WATER DISTRIBUTION NETWORK ANALYSIS OF NASARAWA LOCAL GOVERNMENT AREA, NASARAWA STATE.

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ABSTRACT

This study was carried out to appraise the existing distribution network; and to analyse the present water distribution network using Epanet software which underscored the fundamental objectives of the Sustainable Development Goals (SDGs). EPANET software was employed to modelled the water distribution piping systems in Nasarawa town. It performed extended period simulation of the water movement and quality behaviour within pressurized pipe networks. The analysis carried showed that the design capacity of the distribution network is not adequately sufficient for the present population and the situation is compounded by inadequate supply of water from the production point to the system. Nasarawa Local Government Area has a population of 189,835 based on the census exercise in 2006 (NPC, 2006). Water consumption per meter length of pipe for each loop is dependent on the population per loop and the average daily consumption per day. This implied that consumption is affected by total length of pipes in a loop. Domestic water demand for the loop involved the water required for drinking, cooking, bathing, cleaning, gardening, and sanitary purposes. From the population distribution and water demand for each loop. Loop three (3) is the largest loop and has the maximum demand of 0.1. m^3/s, while loop one (I) which is the smallest loop has the minimum demand of 0.008 m^3/s. The total water demand is 0.718 m^3/s which is equal to 62,035.20 m^3/day as compared to 27,000 m^3/day used for the design capacity for a population of 150,000 which is the population equivalent adopted for the construction of the facility. The distribution network required modification to *cope with the present reality of water demand and by implication the future water demand of the inhabitants.*

Keywords: *Epanet, Water distribution, Population, Network, Nasarawa town*

INTRODUCTION

Water is essential for the survival of every living creatures And its availability and provision to any community is very important (Alkali et al, 2017)**.** It is considered an inevitable and invaluable resource to all earthly creatures due to the properties associated with it. As the world population is growing rapidly water resource is becoming scarce and insufficient, as there is no corresponding increase in the resource. Access to safe and affordable water is critical to the development of a nation (Jimoh, 2010). The provision of water has a lot of economic benefit to a community that is small scale industries like packaged/sachet water, block making industries among others are encouraged which invariably attracts population. There are two basic requirements for a robust water system: the water consumption demand and the reliability requirements. It is expected of the system to deliver adequate amounts of water to meet the consumption need as well as being available twenty four hours a day (Tahal, 1995). The ability of existing and proposed water supply system to operate satisfactorily under the wide range of possible future demand and hydrological condition is an important characteristic. The likely performance of water is often described by the mean variance of benefit, pollutant concentrations or some operating variables. These performance measures are used in the selection of water supply system capacities, configuration operating policies and target (Cairncross, 1981). Significant progress has been made in recent times in various aspects of water supply and distribution. Water distribution is the process of bringing water to consumers. It takes a number of forms around the world from pressurized municipal water that delivers water directly into homes to travelling tanker trucks that distribute water to community access points. Water distribution is not just about getting water to people who need it, but about efficient allocation coverage. The process of water distributions starts with identifying a source of water and determining what kind of treatment may be needed to make it usable. The water is moved through treatment facilities into distribution systems, including network of pipes, canals and aqueducts.

Flows through network of pipes are a function of difference in pressure at the inlet or outlet points. A pipeline system is designed to carry a certain flow. The size of pipes must not be unnecessarily over-dimensioned and at the same time there should be sufficient pressure throughout the system.

EPANET models a water distribution system as a collection of links connected to nodes and also helps to evaluate the pressure at every node. The links represent pipes, pumps, and control valves. The nodes represent junctions, tanks, and reservoirs (Rossman, 2000). Figure 1 illustrates how these objects can be connected to one another to form a network.

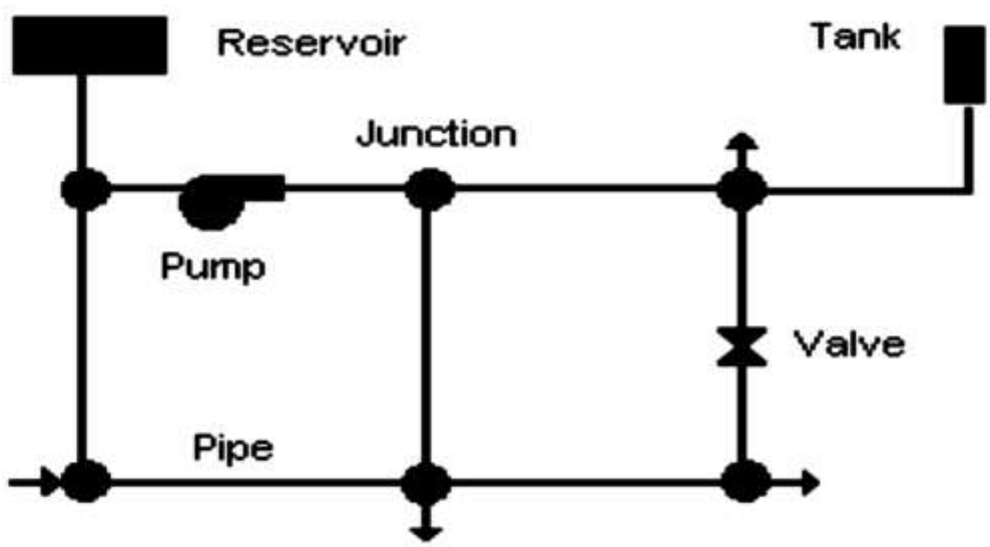


Figure 1: Components in a Water Distribution System

MATERIALS AND METHODS

The Study Area

The study was conducted at the Nasarawa town of Nasarawa Local Government. The local government is about 167 km from the state capital, Lafia and 100 km from Abuja the Federal capital city of Nigeria. According to the 2006 population census (NPC, 2006), it has a population of 189,835 with total area coverage of 370.7 km^2. And it is within the Guinea Savannah and the tropical climate condition of the study area is not far from the climatic condition of Nigeria (Raining and Dry seasons) with an average temperature of 28 ^{0}C, and a mean annual rainfall of 1,357 mm (Nigerian Meteorological Agency, Lafia, 2012). It is situated at an average altitude of 450 m above mean sea level (MSL) and bounded by latitude 8°30"N to 8°40"N and longitude 7°34'E to 7°45'E. The rainfall starts in March and lasts till October while dry season commences from November and lasts till February. The rainy season on average lasts for 215 days while the dry season lasts for 150 days. The vegetation type is an open forest and it is affected in most places by human activities. The relief of the study area is relatively undulating highlands. River 'Uke' and 'Kotto' constitute the main drainage system with other seasonal streams as their tributaries giving a dendritic pattern of drainage. All rivers flow through the town from the north to the south, to empty their water into river Benue.

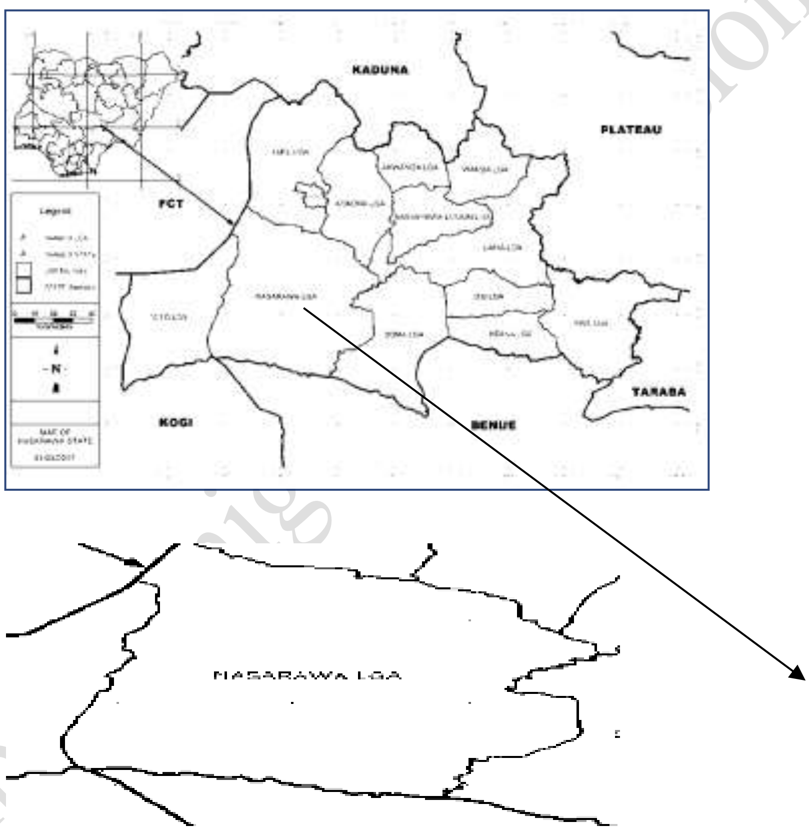


Figure 2: The Study Area

Hydraulic of Water Distribution

The hydraulic equations, which describe pipe network system, are obtained from continuity and energy equations. For any good network design, basic equations must be satisfied. Hydraulic properties of the water and the characteristics of pipe network materials influence greatly the flow.

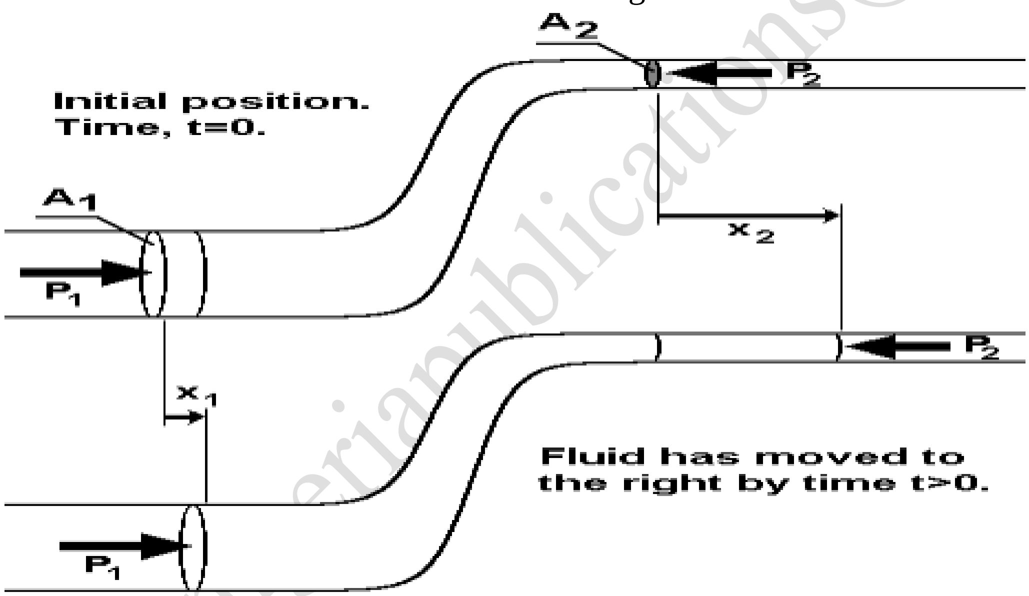
$$Q = A \, x \, V \quad (2.12)$$

where: Q = Flow rate (m^3 / sec)

A = Cross-sectional Area of the pipe (m^2)

V = Velocity of flow in pipe (m/s)

The Bernoulli's equation states: If the steady flow of frictionless, incompressible fluid along a streamline is considered, the total energy of a unit fluid mass would remain the same considering two sections.



$$P_1/\rho g + V_1^2/2g + X_1 = P_2/\rho g + V_2^2/2g + X_2 + h_f \quad (2.3)$$

or

$$X_1 - X_2 + \frac{P_1 - P_2}{\rho g} + \frac{V_1^2 - V_2^2}{\rho g} - h_f = 0 \quad (2.4)$$

Where: V = Mean velocity at section.

$V^2/2g$ = Velocity head (m) or the kinetic energy of the water

$P/\rho g$ = Pressure head (m)

X = The elevation head above a datum (m) or the potential energy

h_f = Head loss due to friction between the points of measurement.

This equation shows that it is the difference in potential energy, flow energy, and kinetic energy that actually has significance. The $X_1 - X_2$ is independent of the particular elevation datum, as it is the difference in elevation of the two points.

Similarly, $P_1/\rho g - P_2/\rho g$ is the difference in pressure heads expressed in units of length of the fluid flowing and is not altered by the particular pressure datum selected. Since the velocity terms are not linear, their datum is fixed. Many methods of pipe network analysis have been used in finding solution to pipe network problems. One of the techniques of solving the problem of steady flow in pipe network is hardy cross method (Cross, 1936).

Data Collation

Data required and collated for this study are: Population Data of Nasarawa gotten from 2006 Population Census. Population Data of the loop based on Town Development Committee assessment. Water Supply Guide Map showing the Distribution Network obtained from Nasarawa State Water Board. Data on the capacities of reservoirs, and storage capacities. An accurate population data of the town is necessary to determine water requirement of the town. The population data, for the purpose of a water system, include all persons who will depend upon it for their drinking water, patients in the health posts, students living in dormitories, and employees in government offices. It is imperative to take into consideration the needs for the present and future population of the area to be served with water.

The area under review is undergoing rapid development; therefore the initial phase of population growth will be rapid. In view of this, the compound method of population forecasting was considered. The future population was estimated using equation

$P_n = P_i (l + r)^n$; (3.1)

Where: P_n = the projected population for the year, n

p_1 = Initial Population

r = Population growth rate

n = design period in year n

Water demand fluctuates both in dry and raining season, the design was based on dry season demand which is higher than the wet season. The amount of domestic water consumption per person varies according to the living condition of the consumers; average daily consumption of 120 litres per day (National Water Supply and Sanitation Policy 2000) is used for this work. The total water demand generally amounts to 50 to 55% of the domestic water consumption (Chatlerjee, 1987).
Average daily demand = population x per capita consumption Peak daily demand = 2 x Daily average demand

Modelling Procedure
The following steps were used in analyzing the water distribution system of Nasarawa Town. Network was digitalized using AutoCAD. The basic description of the network placed in a text was imported from AutoCAD. EPANET has the ability to import a geometric description of a pipe network in a simple text format. This description simply contains the ID labels and map coordinates of the nodes and the TD labels and end nodes of the links. This simplifies the process of using other programs, such as CAD and G1S packages, to digitize network geometric data and then transfer these data to EPANET. The properties of the objects that make up the system were edited. The Property Editor is used to edit the properties of objects that can appear on the Network Map (Junctions, Reservoirs, Tanks, Pipes, Pumps, Valves, or Labels). To edit one of these objects, select the object on the map or from the Data Browser, then click the Edit button on the Data Browser (or simply double-click the object on the map). The basic Epanet workspace is shown in Figure 3a below. It consists of the following user interface elements: a Menu Bar, two Toolbars, a Status Bar, the Network Map window, a Browser window and a Property Editor window (Rossman, 2000). The system operation was then described. Curves, Time Patterns, and Controls have special editors that are used to define their properties. Once the analysis runs successfully the icon will appear in the Run Status section of the Status Bar at the bottom of the EPANET workspace. Results of the analysis can be viewed directly on the Network Map (Rossman, 2000). The optimum water distribution systems on the respective present and future water demand scenario was subsequently obtained.

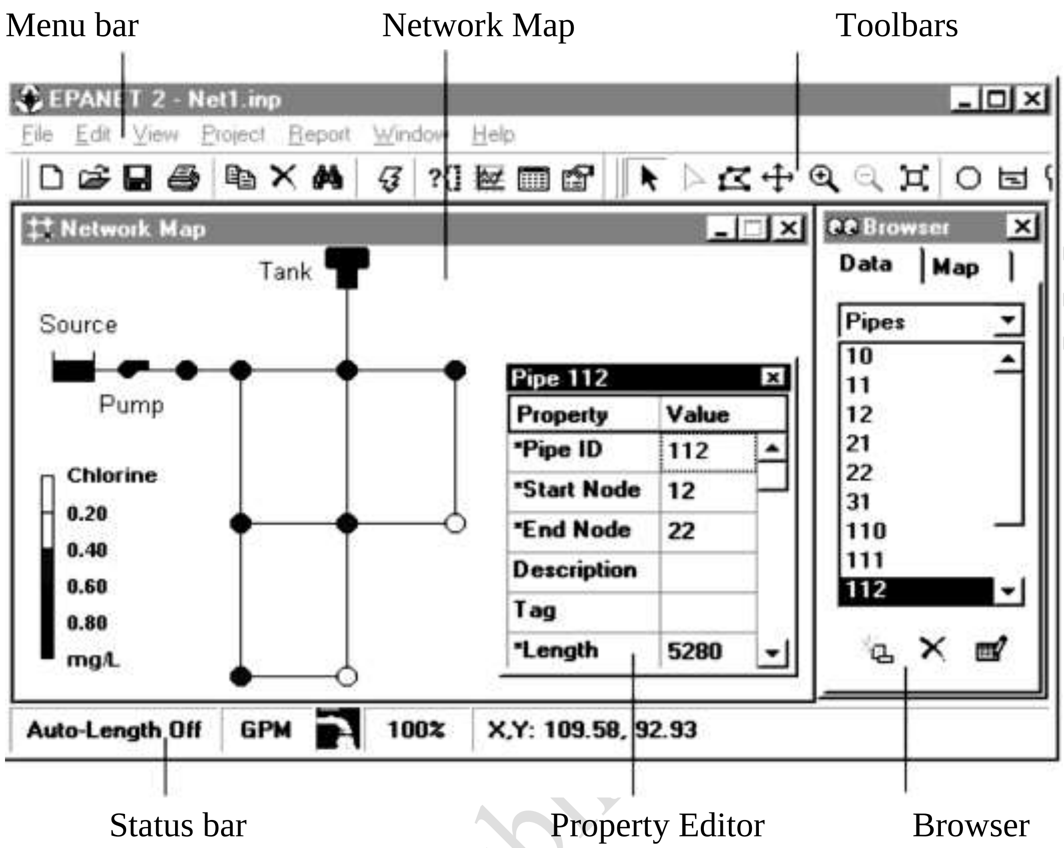


Figure 3a: Epanet's Workspace

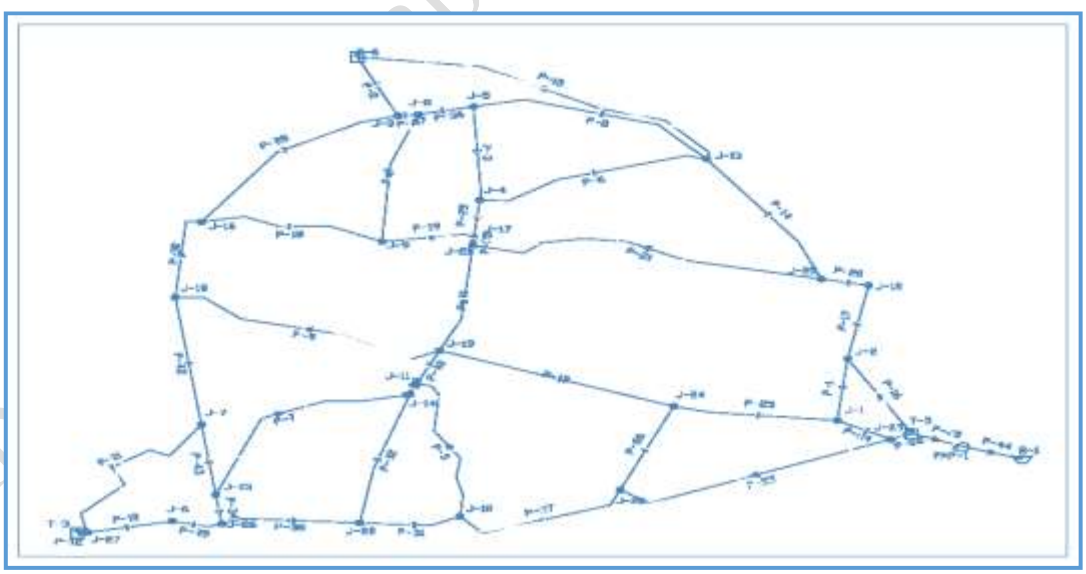


Figure 3b: System Layout of the Network

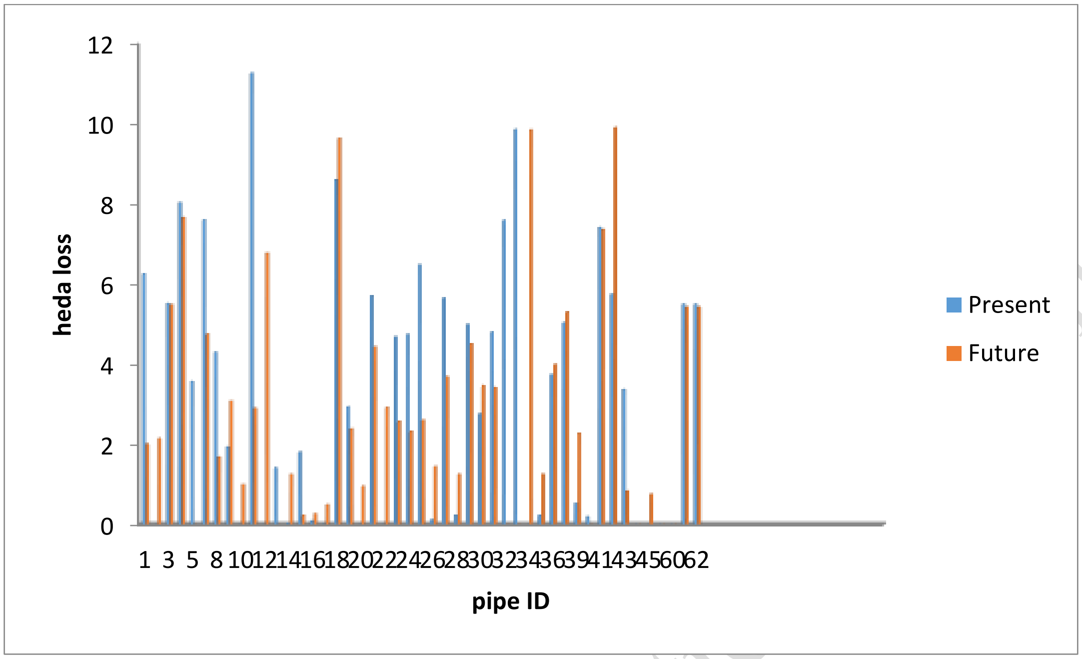


Figure 4: Head losses for existing and future scenario

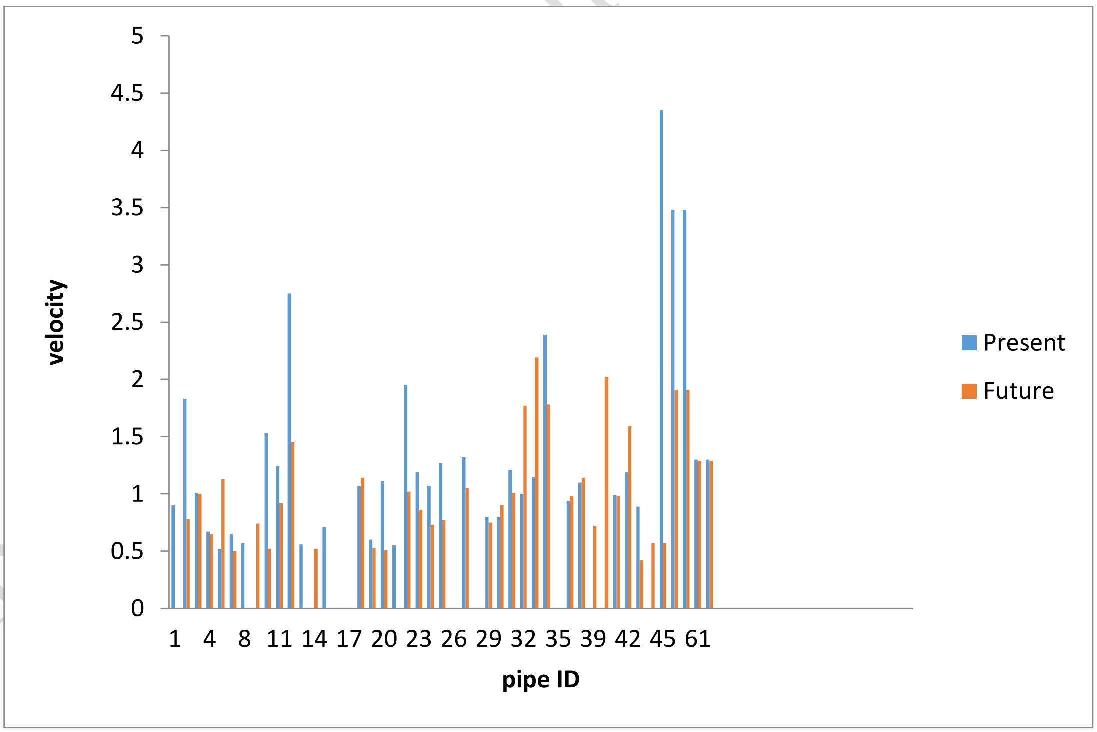


Figure 5: Velocity for existing and future scenario

CONCLUSION AND RECOMMENDATION

The relationship between head losses and velocities in the existing and future scenario are represented in figures 4 and 5 respectively. The relationship in the charts shows considerable reduction in the number of pipes with high head loss from nine (9) in the existing scenario to six (6) in future situation. The numbers of pipes with low velocity, however, remains the same for both present and future situations. Therefore, the present situation of Nasarawa distribution network is significantly inadequate in meeting with the demand of the consumers. The design capacity is not adequate for the present population and it is compounded by insufficient supply of water from the production point to the system. Hence, there is need to modify the distribution network to cope with both the present and future water demand of the inhabitants of the town even if there is adequate supply from the production unit. In order to meet up with the future demand and population challenges there is need for changes in some pipe diameters as solution to low velocity and high head loss experienced. This would further serves as a driver to achieving one of the core objectives of the Sustainable Development Goals (SDGs) which is to ensure the availability and sustainable management of water for all by year 2030 (https://sustainabledevelopment.un.org).

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