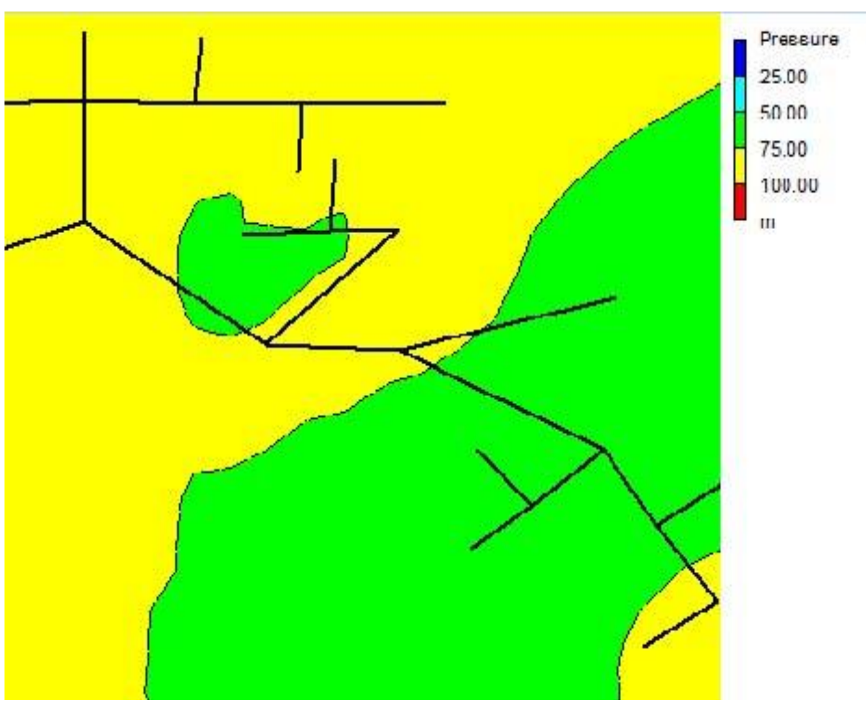


FIG 5 CONTPRESSURE

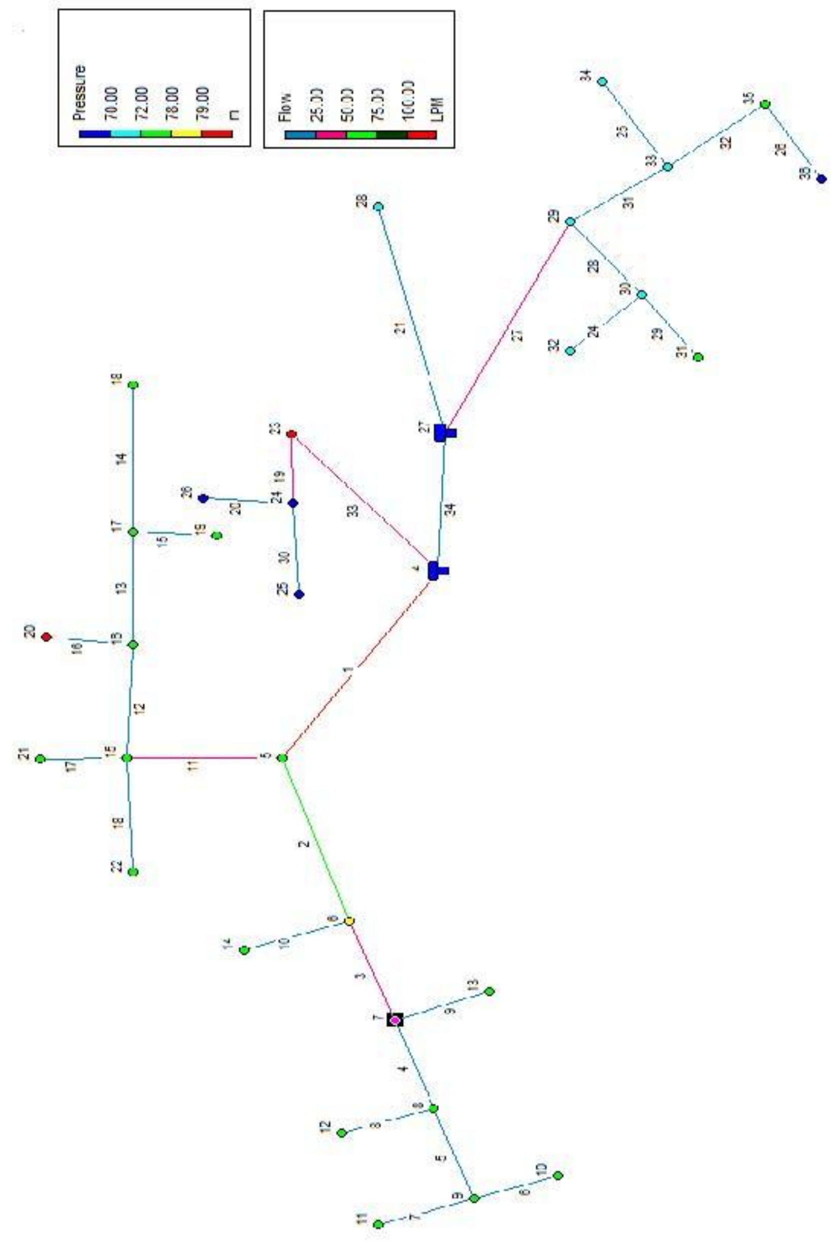


FIG 6. ELEVATION VS DIAMETER DISTRIBUTION

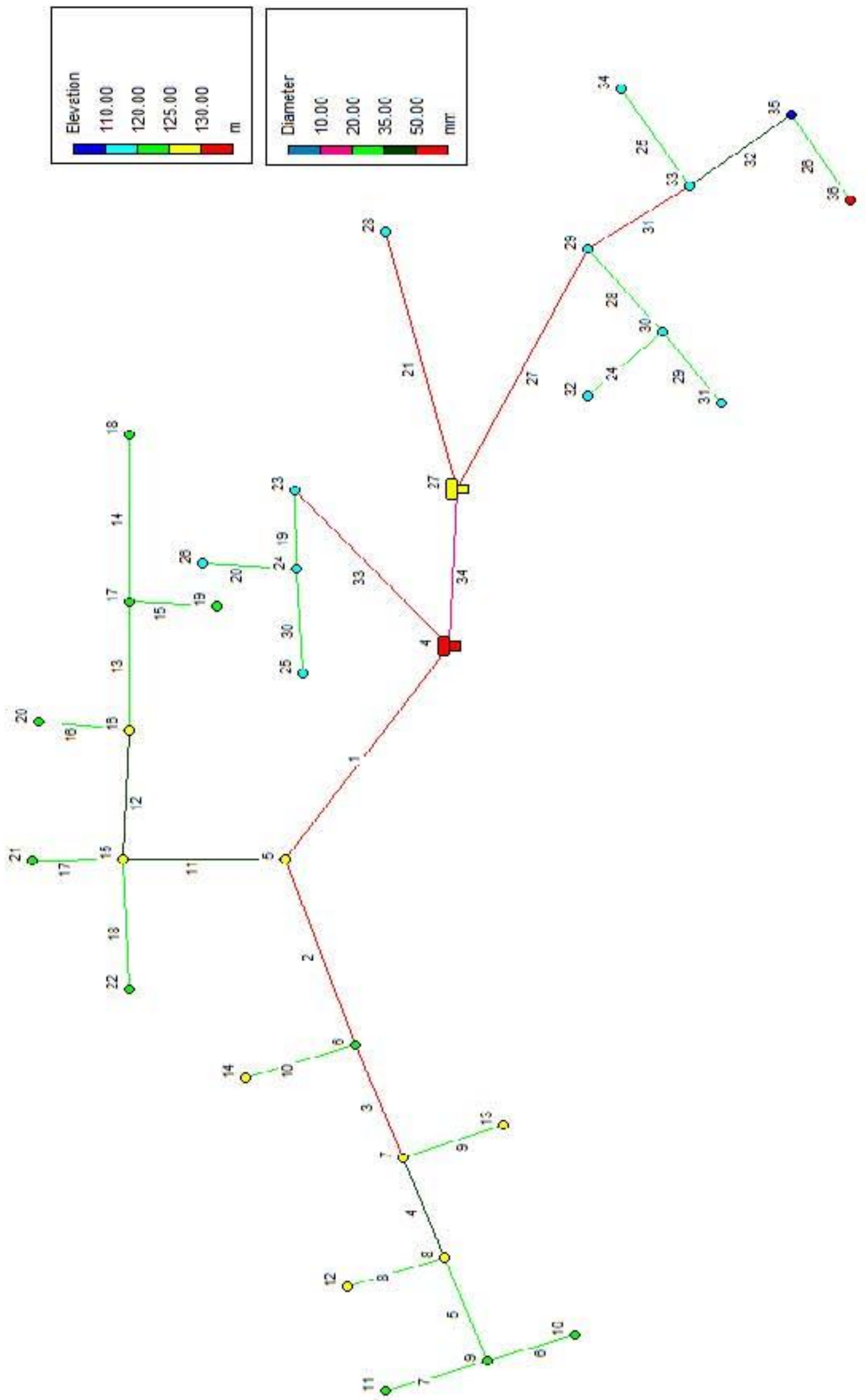
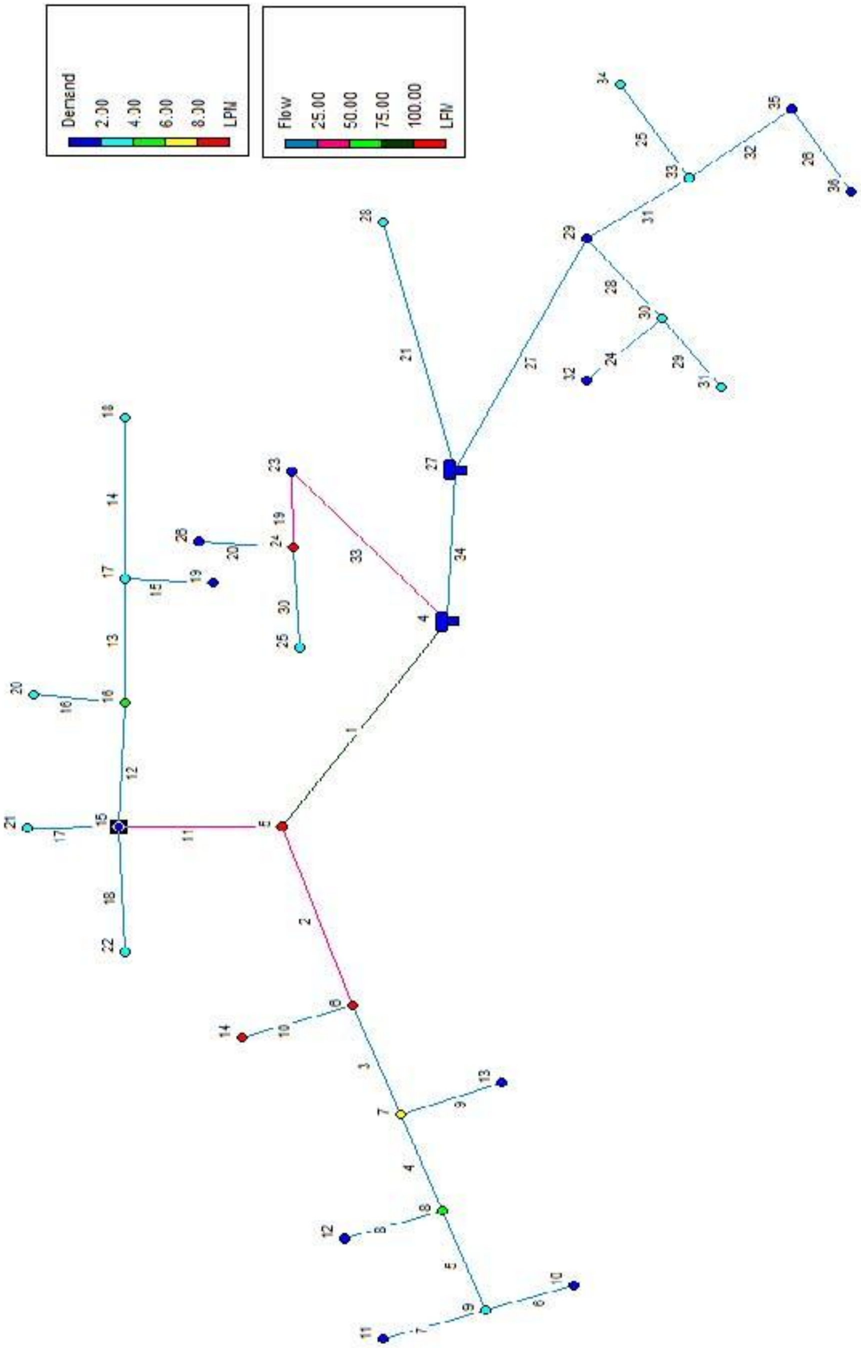


FIG 7. DEMAND VS FLOW DISTRIBUTION

FIG 8. DEMAND VS UNIT HEADLOSS DISTRIBUTION



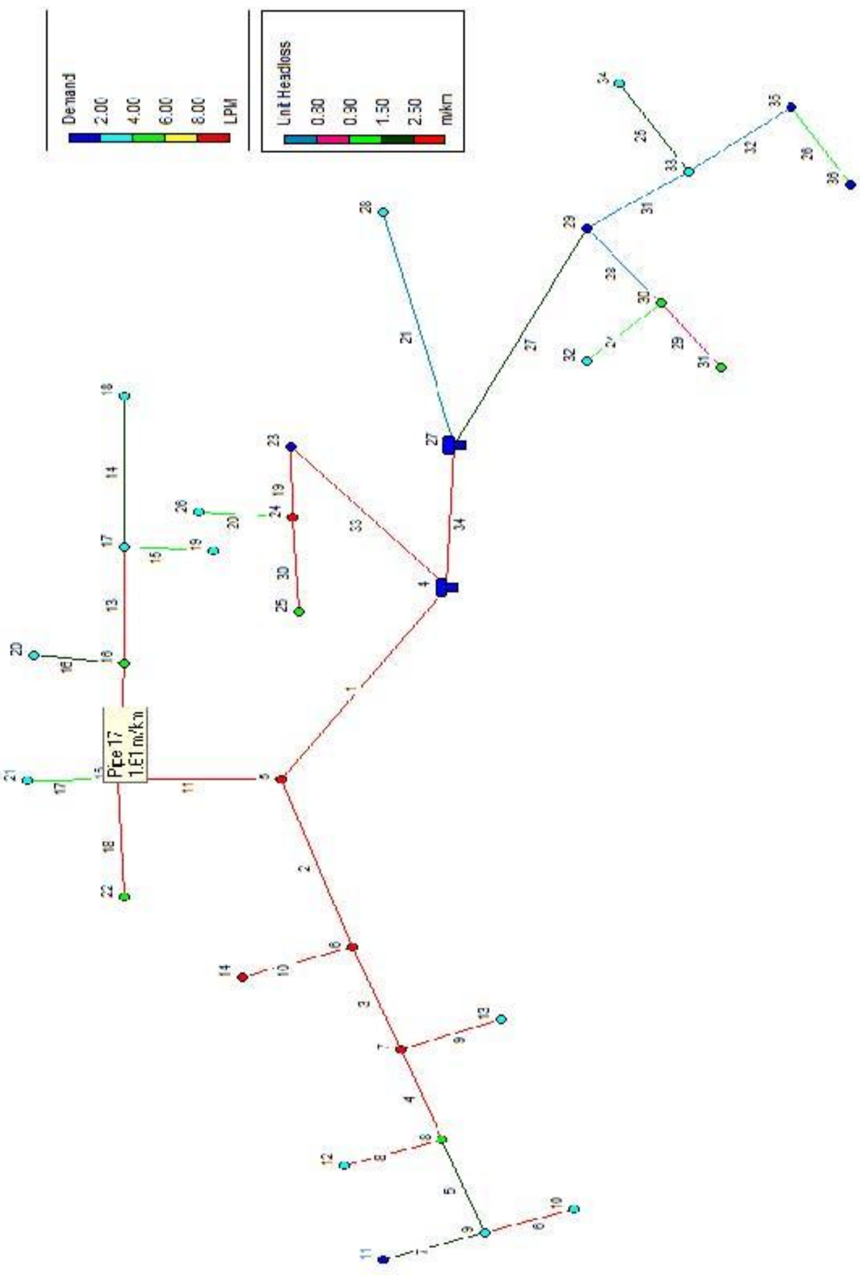


FIG 9. PRESSURE VS FLOW DISTRIBUTION

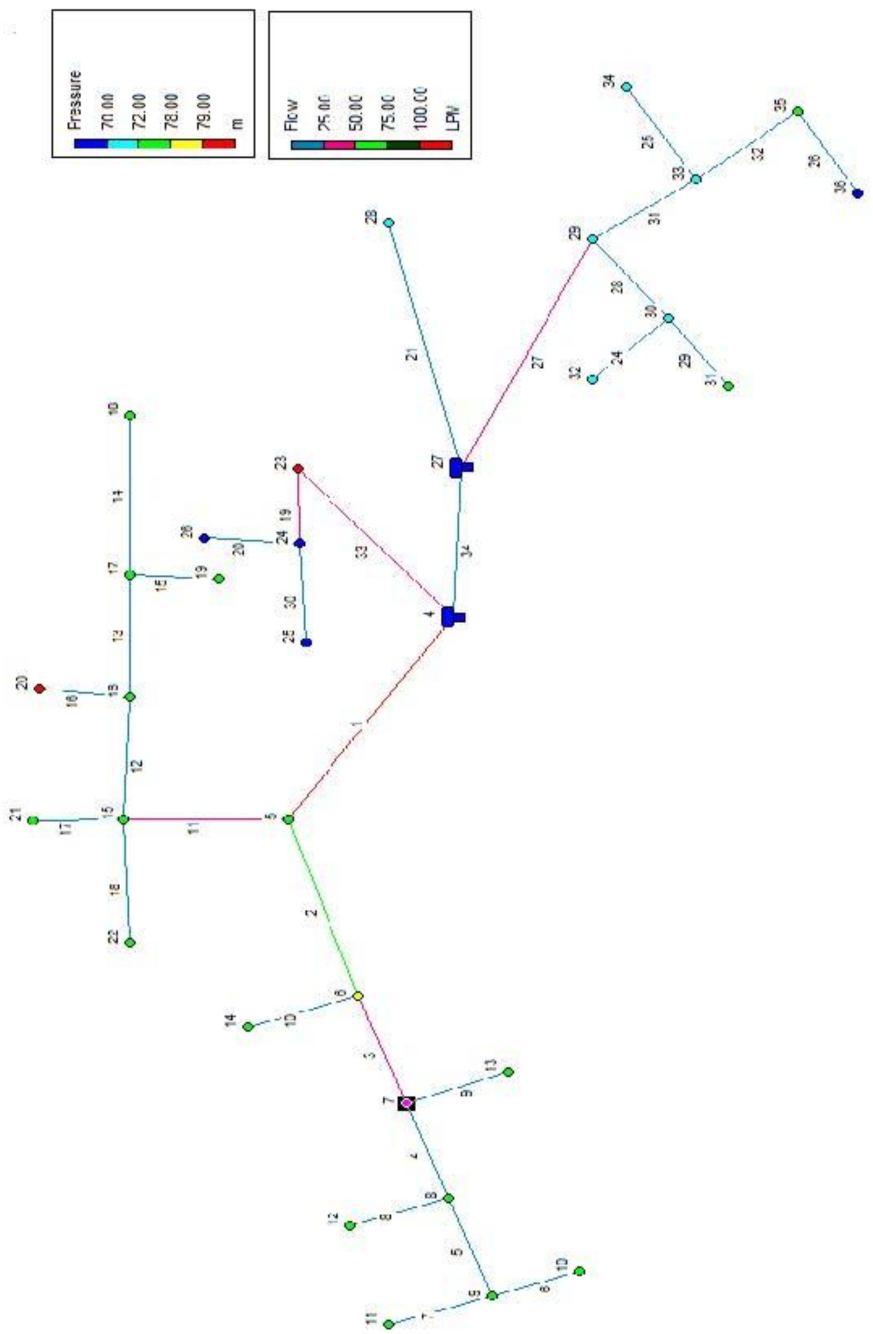


FIG 10. PRESSURE VS VELOCITY DISTRIBUTION

FIG 5.11 PRESSURE GRAPH FOR NODEB 5

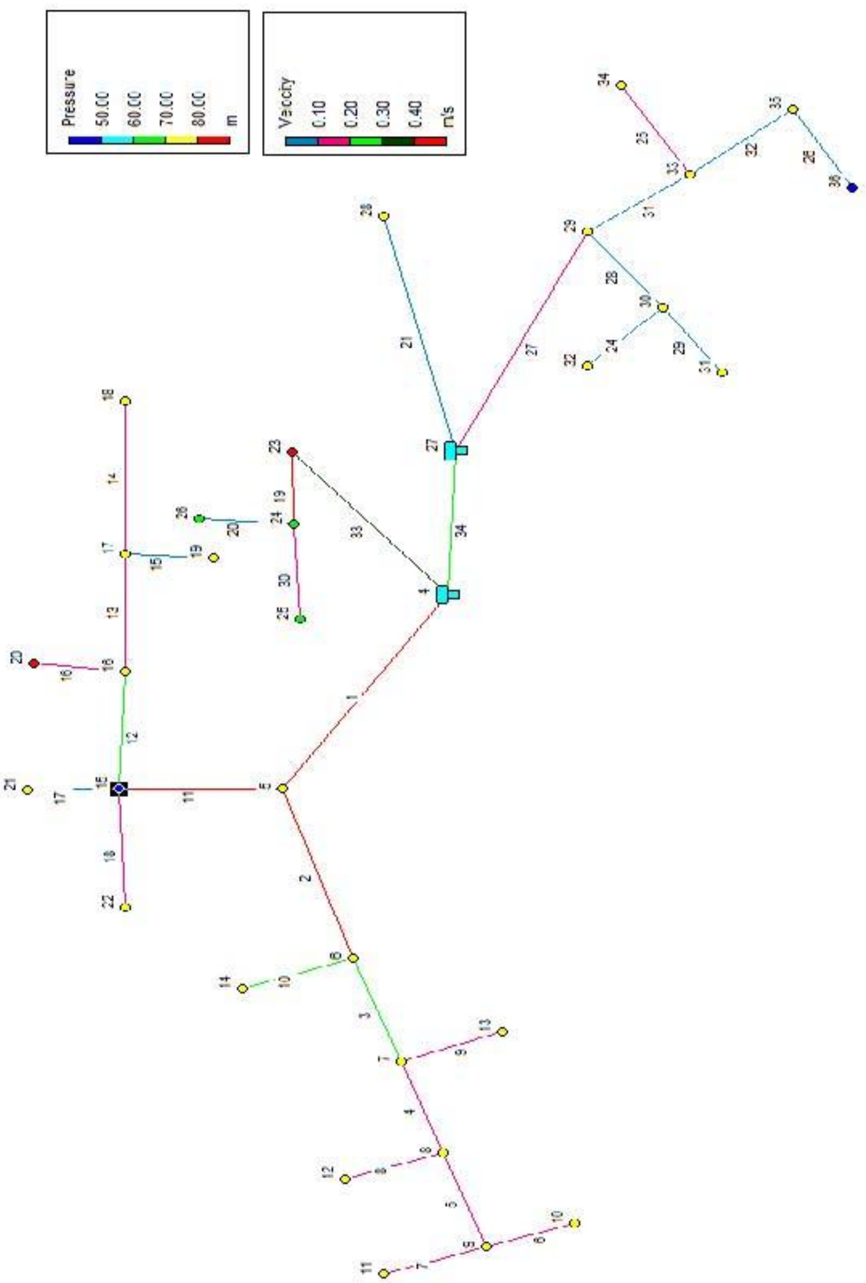
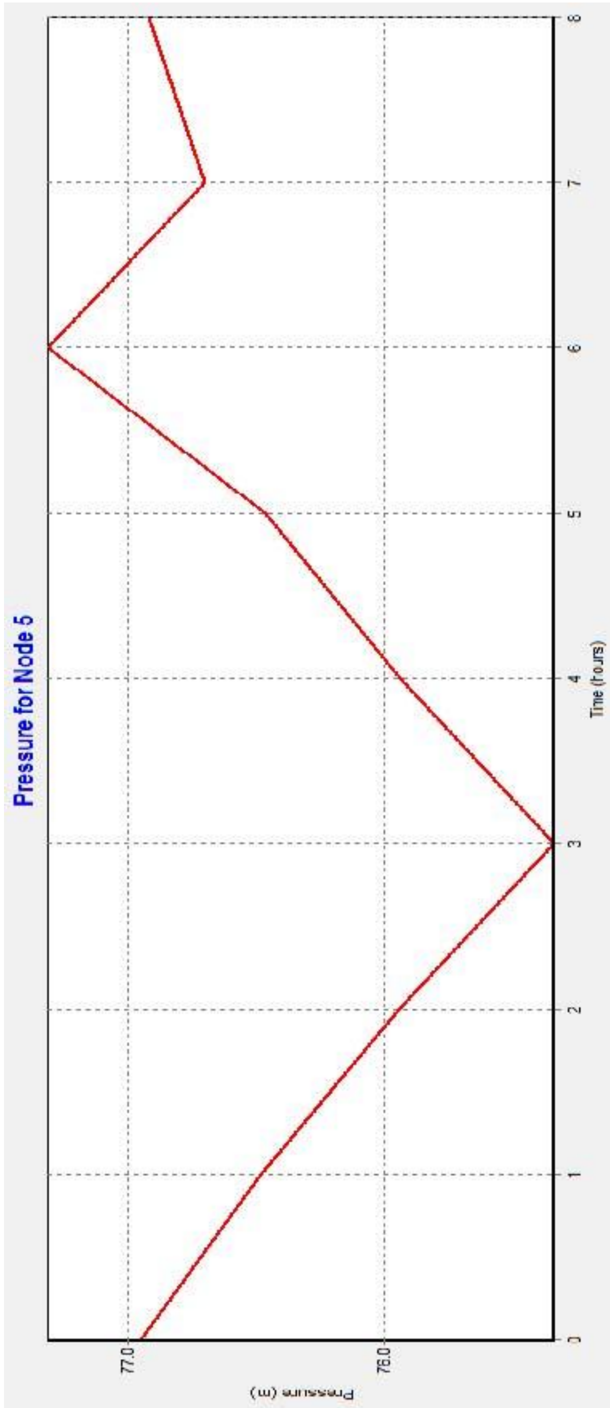


FIG 12. DEMAND GRAPH FOR NODE 7


Pressure for Node 5
Pressure (m)
77.0
76.0
Time (hours)
0
1
2
3
4
5
6
7
8

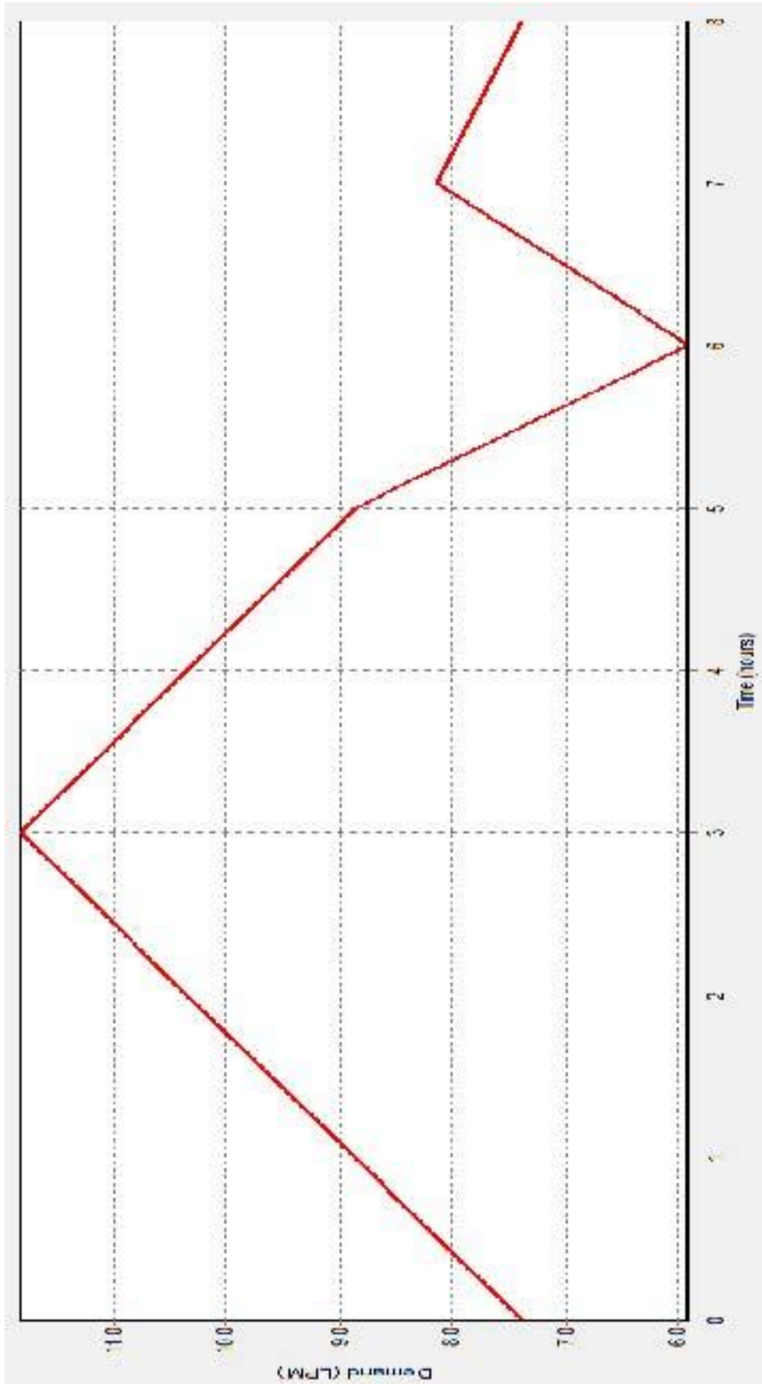


FIG 13 SYSTEM FLOW BALANCE

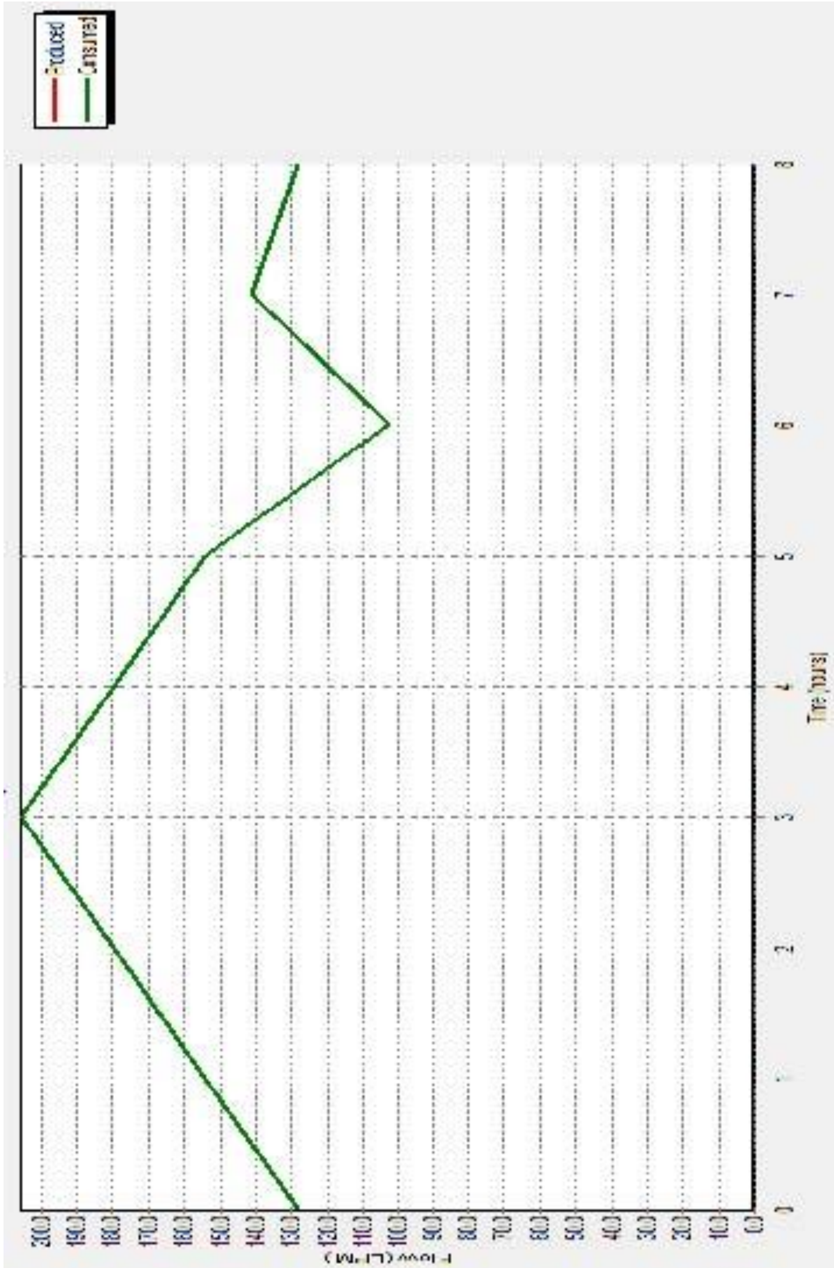


FIG 14.PRESSURE GRAPH AT NODE 29

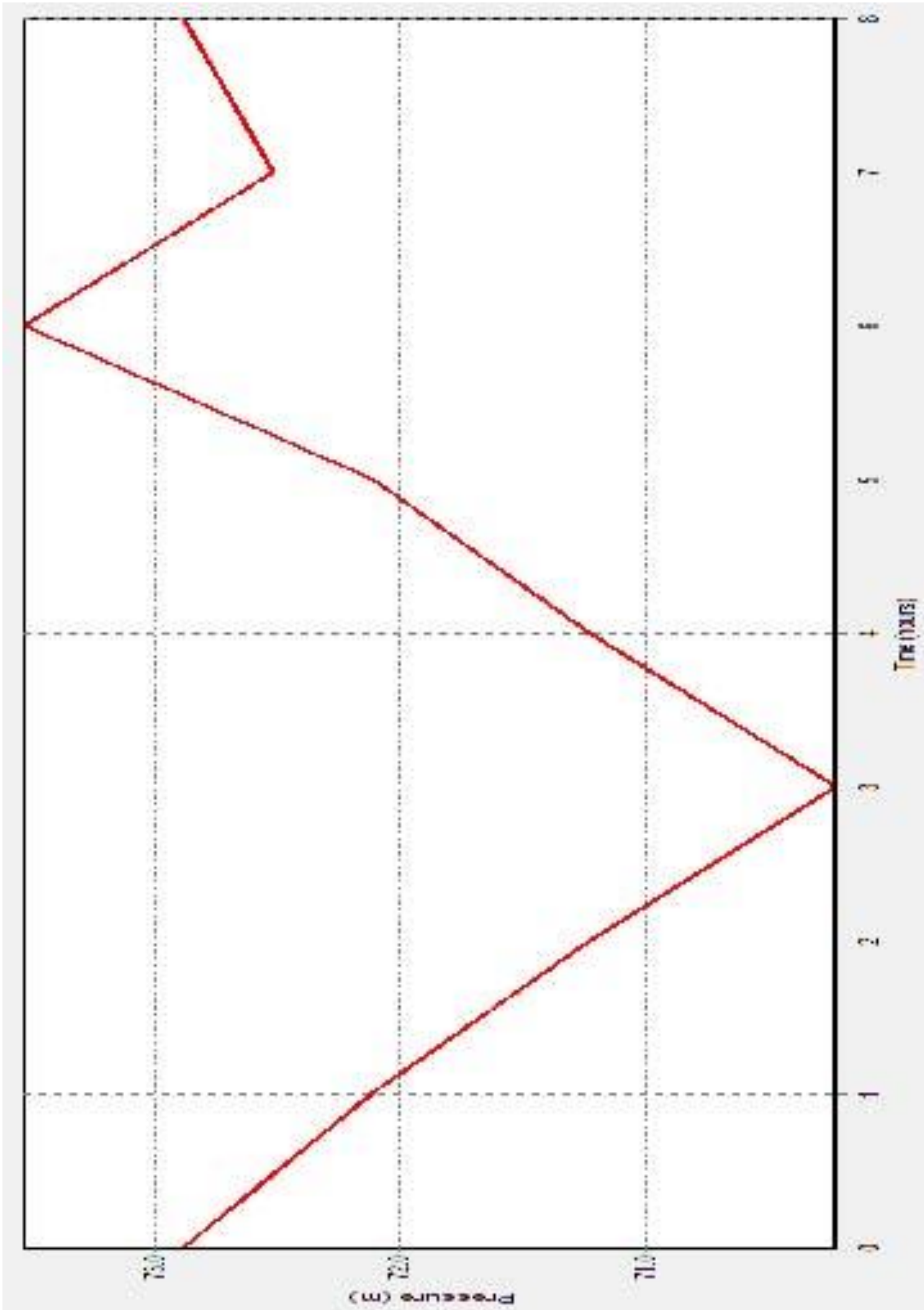


FIG 15. PRESSURE GRAPH AT NODE 15

CONCLUSION

In this work, the water distribution system has been design with the help of EPANET in which we use number of nodes, elevation, number of pipes and demands of Kathgarh area. First we surveyed the area and take information about the population and per capita demand of the people. And according to that we design the distribution system for the area. In this system 2 centrifugal pumps are used having power of 10hp. In storage two overhead tanks are used having capacity of 88700litres.

Here during the day time hours that is peak hours during morning time the demand of water is more as compared to the other time so the maximum supply is given for 8 hours a day. And also we concluded from the graphs that we obtained from EPANET shows that the demand is more during the peak hours.

The different nodes shows different variation of pressures and demand like the demand is more at nodes 19,24,32,29 as compared to others. The pressures at node 24, 25, 26 are more due to their elevation.

The method of distribution used here is combined gravity and pumping system as firstly the water is pumped with the help of centrifugal pumps from underground water source i.e. from aquifers and then they are lifted up to the overhead water tanks and through there with the help of gravity system is transferred to the main rising pipe. The distribution layout used here is tree system or dead end system which is according to the layout of the Kathgarh area.

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