International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

Evaluating Hydraulic Performance Of Water Supply Distribution Network: A Case of Asella Town, Ethiopia

Shambel Belachew[a], Tadele Shiferaw[b], Dr.Dawud Temam[c],and Habtamu Diriba[d]

[a]School of Graduate Studies, Jimma Institute of Technology, School of Civil and Environmental Engineering,Hydraulic Engineering studies, Jimma University, Oromia, Ethiopia

[b]Jimma University, School of Civil and Environmental Engineering, Chair of Hydrology and Hydraulic Engineering,Oromia, Ethiopia

[c]Jimma University, School of Civil and Environmental Engineering, Chair of Hydrology and Hydraulic Engineering,Oromia, Ethiopia

[d]College of Environmental Science and Engineering, State Key Laboratory of Pollution Control and Resource Reuse Study, Tongji University, Siping Rd 1239, Shanghai, 200092, PR China

Submitted: 15-10-2021 Revised: 28-10-2021 Accepted: 30-10-2021

ABSTRACT

Population growth in the town usually exerts enormous pressure on existing water supply systems. The continuous and repeated deficiency in the performance of the water network becomes one of the most critical issues in the water supply sector that requires immediate action. Asella town water supply system has problems related to water supply coverage, water quantity, velocity, and system pressure. The main objective of this study is to evaluate the hydraulic performance of Asella town's existing water supply distribution system with respect to pressure and velocity using Bentley Water GEMS v8i software. The average daily per capita water consumption and water supply coverage of the town in 2020 G.C is 35.31 l/p/d and 42.249% respectively.The simulated result for extended period simulation at peak hour consumption showed that the performance of distribution system related to pressure 47.08% for pressure value (<15m), 32.92% for pressure value (15-60m) and 20% for pressure value (>60m) head and the pressure at minimum consumption hour is 10% for pressure value (<15m), 45.85% for pressure value (15-60m) and 44.15% for pressure value (>60m. The velocity of pipe flow at peak hour consumption showed that 79.56% ofthe velocity (<0.6m/s), 14.09% ofthe velocity range (0.6-2m/s) and 6.35% ofthe velocity (>2m/s). From the total 650 nodes in the model, 306 nodes receive water with less than 15m pressure head of water and it indicates the critical point showing that needs a modification. The amount of water which actually reached the consumers on average from 2016 G.C to 2020 G.C is 64.76% of the total annual water production. It is recommended that, the water utility hasadded new water source to deliver adequate water and add parallel pipes or increasing its diameter to deliver water with the required pressure.

Key Words: Asella Town; Hydraulic Model; Water Distribution Network; Water GEMS

Corresponding author: E-mail: shambelbelachew2007@gmail.com Tel:+251-926201181.

I. INTRODUCTION

Water is one of the most essential commodities of every living being in the world.Globally, the population using piped drinking water supplies between 2000 and 2017 year is increased from 3.5 billion to 4.8 billion, this equates to an average of 85,000 people per day over a 17-year period [12]. While over the same period, the population using non-piped drinking water supplies increased from 1.6 billion to 2.2 billion. In Ethiopia accessibility is equally low in rural (5%) and urban (72%) there is a 67 percentage point gap between rural and urban areas [12].

According to second Growth and Transformation Plan (GTP-2) the goal were set to

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

provide rural water supply access with minimum service level of 25 l/c/day within a distance of 1 km from the water delivery point for 85% of the rural population of which 20% are provided with rural piped systems and to provide urban water supply access minimum service level of 100 l/c/day for category-1 towns/cities, 80 l/c/day for category 2 towns/cities, 60 l/c/d for category-3 towns/cities, 50 l/c/day for category-4 towns/cities, up to the premises and 40 l/c/day for category-5 towns/cities within a distance of 250 m with piped system for 75% of the population [9]. The total average daily per capita water consumption of the Asella town is 35.31 l/c/day which is very low as compared to the value set by MoWIE (2019) for GTP-2which 60 l/c/d for category-3 town.

Water distribution systems can be either looped or branched. Looped systems are generally preferable to branching systems because pipe breaks can be isolated and repaired with minimal impact on users outside the immediate area of the looped system. In a branched system, on the other hand, all users downstream from the break will have their water supply cut off until the repairs are completed.[10]. Water distribution systems are required to supply water to domestic, commercial, and industrial entities above or at a threshold pressure with consumer demands that vary throughout the day, weak, season and year. The minimum pressure that should be observed at junctions throughout the system varies depending on the type of water consumption [8].

According to the report of Asella town water supply service enterprise the existing Asella town water supply system is defined as one pressure zone. The town has a geodetic difference of about 550m, from south to north; necessitating for creation of pressure zoning of the distribution network and hence resulted in unbalanced supply from the existing distribution network. Due to the low pressure of water in the distribution network, consumers at relatively higher spots and expansion areas of the town cannot get water.

Models are used to predict pressures under specific demand conditions and under a wide variety of scenarios to identify low pressures and to select infrastructure that will improve flow or less pressure deficiency [4]. Hydraulic modeling simplifies the analysis of water distribution system and it helps to predict uncertainties in present and future demands of existing distribution systems [11]. In Assella town damaged water pipe and topography of the area are the major problems which can cause low water pressure and uncertainty of water demand in existing water supply distribution system. So, to increase the sustainability, evaluation of hydraulic performance in the distribution system is significant.

II. MATERIAL AND METHODS

2.1. Description of the Study Area

Asella town is situated in the Arsi zone, being the zonal capital, at a road distance of 175km from Addis Ababa or 75km from Adama town. It is accessed through asphalt road running from Addis Ababa via Adama to Bale Robe. The town is bounded by geographical coordinates between UTM $39^0$7’0”E to $39^0$9’0”E longitude and $7^0$54’30”N to $7^0$58’30”N latitudes.

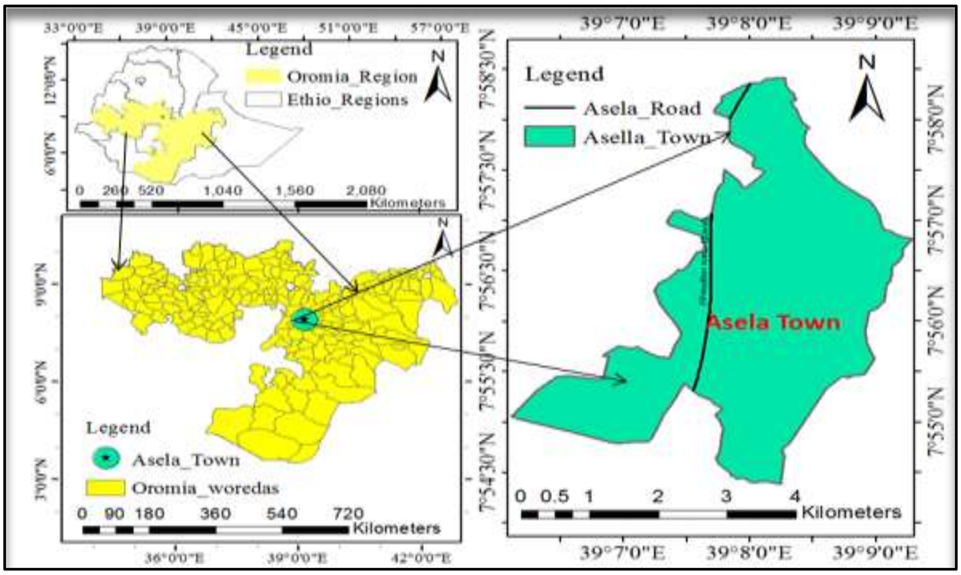


Figure 1.Map of the study area (adopted from ArcGIS).

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

2.2. Materials used

2.2.1. Equipment

The Global Positioning System instrument was used to collect the required elevation data during pressure reading. Pressure readings were done using pressure gauge which is commonly taken in the selected points of the distribution system.

2.2.2. Software: Water GEMS

The model is something that represents things in the real world and computer model uses mathematical equations to explain and predict physical events. Modeling of water distribution systems can allow determining system pressure and flowing rate under a variety of different conditions without having to go out and physically monitor the system [2].

Bentley water GEMS V8i is selected for this study because of the following reason:- Graphical user interferences as compared to Epanet software, integration with external software, like Auto CAD and ArcGIS and requires less effort and shorter time to build a model than others.

2.3. Data Collection

The data collection process was performed using both primary and secondary data collection techniques to get the required information. Water production and consumption data used to evaluate water losses and water supply coverage of the town. Survey, design data, and the town existing water distribution network layout were used to construct the model using Water GEMS v8i software and the pressure for ten sample nodes was measured by using a pressure gauge to calibrate the model.

2.4. Data Analysis

Primary and secondary data can be analyzed both qualitatively and quantitatively. Qualitatively, the data's are analyzed with the help of tables, charts or in words and quantitative data was analyzed with the help of Bentley Water GEMS v8i software. GPS and Arc map 10.1 is used to collect data and to generate maps of the study area respectively. Qualitative data were interpreted with the help of Microsoft Excel. The volume of water consumed for domestic purpose is estimated by converting the annual consumption data to average daily per capita consumption using the projected total population figure during (2020 G.C).

2.4.1. Water Supply Coverage Analysis and Water Loss Analysis

2.4.1.1. Water Supply Coverage Analysis

The volume of water consumed for domestic purpose is estimated by converting the annual consumption data to average daily per capita consumption using the projected total population figure during (2020 G.C). The following formula was applied for the determination of per capita consumption (liter/person/day) [5].

$$\text{Per capital water consumption} = \frac{\text{Annual consuption } (m*^3*1000\frac{l}{m^3}}{\text{Population } *365} \quad \text{………..………} \quad \text{(Eq.3.1)}$$

The water supply coverage of the town has been evaluated based on annual water production and annual water demand as follows:-

$$\text{Water supply coverage} = \frac{(\text{annual production } *100\ \%)}{\text{Annual demand}} \quad \text{…………………..…………} \quad \text{(Eq.3.2)}$$

2.4.1.2. Water Loss Analysis

The water loss analysis of Asella town was evaluated in aggregated form in numerical as well as a percentage of the non-revenue water, which was obtained from the total water production and water consumption. Unaccounted-for-water, expressed as a percentage, is calculated as the amount of water produced by the public water system minus the metered customer use divided by the amount of water produced multiplied by 100 as follow [7].

$$\text{Total water loss } (\%) = \frac{(\text{Total water produced } - \text{Total water billed })*100}{\text{Total water produced}} \text{…………} \text{……. (Eq.3.3)}$$

2.4.2. Model Representation

The model is constructed using Water GEMS software by giving all the necessary inputs collected from Asella town water supply distribution network layout, Pipe data, such as pipe diameter (mm), C-value and length (m) are assigned to the network. Input nodes are elevation (m), water demand (LPs) and time pattern. Pump head (m) and flow (LPs) are required data for the construction of the pump curve. Figure 2 shows the constructed model of the water supply network from source to the WTP and WTP to service reservoir.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

Figure 2. Layout of the Existing water system of Asella town.

2.4.3. Hydraulic Modeling of water supply Distribution Network using Bentley Water GEMS V8i

Analysis of water distribution network provides the basis for the design of new systems, the extensions, and control of existing systems. The flow and pressure distributions across a network are affected by the arrangement and sizes of the pipes and the distribution of the demand flows.

2.4.3.1. Assigning Base Water Demands to Each Node

To assign base demand to each supply node, it is necessary to estimate base demand of each node in the distribution network by following the steps below:

Step One: Population Forecasting: -In order to avoid over or underestimation of the future population 2007 CSA population projection using 1994 medium variant growth rate set for Oromia region was used. The exponential population forecasting method is used to forecast the current Asella town population.This method is useful for projections on a short term basis hence extrapolation over a five-year period makes it suitable. It is a hybrid of the geometric and arithmetic methods and corrects the anomalies of the methods [1].

$$P_n = p_0 E^{rn} \ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq.3.4)}$$

Where: Pn=population at n decades or year, PO=initial population (from census), are=growth rate, and =decade or year, e=constant exponential value (2.718).

Step Two: Identification of a number of houses around each supply node: -In ArcMAP, the orthomap of Asella town was opened and the town water supply distribution network constructed in Water GEMS by using model builder was exported into the AutoCAD DXF file and imported into ArcGIS was overlapped with it.

$$\text{Average people per house} = \frac{\text{Total current population}}{\text{Total number of houses}} \ldots\ldots\ldots\ldots \text{(Eq.3.5)}$$

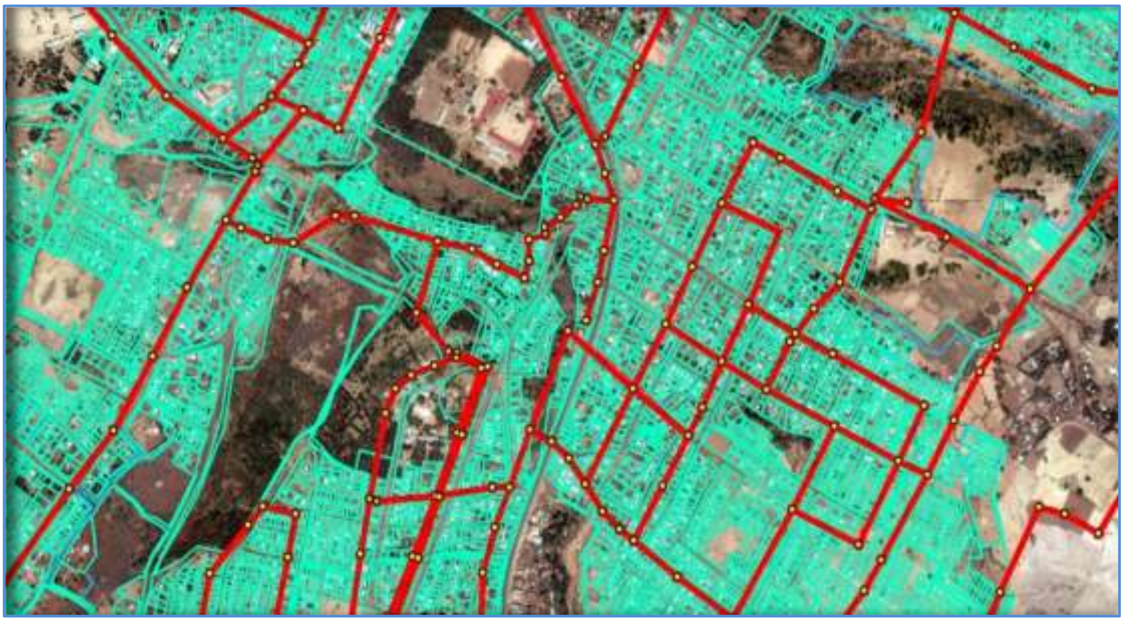


Figure 3. Distribution network overlapped on the map of the Asella town.

Step Three: Determination number of people per single-family residence each supply node: - Currently, the population of the town is about 97,118 peoples. The total number of houses identified was 20,475, giving an average count of 4.74 people per house. To calculate the population served to each node multiply assigned by that node by the average number of people in each house as follows:

$$\text{Number of people for supply} = \left(\begin{array}{c}\text{Number of houses assigned by} \\ \text{that node} * \text{average number of people} \\ \text{in each house}\end{array}\right) \text{Eq.3.6)}$$

Step Four: Determination of average day water demand of Asella Town: -Average water demand of the town was calculated by multiplying the average per capital demand with the estimated number of populations as follows

$$\text{ADD} = \text{Per capital water consumption} * \text{total population}$$

Step Five: Determination base water demand in each supply node: -After the average daily water demand of the system was determined, base water demand for the particular supplied node were calculated by using equation 3.7 and finally assigning into the node manually.

$$\text{Base demand for supply node} = \frac{\text{The population served by node}}{\text{Total population}} * \text{ADD} \ldots\ldots\ldots\ (\text{Eq.3.7})$$

2.4.3.2. Assigning Roughness Coefficients to Pipelines

Hazen-William roughness factors were used to incorporate frictional losses and the following roughness coefficients are suggested for existing pipes, depending on age and the material and the remaining pipe sections are adjusted for their C-values.

2.4.3.3. Assigning Demand Patterns

The type of simulation used for this modeling is the extended period simulation to evaluate system performance over time. For such type of simulation, the demand patterns of the town for each node should be identified and the demand variation of each pattern has to be clearly set as well. The major demand patterns of the town are: Residential, Commercial, Public, and Industrial are the major ones.

2.5. Model Calibration

For model calibration and validation effort data were collected from field selected sample locations. This involves making minor adjustments to the input data, then the model accurately simulated the pressure rate in the system. Pressures are measured throughout the water distribution system using pressure gage instrument to use the data for model calibration.

2.5.1. Pressure Measurement

Pressures are measured throughout the water distribution system to monitor the level of service and to collect data for use in model calibration. In this study the pressure measurements were taken at a direct connection to the water main nodes and nearer to the supply main nodes at homes faucet as shown in figure 4 below.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

Figure 4. Pressure measurement at different location.

2.5.2. Network Simulation

Extended period simulations are used to evaluate system performance over time. Modeling tanks filling and draining, regulating valves opening and closing, and pressures and flow rates changing throughout the system in response to variable demand circumstances and automatic control strategies developed by the modeler are all possible with this type of analysis.

III. RESULT AND DISCUSSIONS

2.6. Water Supply Coverage Analysis and Water Loss Analysis

2.6.1. Water Supply Coverage Analysis

2.6.1.1. Average Per Capita Demand Coverage

The water supply coverage of the town is evaluated based on the average per capita consumption. The average water consumption per capita was derived from the town's annual consumption, which was aggregated from the individual water meter and the public tap. Thus, the annual water consumption data are converted to average daily per capita consumption using the population data of the town.Average daily per capita water consumption of the town in 2020 G.C was calculated from the total annual recorded consumption of the town by using equation 3.1.

$$\text{Per capita consumption (LCD)} = \frac{(1{,}251{,}806.00\text{m3} * 1000\text{l/m3})}{(97118 * 365 \text{ day})} = 35.31 \text{ lcd}$$

The average domestic water supply coverage of the town is 35.31 l/c/day. This average per capita consumption is very low as compared to the value set by MoWIE (2019) for GTP-2which 60 l/c/d for category-3 towns/cities within a distance of 250 m. The annual water demand for the year 2020 is 13427.49 m^3/day * 365 days which is 4901033.85m^3 and the annual water production of the town in 2020 G.C is 2070653m^3. So the water supply coverage is the ratio of annual water production and annual water demand.

$$\text{Water Supply Coverage}(\%) = \frac{2070653\,\text{m3}}{4901033.85\,\text{m3}} * 100 = 42.249\%$$

2.6.2. Water Losses Analysis

The total water loss for the town was calculated using the total annual water produced and distributed to the distribution system, as well as the water billed from individual customer meter readings.The water loss is usually expressed in terms of percentage unaccounted for water (UFW), loss per kilometer length of main pipes and loss per properties or number of connections. The total water loss has been evaluated based on the three measurement approaches as explained here below.

2.6.2.1. Total Water Loss Expressed as Percentage (UFW)

The total annual water produced and distributed to the system within the specified year of 2020 G.C is 2,070,653 cubic meters and the annual total water loss is 818,847 cubic meters that

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

accounts for 39.55 % of the total water production. As depicted in **figure 5** below the total annual water loss of the water supply system is 28.39% in 2016, 31.83% in 2017, 39.28% in 2018, 37.16% in 2019 and 39.55% in 2020 G.C.The average amount of water, which actually reached the consumers in Asella town accounts for only 64.76% of the total water produced. As it is shown**figure 5** below, non-revenue water from the system is varied from year to year due to the aging of pipe that leads to leakage, pipe bursting, installation (extension of network in new area) and illegal connection.

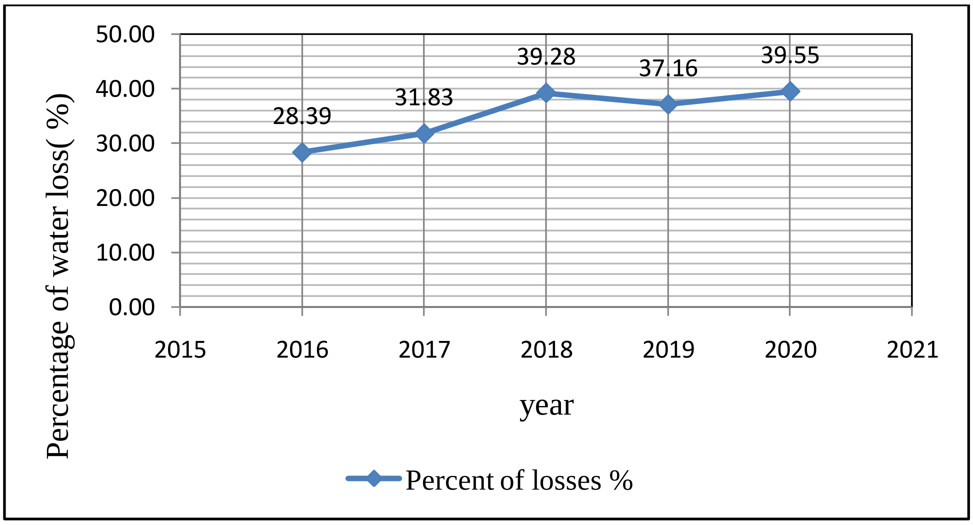


Figure 5. Annual water losses of the town.

2.6.2.2. Water Loss Expressed as Per Number of Connection

Water loss expressed as a percentage is an appropriate means to show the extent of the loss within a given environment, but it is not a good indicator for comparing the losses from one area to another. Taking the total number of connections in the town as 18,200 the water loss per connection for the similar duration was derived as,Water loss = 818847 x1000÷ (18200×365) = 123.26 liter/connection /day. This figure shows as litters per service connection per day increase water losses also increases.

2.6.2.3. Water Loss Expressed as Per Length of Pipes

Water loss expressed as per kilometer length of main pipes is also used as indicator to compare water loss. This indicator is usually recommended for non- densely populated areas. The total length of pipes of greater or equal to 50mm diameter have been used to evaluate total water loss of the entire town is 98.021km. Using total pipe length of the entire town, the water loss per kilometer length of main pipes was derived to be 818847 ÷ (98.021 km×365days) = 22.8871m^3/km/day**.** This shows that as the length of the pipe increases the amount of water losses per day increases.

2.6.2.4. Possible Reasons of High Water Loss

Regarding the system efficiency of the existing distribution system, the data obtained from the water supply service enterprise bill data has been used to estimate the water loss within the system. As depicted in **figure 5** above the losses of water within the system don't have a uniform trend of increase or decrease instead it undulate from year to year.

2.7. Model Calibration and Validation

2.7.1. Calibration of Hydraulic Network Model

Calibration is the process of comparing the model results to field observations and, if necessary, adjusting the data describing the system until model-predicted performance reasonably agrees with measured system performance over a wide range of operating conditions. Ten data sets were selected from field observation and from simulated results for calibrating the model.

2.7.1.1. Pressure Calibration

The degree of accuracy varies depending on the size of the system and the amount of field data and testing available to the modeler. Bentley (2008), states that the average difference of ±1.5m to a maximum of ± 5.0m for a good data set and ±

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

3.0 to ± 10m for a bad data set would be a reasonable target.

Table 1. Data arrangement for pressure calibration and time series with pressure networks.

S.NO	Sample Location pints	Location			Observed Pressure (m)	Computed Pressure	Difference pressure error	Measured Time	Scenario
		x (m)	y (m)	Elevation					
1	J-199	514382.24	875689.38	2542.42	10	15.65	5.65	6:30	Base scenario
2	J-208	513759.03	879858.54	2362.24	1	0.26	-0.74	7:15	
3	J-171	513621.56	875785.56	2521.1	23	26.67	3.67	7:45	
4	J-388	514393.67	878118.78	2451.26	16	18.42	2.42	8:30	
5	J-75	515792.26	879088.09	2462.73	12	9.01	-2.99	9:00	
6	J-233	513925.7	879367.74	2371.79	64	63.12	-0.88	10:00	
7	J-107	514094.97	877521.32	2488.24	40	45.08	5.08	10:45	
8	J-140	516035.76	878974.14	2485.12	35	37.7	2.7	11:30	
9	J-169	515469.79	877807.04	2514.32	8	9.27	1.27	12:00	
10	J-582	514749.45	877787.97	2458	9.5	11.01	1.51	1:00	
Average Error							1.769		

As shown in **table 1** above, computed values are within an average error of 1.769m pressure simulated observed values. Hence, the model is acceptable calibrated which is satisfied the setting pressure calibration and validation criteria under average level (average +1.5m to the maximum +5m). The agreement between the observed field data and the model result graphically sketched to show the overall relationship in between the two data sets as follows.

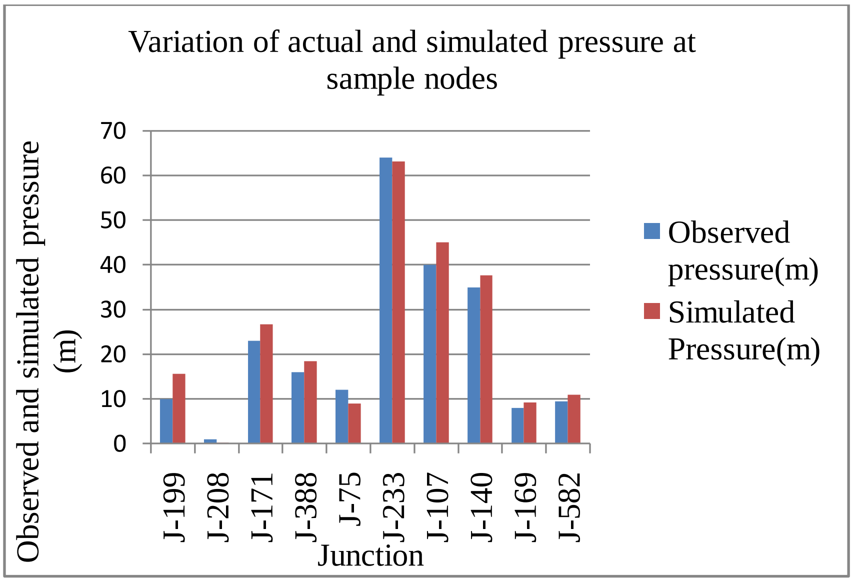


Figure6. Actual and simulated pressure at samples node.

Pressures were measured in the field in order to compare with the results of the distribution system. **Figure 7** below is a comparison plot of observed pressures versus calculated pressures at various distribution lines and taps throughout the system.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

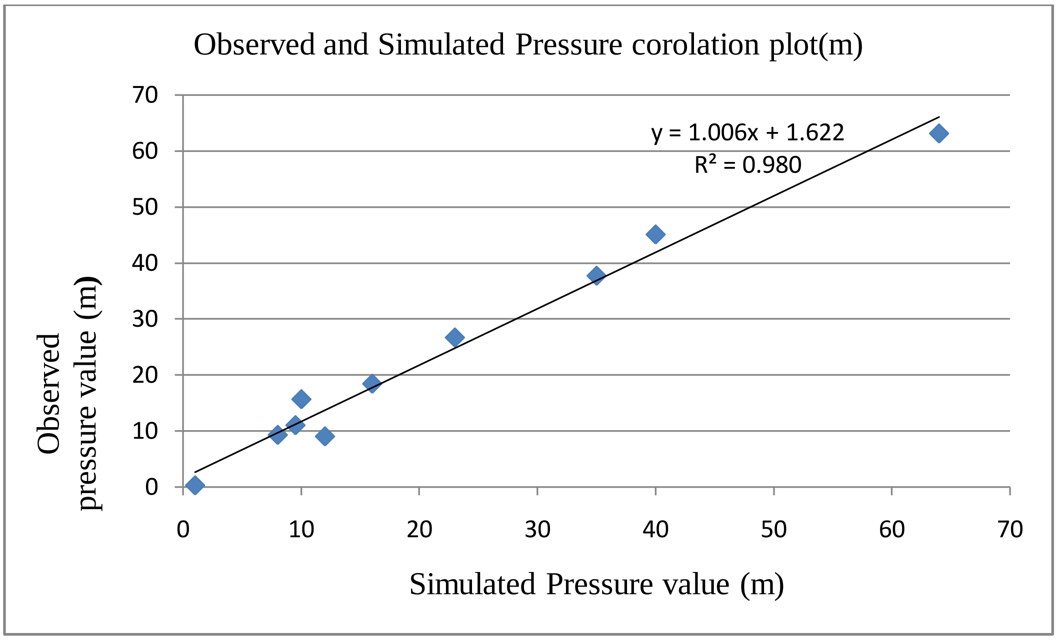


Figure 7. Correlation between observed and simulated pressure parameters.

The diagonal line on the plot represents the line of perfect correlation in **figure 7** above. Ideally, all the points should align themselves on this line; meaning that all observed pressures are equal to the computed pressures, giving a correlation coefficient of 1 that is the best correlation between observed and simulated. The linear correlation coefficient (R^2) of observed versus computed pressures is 0.9805. The coefficient of determination (R^2) value was 98.05%, it indicates that observed and simulated relation is strongly as values tend to 1(the computed pressures are within the acceptable limit).

2.8. Model Analysis

The system conditions have been computed over twenty-four hours with a specified time increment of one hour and starting model run time at 12:00 PM. The software simulates non-steady-State hydraulic calculation based on mass and energy conservation principle. The model is simulated for every one-hour time setup in the twenty-four hour duration. However, for the analysis the peak and minimum hour demand are simulated to identify the current problems of the system and to locate the critical points in existing water supply distribution network.

2.8.1. Hydraulic Parameter on Existing Water Supply Distribution Network

2.8.1.1. Pressure

In this study, the model run from the input of existing data a total node of 650 was reported from the project inventory dialog box. The minimum pressure adopted for this study is 15m of water head. As depicted in **Table 2** below about 306 out of 650 Nodes are below the minimum adopted system pressure. This indicates that the pressure within the distribution system is 47.08% of nodes are below the minimum desirable pressures during peak hour demand and these nodes are not capable of supplying the necessary demand to consumers and 20.00% of nodes are exceeded to maximum allowable pressures of 60m at normal condition as described in **table 5** under the methodology part. While 32.92% of nodes are within the permissible pressure ranges of minimum 15m and maximum 60m pressure head. At this peak hour level the water consumption demand expected to more over all the hour demands.

There are some reasons that are why the negative pressure is occurring in the water supply distribution system is as a result of the following: elevations difference, high demands, pipes of inadequate capacity (too small diameter), rough pipes (e.g. corroding iron pipes or pipes with a build-up of sediment), and equipment failures (e.g. Pumps and valves).

The low pressure nodes are normally those nodes which are locatedrelatively at high elevations and far from the supply points. Low pressure can cause reduction of quantities of water supplied to the consumer and entry of a contaminant or self-deterioration of water quality within the network itself a severe damage to public health.

As described in **figure 8** below the area highlighted by green color is indicate lower pressure (negative pressure) below 15m of water head, the area highlighted by aqua color is indicate permissible pressure range between15m to 60m water head and the area highlighted by red color are indicate pressure above maximum allowable operating pressures 60m of water head at normal condition

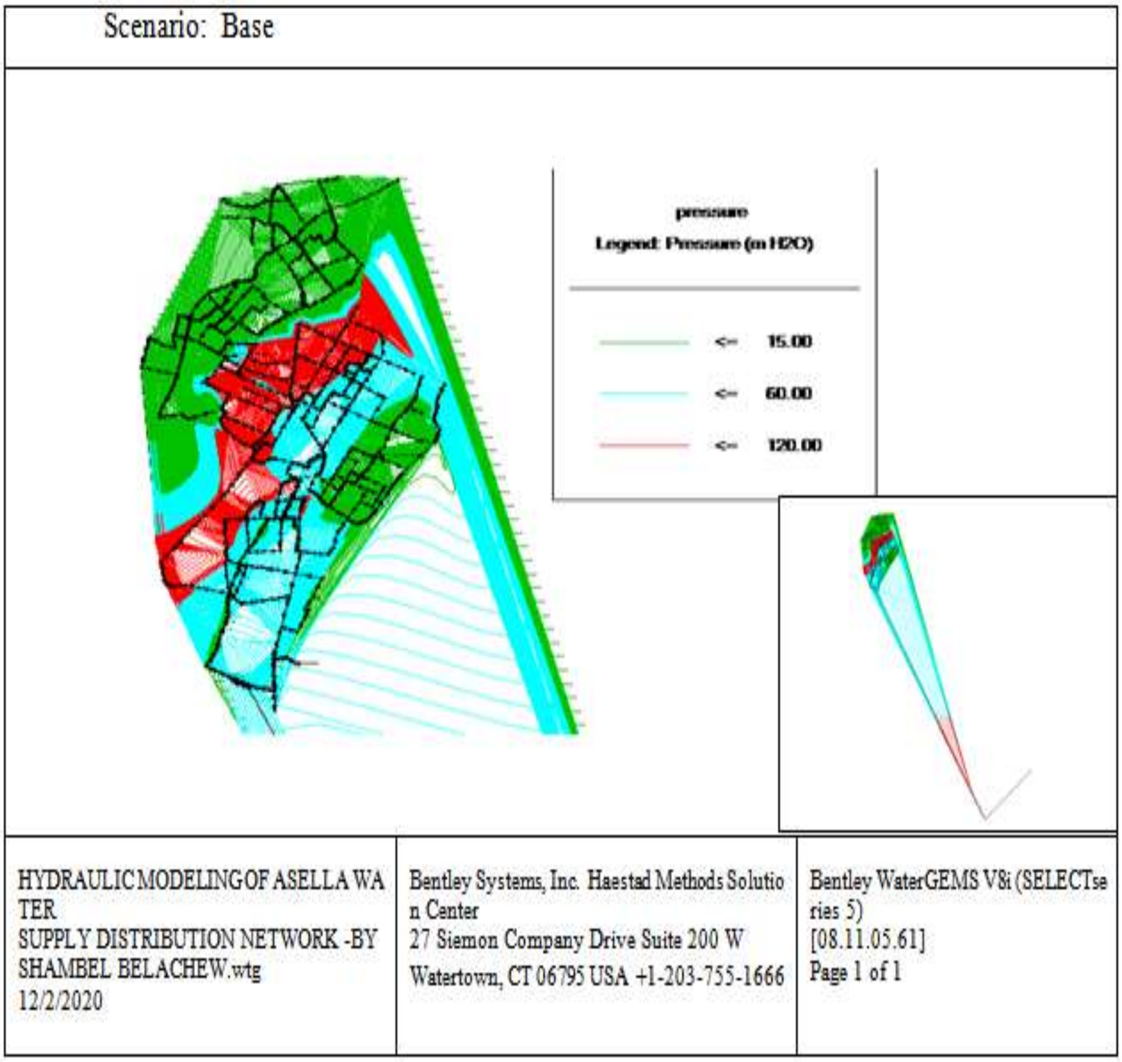


Figure 8. Pressure contour map of nodes at maximum consumption hours.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

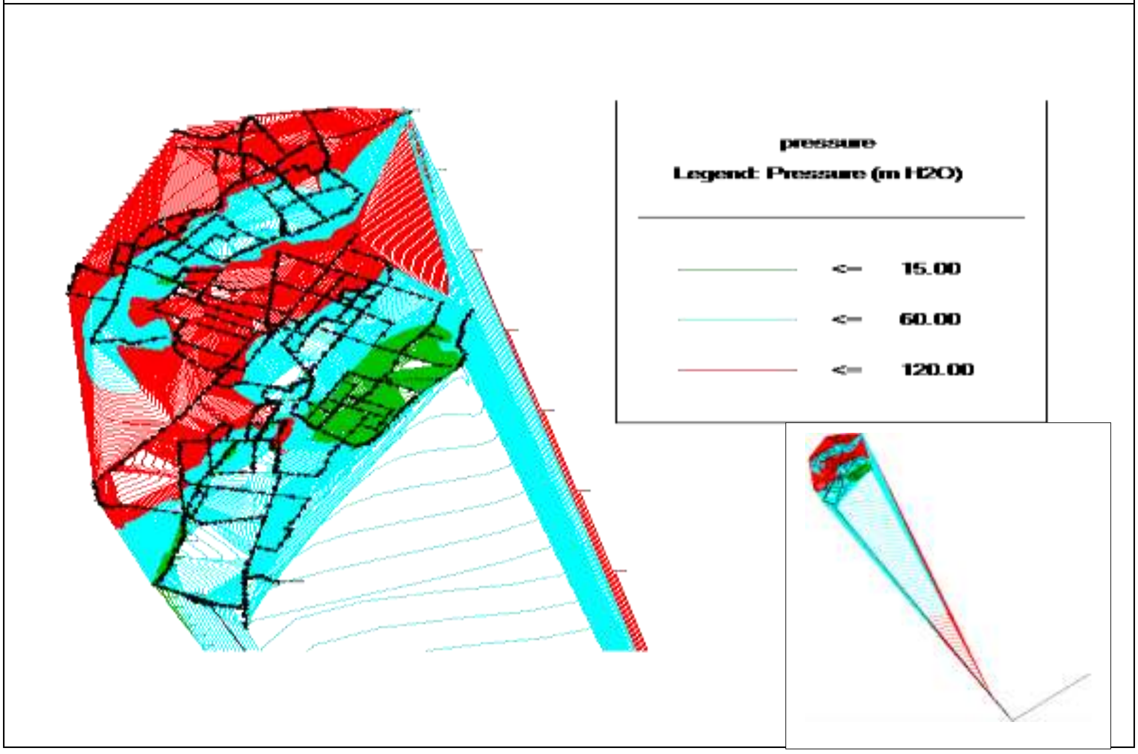
Table 2. Distribution of pressure at minimum and maximum consumption hours.

Pressure (mH2O)	pressure at minimum consumption hours		pressure at maximum consumption hours	
	Node number	Percentage (%)	Node number	Percentage (%)
<10	51	7.85	290	44.62
10-15	14	2.15	16	2.46
15-20	32	4.92	23	3.54
21-30	51	7.85	36	5.54
31-40	67	10.31	52	8.00
41-50	63	9.69	49	7.54
51-60	85	13.08	54	8.31
61-70	83	12.77	52	8.00
>70	204	31.38	78	12.00
	650	100.00	650	100.00

During low flow typically at mid-night distribution system of the case study is marked by excessive pressure. As shown in **table 2** above, **Figure 9** below and detailed in appendix D, 10% and 44.15% of nodes below minimum and exceed maximum allowable operating pressures in the distribution network respectively. Minimum pressure is also observed during low consumption period. Only 45.85% of nodes are received the water of optimum pressure at the low consumption hour. As compared to distribution of pressure at maximum consumption hour **table** 2 above, shows only 32.92% nodes are with permissible pressure due to excessive demand.

As described in **figure 9** below the area highlighted by green color is indicate lower pressure (negative pressure) below 15m of water head, the area highlighted by aqua color is indicate permissible pressure range between 15m to 60m of water head and the area highlighted by red color are indicate pressure above maximum allowable operating pressures 60m of water head at normal condition.

Scenario: Base



International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

HYDRAULIC MODELING OF AS ELLA WATER SUPPLY DISTRIBUTION NETW ORK -BY SHAMBEL BELACHEW.Wtg 12/2/2020	Bentley Systems, Inc. Haestad Me thods Solution Center 27 Siemon Company Drive, Suite 200 W Watertown, CT 06795 USA +1-203-755-1666	Bentley WaterGEMS V8 i (SELECTseries 5) [08.11.05.61] Page 1 of 1

Figure 9. Pressure contour map of nodes at maximum consumption hours.

According to this study output for Asella town, pressure zones (for elevated area, lower area and commercial or institutional area) may be better to see for modification. Because of during intermit supply pressure become above simulated pressure head. This also affects the hydraulic performance of the network.

Households located at higher elevations and close to reservoir site have got water at low water pressure. Variations of pressure during day and night can create operational problems, resulting in increased leakage and malfunctioning of water appliances. Reducing the pressure fluctuations in the system is therefore required [3]. The effect of distance and elevation in pressure distribution of selected nodes is given **figure 10**below.

Figure 10 below shows that, effects of distance and elevation in pressure distribution for selected junctions. The first (junction 199) and the last (junction 193) have an elevator and pressure head of 2542.42m a.s.l with 15.65m pressure and 2534.93m with 10.39m pressure respectively. When the elevation decrease from junction 199 to a lower point, pressure increases to that point and after the lowest point (at junction 142) elevation starts to increase and pressure starts to decrease and continue up to the last junction. At junction 176 elevationsstartwithdrops, but pressure suddenly increases.

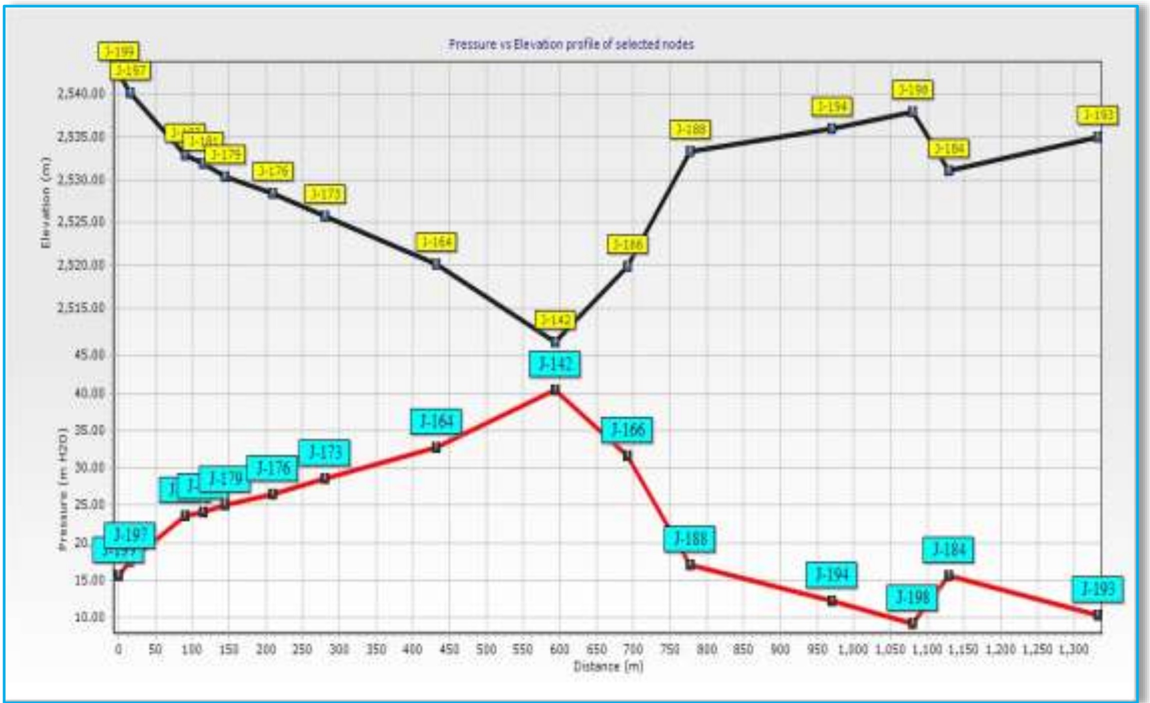


Figure 10. Profiles of pressure vs. Elevation of selected nodes showing distance from junction 199 to the farthest point.

The high value of pressures affects adversely the hydraulic performance of the distribution network at night time during low consumption period, the pressure in the system becomeshigher and it causes a pipe burst at the lower location. Also produce low velocities which accelerate the deterioration and corrosion of the pipes in the distribution system and leakage rate are expected to be high because at this time no water flow occurred in the distribution.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

2.8.1.2. Velocity

The velocity of water flow in a pipe is one of the important parameters in the hydraulic modeling, performance evaluation of the efficiency of water supply distribution and transmission line. Velocity distribution also varies with demand pattern changes. Water velocity should maintain at less than 2m/sec, in the distribution system and not more than 2.5 m/s in a transmission system. A minimum velocity of 0.6 m/sec had taken. At the peak hour demand the values are different as compared to the minimum consumption hour. The water supply system network velocity during peak hour demand is summarized in the **table 3** below.

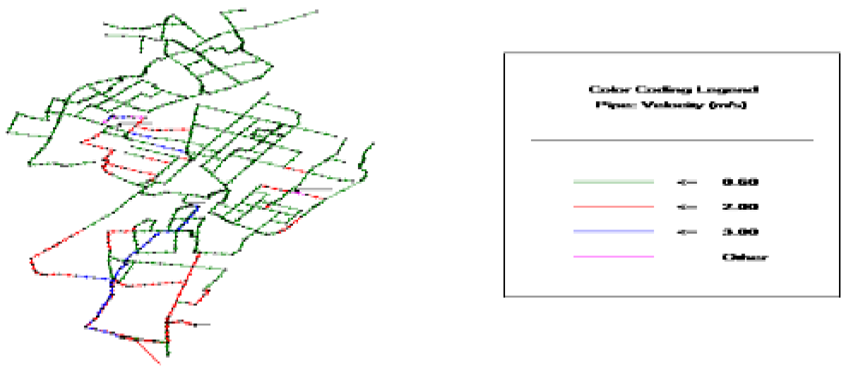
Table 3. Velocity Distribution in Pipeat peak hour demand.

Velocity range (m/s)	Count	Count (%)	Effect
≤0.6	576	79.56	Sedimentation problem
0.6-2	102	14.09	Normal
≥2	46	6.35	Erosion and high head loss occurred

As depicted in **table 3** above, during the peak hour demand situations about 6.35% of the pipes are failing to satisfy the permissible velocity or maximum velocity in distribution and transmission line (>2 m/s), in addition to that, 79.56% of the pipes also below the minimum velocity in a distribution line (<0.6 m/s). While, only 14.09% of the pipes are in the permissible velocity ranges. Velocity has also a great impact on water quality as turbidity and the likes.

Low velocities are undesirable because they lead to lower pipe flows, since discharge is a function of velocity. Also low velocities are undesirable for reasons of hygiene and sedimentation problem. In the opposite way, higher velocity, not more than 2.0 m/s and 2.5 m/s in distribution system and transmission system respectively to prevent erosion and high head losses.

Scenario: Base



HYDRAULIC MODELING OF ASE LLA WATER SUPPLY DISTRIBUTION NETWO RK -BY SHAMBEL BELACHEW.Wtg 12/8/2020	Bentley Systems, Inc. Haestad Method s Solution Center 27 Siemon Company Drive, Suite 200 W Watertown, CT 06795 USA +1-203-755-1666	Bentley WaterGEM S V8i (SELECTseri es 5) [08.11.05.61] Page 1 of 1

Figure 11. Velocity Distribution in Pipeat peak hour demand.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

In general the study area of water distribution system has some problems with respect to hydraulic network modeling. These are low pressure, high pressure, high velocity, and low velocity due to undersized and oversized service pipe diameter and inadequate water supply. The Low pressure problem is due to high elevation and undersized pipe diameter and high pressures are usually caused by low elevation and oversized service pipe diameter.

2.8.1.2.1. Possible Reasons of Low Velocity in Pipe System

Since discharge is a function of velocity and velocity is a function of pipe size, the results of discharge and velocity is used for the judgment in solving the distribution network problems related to pipe size. Inadequate water supply, oversized service pipe diameter and topography is the major problem which causes low velocity of water in the pipe system. Topography of Asella town is characterized as rugged and inclined. At low elevation and oversized service pipe diameter, the velocity of water is low and the pressure is high.

2.8.1.2.2. Head Losses in the Pipes

The modeled head losses enable to judge whether booster stations are needed or not to boost the water pressure and add energy to let the flow continue. The model simulated shows that head loss in p-269, p-270, p-271, p-272, p-273, p-274, p-275, p-279, p-280, p-285, p-286, p-288, p-488, p-489, p-498, p-499, p-500, p-501, p-502, p-503, p-506, p-507, p-508, p-509, p-510, p-511, p-512, p-513, p-514, p-515, p-516, p-660, p-661, p-662, p-663, p-664, p-665, p-666, p-667, p-668, p-669, p-675, p690, p-723, p-724 are very high.

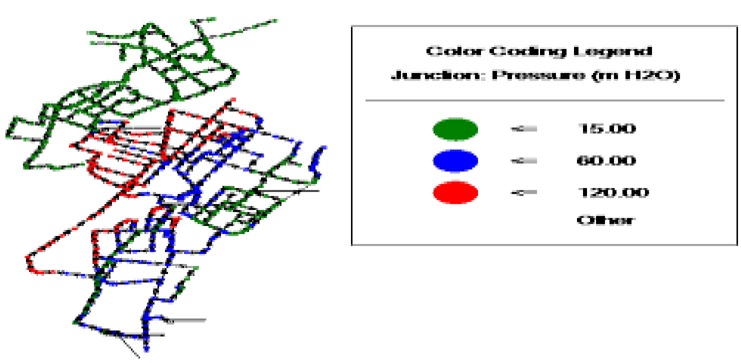
Generally, undersized pipes would lead to increased head losses due to increased friction. However, over sizing pipes beyond reasonable limits would increase the contracting cost. As the length of the network increases and the number of pipes, valves, fittings and other obstructions in the system increase, both major and minor losses increases.

2.8.1.3. Identification of the Location of Critical Points

If a pipe is too small, it may become a problem only during high flow conditions; the best time for diagnosing problems is the model simulation during peak hour flow. A color coding is specified for several ranges of pressure heads at the junctions and was helped to understand the difference in the pressure range at various junctions.

There are total 650 nodes in the model, out of them 306 nodes receive water with less than two 15m pressure head of water, which is inadequate and 52 nodes receive water with greater than to 60m pressure head of water and those nodes denotes as critical points. It is observed that the pipe capacity is insufficient and oversized diameter to deliver water with the required pressure. To maintain the pressure head at those nodes, it is better to add parallel pipes in the distribution network. Use pressure sustaining valves to control the occurrences of minimum pressures and pressure reducing valve to control occurrences of maximum pressures for parts of the high elevation network.

Scenario: Base



HYDRAULIC MODELING OF A SELLA WATER SUPPLY DISTRIBUTION NETW ORK -BY SHAMBEL BELACHEW.Wtg 12/8/2020	Bentley Systems, Inc. Haestad Me thods Solution Center 27 Siemon Company Drive, Suite 200 W Watertown, CT 06795 USA +1-203-755-1666	Bentley WaterGEM S V8i (SELECTseri es 5) [08.11.05.61] Page 1 of 1

Figure 12. Identification of critical points in the distribution system.

In the **figure 12** above the green color nodes have a pressure head below 15m of water head, red color nodes have a pressure head above 60m of water head and they denote as the critical points in the distribution network while the nodes in the blue have a pressure head between 15m-60m of water head.

2.8.2. To Cope-up the Above Problems

Asella town water supply and sewerage enterprise must redesign the water distribution system at peak hour with maximum day demand. By examining what is going on the system as a result of peak hour, solutions are given to the problems faced (pressures and velocities out of the design limit) within the network. Take a modification to the problems by creating new alternatives and scenarios. At peak hour demand the velocities out of the design range are modified by resizing pipe diameters and pressures at junction of lower portion were high, reduction to the desired pressure has been made by using pressure reducer valves and pressures at junction of higher portion were low, uses pressure sustaining valves to control the occurrences of minimum pressures.

IV. CONCLUSIONS

Asella town is suffering from the discontinuous supply of water in the distribution systems. Pressures in distribution system fail at the maximum consumption hour and high during night time as consumption decreases. The deficiency of hydraulic parameter (flow velocity and pressure) occurred due to random connection (placement) for nodes and pipe without any scientific method/mathematical calculation of flow and pressure. Therefore, this study is used to evaluate the hydraulic performance of a water supply distribution system of Asella town by using Bentley water GEMS V8i. The total annual water loss of the water supply system is 28.39% in 2016, 31.83% in 2017, 39.28% in 2018, 37.16% in 2019 and 39.55% in 2020 G.C.

In extended period simulation of peak hour consumption, parts of the distribution system receive water with low pressure and under any circumstances risk of obtaining no water is observed because of the pressure in the distribution system is below the permissible minimum requirement. Nodes below minimum and exceed maximum allowable operating pressures in the distribution network represent the critical points. The town water supply distribution system service coverage was also evaluated using the water demand and water production having 42.249 % coverage for the year 2020G.C.

V. ACKNOWLEDGEMENT

I would like to give thanks and praise God for his provision, grace and mercy in all the paths of my life who, favoring me with health, knowledge, wisdom and courage to finalize my study and do this research. I am grateful to my Advisor **Dr. Dawud Temam** for his efforts, useful suggestions, and encouragements, which provided valuable guidance for me starting from the proposal up to the whole thesis work.I am very grateful to express my sincere thanks to my co-advisor **Mr. Tadele Shiferaw (MSc)**for his-constructive comments, his guidance helped me in all the time writing of my thesis and guiding me in the right direction to- accomplish this work successfully.I would like to express my gratitude to the staff of Asella Town water supply office that helped me a lot to get all required data and finally I would like to express my deepest gratitude to all my friends for those share supportive idea in doing the research.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

[1]. Mekuriaw, T. Analysis of Current and Future Water Demand Scenario in Yejube. International Journal of Advanced Science and Engineering 2019, 6(2),1291-1304.

[2]. Dr. R. M. Damgir; Supriya, P. Hydraulic Modelling of Water Distribution System with Reference to Technical Sustainability by using Water Gems.International Journal of Innovative Research in Science,

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 1418-1433 www.ijaem.net ISSN: 2395-5252

Engineering and Technology 2017,6(6), 10832–10838.

[3]. Ermias,M. Assessment of urban water supply and sanitation: the case of Bedesa Town, Damot Woyde woreda of Wolaita Zone, Southern Ethiopia. Journal of Biology, Agriculture and Healthcare 2016,6,60-64.

[4]. American Water Works Association. Computer Modeling of Water Distribution Systems. Manual of Water Supply Practices—M32,2017.

[5]. Desalegn, W. B. Water Supply Coverage and Water Loss in Distribution Systems The case of Addis Ababa.Procedia Engineering 2005, 70(1) 958-966.

[6]. Bentley Water GEMs .Water Distribution Design and Modeling, Full Version V8i. 2008.

[7]. EPA (2010) Control and mitigation of drinking water losses in distribution systems'.

[8]. Hopkins,M. Critical node analysis of water distribution system using flow distribution. MSc Thesis. California Polytechnic State University, San Luis Obispo 2012.

[9]. MoWIE (2019). 'Water Supply & Sanitation Sector National ODF Campaign Framework .

[10]. MD. ATIQUZZAMAN. Water distribution network modeling: Hydroinformatics approach. ScholarBank@NUS Repository 2004.

[11]. Udhane, D.; Kataria, N.; Sankhe, S.; Pore, T. And Motegaonkar, S. Hydraulic Modeling and Simulation of Smart Water Distribution Network. International Research Journal of Engineering and Technology 2018, 5(4) 3636-3639.

[12]. WHO/UNICEF. Progress on household drinking water, sanitation and hygiene I 2000-2017:World Health Organization and United Nations Children's Fund Joint Monitoring Program for Water Supply and Sanitation 2017.