CEDTECH International Journal of Environmental Science & Biotechnology
Volume 4, Number 2, June2023
http://www.cedtechjournals.org
ISSN: 2756-4541

ANALYSIS OF WATER DISTRIBUTION NETWORK FOR ACCOMMODATING POPULATION PROJECTION USING EPANET IN BATAGARAWA MUNICIPAL AREA, BATAGARAWA L.G.A, KATSINA STATE

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Abstracts: The development of water distribution network begins with projecting the population to 2040 planning using the geometric Arithmetic and exponential methods with 200mm diameter pipes for upcoming Batagarawa water demands, the water distribution network have met the pressure requirement in the range 6.62m – 26.83m for small water distribution network. Also the range of pipe unit head loss is 0.89 – 0.18 m/km with velocity range of 0.01 – 0.89 m/s,with some pipe not meeting the velocity criteria which suggests adding pump stations and reservoirs at the locations.

Keyword: *Water Distribution Network, EPANET, Hydraulic Simulation, Nodes, Pressure variation and Demands.*

INTRODUCTION

Water Distribution System

The need of this study is to check the flow of water in pipes and to check the final discharge at consumer's point is quite enough for population projection up to 2040 for Batagarawa town of Batagarawa local government area of Katsina state. A good water distribution network is the one which give equal pressure even at the far most point of the distribution with less loss. EPANET software is most advanced software which models the hydraulic and water ability behavior of water distribution piping system. This study area is subjected to rapid population growth. Hence the need for population rise in design is important, which can be easily achieve using advance design software such as EPANET. A water system has two essential pre-requisites, first and foremost it needs to convey adequate measures of water to meet utilization pre-requisites. Besides, the water frame work should be solid, the necessary measure of water should be accessible 24 hours per day.

The sustainable management of water resources also plays a key role in the development of human societies. One of the ways to effectively manage the water distribution system is by using a model. A water distribution system model aides the experts in administration, support, and expansion population needs. A model can assist the authority with understanding when the current water distribution needs development and what adjustment ought to be madeto fulfil the need of the increase in populace.

Computer-based software for water distribution Network analysis

Following the advert of window based packages introduced by Microsoft and Apple macintosh software, developers started developing software like FORTRAN,BASIC,COBOL, C++,Ms Excel e.t.c. These softwares have logic circuits and capacities to carry out complex calculation in short period (Adeniran,2007).Recently, researchers focus on stochastic optimization methods that deal with a set of points simultaneously in its search for the global optimum savic and walters(1997) combined gradient algorithm with EPANET network solver. many modeling programs are now available for commercial and educational use. Recently, several computer programs running on personal computer, such as EPANET,UNWB – LOOP,WADISO,U of K KYPIPE and WATER have been created and made available.

JUSTIFICATION OF USING EPANET.

The EPANET is a software developed by the USA environmental protection agency, is adopted because it is for general public and educational use and it is available free on – line, it is not only free but it requires relatively small computer space to operate.It has unlimited number of pipes that can be analyzed EP**ANET application in solving and** or optimizing water distribution network problems have been reported by fabunmi (2010),Guidolinetal (2010), ingeduldetal (2006) and Abubakar and Sagir (2013).This present study applies EPANET to analyze the exiting municipal drinking water distribution network of Batagarawa town.

METHODOLOGY

Study Area

Batagarawa town is inhabited by Hausa peoples and serves as the capital of the mallamawa district in the katsina Emirate of the north western state.

Batagarawa is situated in katsina (k), Katsina, Nigeria, its geographical coordinates are 12° 54'0" North 7° 37'0" East, with area coverage of 0.397 km2 .

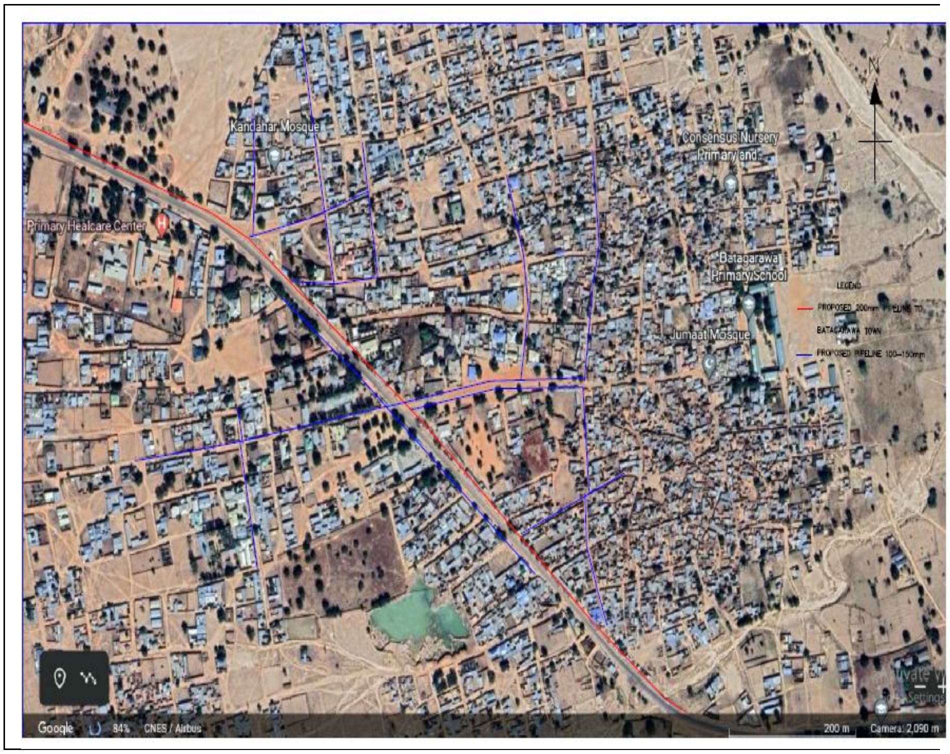


Fig.2.0 Batagarawa town.

SERVICE PRESSURE CRITERIA.

The pressure required in the mains for normal domestic consumption depends upon the height of the building served directly without pumping within the buildings. For small community water supply systems, a minimum pressure of 6meter head of water is considered adequate in most instances,(Hofkes and others,1991). The required head recommended by united nation survey must be at 10psi (7.0 meter) for small water supply systems, for multi storied houses, minimum should be 70psi (49.30 meter head).

FLOW VELOCITY CRITERIA.

Maximum velocity in a main line becomes more pronounced and water hammer occurs with pressure usually start to drop off when velocities reach 3m/s.(walski and others 2003).The threshold design velocity for self-cleaning drinking water distribution system is set at 0.4m/s. This value is considered conservative hence a regular occurring velocity of 0.2ml/s or less may be enough. Hence a range of (0.2 – 1.5m/s) is adequate.

HYDRAULIC LOSS GRADIENT.

Based on the American water works association (AWWA) recommendations (Akdogen,2005) the following criteria apples.

Table 2.1 **HYDRAULIC LOSS GRADIENT.**

S/N	PIPE DIAMETER (MM)	HYDRAULIC.LOSS GRADIENT (M/KM).
1.	80	50
2.	100	35
3.	125	25
4.	150	15.22
5.	200	6.62
6.	250	2.88
7.	300	1.25
8.	350	0.54

PER CAPITAL DAILY WATER CONSUMPTION.

Analysis indicates that per capita daily water consumption is higher during dry season than rainy season in north western Nigeria. The proportion of households minimum daily requirement recommended by the world health organization (Dieterich& Henderson,1963) is 150 liters per day, increases from 29% during the rainy season to 67% during the dry season.

METHODOLOGY.

THE DATA COLLECTION

Two types of data were collected to carry out the study, primary and secondary data. primary data is the observation of the water distribution network in the service area of Batagarawa town ship followed by the contour lines file (km2) from Google Earth to elevation file(gpx), to see elevation of the reservoir, pipes, pumps and nodes of the WDN system. Secondary data is the search activity through literature reviews, e.g population data were collected for the years 1990 2000,and 2020 from European commission's joint research center as shown in table 2.0 below.

Table.**3.1.** Batagarawa – population Trends and Demographic – city facts.

Year	Estimated population	Average 10 years growth%
1990	4,265	NA.
2000	4,900	14.9%
2020	5,702	7.9%
2030	7,229	26.8%
2040	8,962	24%

Sources: JRC, European commission joint research center.
hEEPS://do;.org/10.5194/essd – 9 – 927 – 2017.

DATA PROCESSING.

After collecting the required data and converting the contour lines to elevation, input all into Epanet 2.0 software for simulation which calculates water demands, fluctuations in water requirement, water supply, and the reservoirs cumulative contents from 2020 until 2040.The data inputs required are network map nodes/junctions, elevations, lengths of distribution pipes, the pipes diameter, type of pipe used, pump characteristics reservoir shape and size and water demand on each nodes, after successfully imputing the required data the program will automatically analyze some of the result data and the outputs obtained: Hydraulic head for each point, pressure velocity and head loss unit.

Google Earth pro.

The google Earth pro was used to get the location of the area and enable extraction of contours for elevation generation of the water distribution layout. Analysis of calculations with software tools in the analysis of Batagarawa clean water distribution systems, Calculations are need for the projection population growth up to 2040.The software Epanet 2.0 was used to calculate pipelines network modeling to simulate water hydraulic behavior in a water distribution pipe line system. The following steps was carried out for the simulation:

(a)Draw a water distribution network over the backdrop for Batagarawa layout to accommodate population projection.

(b)Edit the EPANET parameters such as length, diameters, roughness coefficient, water demand, Demand pattern, Elevation of the node, properties of the overhead tank.

(c)Set the simulation for 24 hours.

(d)Run the hydraulic analysis.
(e) Check the results and analysis.

THE PROJECTION OF POPULATION GROWTH.

The calculation of population growth projection is a method to determine the estimated number of consumers in the coming years. Geometric method of projection growth analysis for customer projection purposes, will be use to forecast the projection.

THE GOEMETRIC METHOD.

This method predicts data or other events whose development or a fast growth for customer projection purposes. This method is used when the number of subscribers shows a rapid increase over time. This method is appropriate for high population growth and rapid urban development.

Formula:

$P=Po(1+r)^{n}$ ....(1).

$R= Po(1+r)^{1/n}$ ....(2).

Where:
P=Total population in the nth year.
Po= Number of the current population
R=population growth rate per year (%)
N=number of projection years.

THE ARITHEMATIC METHOD.

This method is used when periodic data shows the number of increments (absolute number), which is relatively the same every year. This technique is used in cities with a relatively small area, economic rate, and low city development.

Formula

Pn = p (I-rn) (3).

Where:
Pn = Total population in the n^{th} years
Po = Number of the current population
r = Population growth rate per year (%)
n = Number of projection years.

THE EXPONENTIAL REGRESSION METHOD.

This method is almost the same as the Geometric method; the difference is that this method uses Numbers (9)

Formula:

$$Pn = Po.e^{rn} \quad (4)$$

Where

Pŋ = Total Population in the ŋ[th] year

Po = Number of current population

r = Population growth rate per year (%)

ŋ = Number of projection years.

E = Natural logarithm number (2.7182818)

THE CORRELATION COEFFICIENT TEST.

The selection of the population growth projection method above is based on statistical testing methods based on the correlation coefficient values the correlation coefficient is as follows.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{(n\Sigma x^2 - (\Sigma x)^2 (n\Sigma y^2 - (\Sigma y)^2)}}$$

(5).

Where:

r = correlation coefficient

ŋ = the amount of years

x = Total population of each year from the base year

y = Total population per projected year

The valve of r is a value close to +1. If r = 0 or close to 0, then the relationship between the two variables is very weak or there is no relationship. If r = 1 or close to 1, than the correlation between the two variables is positive and very strong.

RESULTS AND DISCUSSION.

Average population growth rate.

The population growth rate is used to assess an area's population growth, which will be used for planning projection water demand. The population growth rate for Batagarawa town based on the existing population obtained from JRC, European commission joint Research center for Batagarawa municipal area. The total population in 1990 = 4,265 inhabitants. The total population in 2000 = 4,900 inhabitants. The total population in 2020 = 5,702 inhabitants. The population growth rate (r) and population of inhabitants for the year 2030 and 2040 can be calculated as follow:

The population growth rate (r) using Geometry formula; n = 10yers.

$P_ŋ = Po(1+r)^n$ (6)

Where: n = number of years = 10 years

$$r = \left[\frac{In\,(\frac{pn}{po})}{10}\right] x\ 100\% = \left[\frac{In\,(\frac{5702}{4900})}{10}\right] x\ 100$$

r = 1.5%

population project for2030.

4.1 Geometric formula

Using equation 1 above $Pn = Po\,(1+r)^{ŋ}$

$Pn = 5{,}702\,(1+0.015)^{10}$

$P30 = 5{,}702\,(1.015)^{ŋ}$

= 5,702 x 1.161

= 6.617.4

Arithmetic method

Using equation 2 above Pn = P (1-rn)

$P_{30} = 5{,}702\,(1 – 0.015)$

$P_{30} = 5616$

Exponential regression formula

Using equation 3 above $Pn = Po\,e^{rn}$

$P_{30} = 5{,}702\,e^{0.015} = 5.702 \times 2.72^{0.015}$

$P_{30} = 5{,}702 \times 1.015$

$P_{30} = 5{,}788$

Population growth rate (r)

$$r = \left[\frac{in\,(\frac{5702}{4900})}{20}\right] x\ 100$$

r = 0.78%

For population projection of 2040.

(a) Geometric formula.

$P_ŋ = Po\,(1+r)^n$

$P_{40} = 5{,}702\,(1.015)^{20}$

$P_{40} = 7{,}679.8$

(b) Arithmetic formula.

$P_ŋ = P(1-rn)$

$P_{40} = 5702\,(1-0.0078)$

$P_{40} = 5657.5$

4.2 Exponential regression formula.

$Pn = Po\ e^{rn}$

$P_{40} = 5.702 \times 2.72^{0.0078}$

$= 5,746.7$

Table 4.1 below shown the results applying Geometric, Arithmetic and exponential method to the population data.

Table 4.1

Year	Population Projection methods		
	Geometric	Exponential	Arithmetic
2030	6,617	5,788	5616
2040	7,680	5,747	5658

CORRELATION COEFFICIENT TEST.

Table 4.1 above depicts geometric has the highest population and arithmetic has the lowest result. To determine which method is suitable to use in the projection years, the correlation coefficient calculation is carried out. The formula is obtained from equation 5 the calculations is shown below.

Table 4.2 Regression determination data.

Year	n	Geometric method				
		Total Population	Y	Xy	X^2	Y^2
2020	0	5,702	0	0	0	0
2030	10	7,229	6,617	47,834,293	52,258,441	43,784,689
2040	20	8,962	7,680	68,828,160	80,317,444	58,982,400

Exponential method

Year	n	Total Population	Y	Xy	X^2	Y^2
2030	10	7,229	5,788	41,841,452	52,258,441	33,500,944
2040	20	8,962	5,747	51,504,614	80,317,444	33,028,009

Arithmetic method.

Year	n	Total Population	Y	Xy	X^2	Y^2
2030	10	7,229	5616	40,598,064	52,298,441	31,539,456
2040	20	8,962	5658	50,706,996	80,317,444	32,012,964
Sum.		16,191	11,274	91,305,060	132,575,885	63,552,420

Table 4.3 Conformity test of the population projection.

No	Conformity Test	Methods		
		Geometric	Arithmetic	Exponential
1	Correlation coefficient (r)	0.94770	0.9424	0.94158

From the table above the correlation coefficients for population projection for geometric indicate a higher valve which is 0.94770, which is more close to +1, which means that the two variables have a strong linear relationship for projection. The other two methods Arithmetic and exponential indicate a lower values than geometric projection, therefore the geometric projection was chosen for the projection of water demand in Batagarawa township until 2040.

The existing conditions of the distribution system in Batagarawa township.
PIPES AND NODAL OUTLETS LAYOUT.

Figure4.1 above display a map of the studied area from Google map. Indicating pipes nodal outlets.

NODAL DEMAND ANALYSIS.

The water distribution of Batagarawatownship Network consist of pipes, nodes and nodes elevation with supply from gravity overhead tanks every household uses nodes along the network as a source of supply the analysis of Demand at every nodes within the system is as follow:

Population projection for 2040 = 7,680 population from table 4.1.

Per capital daily water demand = 250.5 liters (67% increase for dry season as explained in section 2.5.

Number of Nodes in distribution system = 30

1) Population per Node

$$\frac{7{,}680}{30} = 256.0 = 256$$

2) Daily water Demand

   = 251 x 256 = 64,256 L/d

   $= \frac{64{,}256}{60 \; x \; 60 \; x \; 24} = 0.74 L/s$

3) Fire Demand (10%)

   = 0.074L/S

4) Waste Demand (5%)

   = 0.037L/S

5) Un accounted for water demand (ufw) (15%) = 0.111 L/S

: Total Nodal demand

= 0.74 x 0.074 x 0.037 x 0.111 = 0.96L/S

Running water Distribution Simulation.

Using theEpanet2.0 software, the pipe lengths, pipe diameter, Node demand, Nodes elevation, reservoir elevation, tank elevation data were inputted and the simulation was run successful for 24hours.

Epanet Simulation Results.

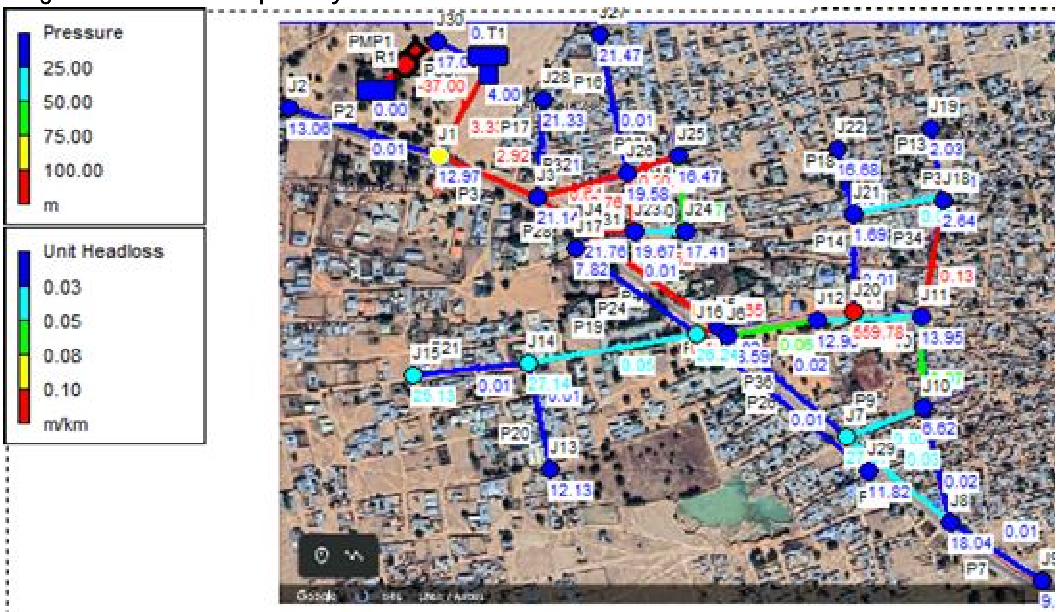
By using the Epanet 2.0 software, the following is the result of water distribution Network which indicates the different color of the component during peak hour Simulation.

Table 4.4 Nodal output Results.

Network Table - Nodes **NODES OUTPUT RESULTS.**

	Elevation	Base Demand	Demand	Head	Pressure	Quality
Node ID	m	LPS	LPS	m	m	
Junc J1	557.7	0.96	0.96	570.67	12.97	0
Junc J2	557.6	0.96	0.96	570.66	13.06	0
Junc J3	543.7	0.96	0.96	564.84	21.14	0
Junc J4	541.8	0.96	0.96	563.56	21.76	0
Junc J5	541.7	0.96	0.96	560.52	18.82	0
Junc J6	541.6	0.96	0.96	560.19	18.59	0
Junc J7	533.1	0.96	0.96	560.17	27.07	0
Junc J8	542.1	0.96	0.96	560.14	18.04	0
Junc J9	550.8	0.96	0.96	560.13	9.33	0
Junc J10	553.5	0.96	0.96	560.12	6.62	0
Junc J11	546.1	0.96	0.96	560.05	13.95	0
Junc J12	547.2	0.96	0.96	560.1	12.9	0
Junc J13	548.1	0.96	0.96	560.23	12.13	0
Junc J14	533.1	0.96	0.96	560.24	27.14	0
Junc J15	535.1	0.96	0.96	560.23	25.13	0
Junc J16	534.1	0.96	0.96	560.34	26.24	0
Junc J17	552.5	0.96	0.96	560.32	7.82	0
Junc J18	537.2	0.96	0.96	559.84	22.64	0
Junc J19	533	0.96	0.96	559.83	26.83	0
Junc J20	534	0.96	0.96	559.78	25.78	0
Junc J21	548	0.96	0.96	559.79	11.79	0
Junc J22	543.1	0.96	0.96	559.78	16.68	0
Junc J23	544.2	0.96	0.96	563.87	19.67	0
Junc J24	546.5	0.96	0.96	563.91	17.41	0
Junc J25	547.5	0.96	0.96	563.97	16.47	0
Junc J26	544.5	0.96	0.96	564.08	19.58	0
Junc J27	542.6	0.96	0.96	564.07	21.47	0
Junc J28	543.5	0.96	0.96	564.83	21.33	0
Junc J29	548.5	0.96	0.96	560.32	11.82	0
Junc J30	557	0.96	0.96	574	17	0
Resvr R1	537	#N/A	-0.77	537	0	0
Tank T1	570	#N/A	-28.03	574	4	0

Fig 4.2 Nodal frequency distribution results

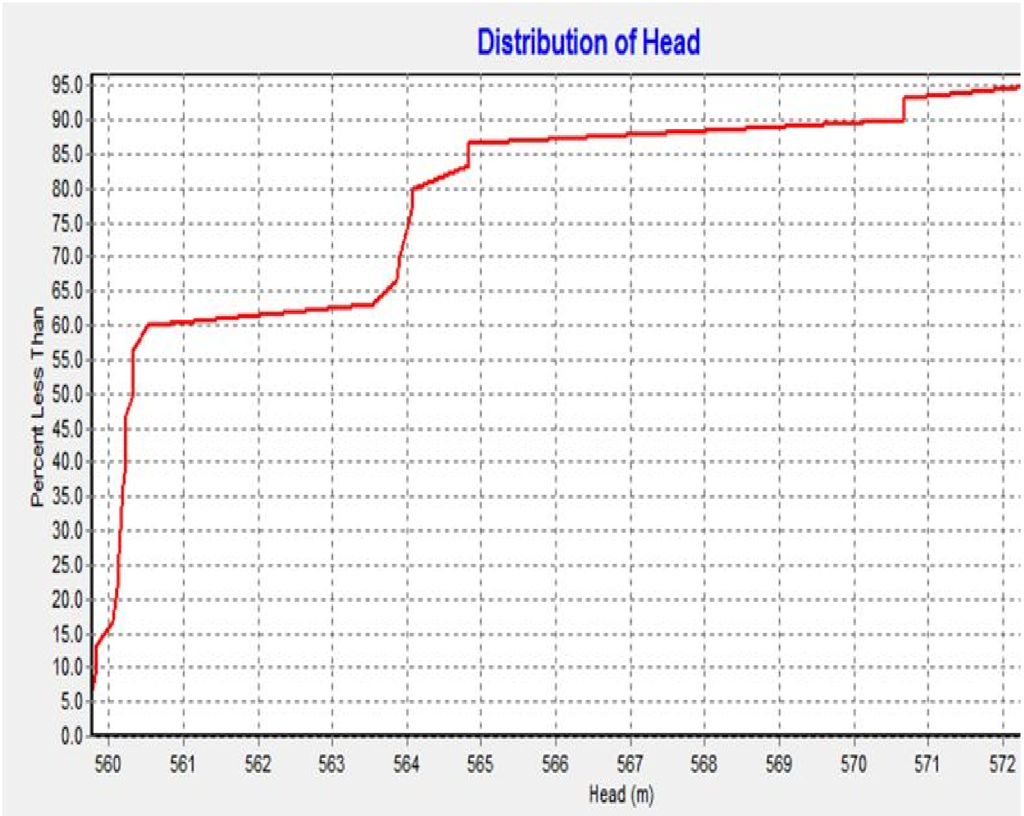


LAYOUT MAP RESULTS FOR NODES PRESSURE AND PIPES UNIT HEAD LOSS.

Table 4.5 Pipe Output Results.

Network Table - Links PIPE OUTPUT RESULTS.

	Length	Diameter	Roughness	Flow	Velocity	Unit Headloss	Friction Factor
Link ID	m	mm		LPS	m/s	m/km	
Pipe P1	1000	200	150	27.84	0.89	3.33	0.017
Pipe P2	2000	200	150	0.96	0.03	0.01	0.027
Pipe P3	2000	200	150	25.92	0.83	2.92	0.017
Pipe P4	2000	200	150	18.24	0.58	1.52	0.018
Pipe P5	1000	200	150	1.83	0.06	0.02	0.025
Pipe P6	2000	200	150	1.47	0.05	0.01	0.026
Pipe P7	2000	200	150	0.96	0.03	0.01	0.027
Pipe P8	1000	200	150	1.68	0.05	0.02	0.025
Pipe P9	1000	200	150	-2.78	0.09	0.05	0.023
Pipe P10	1000	200	150	3.5	0.11	0.07	0.023
Pipe P11	1500	200	150	-2.26	0.07	0.03	0.024
Pipe P12	1500	200	150	-3.22	0.1	0.06	0.023
Pipe P13	1500	200	150	0.96	0.03	0.01	0.027
Pipe P14	1500	200	150	-0.96	0.03	0.01	0.027
Pipe P15	1000	200	150	-3.39	0.11	0.07	0.023
Pipe P16	1500	200	150	0.96	0.03	0.01	0.027
Pipe P17	1500	200	150	0.96	0.03	0.01	0.027
Pipe P18	1000	200	150	0.96	0.03	0.01	0.028
Pipe P19	2000	200	150	2.88	0.09	0.05	0.023
Pipe P20	1500	200	150	0.96	0.03	0.01	0.027
Pipe P21	1000	200	150	0.96	0.03	0.01	0.028
Pipe P22	500	200	150	11.52	0.37	0.65	0.019
Pipe P23	1000	200	150	1.83	0.06	0.02	0.025
Pipe P24	2000	200	150	-0.96	0.03	0.01	0.027
Pipe P25	1000	200	150	1.83	0.06	0.02	0.025
Pipe P26	1000	200	150	1.83	0.06	0.02	0.025
Pipe P27	1000	200	150	2.13	0.07	0.03	0.024
Pipe P28	2000	200	150	11.45	0.36	0.64	0.019
Pipe P29	1000	200	150	-7.75	0.25	0.31	0.02
Pipe P30	1000	200	150	-2.43	0.08	0.04	0.024
Pipe P31	1000	200	150	6.28	0.2	0.21	0.021
Pipe P32	1000	200	150	-12.55	0.4	0.76	0.019
Pipe P33	1000	200	150	4.35	0.14	0.11	0.022
Pipe P34	1700	200	150	4.8	0.15	0.13	0.022
Pipe P35	1000	200	150	2.88	0.09	0.05	0.023
Pipe P36	2000	200	150	-0.96	0.03	0.01	0.027
Pipe P37	1000	200	150	5.76	0.18	0.18	0.021
Pipe P38	300	200	150	-0.19	0.01	0	0.038
Pump PMP1	#N/A	#N/A	#N/A	0.77	0	-37	0



Nodes pressure head distribution graph.

Fig 4.3, Nodes pressure Head Distribution Graph.

From table 4.4 figure 4.2, figure 4.3 and table 4.5,the pressure output for all the nodes are adequate for service pressure criteria for small water supply systems such as Batagarawa layout, except node 10 with pressure of 6.62m, this is due to higher elevation of node 10 on the layout, as indicated in fig 4.2. Also from Table 4.5 for head loss iswithin the range required the unit head loss for 200mm pipe also are less than 6.62m/km which is okay. In general, the simulation results with Epanet 2.0 on the water distribution network of Batagarawa ran well and successfully for 2040 water projection demands with 200mm diameter PVC pipe over head tank of 10m above ground level, reservoir level of 20m below ground level and pump head of 30m. anywhere the nodes did not deliver adequate water to the consumers along the distribution the velocityneed to be accelerated by reducing the pipes diameter and add more pump station and reservoirs at the location where the velocity did not meet the criteria.

CONCLUSIONS.

5.1 Overall, the simulations show that water pressure has complied with standards that were mentioned in 2.2 and 2.3 with the layout of using 200mm diameter PVC pipe, and the population projection results based on the geometric method, it is predicted to supply enough water to approximately 8,962 people in the service area, and also the hydraulic loss gradient and velocity are adequate as stated in 2.3 and 2.4.

Acknowledgement

We would like to thank the former director ministry of water Resources Katsina and the staff for providing the data and their invaluable assistance, we would also like to thank the staffs of Batagarawa Local Government area Katsina for their support and guidance during the process of writing this journal.

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