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Title: Hydraulic performance Analysis of water supply distribution network using water GEM v8i

Authors: 1) Dessalegn Geleta Ebsa

2) Fekadu Fufa

Affiliation

(1) Dessalegn Geleta Ebsa (MSc); Lecture of Water Supply and Environmental Engineering Department in School of Civil and Environmental Engineering, Jimma University Institute of Technology, Jimma University, Ethiopia

(2) Dr. Ing Fekadu Fufa (PhD), Associate Professor Water Resources and Environmental Engineering, School of Civil and Environmental Engineering, Jimma Institute of Technology, Jimma University, Ethiopia

Abstract: The study evaluates the hydraulic analysis of water supply distribution network using water GEMS v8i. which used for modeling and Simulation of hydraulic parameters in the distribution networks. The hydraulic parameters which analyzed by using this software were junction pressure, velocity of water in networking system, and nodal demands and the overall result of water supply did not satisfied demand. The water distribution system has been analyzed for steady state and extended period simulation for the present population scenario for intermittent water supply using water Gems v8i. About 14 percent of the total number of nodes analyzed had negative pressures while 68 percent of the nodes had pressures less than the adopted pressure for the analysis. These negative pressures indicate that there is inadequate head within the distribution network for water conveyance to all the sections. In the same manner 85.6 percent of flow velocities in the pipes were within the adopted velocity while around 14.4 percent of the velocities exceeded the adopted velocity. The results in this study revealed that the performance of the water distribution system of under current demand is inefficient.

Key words: Junction pressure, Water velocity, Water distribution network, Water GEMS v8i

1. INTRODUCTION

Water is an essential element required for the sustenance of life, which play important role in socio-economic development of a country (Ms. P. S. Salunke, An Overview of water Distribution Network by Using Water GEMS Software, 2018; TINA MAV, 2019; Rameshwari D. Bhoyar1,

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2017). However, approximately two and a half billion people on earth do not have access to safe drinking water (Pravinkumar Shinde 1, 2018; Berihun, 2017; Salunke, 2018; Wonduante, 2013), due to this, acute crisis of water is looming time to time in this world, which is important to optimize the supply and reduce losses. According to, (Desalegn, 2015; Damgir, 2017; Rossman, 2000; THOMAS J . KUEHN, 2018; Zewdu A. , 2014), the adequate provision of water supply distribution networks efficiently can eradicate poverty and ultimately provide the environment for sustainable development. However, water supply utilities in developing countries are faced with challenges of low service coverage and high unaccounted losses of water. The accessibility of water supply system in most of Ethiopian town, is becoming the most challenger terms of its quality and quantity to the water utilities. The estimated water supply service level of Ethiopia, interims of its coverage, quantity, quality and reliability is very low (Desalegn, 2015; Damgir, 2017). Consequently, water demand is increasing drastically due to population growth rate and per-urbanization of the town through this country. The hydraulic analysis of flows and pressures in a distribution system has been a standard form of engineering analysis since its development by Hardy Cross in 1936 (Affairs, 1936). The demand usually reaches a peak in the morning when people are at home and preparing their meal and its second peak in the evening maximum water use and minimum water use, usually related to average water use by multiplication of peaking factors (Maina, 2015).The prime purpose of water supply distribution networking was for delivering access water supply for the required station with efficient pressure and velocity after treatment plant (Rameshwari D. Bhoyar1, 2017). This distribution network is an essential hydraulic infrastructure which is a part of the water supply system composed of a different set of pipes, hydraulic devices and storage reservoirs (Pravinkumar Shinde 1, 2018). The distribution system of a water works consists of the pipes, valves, hydrants and appurtenances used for distributing the water, the elevated tank and reservoir used for fire protection and for equalizing pressures and pump discharges and meters (IZINYON AND B. U., 2010; Ms. P. S. Salunke, An Overview: Water Distribution Network by Using Water GEMS Software, 2018). Water GEMS track flow of water in each pipe, the pressure at each junction, the height of water in each tank, and the concentration of water throughout the network during a simulation period.

2. Methods and materials

2.1. Study Area Description

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The study was conducted in Oromia Regional state of Alibo town, East Wellega Ethiopia which
60 is located 365 km from Addis Ababa which is located at altitude of 2410m above sea level in the geographical coordinate system of 9°32‟N and 37° 04‟ E as indicate in Figure 1. According to Ethiopian metrological agency of Alibo branch, the climatic condition of the district was divided in to three seasons, those are, Summer season on which the average max and min temperature is
64 27.63^0 C and 8.73^0 C respectively, were as in Autumn season; the max and min temperature 28.70 C and 11.5^0 C, and, for the Winter season the max and min temperature is 27.13^0 C and 11.20^0 C.

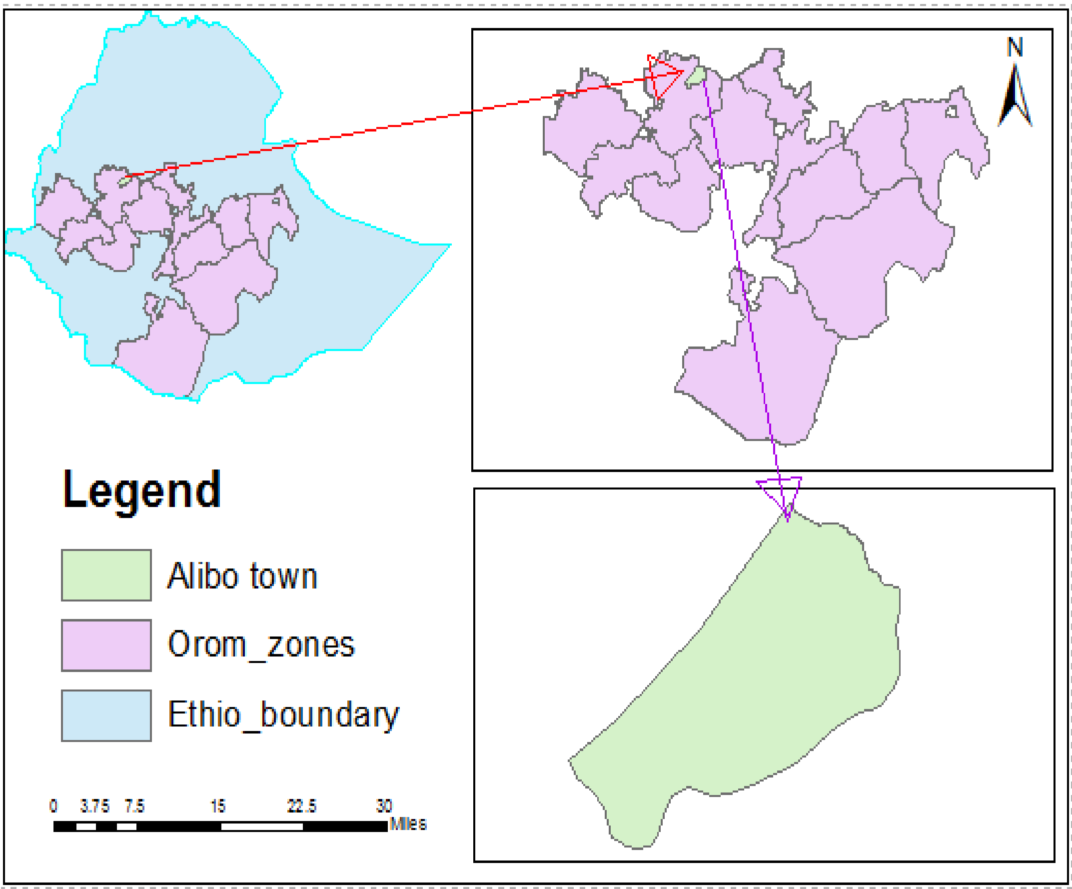

Figure 1: Map of study area

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2.2 Study design flowchart for methodology

Research design referred to as a master plan, blueprint, and even a sequence of research tasks. Hence, this study is exploratory, descriptive, and applied study.

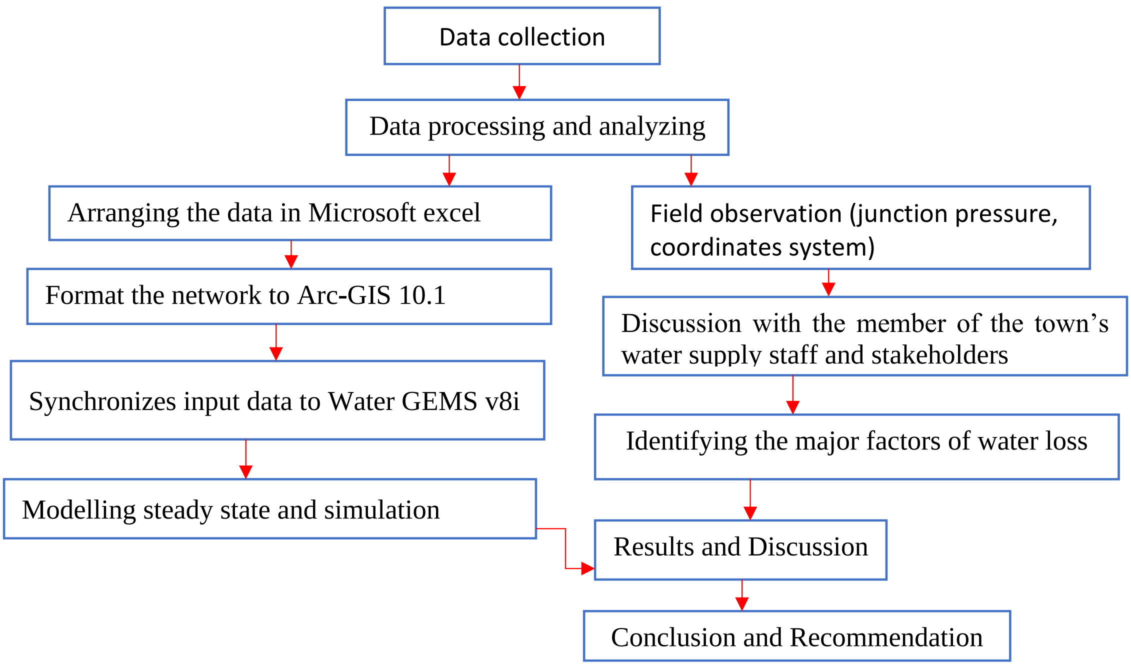

Figure 2: Flow chart diagram

2.3 Input data collection

The input data required for hydraulic network modeling were associated with to the component of distribution network for each links. This data can collect in each node of pipe link are, pipe label, pipe material, pipe length, pipe diameter, starting node, stopping node, and pipe roughness are some of the pipe input data requires for the modeling and simulation of water distribution network. The other input data associated are, pressure junction at node/link which includes junction label, junction elevation, and junction demand. Tank data requires are base elevation, minimum elevation, maximum elevation, initial elevation and tank diameters. The pump input data collection is, design flow, maximum operation flow, design head, maximum operating head, maximum operating head, shut off design and coordinate system.

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2.5 Modeling process for water GEMS v8i

Hydraulic models are often used to validate the design of water distribution systems (Bentley, 2008) as indicated in Figure 3.

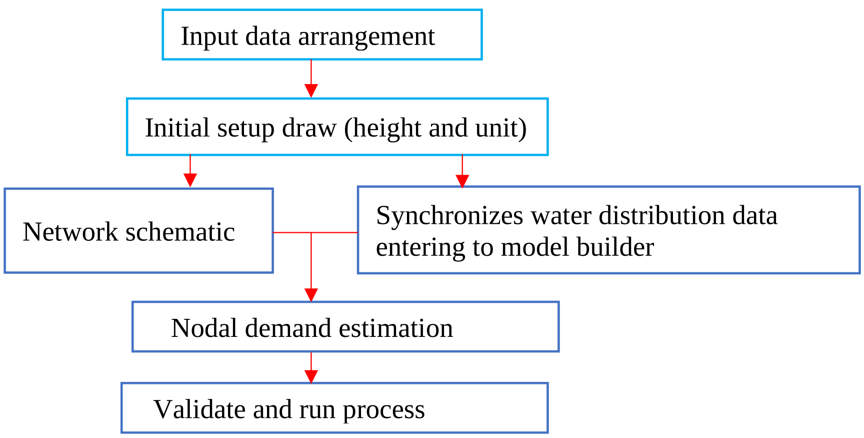

Figure 3: Flow diagram of the study

2.6 Population projection

Population projection provides information on the future size, configuration of the study area which is a fundamental in goal of development to satisfy the future need of population in the area of water demand. Among different methods of population projection techniques, the study was considered overall current situations of the targeted town having the minimum error calculation among each method as indicated in Table1. The Central Statistics Agency of Ethiopia calculated this population growth rate from 2008 to 2030 as justified.

Table 1: selection of population projection among preferable by considering minimum

Year	n	Arithmetic methods	Geometric	ECSA	Calculating error in each method
		$P_n = P_o + kn$	$P_n = P_o(1+k)^n$	$P_n = P_o e^{kn}$	$\frac{\text{Actual popn} - \text{proj. popn}}{\text{Actual population}} x100\%$
2035	23				

2.7 Estimation of present and future water demand deficit

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The design and execution of any water supply scheme requires an estimate of the total amount of water required by community. Designing the water supply scheme for a town is necessary to determine the total quantity of water required for various purposes for Alibo town has categories,

2.7.1 domestic water demand

The water demand for actual household activity is known as domestic water demand. The demand will depend on many factors, the most important of which are economic, social and climatic factors. The water demand is calculated for the domestic water demand, per capita domestic water demand, non-domestic water demand, and institutional water demand, commercial water demand, industrial water demand.

2.7.2 Non-domestic water demand

Accordingly, estimated domestic water demand is 10% for institutional and commercial demand, 10% for industrial water demand and 5% for firefighting water demand were added to get the average daily water demand.

2.8 Model calibration and validation

The study was measured the water pressure to evaluate the model performance. The method of pressure readings was done from Feb 24, 2020 to Mar 01, 2020 using pressure gauge meters commonly taken both at higher and lower zone of the selected points in distribution network; such as raw water pump stations, service reservoir, public fountains and different end user taps. In this way, the perceived pressure data was taken a total of 10 samples for peak demand time analysis five samples were taken from lower zone and five samples from higher zone. From pressure junction and its coordinate system were collects for 10 nodes as a sample for validation the study result (J-45, J-12, J-1, J-43, J-10, J-61, J-54, J-76, J-28, and J-87) measured near the corresponding location using pressure gauge.

2.9 Hydraulic parameter modeling

The design criteria used in the design of pressure zone boundaries, nodal pressure during the period of peak demand, and optimum velocities of the transfer and distribution mains are (pressure and velocity).

Pressure: The operating pressures in the distribution network according to MoWR urban water supply design criterion shall be 15m to 80 ranges. Accordingly, MoWR reports that there are two main criteria to determine the pressure in the distribution networks whether it's in the ranges of scope.

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Velocity: According to MoWR urban water supply design criterion water velocities shall be maintained at less than 2 m/sec, except in short sections & for pumps. Velocities in small diameter pipes may need even lower limiting velocities. A minimum velocity of 0.3 m/sec can be taken, but for looped systems there are also pipelines with sections having velocity <0.1m/sec.This shows that a pipe designed to flow at a velocity between 0.6 and 2 m/sec, depending on diameter, is usually at optimum condition. The shortest sections, particularly at special cases, at inlet and outlet of pumps, may be designed for higher velocities.

3 Results and Discussion

3.1 Population projection

Among different techniques of population projection methods, the study analyzed the minimum error and used the arithmetic method for estimation of population. Accordingly, the projected population at the end of design period was 437956 of population, which implies that the current populations were increased by 236808 populations on water consumption. Therefore, Alibo town population projection from year (2012-2035) was tabulated in the following Figure 4.

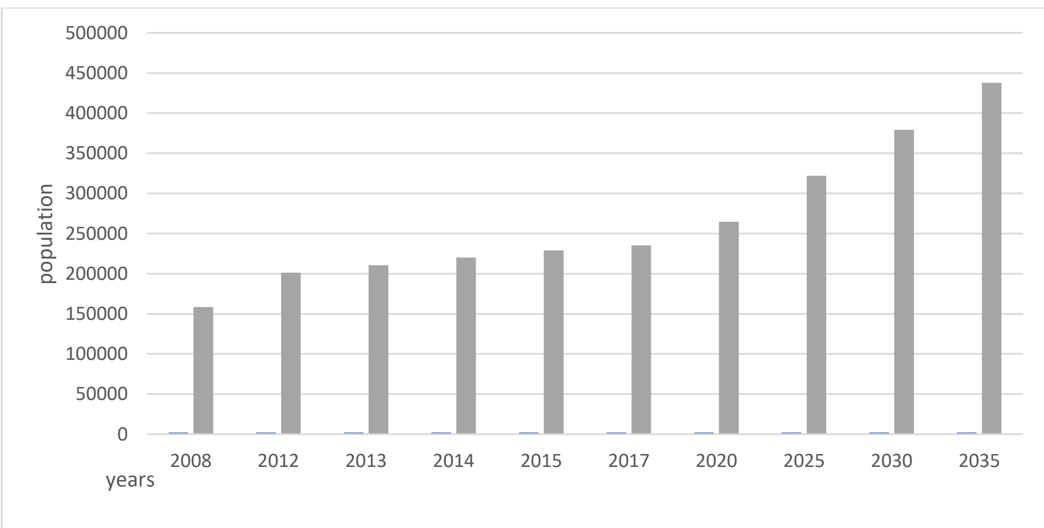

Figure 4. Alibo town projected population (2008 to 2035)

3.2 Domestic water demand analysis

For this projected population, based on the study area capacity and other limited resources and climate of Alibo town, the average water demand varied from 20 L/c/d to 25 l/c/d at the end of the

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design period (2008) and the average daily water demand of Alibo town was 5,486.8 m^3/d. Whereas the peak hour demand of the town was 8,778.8 m^3/d and peak hour demand is the highest demand of any one hour over the maximum day. Domestic water demand is the daily water requirement for use by human being for different domestic purposes like drinking, cooking, bathing, gardening, etc. According to (MOIE, 2016) report the towns and cities of Ethiopia were categorized based on population number for effective design of water supply distribution system. The design period populations of Alibo town were 437956 which have been categorized under catogry-3. The variation of water demand was developed through each year consequently which have a great effort on the design of water supply for the study area. Hence the average daily demands of the study area for 2015, 2020, 2025, 2030 and 2035 were increased by 6.45 %, 8.99 %, 50.97 %, 94.23 % and 147.41 % respectively as compared to 2017 average daily water demand. While maximum daily demand and peak hour demand were increased by 2.08%, 10.4%, 26.94%, 94.20% and 142.2% and 5.6%, 7.33%, 65.90%, 98.73% and 143.02%, respectively.

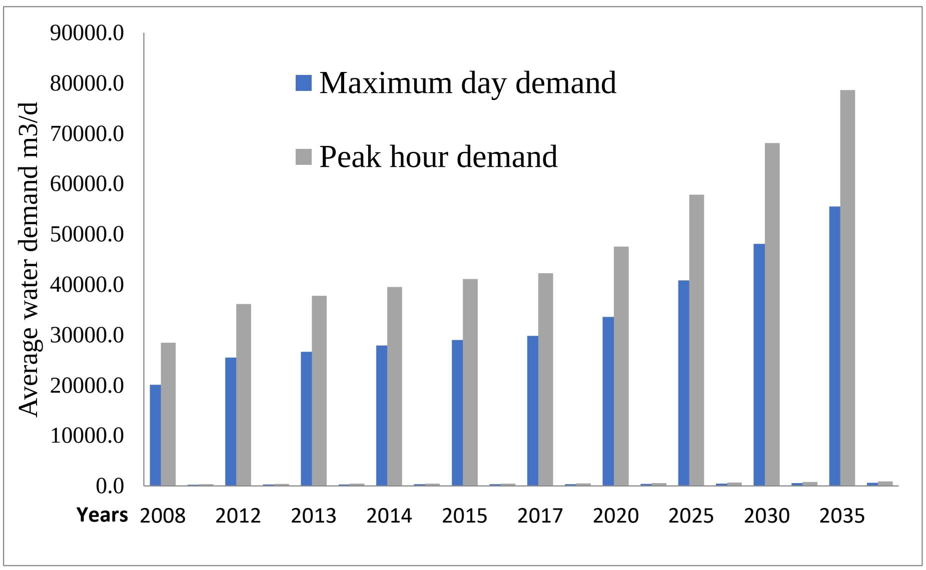

Figure 5**:** Maximum day demand and Peak hour water demand

3.3 Prediction of future water demand deficits

The estimated water demand deficits versus water supply production of the study area were plot in Figure 6. Accordingly, the productions of water supply for were only meeting the water demand requirement for different consumption rates averagely up 2020 years. Beyond this year water

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requirement of the town were less than year water production to area due to limited supply and

200 water demand was becomes day to day distressing.

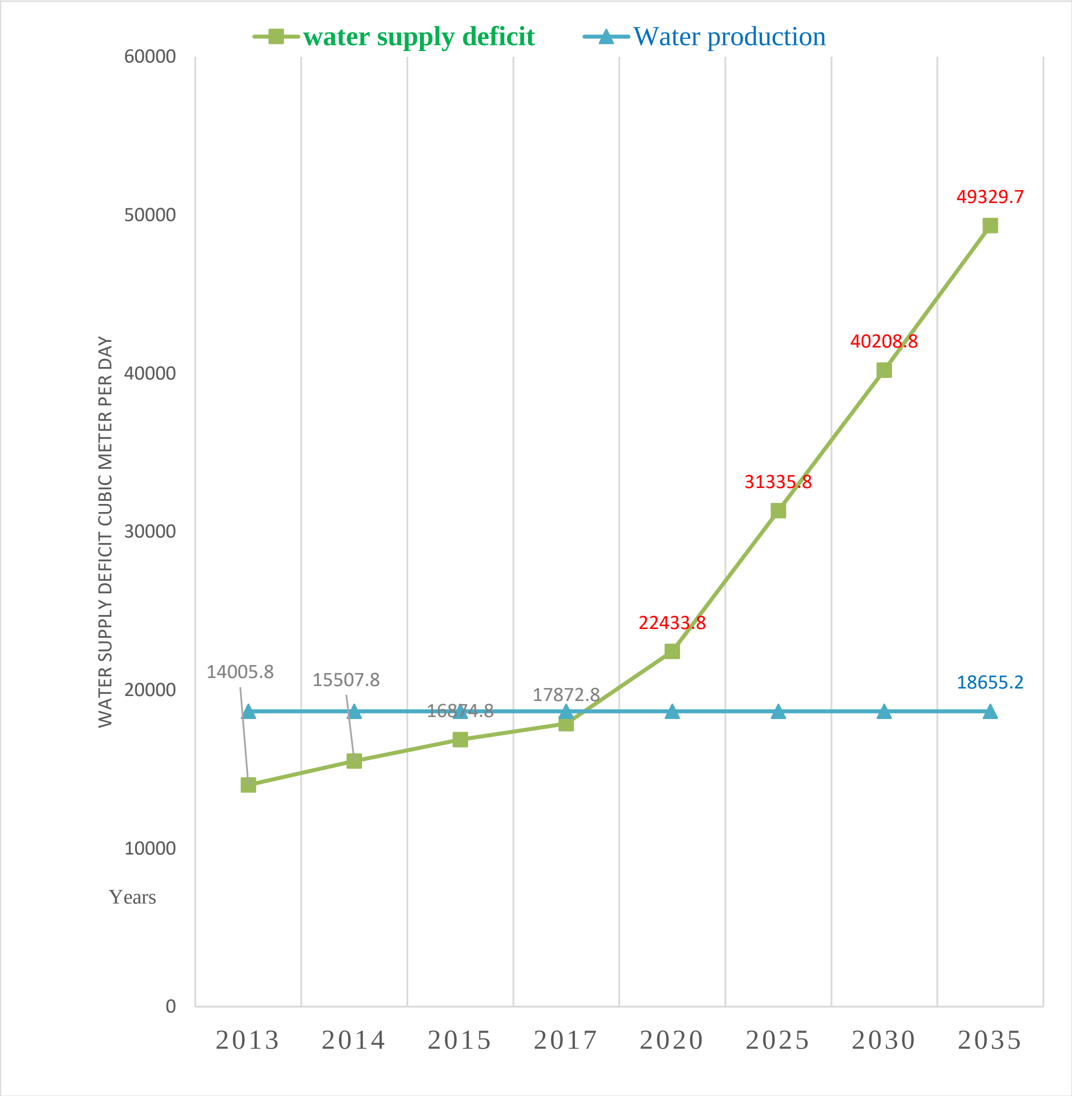

Figure 6: Alibo town water production and water demand deficit

204 **3.4 Analysis of water demand variation in distribution networks**

It represents the daily variations in water demand resulting from the behavioral patterns of the local population. Experience clearly demonstrates that the peak hour factor is greater for a smaller

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population. Hence, this peak hour demand result did not match with that of the growing population of the town and this demand can vary from each distribution networks as shown in Figure 7.

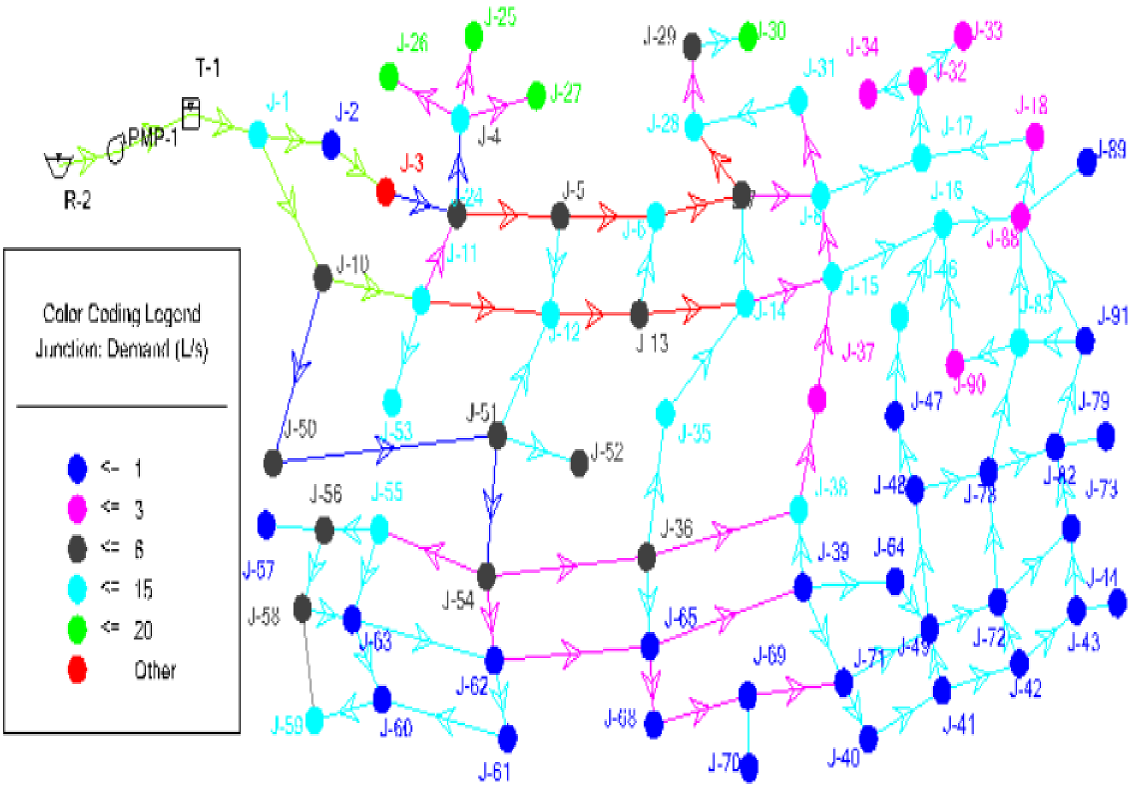

Figure 7: Variation of water demand in the distribution pipe networks

3.5 Analysis of Pressure in the Networks

Water distribution network was designed based on pressure criteria and in accordance with the existing criteria on minimum and maximum pressure in the network. The operating pressures in the distribution network according to minister of water resources, urban water supply design criterion shall be 15m to 80m ranges. Accordingly, this study result of the pressures distribution networking is avail in within this ranges. However, as the researcher analyzed, negative pressure was observed / recorded in 8 junctions, which shows that no water flows/ currents reached to this segment of distribution network, meaning by no provisioning of water to the consumers. This negative pressure may occur due to size of pipe, and levels of water, avail in distribution network

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which has a great impact on societies. It was attempted in the design to meet the optimal diameter and minimum pressure in the network as shown in Figure 8.

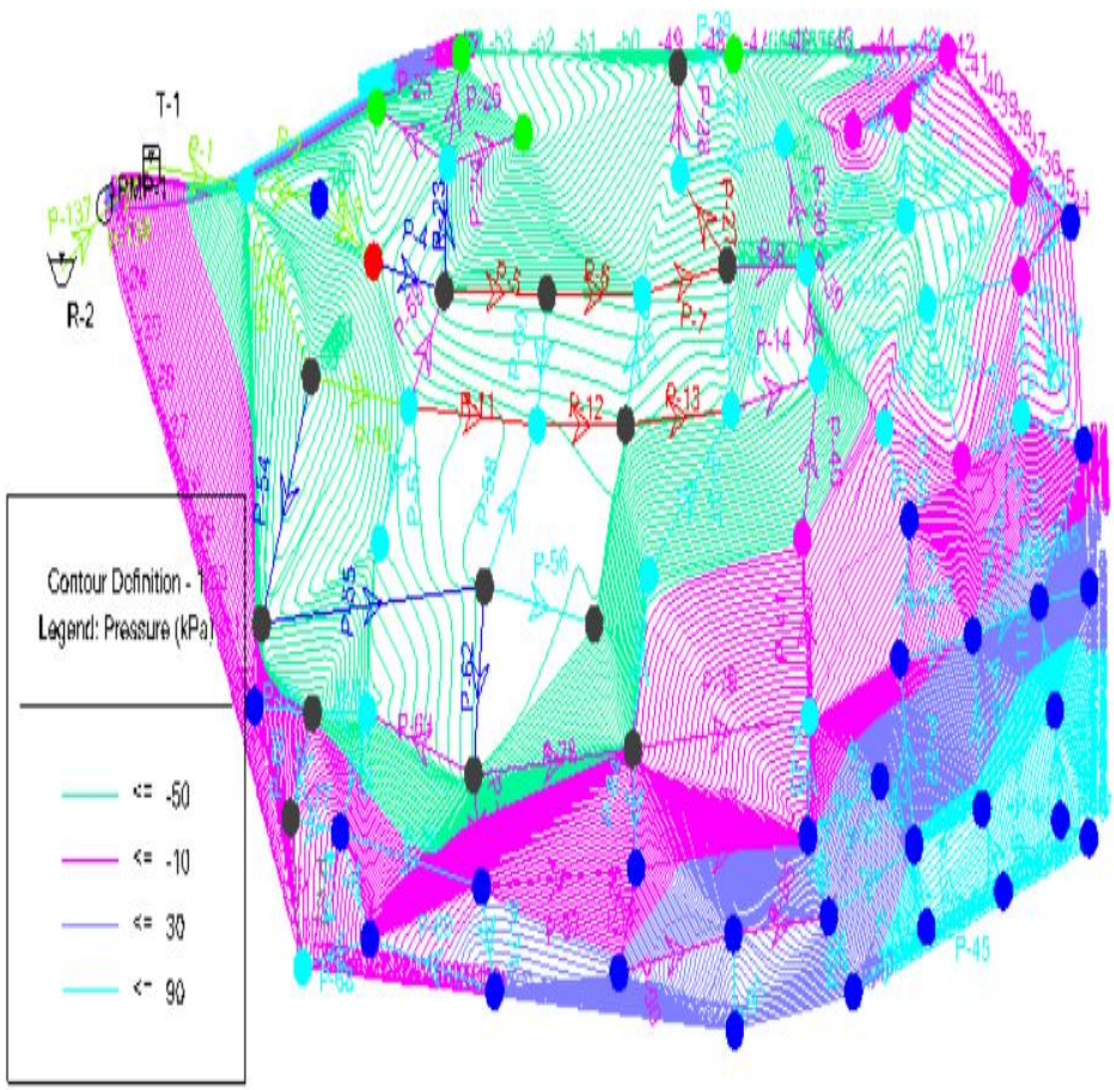

Figure 8: Pressure/contour map for the Alibo town water distribution networks

3.6 Analysis of Network Profile

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The software has the potential to give a variety of information, including hydraulic profile, velocity profile, and pressure gradient at any point in the network to the user. One of the town s main line is shown in figure with respectively.

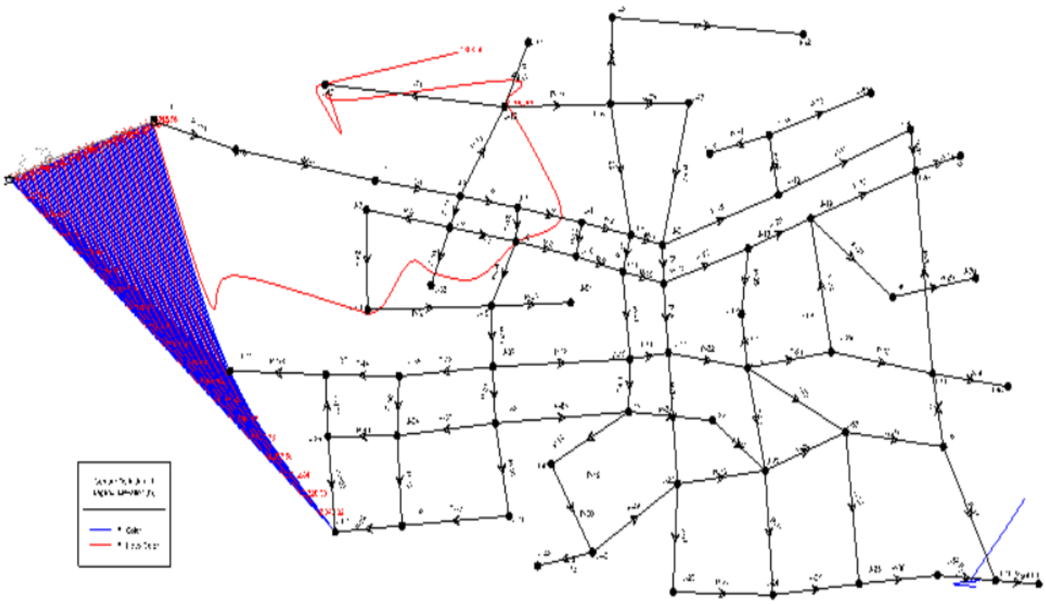

Figure 9. Elevation profile of the distribution from reservoir to end costumer pipes

In the distribution main lines of the study area the locations of nodes in the water distribution line are in close proximity to each other. The maximum and minimum water pressure in the distribution system was 98.45 and 8m from the reservoir head to the ends of costumer services pipe. According to the design criteria of the FDRE; Minster of water, irrigation and energy, the maximum and minimum water pressure in the distribution system is 80m and 15m, respectively. This is because of; water was delivered to the distribution main by gravity means, and the system were served beyond its design life. Nodes having low values of pressure, Steady state Analysis(5<=P<=10m) and Nodes having high values of Pressure, Steady state analysis (80>=P<=98.45m).

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The hydraulic grade line and base elevation starting from Tank to the distribution system were plot as shown in Figure 10.

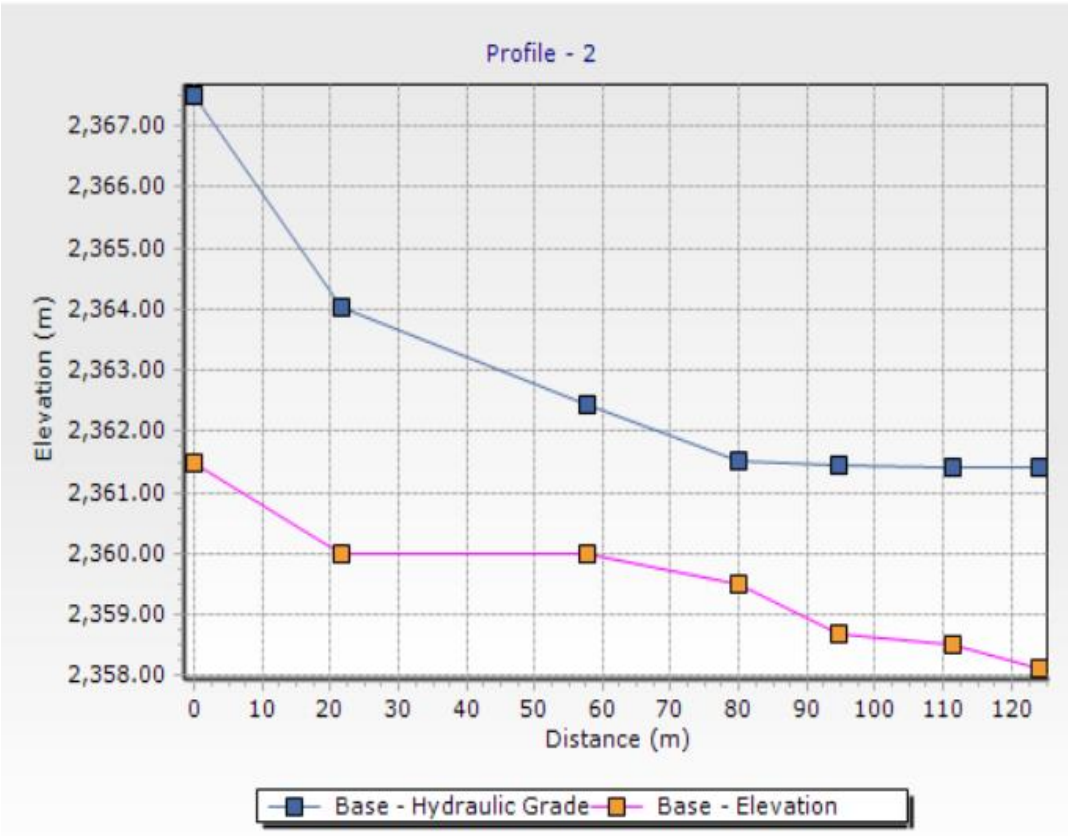

Figure 10: Hydraulic grade line versus Base Elevation from Tank and distribution system

3.7 Analysis of Pump capacity

According to field observed data and model simulated result, the pump brake horse power and maximum water power were collected as 55.83 kW and 24.4 kW, respectively. Therefore, the 78.67% of the pump efficiency was shown that currently these pumps were operating in good performance and did not deliver sufficient water to treatment plant continuously. Network pressure zoning is necessary in the existing water distribution networks or in the study of the development plans of facilities and water distribution network of towns and villages with a gap at the level of the town. Pressure zoning at the level of network includes all the measures that would keep the pressure within the standards or pressure management.

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The developed pump head curves during model simulation work were presented as Figure 11
252 below.

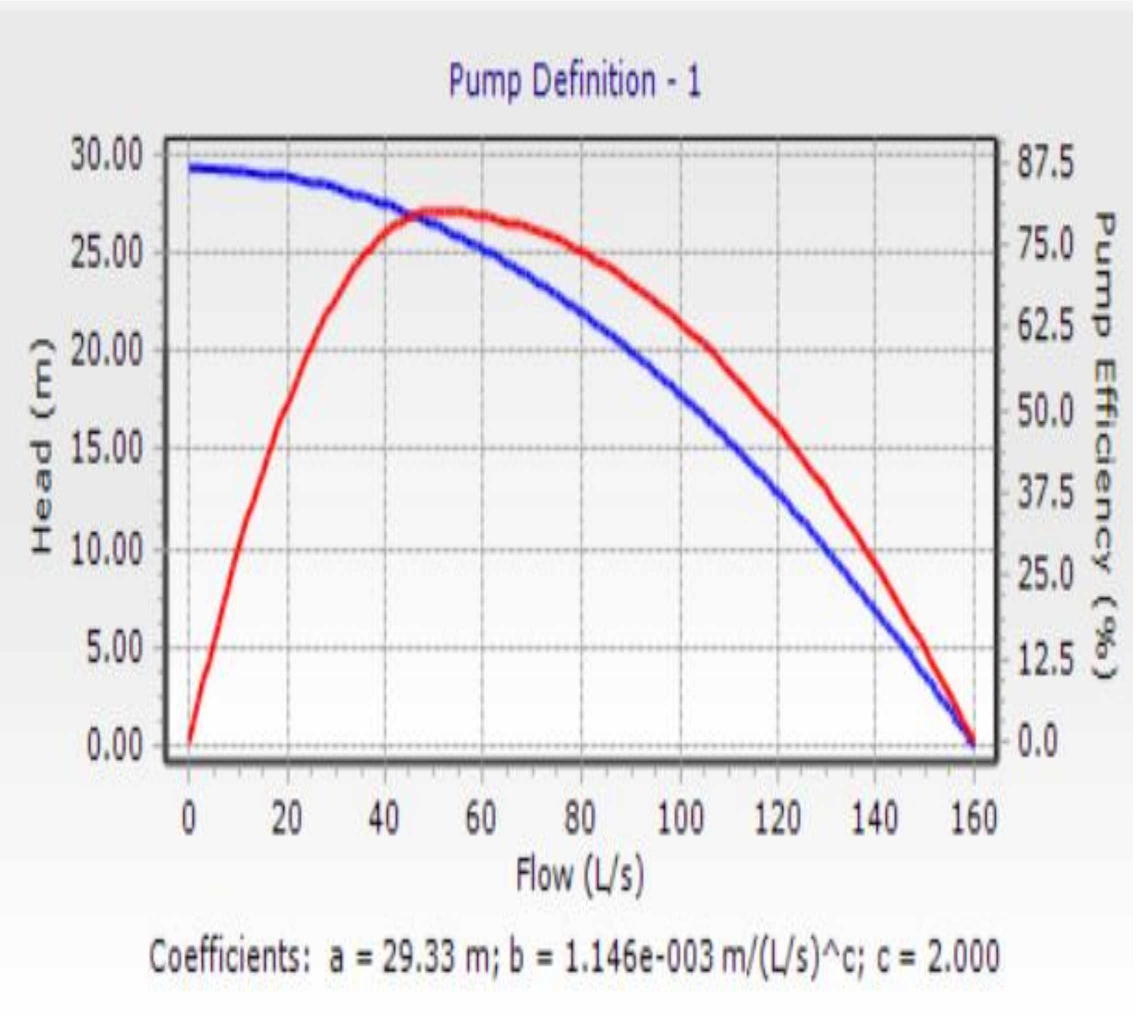

Figure 11: Raw water pump capacity and its efficiency in the distribution networks

3.8 Velocity Analysis

256 Through the distribution networks about 18 pipes in the system has a velocity less than the minimum limits, of minimum velocities which is 0.05 - 0.3 m/s. Minimum velocities should be avoided from the system in order to avoid stagnation and water quality problems. A minimum velocity of 0.3 m/sec can be taken, but for looped systems there are also pipelines with sections
260 having velocity <0.05 m/sec. Maximum static head within a pressure zone was limited to 100 m.

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Minimum dynamic head was established at 22 m and the maximum velocities of major transmission mains < 2.5 m/s. Maximum velocities of distribution mains < 2 m/s and the minimum velocities range 0.05-0.3 m/s within the system.

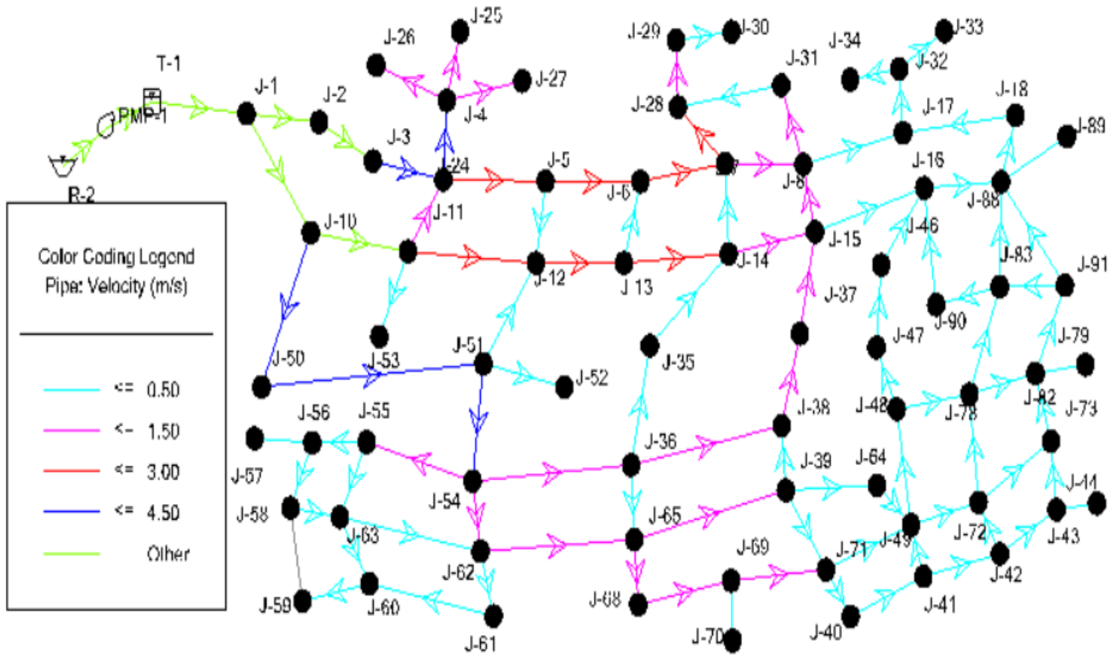

Figure 12: Velocity map of links for average day demand

CONCLUSION

The study analysis the main challenges of water distribution networks, which could limit quantity of water supply due to volume of existing reservoirs size and pre-urbanization (population expansion). To provide the minimum pressure and prevent from increasing pressure which increase in water tragedies and unnecessary use of water, pressure should be carried out by the appropriate selection of the tank and pressure zoning of the network. The existing water distribution network of Alibo town was designed for estimated population of 69,160. However, the current population figures out 118,339, which is being served beyond the design life and low coverage in the town, which causes scarcity of drinking water supply in the town. Accordingly, there was complain from the customer because their demand was not being met to fulfill their

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satisfaction since distribution system is intermittent. In the distribution network system same velocity can be less than permitted level of MoWR and the negative pressure junction can also occur in the systems of networking distribution. Some of the nodes have low values of pressure, steady state analysis (-5<=P<=10m) and nodes having high values of pressure, steady state analysis (80>=P<=128.45m). The software finds the lowest allowable diameter for each pipe segment that was allow the system to function, or more specifically, to meet the minimum pressure requirements at all junctions.

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