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A DEMAND-DRIVEN WATER MANAGEMENT FRAMEWORK FOR RAJSHAHI CITY CORPORATION IN BANGLADESH

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ABSTRACT

Globally, the major concern of a water supply system is to provide sufficient quantity of water with acceptable quality to ensure the safe health and well-being of the consumers. However, the continued growth of population and increasing urbanization coupled with the reduction in freshwater supplies makes the demand management quite challenging. Furthermore, the increasing cost of water supply and management infrastructures and the potential impact of climate change on water resources impose additional burdens over the water supply authority all over the world. In Bangladesh, groundwater is a major source of potable water supply as it is available abundantly in the shallow depth and surface water sources are highly polluted. About 80% of drinking water supply comes from the groundwater source. However, increasing population and uncontrolled urbanization combined with natural arsenic pollution causes increasing demand for freshwater which causes serious impact on this finite water resource of the country.

Rajshahi City Corporation (RCC) of Bangladesh is currently facing the shortages in freshwater supplies, which is being caused by the fluctuations of pressure in the water distribution networks. In 2018, the freshwater demand for RCC is estimated to be 118 million liters per day (MLD) and only 72 MLD is supplied by the Rajshahi Water Supply and Sewerage Authority (RWASA) authority. Water shortage is estimated to be about 46 MLD, which is expected to be about 67 MLD in 2031. Therefore, an optimal water management framework is indispensable for RCC of Bangladesh. Hence, an attempt is made in this study to develop an optimal water management framework for Rajshahi City Corporation of Bangladesh by considering existing water demand, supply and consumption patterns. The performance of the water supply network of RCC is analyzed in the ArcGIS platform. Based on the analysis, necessary improvements and/or modifications of the existing water supply network as well as the mode of operation for quantity and quality improvement are identified. It is found that there is a large variation in pressure head and the pressure supplied in the supply network and thus it is not adequate to satisfy the water demand of RCC at the consumer level. The results also indicate that a number of pipe sections and nodal points have been identified where modifications and/or improvements are required for optimum operation of the water supply network in the Rajshahi City Corporation of Bangladesh.

Keywords: *Demand, Supply, Water management, ArcGIS, Water quality, Rajshahi City Corporation.*

1. INTRODUCTION

Development activity in a country is currently associated with its water consumption. Globally, the demand for freshwater is continuously increasing with the growing population and uncontrolled development activities. The situation is more complex particularly in the urban part of a country (Garcia et al., 2008). However, the increasing trend in water consumption in Bangladesh during the last decades has been counteracted by a decrease in available water resources due to the impact of climate change, mainly in summer and uncontrolled human interventions. Urban population is growing rapidly in the country due to the natural urban growth and disaster-induced migration from rural areas (Karim and Mohsin, 2009). The current urban population in Bangladesh is about 38 million and is expected to be reached to about 74 million by 2035 (BBS, 2005). This fact has put an obligation to establish an appropriate management policy that can ensure a stability of both water resources as well as development activities. It is also highlighted in the National Water Polity (NWP) of Bangladesh, which states that all required means and measures should be adopted to manage water resources of the country in a comprehensive, integrated and equitable manner (NWP, 1999).

Establishing sustainable water source is an indispensable component in any urban water supply scheme. In Bangladesh, municipal water supply mainly comes from the surface water and groundwater sources. About 85% of the freshwater comes from the groundwater sources and in some rural areas, increasing demand for irrigation water affects the availability of drinking water (Haque et al., 2012). The reason behind this is that most of the SW sources in Bangladesh is usually polluted with different degrees and thus requires appropriate treatment prior to consumption (Das Gupta et al., 2005). As a result, the associated cost of operation and supply of the water supply systems increases and causes a huge burden on consumers. In recent years, there is a declining trend in the groundwater table due to the uncontrolled abstraction of groundwater, mainly for irrigation purposes in Bangladesh in order to support its huge amount of population (Ahmed et al., 1999). Therefore, the optimal management and supply system is essential for the sustainable development and the existence of the future generation.

Rajshahi City Corporation (RCC) of Bangladesh, located in the north-west region of the country, is currently facing the shortages in freshwater supplies, which is being caused by the fluctuations of pressure in the water distribution networks. In 2018, the freshwater demand for RCC is estimated to be 118 million liters per day (MLD) and only 72 MLD is supplied by the Rajshahi Water Supply and Sewerage Authority (RWASA). Water shortage is estimated to be about 46 MLD, which is expected to be about 67 MLD in 2031. Every year, the groundwater table in RCC is declining by 2 to 3m. This causes the management of water supply and/or demand satisfaction more challenging since domestic or residential water demand from the system is the highest during the dry season (Ahmed et al., 1999). Therefore, an optimal water management framework is indispensable for RCC of Bangladesh. Hence, the objective of the current study is to develop an optimal water management framework for Rajshahi City Corporation of Bangladesh by considering existing water demand, supply and consumption patterns.

2. MATERIALS AND METHODS

2.1 Study Area

Rajshahi City Corporation (RCC) is selected as a case study area to carry out this study, which is situated in between 24°20′ and 24°25′ north latitudes and between 88°32′ and 88°40′ east longitudes. The city is bounded by Paba Upazila on all sides as shown in Figure 1, which consists of 30 wards. Geographically, the city is located within the Barind Tract that lies approximately 23 m above the mean sea level. The city is located on the alluvial plains of the Padma River that runs through southern side of the city. RCC covers an area about 95 sq. km with a total population of about 2.3 million. The city has a hot tropical climate where most of the rainfall occurs in the summer and monsoon seasons. The average annual rainfall of the city varies from 1542.1 mm to 2235.8 mm. The annual temperature in RCC varies from 18.5°C to 29.4°C and June is identified as the hottest month in most cases.

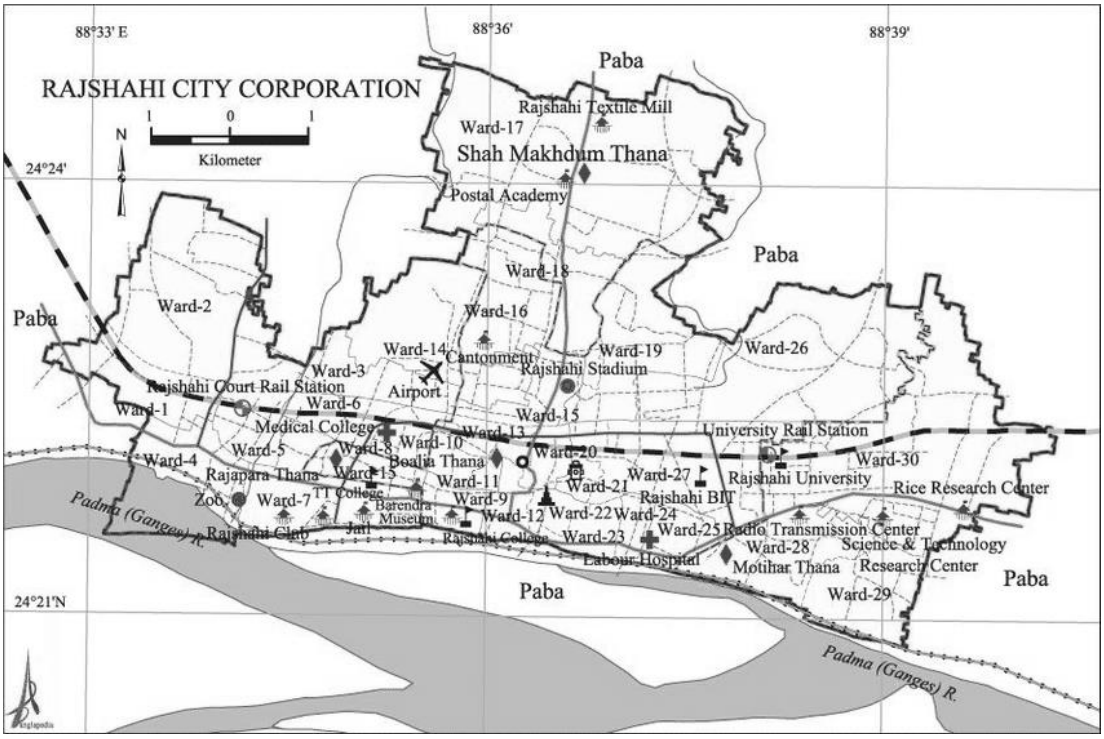

Figure 1: Location of Study Area in the North East Region of Bangladesh

2.2 Methods

The framework of methodology to develop a demand-driven water management framework for RCC of Bangladesh is given in Figure 2. As can be seen from the figure, different secondary data related to water demand and consumption are collected from the various data providing agencies. The agencies include RCC authority, Bangladesh Water Development Board (BWDB), Rajshahi Water Supply and Sewerage Authority (RWASA), Rajshahi Barind Area Authority, Bangladesh Meteorological Department (BMD) and Bangladesh Bureau of Statistics (BBS). Primary data such as water quality of surface water and groundwater are obtained through the lab test results. The water supply network is simulated based on the existing water demand and available pressure in the different nodes of the network. The network is also simulated for the projected population and increased demand for water supply. The simulation is undertaken on the ArcGISv10.5 platform and results are analyzed for decision making.

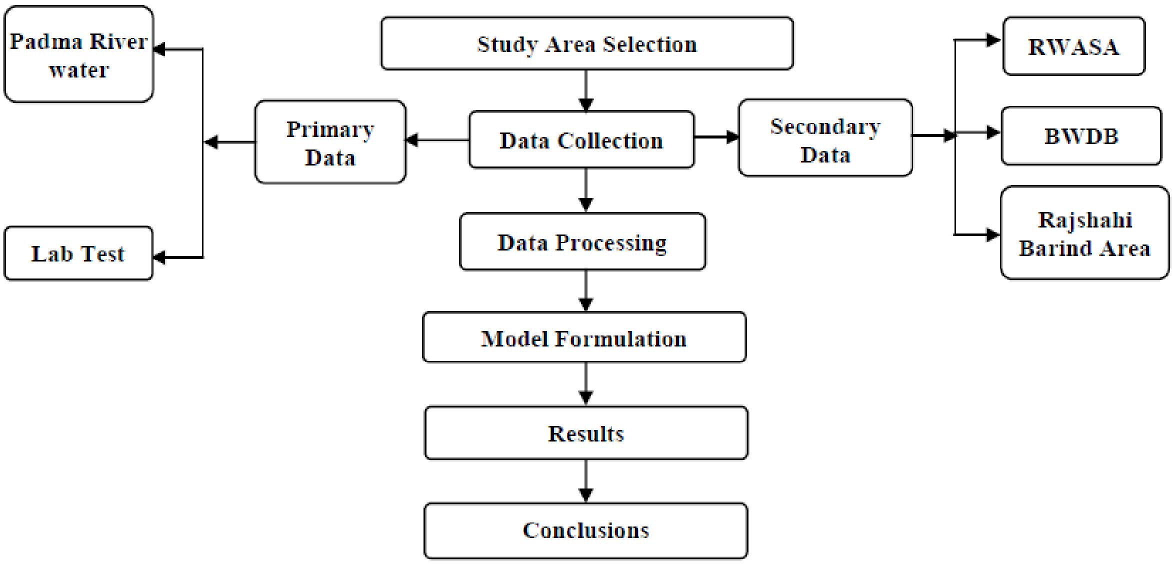

Figure 2: Methodological framework adopted in the current study

3. RESULTS AND DISCUSSION

For analyzing the water supply network system of RCC, hydraulic design of the network is undertaken using the Loop software and then the network is simulated and analyzed on the ArcGIS and MSExcel platform. The network modeling with various pipe network and nodes are shown in Figure 3.

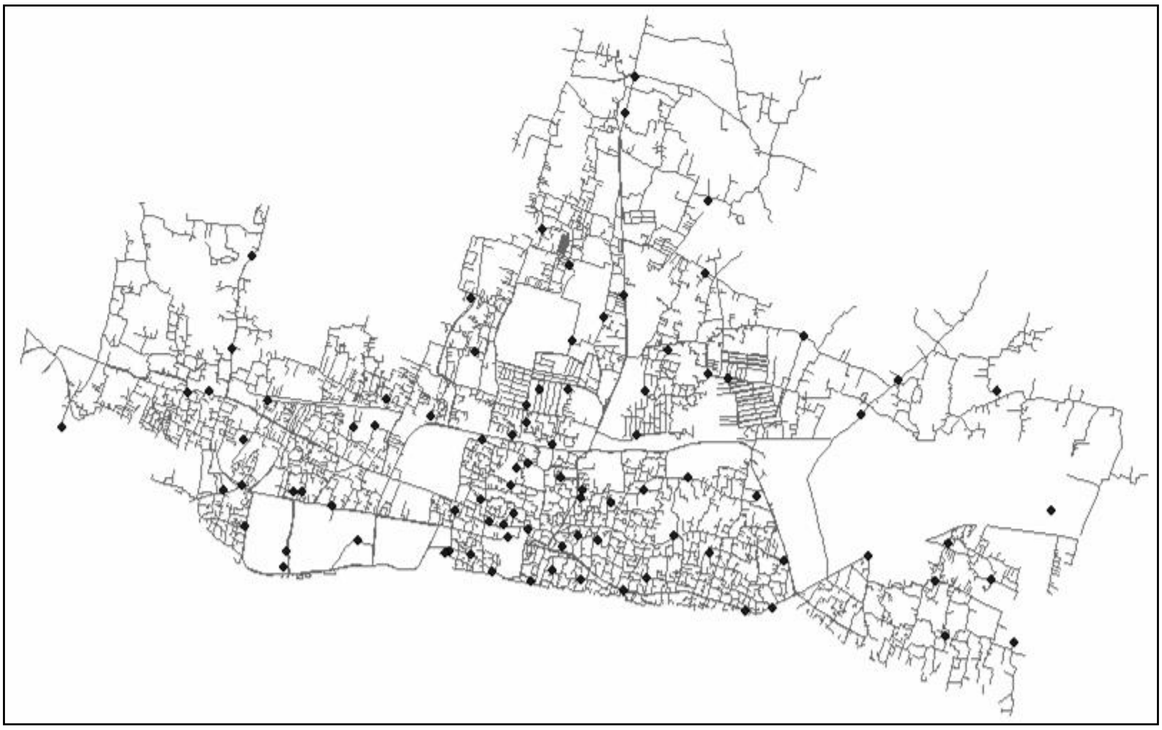

Figure 3: Branched networks of existing water distribution network of RCC

For efficient and equitable distribution of water, a grid pattern is recommended where different mains are interconnected keeping dead ends to a minimum. This system facilitates supplying of water to any one point in the grid at least from two different directions. The water supply network system is designed for future demand in such a way to supply water from the adjacent grid to the later developments where the growth of the city has not been orderly planned, with several pockets just in developing stage and some areas still remaining agricultural and/or unused lands. Theoretical future demand is estimated based on the projection of present population for the feeders where streets are not formed. Hence the supply and distribution pipes can be extended as and when development takes place in future. The system is designed for the projected population for the year 2021 and 2031 and for the per capita water supply at 215 lpcd.

Daily demand is increased day by day due to the increase in population of RCC and decrease in the quantity of groundwater supply. Surface water supply is also limited by the uncertainty in regular supply from the nearby Padma River due to the upstream diversion (Farakka Barrage) located outside the country. Population growth rate is remarkably responsible for the proposition. The projection of population for the design period of 10 years is calculated by the geometric progression method, which can be expressed by Eq. (1) as follows.

$$P_n = P_0(1 + r)^{\ n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

P_n = Projected population in ‘n’ year
P_0 = Present population
r = Growth rate of population
n = Projected year

For population projection, the base year is taken as 2011 and intermediate and final design year are taken as 2018 and 2031, respectively. The projection of the population in RCC obtained by the geometric progression method is presented in Table 1. Increased population directly influences the water supply and demand patterns. In the current study, water demand is estimated for future years by multiplying the current unit demand design values in lpcd by the projected number of future users in the water system. The project water demand in RCC computed in this way is also given in Table 1. It is assumed that new users added to the water supply system will consume water at the same rate as the current users. Taking per capita supply of water as 215 lpcd (185 lpcd + 15% for the unaccounted flow), the water demand for the years 1991, 2001, 2011, 2018, 2021 and 2031 is estimated to be 63.21, 83.64, 96.75, 118.25, 125.35 and 169.48 MLD, respectively. The zoning of the supply coverage is done geometrically with reference to the locations of the head works.

Table 1: Projected population and the corresponding water demand in RCC

Year	1981	1991	2001	2011	2018	2021	2031
Population (Lakh)	2.54	2.94	3.89	4.50	5.50	5.84	7.88
Water demand (MLD)	54.61	63.21	83.64	96.75	118.25	125.35	169.48

The demand and supply at each nodal point (total 88 nodal points) of the water distribution network is shown in Figure 4. As can be seen from the figure, there is a high variation in water supply according to the nodal point values, which also influences the demand and supply for the consumers. There are active 88 nodal points in the distribution network with 30 wards of RCC and population growth rate in each ward is directly responsible for satisfying the demand and supply of the users. To perform hydraulic modeling, the water demand from each defined sub-region is assigned to the corresponding demand nodes in the hydraulic model of the water distribution network. There are 95 nodal points for extracting water and overall 88 points are active for the whole time and thus total nodal points are considered 88 in the analysis. The daily demand for RCC is 118 million liter per day (MLD) and 88 nodal points try to collect the water to meet the demand from the nodal point.

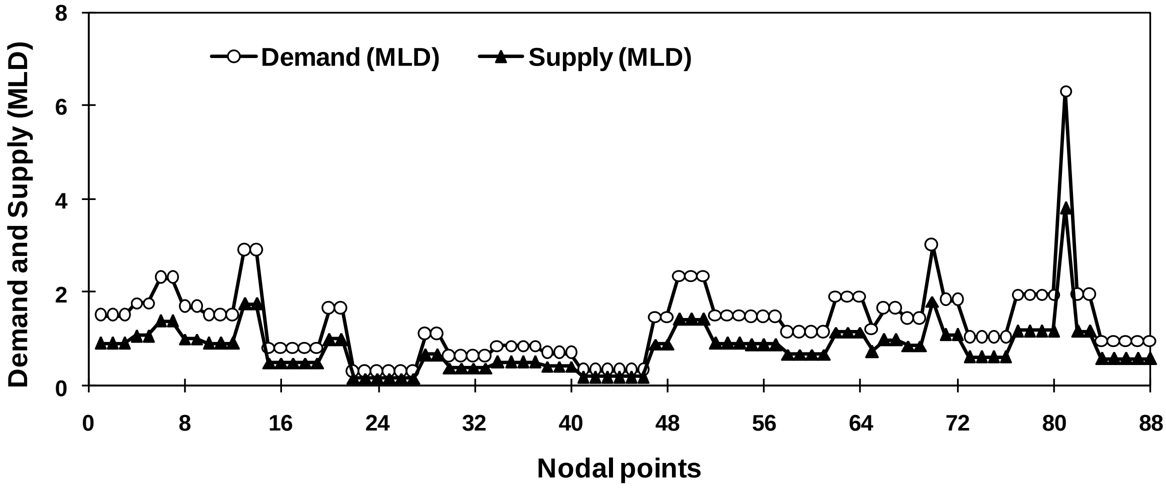

Figure 4: Water demand and supply in each nodal point of total active 88 nodal points of RCC water distribuiton network

The demand and supply curve is shown in Figure 5, which clearly indicates reasonable deficit between demand and supply in 30 wards of RCC area. The daily water demand and supply curves indicate that the existing and future water demand are increasing day by day. The demand curve is always increased upward and supply curve is always lacking. In order to fulfill the increasing demand in such situation, necessary modification in the supply strategy of RCC water supply is required and also alternative sources of water need to be identified and developed. Figure 5 shows that the maximum demand is 7.85 MLD and supply is 4.76 MLD in 27 no. ward of RCC. The population of 27 no. ward is also the maximum among all 30 wards and here the number of pump is bounded by Adorsho School, Tikapara, Baliapukur Upavadra and Seiculture gate pumps.

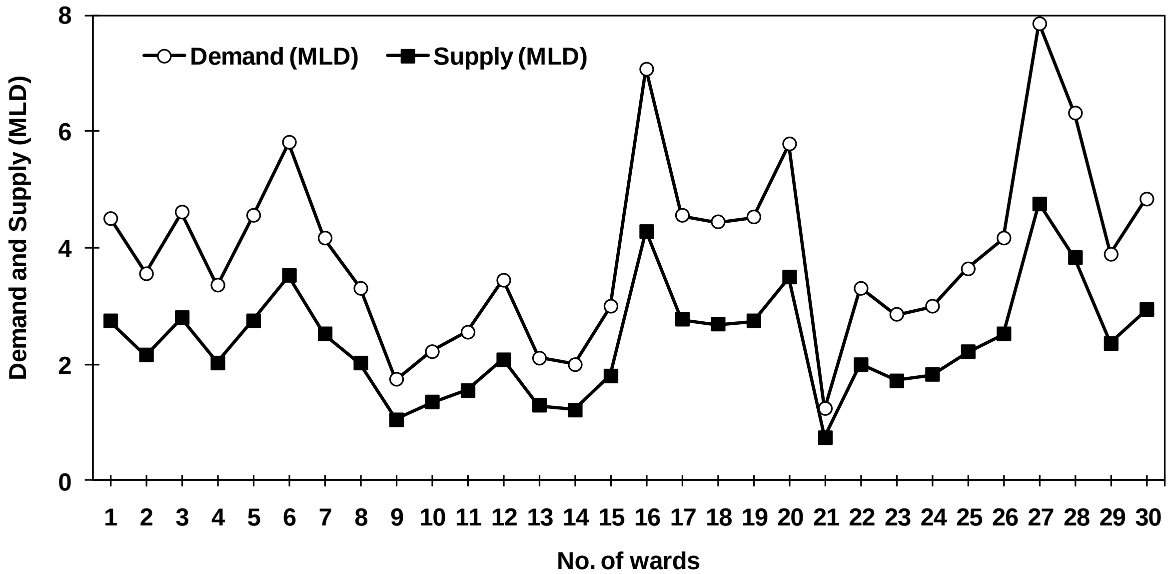

Figure 5: Ward wise demand and supply in RCC area

The water distribution network of RCC area consists of three types of pipelines. They include PVC pipelines of 495.5 km, GI pipelines of 1.5 km, and AC pipelines of 37.5 km, respectively. The fluctuation of head loss and velocity in different nodes of the AC pipelines of RCC area is shown in Figure 6. As can be seen from the figure, the maximum velocity is 2.298 m/s whereas the maximum head loss is 0.84 m, respectively.

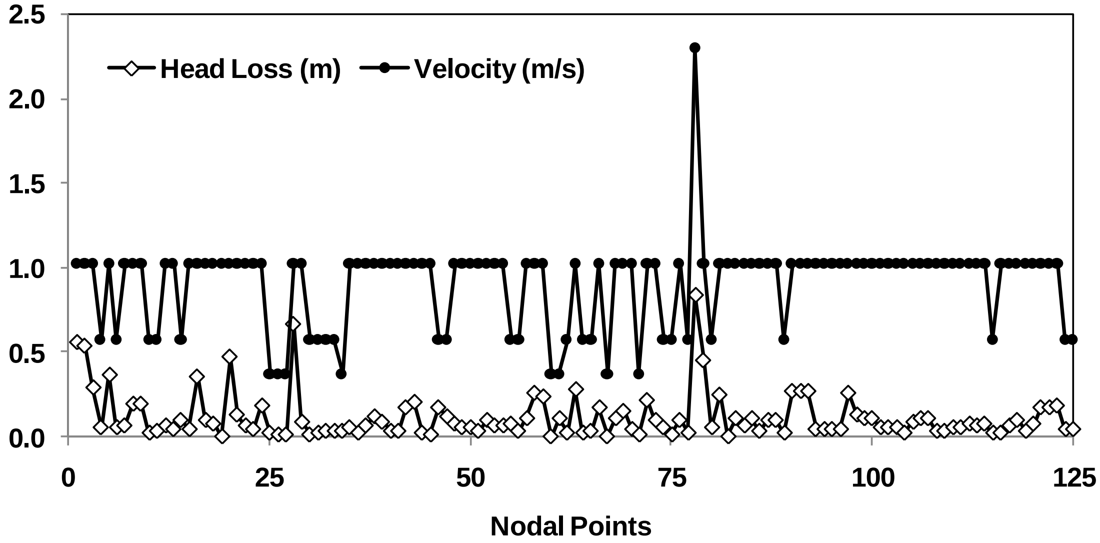

Figure 6: Variations of head loss and velocity distribution for AC pipe in the RCC area

Figure 7 shows the velocity distribution in various points of the water supply network in RCC area. The maximum velocity is found to be 2.4 m/s, which exists only in the PVC pipelines. The maximum velocity in GI pipelines is found to be 1.9 m/s whereas for the AC pipelines, the maximum velocity is obtained as 2.298 m/s, respectively.

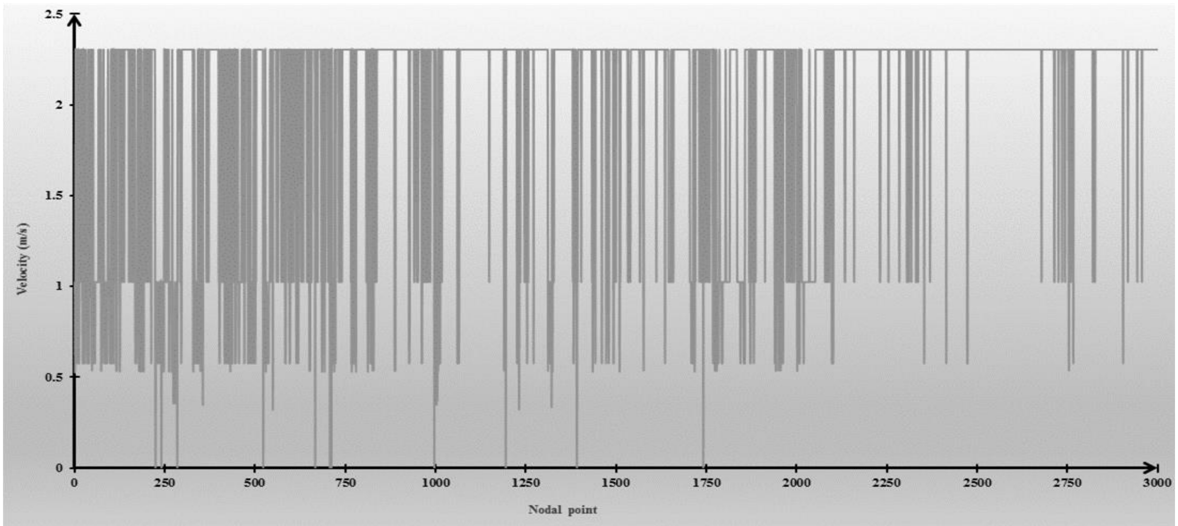

Figure 7: Velocity distribution in pipelines in various sections of RCC water supply network

4. CONCLUSIONS

Rajshahi City Corporation (RCC) of Bangladesh is currently facing the shortages in freshwater supplies, which is being caused by the fluctuations of pressure in the water distribution networks. Therefore, an optimal water management framework is indispensable for RCC of Bangladesh. In the current study, an attempt is made to develop an optimal demand-driven water management framework for RCC by considering existing and projected water demand, supply and consumption patterns. The performance of the water supply network of RCC is analyzed in the ArcGIS platform. Based on the analysis, necessary improvements and/or modifications of the existing water supply network as well as the mode of operation for quantity and quality improvement are identified. It is also identified that there is a great variation in pressure head, velocity and head loss in different nodes of the water distribution network of RCC. Thus, it is not adequate to satisfy the water demand of RCC at the consumer level. The results also indicate that a number of pipe sections and nodal points have been identified where modifications and/or improvements are required for optimal operation of the water supply network in the Rajshahi City Corporation of Bangladesh.

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