Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

WATER DISTRIBUTION SYSTEM MODELING BY USING EPANET 2.0, A CASE STUDY OF CUET

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ABSTRACT

Water is one of the primary needs of people. A community can only thrive if it can ensure the availability of safe drinking water for its members. Hence a good water distribution system is imperative for any community. As the population of any community increases, the demand for water also increases. This increased demand impose additional load to the existing water distribution system. As a result, the existing water distribution system may become unreliable to meet the demand of the increased population. Hence the reliability of the distribution system should be checked for present and future demand. One of the ways to analyze a water distribution system and check its reliability is to use a model. CUET is one of the leading engineering universities of Bangladesh and is going through major development in recent years. It is highly important to ensure sufficient water supply to its residents. In this study, the water distribution system of CUET campus has been modeled using EPANET 2.0 software to check the reliability of the distribution system for present and future demand as per future master plan for cuet. The future demand as per future master plan for cuet is considered as the Engineering Department at CUET has finalized the detailed plan of the new buildings that are going to be constructed. The model shows that at existing demand, the water distribution system at CUET performs satisfactorily without any observation. However considering the future demand, the existing water distribution system may not perform satisfactorily as seen from the results. A few changes have therefore been suggested. If the diameter of the pipe, which will carry water to the three new ladies halls, is increased from 1.5 inches to 3 inches, then the water distribution system will perform satisfactorily for the future water demand as per future master plan for cuet.

Keywords: *CUET, EPANET 2.0, Arc GIS.*

1. INTRODUCTION

Water is one of the basic demands of all life forms. Without water, there can be no life. Historically, settlements and communities relied on natural resources to obtain their water. Around 3500 years ago human began transporting water through pipes (Martínez et al., 1999). These water sources provided water for human daily consumption, irrigation, recreation and all other basic necessities. As these communities flourished, the population dependent on these sources increased. This water supply system facilities the supply of safe drinking water with sufficient quantity, pressure and quality. Good water distribution has a paramount impact on people lives. Even today, diarrhea is considered the main cause of child mortality and in the developing countries, 21 out of the main 37 diseases are water and sanitation related (Ramesh, 2012). Modern water supply system tries to solve this problem by ensuring the supply of safe drinking water to people. And thus the modern water supply system greatly improved the people's quality of life. Building a large water distribution network is a very costly project. In the long run, it saves a lot of money and life, but initially a large investment is needed. Today, the cost contributed towards the water transmission and the water distribution network is nearly 80% to 85% of the total cost of a modern water supply system (Sayed et al., 2014). The objective of the distribution system is to supply water to each and every house, industrial plants, and public places. Each house must be supplied with a sufficient quantity of water at the desired pressure (Muranho, 2014). The distribution system consists of a network of pipes with appurtenance, for transporting water from the source to the consumer's tap. In order that water may flow in the water supply pipes under pressure, the water is normally stored in an elevated service reservoir. More than one reservoir may be needed in large systems. The performance of a distribution system can be judged on the basis of the pressures available in the system for a specific rate of flow (Punmia, 2007).

The sustainable management of water resources plays a key role in the development of human societies. One of the ways to effectively manage the water distribution system is by using a model. A water distribution system model helps the authority in management, maintenance, and extension of the water supply system at hand. A model can help the authority to understand when the existing water distribution needs expansion and what modification should be made to meet the demand of the population. These days many computer software applications are available to model the water distribution system. EPANET 2.0 is such a computer based software, distributed by USEPA, which can model pressurized pipe networks.

1.1 Study Area

This study was carried out in Chittagong University of Engineering and Technology (CUET). It has the largest Engineering university campus of Bangladesh. CUET is situated in the district of Chittagong under Chittagong Division. It is in the Pahartali union under Raozan sub-district, by the north side of the Chittagong-Kaptai road at 22°27′43.50″N 91°58′22.60″E about 25 kilometres from the centre of Chittagong City. The university campus covers an area of 171 acres. The population of the university is almost 3866 including students, teaching and non-teaching staff. The population of CUET grew rapidly in recent years and this population is also expected to grow noticeably in the upcoming years. With the increasing population, the demand for water is also increasing significantly. This increased water demand is going to impose an additional load on the existing water distribution system, which may decrease the effectiveness of the water distribution system. As the population of CUET has increased and is also going to increase considerably in the following years, the increased water demand will have an important impact on the existing water distribution system of CUET. The water distribution system may become unreliable to meet the current water demand also the system might also become unable to meet future water demand.

Hence the objective of this study has been set to evaluate the existing water distribution system of CUET in relation to present and future water demand. Therefore development of a model for the water distribution system present at CUET to develop a management system to supply the water with sufficient pressure.

2. METHODOLOGY

The working flow diagram has been illustrated in figure 1. At first, the design and necessary data of the water distribution system of CUET was collected. The data was provided by the Engineering Department of CUET. The length and diameter of the pipes, the capacity of the overhead tank were collected from the Engineering Department and the demand of the nodes was estimated through field investigation. The elevations of the nodes were found by using ArcGIS 10.4 and Google Earth Pro. After creating the model using this data, the model was simulated and its reliability was checked for the present demand. Then the model was simulated again with the expected growth in demand as per future master plan for cuet. Finally, the reliability of the water distribution system was checked for the future demand as per future master plan for cuet.

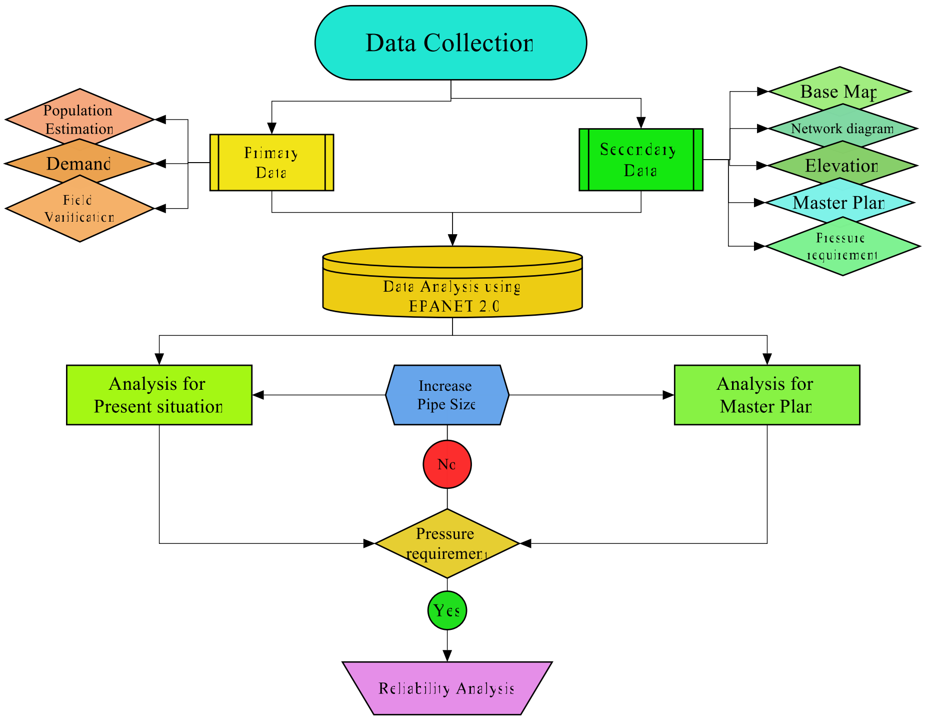
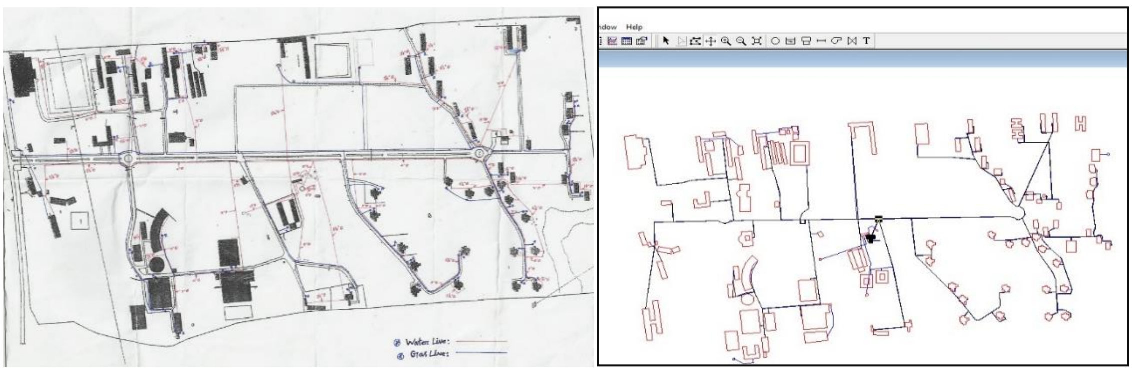


Figure 1: Details methodology showing the working process

2.1 Preparation of water distribution network layout

The map of the existing water distribution network of CUET shown in figure 2(a) was collected from the Engineering Department of CUET. The map contains the present water distribution layout of CUET which includes length and diameter of the pipe network with their relative positions.



(a) (b)

Figure 2: (a) Water distribution layout of CUET; (b) Background layout in EPANET 2.0

AutoCAD 2014 is used to replicate the layout and to prepare the background of the design outline. Then the raw file of the AutoCAD was exported to EPANET 2.0 which has been illustrated in figure 2(b). Using the AutoCAD file as backdrop the pipe network was drawn and the nodes were placed in the EPANET 2.0.

2.2 Assigning invert elevation data

Elevation data was taken using ArcGIS 10.4 from Digital Elevation Model (DEM) data. The data was converted and adjusted with the available datum in CUET. Then the elevation data to each nodes were assigned and the contour map of the CUET found out as shown in figure 3. It has been found that the invert elevation varies from 0 to 60 ft. As CUET is in the hilly region, there is much variation of elevations as a result the distribution network need special attention.

Figure 3: Contour plot of elevation of water distribution system

2.3 Base demand estimation

The water base demand at the nodes has been estimated using the guidelines from BNBC 2015. Total 70 numbers of buildings in CUET have been considered. The buildings are classified as occupancy catagory. The numbers of population has been deremined by field investigation and per capita demand has been taken from BNBC 2015. Total demand then converted to GPM and assigned to the nodes in of the distribution network. The contour plot of base demand are shown in figure 4.

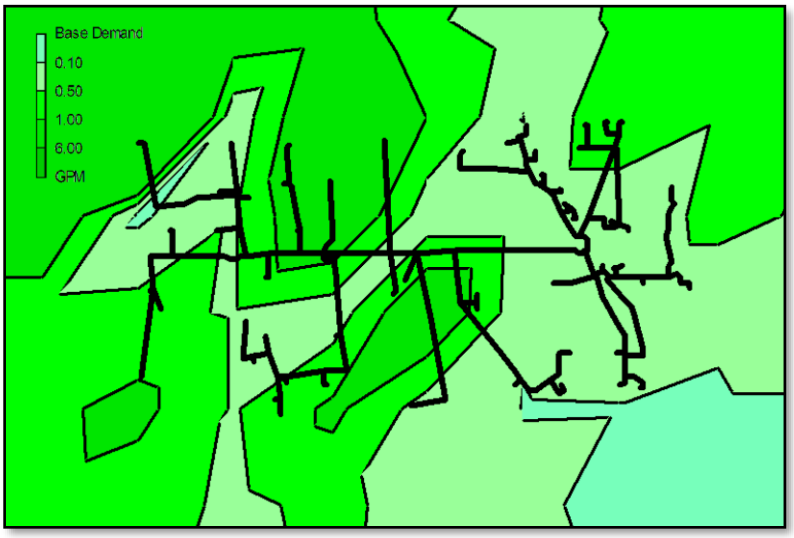


Figure 4: Contour plot of water demand at CUET campus

2.4 Assigning Pipe size

Pipe length and diameter were assigned to the distribution model as shown in figure 5. The water distribution model consist of 138 numbers of pipe. Diameter and length of the pipe have been collected from Planning and development (P & D) department, CUET. The values are varified, adjusted and assigned to the model. It has been found that the supply mains of the water distribution system of CUET campus has a diameter of 4 inches, while the diameter of the submains has a diameter of 3 inches. The branch lines have diameter of 2, 1.5 and 1 inches respectively.

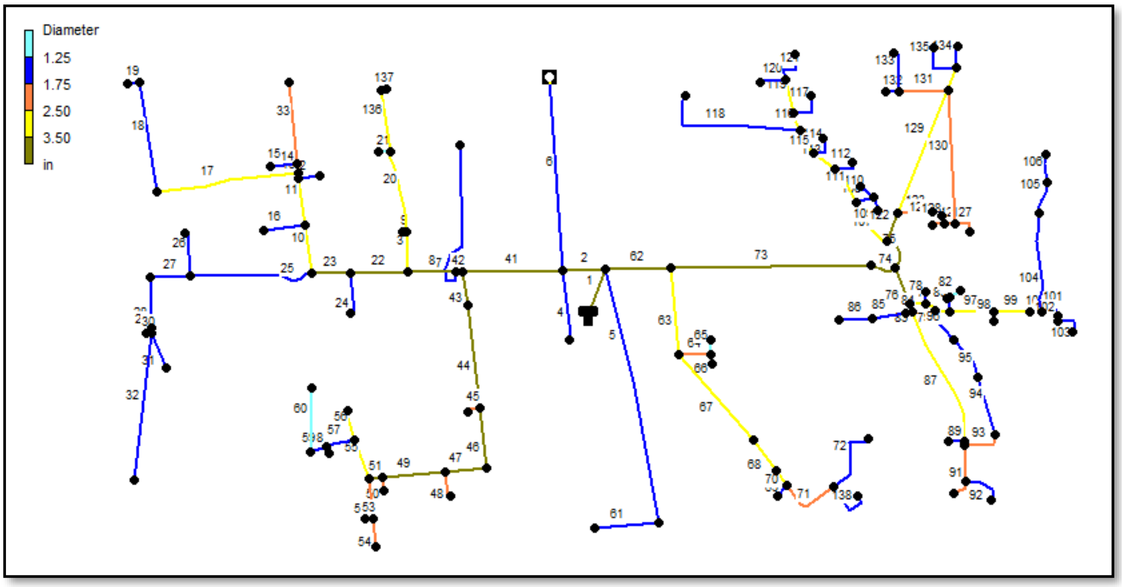


Figure 5: Pipe ID and assigned diameter of the pipes in distribution network

2.5 Future demand calculation as per master plan

Multiple new structures are expected to be constructed as per future master plan for cuet. Fajilatunnesa hall, Samsunnahar hall, 1-Boy's hall, 1-Ladies hall, 1-PG dormitory, 1-Academic building, Central research lab, TSC, Gymnasium, New garage, 1-TSD, 1-10 storied apartment, 1-Guest house, 1-10 storied professor quarter, 1- 5 storied professor quarter, 2-5 storied staff quarter are expected to be active. Hence these buildings are aslo considered for analysis. The position and details has been illustrated in figure 6 as per master plan of CUET.

After assigning all the necessary data, the model was completely prepared . Then the model was simulated, at first for present water demand, and then for future water demand. Validation of the model was done with respect to pressure in the nodes. After that, the result was obtained from the simulation and it was viewed in different formats. The diameter of the pipes was changed to find out the required diameter that results in pressure between the acceptable ranges if necessary. In this way, the reliability of the water distribution system was checked for present and future demand.

3. RESULT AND DISCUSSION

Water distribution system of CUET has been found as dead end or tree system. After assigning all the necessary data of nodes and pipes, the final simulation has been run for. EPANET 2.0 has provided pressure at different nodes and flow rate in the pipes.

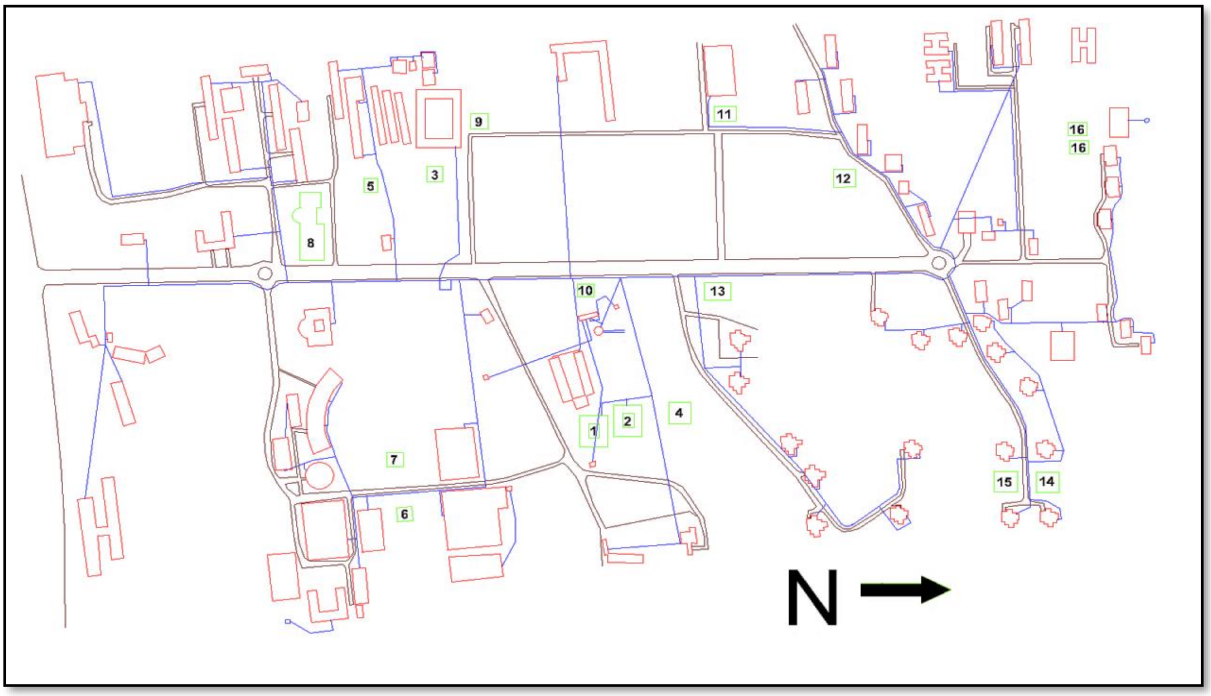


Figure 6: Master plan of CUET

3.1 Analysis of distribution network for present situation

3.1.1 Variation of pressure for different nodes at present situation

After simulation, epanet 2.0 provided the pressure at the nodes of the water distribution system. As illustrated from figure 7 and figure 8 there is no node in the distribution system that has a pressure less than 30 psi which satisfy the minimum pressure limit 20 psi (aziz, 1975). It's indicates that the nodes of the pipe have sufficient pressure and this distribution system is reliable for fulfilling the present water demand.

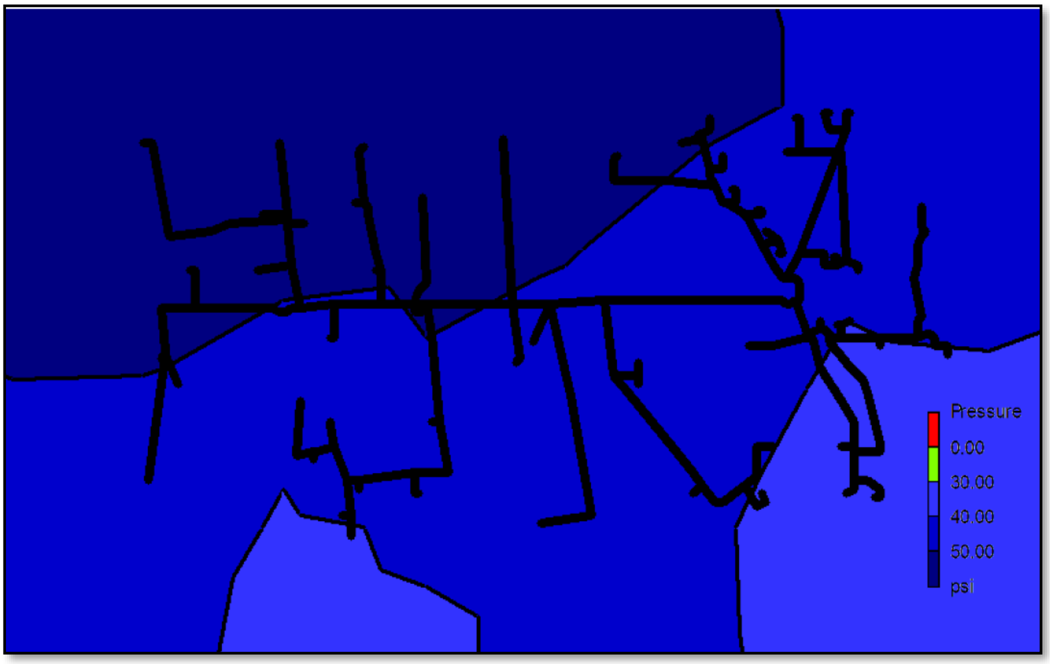


Figure 7: Contour of pressure of the water distribution system

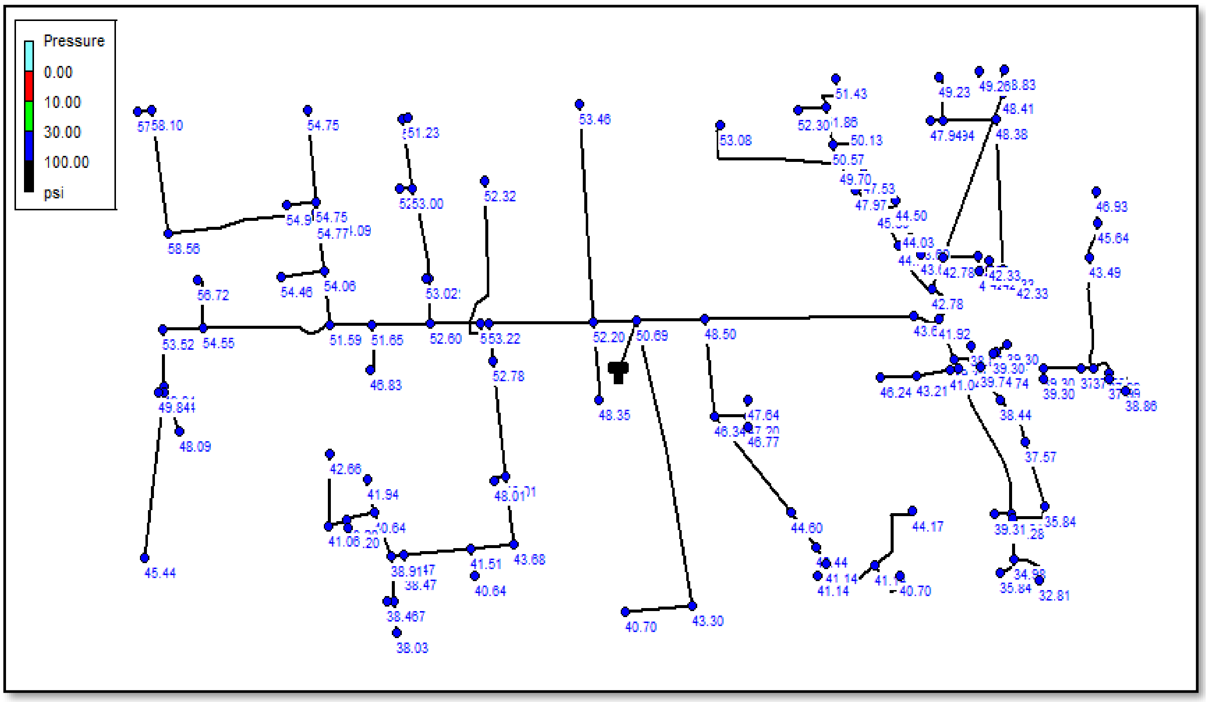


Figure 8: Pressure at the nodes of the distribution system for the present

3.1.2 Validation of the model

To check the accuracy of the model, manual calculation of the pressure of some nodes were done and the data from EPANET 2.0 was compared with them. From figure 9 it's been seen that the result from EPANET 2.0 is very close to the result from hand calculation. The R-squared values R^2 value has been found about 0.9977 that indicates the excellent accuracy of the model. Hence the model is validted from further analysis.

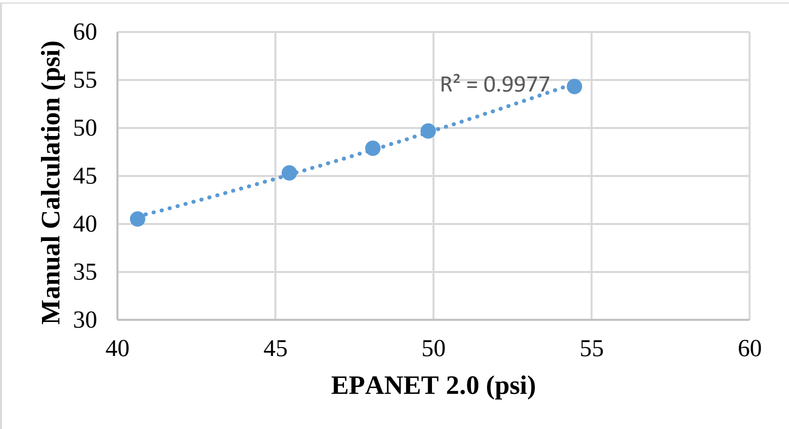


Figure 9: Validation of model.

3.1.3 Variation of demand for different nodes at present situation

From figure 10, it is found that the flow in mains are ranges from 54.08 gpm to 27.01 gpm and in the sub mains 8.99 gpm to 5.05 gpm. Form the model it can be shown that the flow in the pipes corresponds to the water demand in the nodes. When a nodes has a large water demand, the flow in the pipes that carry water to that specific node, also increase. Also it is found that all the pipes of the water distribution system of CUET have appropriate flow in them to fulfil the demand by the supply of water.

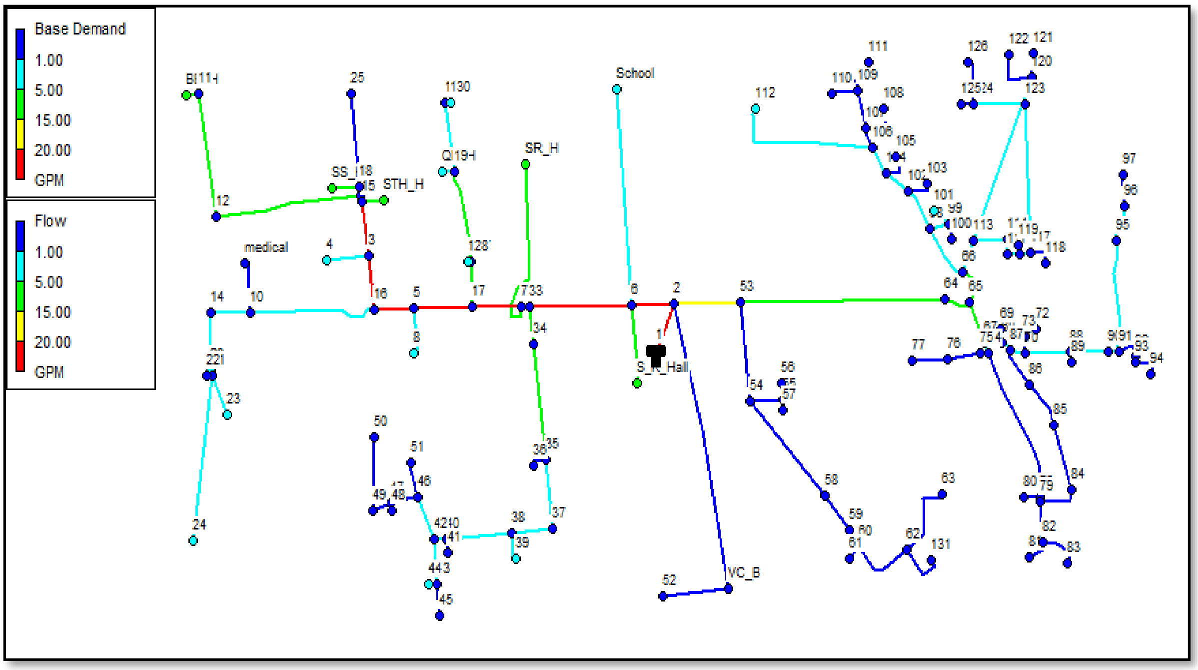


Figure 10: Demand and flow distribution in distribution network

3.2 Analysis of distribution network for future situation

3.2.1 Variation of pressure for different nodes as per master plan

After simulating the distribution network for the future water demand as per master plan of CUET, EPANET 2.0 provided the pressure at different nodes of the distribution system. Contour plot of pressure distribution has been illustrated in figure 11.

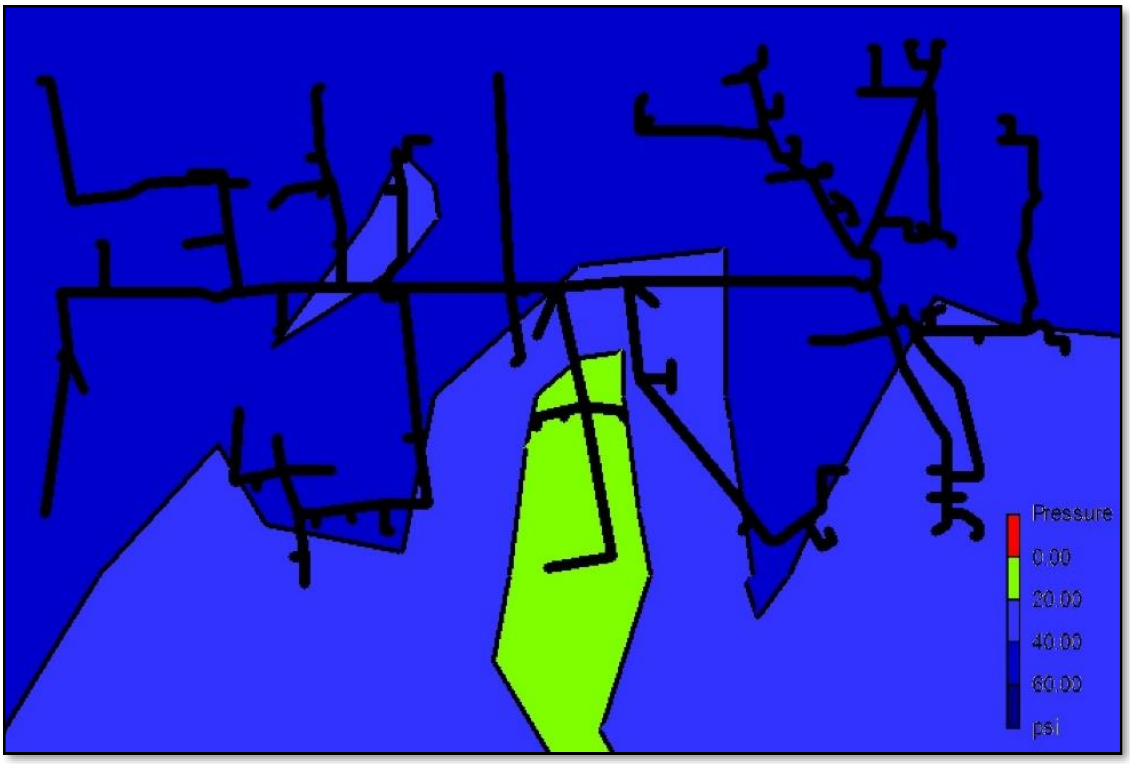


Figure 11: Contour plot of pressure of distribution system for 2020

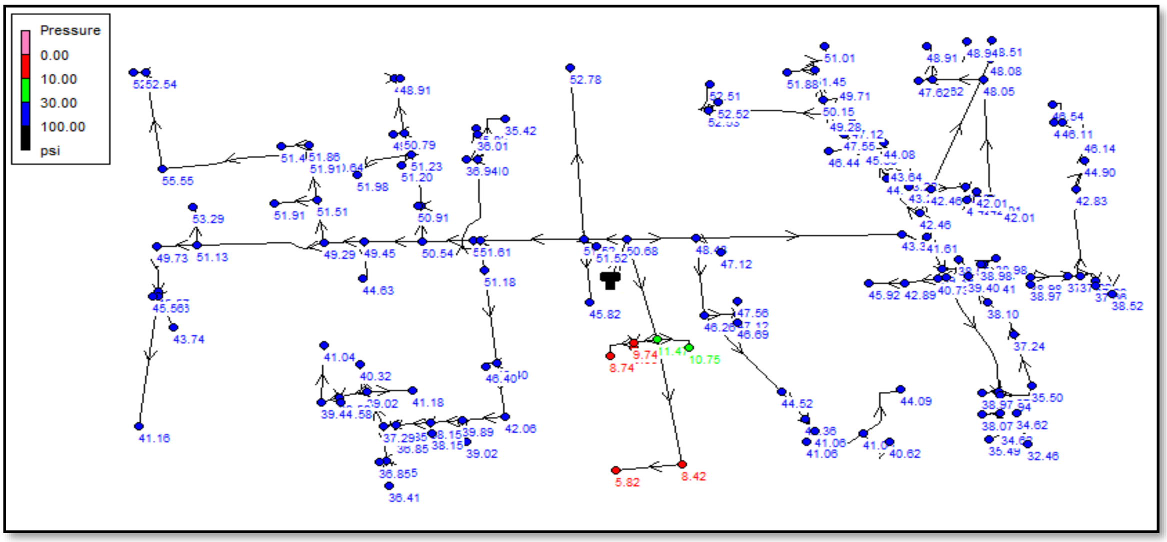


Figure 12: Pressure distribution in different nodes new master plan

rom figure 11 and figure 12, it can be coluted that, after the completion of the construction of the 3 new ladies hall and when they will be connected to the water distribution network of CUET, 5 nodes will experience significant pressure drop. These nodes are Junc 52, Junc VC_B, Junc 132, Junc 133, and Junc 138. They all have a pressure less than 30 psi as shown in figure 13, which indicates 5% nodes have a pressure less than 34 psi.

3.2.2 Measures taken to adopt the problem

From figure 13 and figure 14 it has been found that all of these nodes get water from Junc 134, and Link 5 carry water to Junc 134. Link 5 has a diameter of 1.5 inch, which was sufficient when it only carried water to the nodes Junc VC_B and Junc 52, which have little demand. But when three new residential halls will be supplied water using this Link, the flow in this pipe will increase significantly. As the diameter of the pipe will remain the same, so the velocity in this pipe will increase accordingly. As a result, with the increase of the velocity, following the Bernoulli's Equation ($p + \frac{1}{2}\rho V^2 + z = constant$), the pressure at the nodes will decrease. If Link 5 is replaced with a pipe that has a larger diameter than 1.5 inches, then the pressure at those nodes will increase. If in this study 3 inches diameter pipe has been used and found that the pressure at those nodes are found to be satisfactory. Figure 14 indicates that there are 0% nodes that have a pressure less than 34 psi. So this study suggested using 3 inch diameter pipe to provide a satisfactory pressure in the pipe.

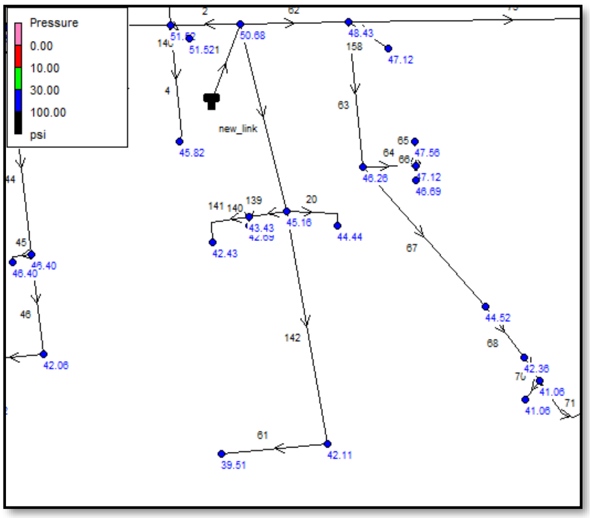


Figure 13: Pressure at nodes after using new link in the water distribution system

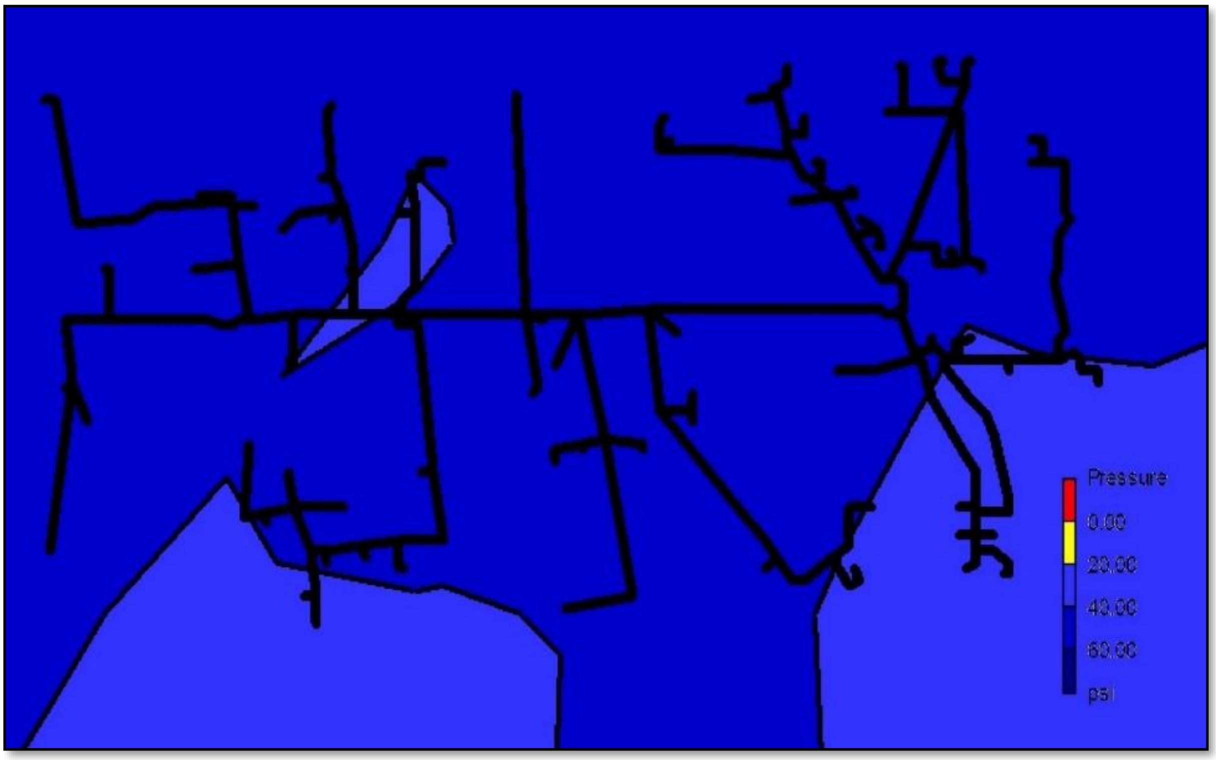


Figure 14: Contour plot of pressure after using new link

4. CONCLUSIONS

In this work, the present water distribution system of CUET has been analyzed with the help of a computer program named EPANET 2.0. The existing water distribution layout of CUET is tree system or dead end system. We used the number of nodes, number of pipes and demands in the EPANET 2.0 and tried to check the reliability of the present distribution system. EPANET 2.0 was used as it offers an integrated environment for editing network input data. The necessary data was collected and the results were obtained in a variety of formats after running the hydraulic simulation. After modeling and running the simulation for present and future demand as per future master plan for cuet the obtained results are

- A model has been developed for the water distribution system present at CUET
- Different scenarios has been developed to evaluate the existing water distribution system of CUET. The system is reliable for the present water demand, and mostly reliable for the future water demand as per future master plan for cuet except some exception in 5 nodes (Junc 52, Junc VC_B, Junc 132, Junc 133, and Junc 138.)
- A management system in relation to the different scenarios has also been developed. It has been found that if the diameter of the link 5 is increased from 1.5 inch to 3 inch, then all the nodes have sufficient pressure.

The existing water distribution system of CUET is reliable for meeting the present water demand. It can supply sufficient water to the nodes. There is no negative pressure in the system and no node has a pressure less than 30 psi. For the future demand as per future master plan for cuet, the existing water distribution system is mostly reliable. From the simulation it has been found that, when water will be supplied to the three new ladies hall, few nodes will experience pressure drop. This can be solved by changing only 1 pipe of the network. According to the model, replacing that particular 1.5 inch dia pipe (link 5) with a 3 inch dia pipe will increase the pressure in the nodes to a satisfactory level. The remaining water distribution network can adequately serve the future demand as per future master plan for cuet.

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