REVIEW ARTICLE

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A Critical Review on Design and Analysis of Water Distribution Network Using WaterGEMS and EPANET Softwares

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Abstract

Water is used by all living beings, including man, animals, and plants, from ancient times for different purposes, circulated from the source by different techniques. The water distribution network (WDN) is an expensive and tortuous system that is designed in such a layout to fulfill the demand of the community with an adequate pressure head. WDNs are designed and analyzed manually and with the help of software such as EPA net, WaterCAD, and WaterGEMS. The paper aims to scrutinize the WDNs, and their design and compare theanalysis developed with the help of WaterGEMS and EPANET software

Keywords: Pressure head, Water distribution network(WDN), WaterGEMS.

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Introduction

Even though it contains no calories or organic nutrients, water is essential for all known forms of life (Wikipedia) and has been utilized in historical times from different sources such as wells, springs, lakes, and rivers. However, due to the rapid increase in population and urbanization, the communities settle far away from the source. Therefore, a water distribution system was initiated to satisfy the requirement of water for various communities, and in order to predict the future demand,the water policymakers rely on population forecasts. (Alkali, Yadima, Usman, Ibrahim, & Lawan, 2017).[3]

A water distribution network is built/developed with an aim to supply water to the required area meeting all the demands at a sufficient pressure head. A distribution system usually consists of storage reservoirs, pumps, rising mains, and pipe appertenances. It is divided into different layouts as per the topography of the area as a dead end, grid iron, radial, and ring/circular system. The radial layout is generally preferred as the area is sub-divided into small areas, and water is conveyed in each area by their respective elevated surface reservoir (Punamia, Jain, & Jain, 2013).[15] In general, Low-flow dead ends and loops should be avoided, but practically it is not always possible. Dead-end sections with the low flow should be as short as possible. By creating long residence periods and parts where sediments can accumulate, both dead ends and loops can trigger problems (Sumithra, Nethaji Mariappan, & Amarnath, 2013). Any deposits in the pipe can be disturbed by changes in flow direction in the loop. Water is customarily supplied in two ways- Continuous and Intermittent systems. In the former system, water is supplied to the consumer 24 hours a day. In an intermittent system, water is available only for a few hours, i.e., 2-3 hours. This system is not desirable as a separate reservoir is to be constructed for the storage of supplied water, and also, a large supply mains is to be laid (Punamia, Jain, & Jain, 2013).) The layout should be such that the pressure difference between different zones within the same zone is no more than 3 to 5 meters (Manual On Water Supply and Treatment, 1999)Ductile iron, pre-stressed concrete, polyvinyl chloride (PVC), reinforced plastic and steel are the most widely used pipes for water mains today. In the past, there has been frequent use of cast iron pipes and asbestos cement pipes (Water Distribution System Analysis:Field Studies,Modeling and Management, 2005)

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Generally, WDNs are designed considering the continuous supply system, but in actual practice, water is supplied intermittently (Rathore, Garg, & Dr.Shrivastava, 2019).

The distribution system is a pipeline network made up of one source node and multiple demand nodes (Salunke, Dumane, Kamble, Nalvade, Pondkule, & Binayke, 2018) establishing the best geometrical configuration for delivering known demands from the source to the consumers over a long period complying to all standards (Rathore, Garg, & Dr.Shrivastava, 2019). One of the other aspects of WDN is to protect the water from the contaminants which may affect the quality of the water supplied to the consumers,introducing taste, odor, or water-borne pathogens to the water. (Ratnayake & Jayatilake, 1999)

This paper illustrates various research works, including the complexities that occurred while designing or rehabilitating the network area, the methodology used, and the application of the WaterGEMS and EPANET software.

WATERGEMS OVERVIEW

WaterGEMS is a software program for designing and analyzing water supply networks. The software is also used to expand anexisting water supply network. The software provides a common and cost-effective interface for designing, analyzing, and troubleshooting new and existing supply networks with precision and speed. WaterGEMS software provides the best solution for any network (Mehta, Yadav, Waikhom, & Prajapati, 2017)

Engineers and consultants may use Water GEMS to model on various interoperable platforms such as ArcGIS for GIS integration, thematic mapping, and publishing, Micro-Station for bridging geospatial planning and engineering design environments, and AutoCAD for CAD layout and drafting. (Mehta, Yadav, Waikhom, & Prajapati, 2017)

The Gradient approach is used in the WaterGEMS software algorithm. The program builds the network, then moves existing data onto it using Model Builder, then applies elevation data with Trex, calculates demand using Load Builder, and finally simulates the network to provide the best possible water supply network architecture. (Sajedkhan & Dr Kahalekar, 2015) Engineers may use the Load Builder and TRex modules in Water GEMS which help toinput water demands and node elevations using geospatial data from shape files, geodata bases, different forms of DEMs, and even CAD drawings. These modules assist engineers in avoiding manual input errors (Mehta, Yadav, Waikhom, & Prajapati, 2017).

Modelers may use the WATERGEMS SCADA Connect module to obtain supervisory control and data acquisition (SCADA) data automatically, resulting in a real-time system simulator that accurately reflects current system conditions. It also allows WATERGEMS model results to be shown on a utility's current SCADA control room screen(s), allowing for better forecasting of operating conditions and possible problems. Based on available budget, construction expense, and pressure and velocity constraints, Darwin Designer automatically considers maximum gain or minimum-cost designs and rehabilitation strategies. (Mehta, Yadav, Waikhom, & Prajapati, 2017)

EPANET OVERVIEW

EPANET software was developed by the USA Environmental Protection Agency. Experts and researchers have used the simulation capabilities of EPANET in the design, management and improvement of various water systems. (Adeniran & Oyelowo, 2013) During the simulation period of multiple phases, EPANET controls the water flow in each tank, the water pressure on each node, the height of a tank, and the concentration of chemical species in the network (Kumar, et al., 2015). It is mainly used as a research tool but can also be used to restore existing or to develop new WDNs. (Awe, Okolie, & Fayomi, 2019)Some of the basic advantages of this software are that it considers minor losses from bends, fittings,etc, and the flow rates are obtained by linear method (Dr. Ramana, Sudheer, & Rajasekhar, 2015). In EPANET, the head can be calculated by Hazen-Williams formula, Darcy-Weisbach formula or by Chezy-Manning formula. (Ahmadullah & Dongshik, 2016). It assumes that the water is flowing in the pipe in full condition from the higher hydraulic head to the lower hydraulic head (Sathyanathan, Hasan, & Deeptha, 2016)The software also models chlorine concentration through first-order kinetic law. (Mensah, Mayabi, & Cheruiyot, 2019)

HISTORY OF HYDRAULIC MODELING

In earlier days, the water flow and pressure in the WDNs was calculated using Hardy-Cross method, which is an iterative method for determining flow in the pipelines where the inputs and output are known, but the flow inside the pipe is unknown. Before this method,distribution of complex pipe system was very challenging because of the nonlinear relationship between head loss and flow. (Adeniran & Oyelowo, 2013)

Soon,with the development of different softwares such as FORTRAN,BASIC,COBOL, C+ + etc, the manual iterations can be performed very easily. (Adeniran & Oyelowo, 2013). Later,with the introduction of the Newton-Raphson method, manual iterations became outdated. (Dr. Ramana, Sudheer, & Rajasekhar, 2015).

EPANET was initially developed in 1993 as a distribution system hydraulic-water quality model.It can be used in either the SI (metric) or British measurement systems. In 2000, EPANET 2 was developed which had a more user-friendly Graphical User Interface (GUI) and programmer's toolkit (Iglesias-Ray, Martinez-Solano, & Ribelles-Aquilar, 2016).

THEORY OF HYDRAULIC MODELING

The concept of hydraulic analysis is based on two fundamental laws;$\sum Q=0$ at junctions and $\sum H=0$ around a loop or circuit,where Q is discharge and H is head loss (Manual On Water Supply and Treatment, 1999).Initially, hydraulic models simulated flow and pressures in a distribution system under steady-state conditions where all demands and operations remained constant. EPS models were created to simulate distribution system activity under time-varying demand and operational conditions, since system demands differ throughout the day (Water Distribution System Analysis:Field Studies,Modeling and Management, 2005).Fluid flow is calculated on three basic principles:-

- Conservation of Mass.
- Conservation of Energy.
- Pipe Friction Head loss.

(Water Distribution System Analysis:Field Studies,Modeling and Management, 2005)

LITERATURE REVIEW

(Sumithra, Nethaji Mariappan, & Amarnath, 2013)The author had designed the water distribution area for the Tirunelvelicorporation and compared the analysis using LOOP and WaterGEMS software.In the study, it was found that the existing network was very old, and the components like CI pipe and AC mains were incrusted,resulting in leakages also there was no scope of expanding the area. Remodeling of WDN was adopted considering factors such as geographical conditions, population forecast for each zone, pressure, frictional losses, pipe sizes, etc. The existing WDN did not cover the entire town, and the mains were deteriorated, resulting in a variation of distribution from 251 lpcd to 130 lpcd. The designed area was analyzed by WaterGEMS and LOOP software, and the conclusions drawn were that the LOOP software did not consider frictional losses for the bends in the pipe and took all the pipes as straight, whereas the WaterGEMS software considered all the bends and the pressure reduced by 2 cm. The LOOP software is limited to only 1000 pipes entries and data was to be added manually, resulting in time consumption.The waterGEMS software has a graphical interface, is user-friendly and modification can be done easily.Hence, it is more convenient and requires lesser time in computationthan the LOOP software.

(Sajedkhan & Dr Kahalekar, 2015). WaterGEMS software was used to evaluate the water quality (chlorine) of a sector of Aurangabad city in this paper.The proposed methodology is studied.The network was designed considering optimization in addition to the cost minimization, minimum head requirement, and minimum residual chlorine requirement. The study area's source was an ESR having an average ground level of 595.43 meters, a staging height of 15 meters, and a fixed capacity. For the supply system and to feed the ESR, various pipe materials such as RCC, CI, and Asbestos cement were laid in the city. Based on head-dependent analysis, the programmeprovided different alternate optimal design solutions for pipe diameters, pipe material, and roughness coefficient.In water quality analysis,it measured the chlorine concentration at all nodes in a water supply network in relation to a given initial concentration and assists in determining what better initial chlorine concentration values could be set in the network.

(Motevalizadeh & Irandoust, 2016).Kerman City's Badamuiyeh water supply complex was chosen for a study on adjusting pressure to control water leaks using waterGEMS software, and the hydraulic analysis was carried out using Demand based method (DDSM) in which the demand is kept constant. The pressure-reducing valves (PRV) were installed at critical points and timed to provide standard pressure in all network nodes, after which the effect of smart pressure control on the water supply system was evaluated.The results revealed that smart pressure control through a PRV was an effective method for water management and leakage reduction. With an average pressure cutting of 45.15 percent, leakage was reduced to 25.67 percent

(Mehta, Yadav, Waikhom, & Prajapati, 2017). This study outlines consumer water shortage issues, specifically leakage in the delivery system, with a description of its causes the possibility of effectively using geographic information systems to assist in the management of this problem.The study area was Punagam,near Surat city, and its WDN was evaluated using waterGEMS V8i software and was compared with the data from Surat Municipal Corporation.It was concluded that the resulting pressures at all junctions, as well as the flows and velocities in all pipes, are sufficient to supply water to the Punagam area. The simulated model appeared to be relatively similar to the real network, based on these comparisons. The software can handle a number of pipe network problems without needing any modifications to the model or mathematical formulation.

(Shinde, Dr More, Rout, & Gadhe, 2017).A study was conducted in Yavatmal city to propose the steps for improving the distribution system, which can easily satisfy the water demand and contribute to the city's growth in the near future.The analysis was carried out using waterGEMS software, considering the continuous supply system.The existing water supply scheme was unable to fulfill the demand of the community.The city was divided into three areas, each with an ESR capacity of ten lakh liters, from which water can be distributed twice daily, pipe size of 400mm was suggested to bear the future demand if a continuous supply system is adopted.PVC pipes were suggested for cost optimization.

(Switnicka, Suchorab, & Kowalska, 2017).In this paper,The Darwin Scheduler module was used to automatically optimize the WDSin order to reduce pumping energy costs,resulting in a reduction of 1.4 percent in daily pump energy consumption. Five new PRVs were designed to remove areas of the higher-pressure head,as a result, the value lowered to 60 m from 69.70.Bentley's WaterGEMS software, which included genetic algorithm modules, proved to be a very useful and universal method for assisting in the maintenance planning decision-making process.

In the study area of RashimBagh, Nagpur,the leakage detection was carried out using EPANET model and it was found in the water auditthat leakages were 40 percent.It was concluded that EPANET software cannot model the software as stand-alone,but the a scenario having leakages upto 10% could be successfully run in the software. (Gajbhiye, Reddy, & Sargaonkar, 2017)

(Shinde, Patil, & Hodage, 2018). This paper examines the hydraulic analysis of Shivaji Nagar in Panvel city using waterGEMS software and Google earth to find out the layout of the area.The distribution network area was about 9.576 km^2 with an ESR capacity of 15 lakh litres.Three zones were developed on the network, zone 1 having 42 junctions, zone two 28 junctions, and zone three 80 junctions. The software was run on the steady-state analysis mode.It was concluded that the waterGEMS software gave the necessary standard design and cost-effective environment for the design of WDN in minimum duration.

(Rathore, Garg, & Dr.Shrivastava, 2019). The authors studied the Veena Nagar area of Indore and suggested the necessary rehabilitation required in the old water distribution network.The existing overhead storage reservoir had a capacity of 30 lakh litres with 20 m staging serving a command area of 1.91 km^2. The water demand was projected as 396 MLD in 2024 and 574 MLD in 2039,HDPE pipes were used for diameter upto 315 mm and DI pipes for diameter above 350 mm.With the help of "Water GEMS," a computerised network study of the area was carried out, taking into account the existing distribution pipe in the area under construction.The area was redesigned for a period of 30 years (2009-2039).The study revealed that the distribution mains were of smaller diameter asnetwork was designed for continuous supply system but the water is supplied intermittently due to which the areas near the OHSR were receiving water at sufficient pressure head in comparison to the areas away from the OHSR,the area was divided into 11 district metered area (DMAs) and new pipelines were proposed where the residual pressure was less than 14 meters.It was also suggested that IMC could provide domestic meters to all households to mitigate leakage by up to 15%.

(Rai & Dohare, 2019) In this study, the water distribution network of area 88.622 km^2 was designed for the Mangalnath area in Ujjain city for the year 2028 using waterGEMSsoftware. The model was run on extended period simulation.The ESR used in Simhastha 2016 was found to be inadequate to meet the area's requirement in 2028. As a result, new OHT were proposed, taking into account the demand in 2028.It was inferred that Watergems software was ideal for designing and analysing vast water supply networks because it is simple to use and effective.

(Berhane & Aregaw, 2020).The authors optimized the design of WDS in Wukrotown Ethiopia using waterGEMS software Darwin designer and Darwin scheduler were applied for finding optimal pipe diameter and operation of pumping systems respectively. On comparing the data with traditional hydraulic analysis,the optimized network reduced the cost by 9.6 percent, also there was a reduction in daily cost of energy consumption by 12.5 percent.

SUMMARY

From the above study and review of the research work, it can be summarized that the demand of water is not constant and will always rise due to rapid increase in population and urbanization.In most of the areas, the distribution system is designed on the basis of continuous supply,but in actual, intermittent supply is adopted due to aging of pipes, change in the layout and leakages (Rathore, Garg, & Dr.Shrivastava, 2019). With the help of application, the low pressure zones can be identified and any improvement can be suggested. The WDNs can be modeled hydraulically with various softwares such as EPAnet, waterCAD,LOOP and waterGEMS. ButwaterGEMS had the best graphical interface and was easy to use and less time consuming in comparison to the others (Sumithra, Nethaji Mariappan, & Amarnath, 2013). WaterGEMS and EPANET work on two models, namely, steady state analysis and extended period simulation.

CONCLUSION

It can be concluded thatWaterGEMS software has the advantage of being able to proficiently model a network before it is designed or updated because network problems can be easily detected and eliminated in simulation, expensive errors can be avoided (Sajedkhan & Dr Kahalekar, 2015).It can run on various platforms such as- ArcGIS,AutoCAD,total station or as a single application (Sajedkhan & Dr Kahalekar, 2015). The application can solve a variety of pipe network problems without requiring any model or mathematical formulation changes.EPANET shows the results in various formats such as color-coded network maps,data tables,time series graphs, and contour plots (Ibrahim, 2015)

Bibliography

[1] (n.d.). Retrieved from Wikipedia: http://en.wikipedia.org/wiki/Water Adeniran, M. A., & Oyelowo, M. A. (2013). An EPANET Analysis of Water Distribution Network of the University of Lagos,Nigeria. Journal of Engineering Research, 18 (2), 69-83.

[2] Ahmadullah, R., & Dongshik, K. (2016). Designing of Hydraulically Balanced Water Distribution Network Based on GIS and EPANET. International Journal of Advance Computer Science and Applications, 7 (2), 118-125.

[3] Alkali, A. N., Yadima, S. G., Usman, B., Ibrahim, U. A., & Lawan, A. G. (2017). Design of Water Supply Distribution Network isong EPANET 2.0:A Case Study of Maiduguri zone 3, Nigeria. Arid Zone Journal of Engineering,Technology and Environment, 13 (3), 347-355.

[4] Awe, O. M., Okolie, S. T., & Fayomi, O. S. (2019). Review of Water Distribution System Modelling and Performance of Analysis Softwares. 1378, pp. 1-8. Ota,Nigeria: Institute of Physics Publishing.

[5] Berhane, T. G., & Aregaw, T. T. (2020). Optimization of Water Distribution System using WaterGEMS: The Case Study of Wukro Town,Ethiopia. International Institute for Science,Technology and Education, 12 (6), 1-14.

[6] Dr. Ramana, G. V., Sudheer, C. V., & Rajasekhar, B. (2015). Network Analysis of Water Distribution System in Rural Areas using

EPANET. Computer Control for Water Industry Conference (pp. 496-505). Leicester,United Kingdom: Elsevier Ltd.
[7] Gajbhiye, A., Reddy, P. H., & Sargaonkar, A. P. (2017). Modeling Leakage in Water Distribution System Using EPANET. Journal of Civil Engineering and Environmental Technology, 4 (3), 211-214.
[8] Ibrahim, T. A. (2015). Design of Kano Metropolitian Water Distribution System using EPANET software. International Journal for Research and Development in Technology, 4 (6), 63-72.
[9] Iglesias-Ray, P. L., Martinez-Solano, F. J., & Ribelles-Aquilar, J. V. (2016). Extending EPANET Capabilities With Add-In Tools. International Conference on Water Distribution Systems Analysis (pp. 626-634). Cartagena,Columbia: Elsevier Ltd.
[10] Kumar, A., Kumar, K., Bharanidharan, B., Matial, N., Dey, E., Singh, M., et al. (2015). Design of Water Distribution System using EPANET. International Journal of Advance Research, 3 (9), 789-812.
[11] (1999). Manual On Water Supply and Treatment. Central Public Health And Environmental Engineering Organisation, New Delhi.
[12] Mehta, D. J., Yadav, V., Waikhom, S. I., & Prajapati, K. (2017, August). Design of Optimal Water Distribution Systems using WaterGEMS:A Case Study of Surat City. International Association for Hydro-environment Engineering and Research , 1-7.
[13] Mensah, A. K., Mayabi, A. O., & Cheruiyot, C. (2019). Optimization of a Water Distribution System in Kenya. International Journal of Engineering and Advanced Technology, 9 (1), 1334-1337.
[14] Motevalizadeh, M., & Irandoust, M. (2016). Hydraulic Analysis of Water Supply Networks and Controlling the leak using WATERGEMS model. International Journal of Advanced Biotechnology and Research, 7 (2), 1453-1458.
[15] Punamia, B. C., Jain, A. K., & Jain, A. K. (2013). Water Supply Engineering. Delhi: Laxmi Publications (P) Limited.
[16] Rai, R., & Dohare, D. (2019). A Review on Application of WaterGEMS in Hydraulic Modeling and Designing of Water Distribution Network for Simhastha Mela Area in Ujjain. Global Journal of Engineering Science and Researches, 6 (5), 400-405.
[17] Rathore, R., Garg, S., & Dr.Shrivastava, R. K. (2019). Rehabilitation of Water Distribution Network of Veena Nagar Overhead Tank Indore- A Case Study. Indian Water Works Association , 60-65.
[18] Ratnayake, N., & Jayatilake, I. N. (1999). Study of Transport of Contaminant in a Pipe Network using the Model EPANET. Water Science and Technology, 40 (2), 115-120.
[19] Sajedkhan, S. P., & Dr Kahalekar, U. J. (2015). Design of Optimal Water Supply Network and its Water Quality Analysis by using WaterGEms. International Journal of Science and Research , 313-317.
[20] Salunke, P. S., Dumane, M. M., Kamble, S. P., Nalvade, O. S., Pondkule, S. P., & Binayke, R. A. (2018). An Overview:Water Distribution Network by Using WaterGEMS Software. Journal of Advances and Scholarly Researches in Allied Education, 15 (2), 28-31.
[21] Sathyanathan, R., Hasan, M., & Deeptha, V. T. (2016). Water Distribution Network Design for SRM University using EPANET. Asian Journal of Applied Sciences, 4 (3), 669-679.
[22] Shinde, P. B., Dr More, A. B., Rout, A. k., & Gadhe, M. R. (2017). Feasibility Analysis of Water Distribution System for Yavatmal City using WaterGEMS Software. International Journal of Innovation Research in Science,Engineering and Technology, 6 (7), 13706-12713.
[23] Shinde, P. K., Patil, P., & Hodage, R. (2018). Design and Analysis of Water Dstribution Network using WaterGEMS. International Journal of Advance Research in Science and Engineering, 7 (3), 545-552.
[24] Sumithra, R. P., Nethaji Mariappan, V. E., & Amarnath, J. (2013). Feasibility Analysis and Design of Water Distribution System for Tirunelveli Corporation using LOOP and Water GEMS Software. International Journal on Applied Bioengineering, 7, 61-70.
[25] Switnicka, K., Suchorab, P., & Kowalska, B. (2017). The Optimization of a Water Distribution System using Bentley WaterGEMS Software. ITM Web of Confeences.15, pp. 1-4. Lublin: EDP Sciences.
[26] (2005). Water Distribution System Analysis:Field Studies,Modeling and Management. US Environmental Protection Agency. Cincinnati: Office of Research and Development.