# Modelling of Direct and Continuous Water Supply System for CST using EPANET.

Kezang Lhamo[1], Namgay Rinchen Jamtsho[2], Sangay Phuntsho[3], Tandin Choden Dorji[4], Dr. Cheki Dorji[5]

Civil Engineering and Architecture Department, College of Science and Technology, Royal University of Bhutan
Email: 02161029.cst@rub.edu.bt[1], 02161044.cst@rub.edu.bt[2], 02161075.cst@rub.edu.bt[3],02161092.cst@rub.edu.bt[4], chekidorji.cst@rub.edu.bt[5]

## Abstract

Continuous water supply has advantage over intermittent water supply system in terms of cost, health and user friendliness. Water networks are usually designed to supply water continuously, but over period of time, water network behaves intermittently, without functioning the way it is designed for. Solutions for existing intermittent water supply networks is required to be studied while redesigning with minimum effect on the existing network. Therefore this study focuses on the design of continuous water supply distribution system by redesigning the existing water network system by connecting the dead ends and making the flow continuous. The pipeline and its features are developed in GIS for the height of the nodes and proper placement of the pipes and as for the analysis, pressure and velocity for the water network system is analyzed in EPANET. While the analysis results for the pipelines of CST showed that the pressures are greatly affected by the distance from the source and also by the number of connections for water withdrawals, providing alternative connections and increment of pipe diameter has solved the associated problems. The flow can be made continuous by connecting the dead ends, as it does not allow stagnation of water, which is common problem of dead end systems. This paper shows the comparative behavior between dead-end and ring system of network in terms of pressure and velocity and the effects of building height and topography in the distribution network using EPANET.

***Key Words:****Continuous water supply system, Geographic Information System, EPANET, Water distribution network, Negative Pressure.*

## 1. INTRODUCTION

Bhutan is known to have abundant water with one of the highest reported water availability per capita in the region. However, issues with water accessibility continue to persist across the country. The problem with the existing water distribution system in Bhutan is that the water is available at the source but is insufficient at the consumer end.

With increase in water demand especially in urban areas due to increase in population, industrial activities are putting on the danger of depletion and exploitation of the natural resources. Most of the urban areas follow intermittent service, where water is delivered to residents for a limited amount of hours per day.

Every year the urban areas become populated and the design period of water distribution of only about 40 years becomes too overloaded. The joining of new pipelines from the existing main pipelines leads to many dead end systems, where waters are not reached to the service ends, causing stagnation of water in the pipes.

CST still faces the problem of having intermittent water supply. Therefore, with proper analysis of the existing water supply network, alternative water supply systems can be established to make the system behave as continuous system.

**Chimmi, L., et al., (2013)** has mapped and analyzed water distribution system of CST using GIS for head loss and also performed pipe analysis to calculate the head losses in pipelines. They concluded that no building height is critical for water availability and even with the water level of 0.5m in the tank; the highest building story will receive water.

**Lungariya, P. et.al. (2015),** studied the Water Distribution in Surat City using EPANET . They analysed the network and observed the resultant pressure in all the junctions with their flow velocity.

**Dighade, R. et.al. (2014)** Discovered that leakage in water distribution systems is an important issue and they studied the infrastructure of the network system and mitigated the problems related to the pipes and nodes.

**Payal. et.al. (2015)** conducted study to analyze the water distribution network and it was observed that the resultant pressures at all the junctions and the flows with their velocities at all pipes are adequate enough to provide water within the study area.

**Sanjay and V. Dahasahastra** conducted a case study in Maharashtra Badlapur city to supply pure drinking water round the clock. A unique method was adopted to convert it to a continuous water distribution network system.

Based on those similar studies, we have proposed to study the network for associated problems and propose a feasible solution to ensure flow continuity by modelling the water distribution network for CST.

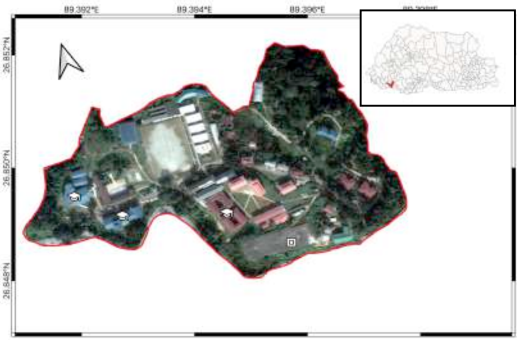

Figure 1: CST campus map

## LOCATION OF STUDY AREA

CST is located in Rinchending under Chukha Dzongkhag at 26.8502°N, 89.3940°E. The area of the campus is around 204281.4 $m^2$ with elevation ranging from 395m to 445m.

The current water supply to CST is pumped from a borewell from Phuentsholing in two stages. It is initially pumped from Phuntsholing to 3km reservoir tank and later from this reservoir to the overhead water tank inside the campus. Figure 1 shows the location of study area, under Chukha dzongkhag.

## 2. AIM

The aim of this study is to design a continuous water supply system without any major changes in the existing network by proposing alternative connections.

## 3. OBJECTIVE

For this study, preparation of GIS based water distribution network for CST is to be done withanalysis of the water distribution network using EPANET so that to identify problems in the existing water distribution network system, which will determine the effect of height of building in water supply distribution.Then finally re-design the water distribution network.

## 4. METHODOLOGY

The overall methodology adopted in the study consists of five sequential stages as shown in figure 2.

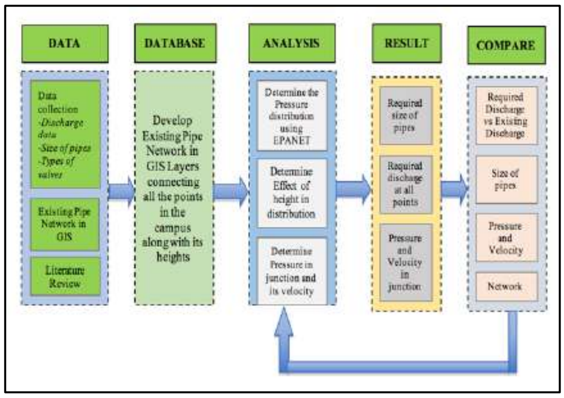


Figure 2: Methodology Flowchart

## 5. DATA COLLECTION

Field Study: population data, Per capita water demand, existing pipe sizes, length and the materials of pipes, types of valves and mapof the study area.

Desk study: background information of the study area, water demand of the area, study of materials of the pipe, pump and nodes with the equations of velocity and pressure that are used in EPANET.

GIS input data: Digital Elevation Model (DEM), topographic maps, imageries captured from the Google earth that can be geo-referenced and can be used for realistic mapping, AutoCAD drawings of building structures are layered in GIS.

EPANET data: Coordinates of the pipes and nodes from GIS, building heights and coefficient of roughness of the pipe, and elevation of nodes from DEM.

The water network for existing system is shown in the Figure 3, and Figure 4 shows the network drawn in EPANET software.

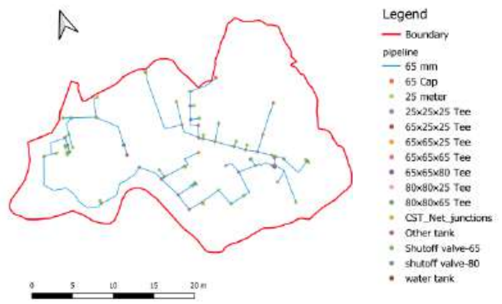


Figure 3: CST Water Distribution Network

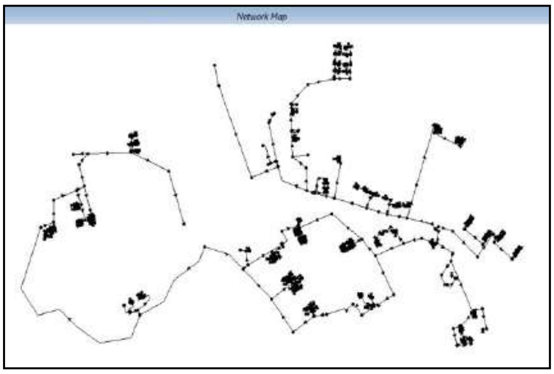


Figure 4: Pipeline Network in EPANET

## 6. DATA ANALYSIS

The basic assumptions during the analysis are as follows:

- The population is assumed not to exceed 1500.
- The water stored in the overhead tank is sufficient to meet the demand.
- The water is conveyed by direct water supply system.

The EPANET simulation displays the flow, velocity, and pressure in the distribution network in the form of color-coded network maps based on the certain range of values. The results can be generated in the form of tables as well, which is shown in later parts of the results.

Simulation isdone in the ground floor and then eventually in the building storeys so as to understand the effect of building height in pressure distribution and the problems associated with it.Logical network incorporating the associated problems are proposedwith minimum influence on the existing system, which best ensures flow continuity by interconnecting the dead ends in the network.

Following observations are made based on the EPANET simulation results obtained for the existing dead end system of the network.

- The ground floor network, Fig.6 shows that there are not much pressure differences and velocity is almost constant throughout.
- With increase in floor height, pressure decreases but the velocity is noticed to bealmost constant.
- The highest velocity in the distribution system is 0.84m/s of the main pipeline near the overhead water tank.
- The lowest velocity is 0.009m/s and pressure of -1.68m at second floor of Class IV staff quarter.
- Other building structures have no negative pressure though pressure decreases by about 3-4m with increase in floor height.

Table 1 shows the pressure values for nodes inside IT building, which although positive, is lower as compared to other buildings, owing to being located at longer distance from the overhead tank.

Table 2 shows the negative pressure generated at the second floor of the class IV staff quarter, as there are more connections along the main pipeline even though the distance from the overhead tank is less than IT building

Table 1: EPANET results for second floor of IT building

| Junction ID | Elevation (m) | Pressure Head (m) |
|---|---|---|
| Junc 536 | 421.88 | 2.8 |
| Junc 537 | 421.88 | 2.8 |
| Junc 538 | 421.88 | 2.8 |
| Junc 539 | 421.88 | 2.8 |
| Junc 540 | 421.88 | 2.8 |

Table 2: Negative pressure generated at second floor of Class IV staff quarter

| Junction ID | Elevation(m) | Pressure head(m) |
|---|---|---|
| Junc 826 | 416.6 | -1.68 |
| Junc 827 | 416.6 | -1.68 |
| Junc 828 | 416.6 | -1.68 |
| Junc 829 | 416.6 | -1.68 |
| Junc 830 | 416.6 | -1.68 |

Figure 5, shows the EPANET results for the dead end system of network in the form of maps generated from EPANET.

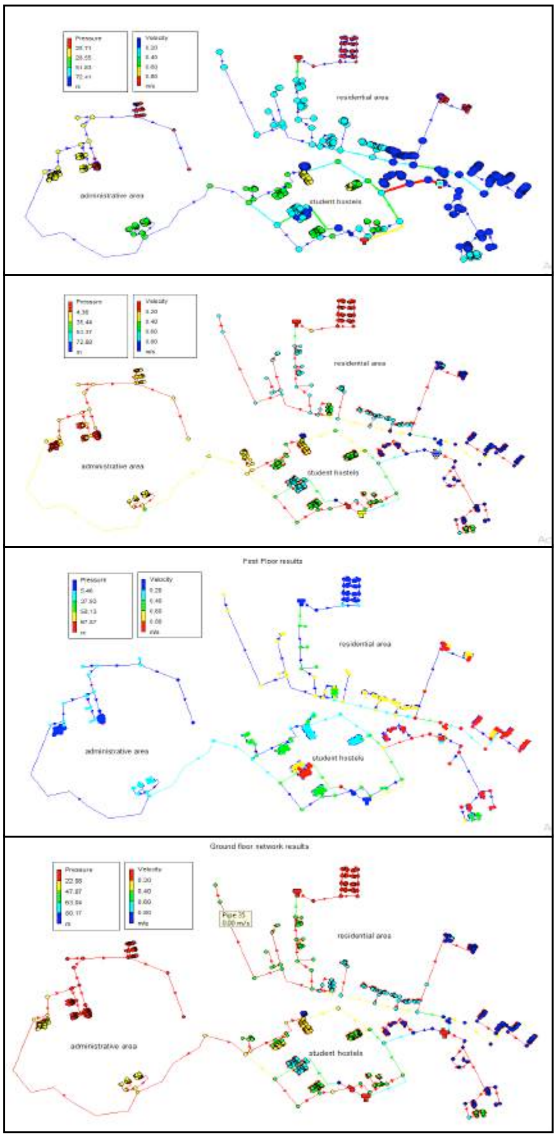

Figure 5: Floor-wise EPANET results

Following graph shows the effect of building height in pressure distribution. Class IV staff quarter has the lowest pressure and those buildings having longer distance from the tank shows reduced pressure. Also the pressure id noticed to drop as we go higher up the building storey.

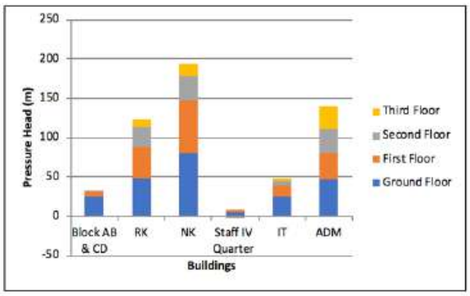


Figure 6: A graph showing the relation betweenpressures and building height

## 7. REMODELING THE EXISTING NETWORK FOR FLOW CONTINUITY

The main aspect of designing is about achieving success through multiple tries to obtain an accurate or maybe a network having minimum imperfections.

For the redesign of the network without much disruption in the existing network, following methods are adopted and the design with best result is chosen:

- Increase some of the diameter of the pipelines especially for the main pipelines.
- An alternative method of increasing pressures can be achieved by use of pumps.
- Changing the positions of unnecessary nodes to reduce the length of overall network.
- Connect the dead ends for continuous water flow.

### 7.1 Analysis of the modified water network

- Using the trial and error method, trying out 4 modified water network, lastly but not the least, the fourth trial, Fig.6, taking into account of previous trials, all the dead ends are connected with a very optimistic results unlike the trials, which has positive pressures throughout the network and good velocity
- The new design is a typical ring system of network, since it is the most reliable and feasible method for the study area. Through this proposed network, continuous water supply 24x7 will be achieved, with the new source of water tank being constructed in the area.

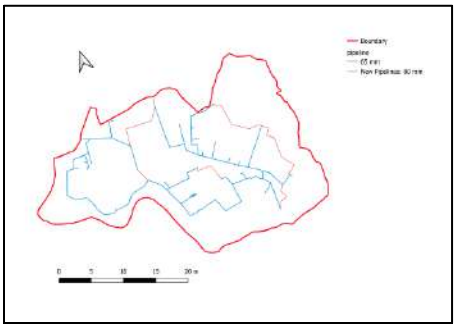

Figure 7: modified network interconnecting dead ends.

## 8. COMPARATIVE RESULTS

### a) Pressure

Unlike the existing water network system where the tapings along the NK line is single and has excess water, which can directly be conveyed to class IV staff Quarter maintaining enough pressure as per the standard that has improved the pressure in the class IV staff quarter after the connection of the network with new supply pipeline from hostel NK**.**

Also in the new water supply network, the increasing diameter of mainlines from 65mm to 80 mm also ensured the pressure improvement in the buildings, but for those buildings where the new pipelines are connected, pressure is found to drop by about 6m, but it still falls in the required standard.

Presently, water supplied directly from the overhead tank is not consumed directly unless boiled or further purified, and hence it has disadvantages and is not recommended while the new water supply network maintains constant pressure and velocity, which prevents the water from contamination.

**b) Velocity**

Velocity and flow in the buildings are also improved, owing to the increment of the pipe diameter in the mains, and also because of the continuity of the flow maintained. The velocity in the IT building pipe, which after the dead ends are connected with other pipes of the other buildings and also with the increment of the pipe diameter shows that the velocity has increased.

## 9. DISCUSSION

Further the nodes, from the main tank, lesser are the pressure. Also when there is more number of branches from the main pipeline, the pressure and other flow parameters get reduced. For building structures such as LT 2 and 3, Class IV staff quarter, and NK have lower pressure of 22.98m with velocity ranging from 0-0.03 m/s, as these buildings are far away from the overhead tank.

The cause of pressure drop is also noticed to happen due to reduction of pipe diameters, which gets reduced from 65mm mains to 40mm and below in service lines inside the buildings and also because of lots of connections inside the building for which the pressure gets distributed. The negative sign in the flow values are shown in some of the pipes indicating the reverse direction of flow with respect to the ID numbering of the nodes.

## 10. CONCLUSION

So this study analysis has shown that though the water supply system is designed to be continuous but with increase in population and urbanization, the designed water supply system is not enough to meet the water demand. Also if the entire water supply system were designed from the scratch then it would not only waste the economy but also cause many water shortage problems to the residents at that place. Keeping these things in account, a careful analysis of the place can be done and a logical network can be designed with less disruption to the existing water supply network. So this study analysis has shown that the pressure is affected by building height, topography and the distance of buildings from the tank. It has also shown that the flow parameters are greatly affected inside the buildings due to numerous branches inside the buildings. The study has also proved that alternative connections can be proposed to improve flow and pressure at the critical locations, which also maintains flow continuity.

## 11. RECOMMENDATIONS

- Studying alternate water source and trying to include in the network can further improve this study.
- Modelling the water network using other advanced software to compare with the results of the EPANET software.
- Trying to expand the water network system analysis beyond the campus boundary.
- Explore other places having similar water shortage problem.

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## REFERENCES

Anisha, G., Kumar, A., Kumar, J., & Raju, P. (2016).

Analysis and Design of Water Distribution Network Using EPANET for Chirala Municipality in Prakasam District of Andhra Pradesh. *International Journal of Engineering and Applied Sciences*, *3*(4), 257682.

Awe, O. M., Okolie, S. T. A., & Fayomi, O. S. I. (2019). Optimization of Water Distribution Systems: A Review. *Journal of Physics: Conference Series*, *1378*(2). https://doi.org/10.1088/1742-6596/1378/2/022068

Ayanshola, A. M., & Jimoh, M. (2017). *Design Analysis of Water Distribution Pipe Network of Royal Valley Housing Estate in Ilorin Using Arc-Gis and Epanet*. *July 2018*.

Community water supply systems. (1951). *American Journal of Public Health*, *41*(5 :2), 117–121.

Dahasahasra, V. (2007). A model for transforming an intermittent into a 24x7. *Geospatial Today*, *August*, 34–39.

Dhumal, J. R., Danale, M. S., & Jadhav, G. H. (2018). Design of continuous water supply system by using WaterGEMS. *8Th National Conference on Emerging Trends in Engineering and Technology*, 147–152.

Dighade, R. R., Kadu, M. S., & Pande, A. M. (2014). Challenges in Water Loss Management of Water Distribution Systems in Developing Countries. *International Journal of Innovative Research in Science, Engineering and Technology*, *3*(6), 13838–13846. www.ijirset.com

Ercumen, A., Arnold, B. F., Kumpel, E., Burt, Z., Ray, I., Nelson, K., & Colford, J. M. (2015). Upgrading a Piped Water Supply from Intermittent to Continuous Delivery and Association with Waterborne Illness: A Matched Cohort Study in Urban India. *PLoS Medicine*, *12*(10). https://doi.org/10.1371/journal.pmed.1001892

Garg, S. K. (2010). *Water Supply Engineering.* Delhi: Khanna Publishers.

Gómez, E., Cabrera, E., Balaguer, M., & Soriano, J. (2015). Direct and indirect water supply: An energy assessment. *Procedia Engineering*, *119*(1), 1088–1097. https://doi.org/10.1016/j.proeng.2015.08.94

Lhamo, C., Choden, D., Rabten, S., & Choden, K. (2012). *INTEGRATED MODELING OF WATER DISTRIBUTION SYSTEM OF*. *May 2013*.

Lungariya, P., Katharotiya, N., Mehta, D., & Waikhom, S. (2016). Analysis of Continuous Water Distribution in Surat City using EPANET : A Case Study. *Recent Advances in Civil Engineering for Global Sustainability*, *March*, 1–7.

Mane, D. B., Dhumal, J. R., Shetage, A. A., & Bamanikar, A. K. (2018). Study on implemented 24×7 water supply schemes. *International Journal for Research in Applied Science and Engineering Technology*, *6*(2), 1074–1076. http://www.ijraset.com/fileserve.php?FID=13324%0Ahttps://www.cabdirect.org/cabdirect/abstract/20183391465

Patil, G., Hore, S., Jayebhaye, S., & Shelke, V. (2017). Transforming an Intermittent into 24x7 Water Supply System : A Case Study. *International Research Journal of Engineering and Technology(IRJET)*, *4*(5), 148–152. https://www.irjet.net/archives/V4/i5/IRJET-V4I524.pdf

Rajeshwari R, B. M. K. (2014). Evaluation of Intermittent Water Supply System and Design of 24x7 for a residential area in Mysore, Karnataka, India. *International Journal of Informative & Futuristic Research*.

Rao, R., Naik, M. G., & Naresh, A. (2015). Simulation of Continuous Water Supply Distribution System : A Case Study Part of Hyderabad Metropolitan City. *20th International Conference on Hydraulics, Water Resources and River Engineering*, *December*, 17–19.

Rossman, L. A. (2000). EPANET 2 Users Manual EPA/600/R-00/57. *Water Supply and Water Resources Division, U.S. Agency, Environmental*

*Protection*, *September*.

Shinde, P., Patil, P., & Hodage, R. (2018). Design and Analysis of Water Distribution Network Using Water GEMS. *International Research Journal of Engineering and Technology (IRJET)*, *07*(03), 545–552.

*The Design of Water Transport and Distribution Systems*. (2006). 122–205. https://doi.org/10.1201/9780203964699.ch4

Tshering, K., Dorji, K., Wangchuk, P., & DOrji, R. (2012). *Water Distribution Network,June*.

Varu, S., & Shah, D. (2018). Design of 24X7 water supply systems – A Case study: Ahmedabad city. *Drinking Water Engineering and Science Discussions*, *July*, 1–6. https://doi.org/10.5194/dwes-2018-14

*Welcome to the QGIS project!* (2012). Retrieved July 7, 2020, from https://qgis.org/en/site/

Zhao, L., Liu, Z., & Mbachu, J. (2019). An Integrated BIM–GIS Method for Planning of Water Distribution System. *ISPRS International Journal of Geo-Information*, *8*(8), 331. https://doi.org/10.3390/ijgi8080331