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Simulation of Existing Water Distribution Network by using EPANET: A Case Study of Surat City

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Abstract

Water is the basic need of all living being of world. Demand of water is increase day by day. Water supply system is a system of engineered hydraulic and components which provide water supply. For the development of nation, water distribution network are very important for development of an area as they serve many purposes in addition to provision of water for human consumption. The water distribution network plays a virtual role in preserving and providing desirable life quality to the public, of which reliability of supply is the major component. It is difficult to provide safe water to the rural people in sufficient quantity, quality and at satisfactory pressure head with achieving economy constraint. EPANET software is used to design and analyze the multi village supply system with reference to technical sustainability. EPANET is computer program that performs extended period simulation of hydraulic behavior within pressurized pipe network. The study presents the hydraulic analysis of pipe line network of Punagam area near Surat city using EPANET 2.0. The area has 600.83 Ha area and 2, 22,252 Population (2016). Source supplies water to city by 109 junction having 144 Pipes divided in two different zones. The water from this source is taken via network of pipes to the GSR (Ground Services Reservoir) across the area. The water from these GSR is then pumped to the Adjacent ESRs (Elevated Storage Reservoirs) during the supply hours and water is supply to the area by gravity. Simulation has been carried out for hydraulic parameter such as had pressure and flow rate. The result obtained verified that the pressure at all junction and the flows with their velocities at all pipes are feasible enough to provide adequate water to the network of study area. The findings will help to understand the pipelines system of the study area in a better way. The study also deals with the future demand of the area.
Keyword- Elevation, EPANET 2.0, Nodes, Pipe Network, Pressure, Water Supply

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I. INTRODUCTION

Water distribution systems transfer water peak from the water source or treatment facility, to the point where it is forwarded to users. Water requirement is maximum during the hours that water is used for personal sanitation cleaning, and when food cooking and their clothes washing are done. Water use is least during the night.

Water distribution system, hydraulic infrastructure be contain in elements such as pipeline, tanks, basin, pumps and valve etc. is necessary to provide water to the consumers elements of a distribution system include distribution mains, arterial mains, storage basin and system elements (valves, hydrants, main line meters, service connections, and back flow preventers). Distribution main are the pipes that make up the distribution complex. Their purpose is to transmit water from water source or treatment work to users. Service connection that connect either other plumbing system or an individual building to distribution system mains.

Water distribution system consist of an inter connected series of pipelines storage facilities and elements that convey waters which is use for drinking and also meeting the fire protection needs for cities, schools, homes, hospitals, industries, businesses and other facilities.

It is required to preserve adequate pressure in the distribution system to defend it from contamination by the ingress of befoul seepage water. For small community provide a minimum pressure of 5-10(MWC-meter of water column) should be adequate in most examples.

A. Aim of the Study

To check the performance of Water Distribution Network of Punagam area of Surat city using hydraulic simulation software i.e. EPANET and to report any improvements required in existing network and the mode of operation, in order to improve the quantity and quality of water distributed to the users.

B. Objective of Study

- Study the existing water supply network of Punagam area of Surat city.
- To study pipe report and junction report of existing network.
- To analyze the data by using EPANET software.
- To check the discharge and pressure head in existing network.

II. STUDY AREA

Surat is located on the western part of India in the state of Gujarat. Piped water supply system for the Surat City was started first time in year 1894 and first water works was setup at Varachha. Initially water was supplied through surface water from the River Tapti. Main source of water for Surat is the river Tapi flowing through the city. Surface water is drawn by intake wells from perennial channel of the river throughout the year.

Punagam area is located in East zone of Surat. The population of study area is 2, 22,252. The study area covers residential area about 600.83 Ha. When the water from the distribution network reaches to the Punagam area there is sudden decrease in the pressure head due to which water related problems arises. Leakages, failure of pipes and other factors are there which affects the water distribution network. Therefore it's required to analyse the existing network of the Punagam area using EPANET and compared computed result with actual result which is obtained from Surat Municipal Corporation. The water distribution system of Punagam area i.e. WDS-E3 consists of following five network systems namely ESR-E7, ESR-E8, ESR-E9, ESR-E9A, ESR-E10. In this paper, we have used WDS-E3-ESR-E10 data i.e pipe report as well as junction report for analysis.

Fig. 1: Map of Punagam Area, Surat City

A. Data Requirements

The data required for analysis of existing distribution network includes map of existing water distribution network, water distribution parameters such as Existing water demand, Surat population, and also distribution network parameters such as; elevations, pipe diameter and pipe length.

III. OVERVIEW OF EPANET SOFTWARE

EPANET is public domain software developed by the Water Supply and Water Resources Division of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory (Rossman, 2000). EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. The hydraulic simulation performed by EPANET delivers information such as flows and head losses in links (pipes, pumps and valves), heads, pressures and demands at junctions, levels and volumes for water storage. This allows computing the pumping energy and cost. EPANET's computational engine is available also as a separate library (called the EPANET Toolkit) for incorporation into other applications. The network hydraulics solver employed by EPANET uses the Gradient Method, first proposed by Todini and Pilati (Todini and Pilati, 1988), which is a variant of Newton-Raphson method.

IV. HYDRAULIC MODELLING CAPABILITIES

Full-featured and accurate hydraulic modeling is a prerequisite for doing effective water quality modeling. EPANET contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

1) Places no limit on the size of the network that can be analyzed
2) Computes friction head loss using the Hazen-William, Darcy-Weisbach or Chezy-Manning formula
3) Includes minor head losses for bends, fittings, etc.
4) Models constant or variable speed pumps
5) Computes pumping energy and cost
6) Models various types of valves including shutoff, check, pressure regulating, and flow control valves
7) Allows storage tanks to have any shape (i.e., diameter can vary with height)
8) Considers multiple demand categories at nodes, each with its own pattern of time variation
9) Models pressure-dependent flow issuing from emitters (sprinkler heads)
10) Can perform system operation on both simple tank level and timer controls and on complex rule-based controls.

Each network element has a hydraulic equation. For pipe equations, the Hazen-Williams formula is used (Brdys and Ulanicki, 1994). In the optimal scheduling problem it is required that all calculated variables satisfy the hydraulic model equations. The network equations are usually non-linear and are embedded as inequality and equality constraints in the optimization problem. The hydraulic model used by the FM optimization model consists of the following network equations:

- Flow continuity at connection nodes
- Mass-balance, average head and volume curve for reservoirs and elevated tanks
- Head-loss for pipes
- Head-loss for TCV valves
- check valves
- PRV valves
- pumping stations

A. Model Input Parameters

In order to analyze the WDN using EPANET following input data files are needed:

1) Junction Report

Junctions are points in the network where links join together and where water enters or leaves the network.
The basic input data required for junctions are:
1) Elevation above some reference (usually mean sea level)
2) Water demand (rate of withdrawal from the network)
3) Initial water quality

The output results computed for junctions at all time periods of a simulation are:
1) Hydraulic head (internal energy per unit weight of fluid)
2) Pressure
3) Water quality

Junctions can also:
- Have their demand vary with time
- Have multiple categories of demands assigned to them
- have negative demands indicating that water is entering the network
- be water quality sources where constituents enter the network
- Contain emitters (or sprinklers) which make the outflow rate depend on the pressure

B. Pipe Report

Pipes are links that convey water from one point in the network to another. EPANET assumes that all pipes are full at all times. Flow direction is from the end at higher hydraulic head (internal energy per weight of water) to that at lower head.
The principal hydraulic input parameters for pipes are:
1) start and end nodes
2) diameter
3) length
4) roughness coefficient (for determining Head-loss)
5) Status (open, closed, or contains a check valve)

Computed outputs for pipes include:
1) flow rate
2) velocity
3) Head-loss
4) Darcy-Weisbach friction factor
5) average reaction rate (over the pipe length)
6) Average water quality (over the pipe length)

The hydraulic head lost by water flowing in a pipe due to friction with the pipe walls can be computed using one of three different formulas:

1) Hazen-Williams formula
2) Darcy-Weisbach formula
3) Chezy-Manning formula

The Hazen-Williams formula is the most commonly used head-loss formula in the US. It cannot be used for liquids other than water and was originally developed for turbulent flow only. The Darcy-Weisbach formula is the most theoretically correct. It applies over all flow regimes and to all liquids. The Chezy-Manning formula is more commonly used for open channel flow. Each formula uses the following equation to compute head-loss between the start and end node of the pipe:

$$h_L = Aq^B$$

Where, h_L= head-loss (Length), q = flow rate (Volume/Time), A = resistance coefficient, and B = flow exponent. Table 1 lists expressions for the resistance coefficient and values for the flow exponent for each of the formulas. Each formula uses a different pipe roughness coefficient that must be determined empirically.

Formula	*Resistance coefficient (a)*	*Flow exponent (b)*
Hazen-Williams	$4.727c^{-1.852}d^{-4.781}L$	*1.852*
Darcy-Weisbach	$0.0252f(\varepsilon,d,q)d^{-5}L$	*2*
Chezy-Manning	$4.66n^2d^{-5.33}L$	*2*
Notes: *c = Hazen-Williams roughness coefficient* *ε = Darcy-Weisbach roughness coefficient (ft)* *f = friction factor (dependent on ε, d, and q)* *n = Manning roughness coefficient* *d = pipe diameter (ft)* *L = pipe length (ft)* *q = flow rate (cfs)*		

Table 1: Pipe Head-loss formula for full flow

Material	*Hazen Williams C*	*Darcy-Weisbach*	*Manning's*
Cast Iron	*130-140*	*0.85*	*0.012 – 0.015*
Concrete or Lined Concrete	*120-140*	*1.0-1.0*	*0.012 – 0.017*
Galvanized Iron	*120*	*0.5*	*0.015 – 0.017*
Plastic	*140-150*	*0.005*	*0.011 – 0.015*
Steel	*140-150*	*0.15*	*0.015 – 0.017*
Vitrified Clay	*110*		*0.013 – 0.015*

Table 2: Roughness Coefficient for new pipe

Pipes can be set open or closed at preset times or when specific conditions exist, such as when tank levels fall below or above certain set points, or when nodal pressures fall below or above certain values.

V. METHODOLOGY

Following steps has been carried out to model a water distribution network using EPANET:

1) Step 1: Draw a network representation of your distribution system or import a basis description of the network placed in a text file.
2) Step 2: Edit the properties of the objects that make up the system. It includes editing the properties and entering of the required data in various objects like reservoir, pipes, nodes or junctions, etc.

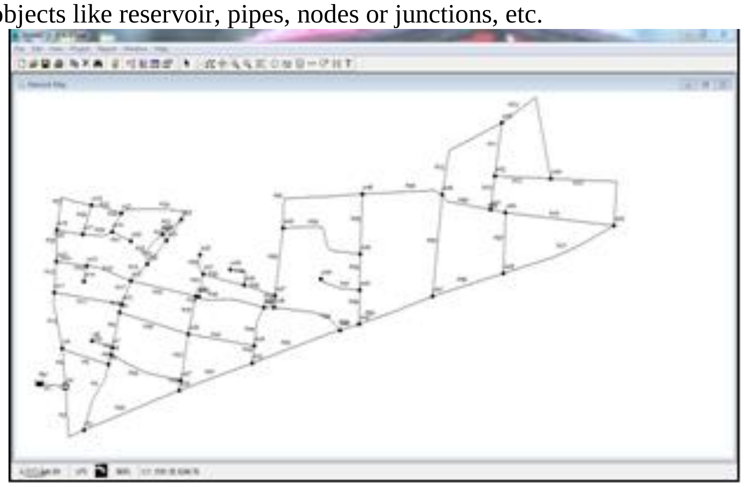

Fig. 2: WDS E3 ESR-E10

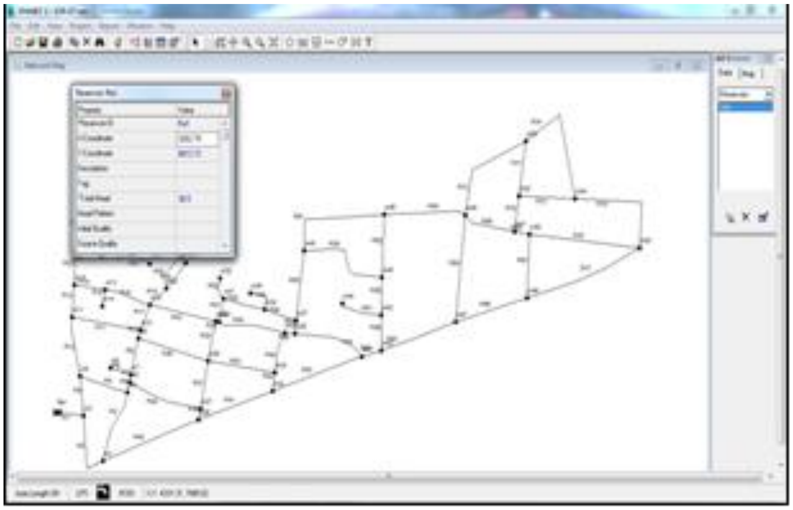

Fig. 3: Reservoir Property Editor

3) Step 3: Describe how the system is operated.
4) Step 4: Select a set of analysis options.

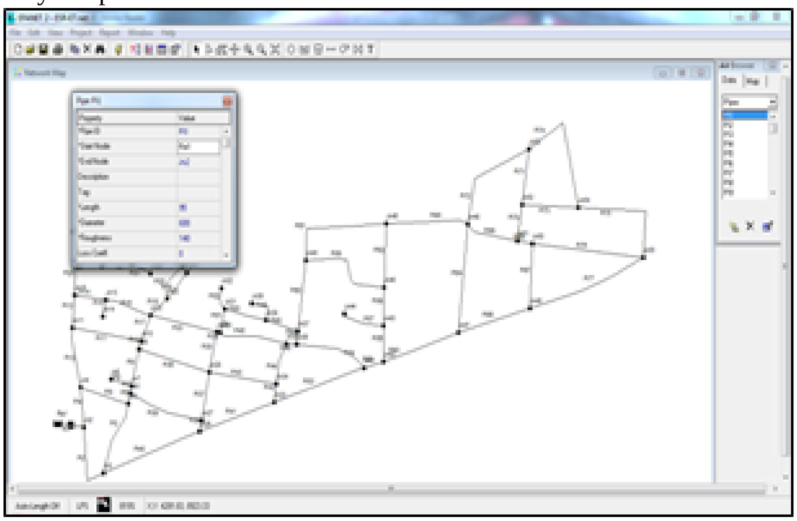

Fig. 4: Property editor for pipe

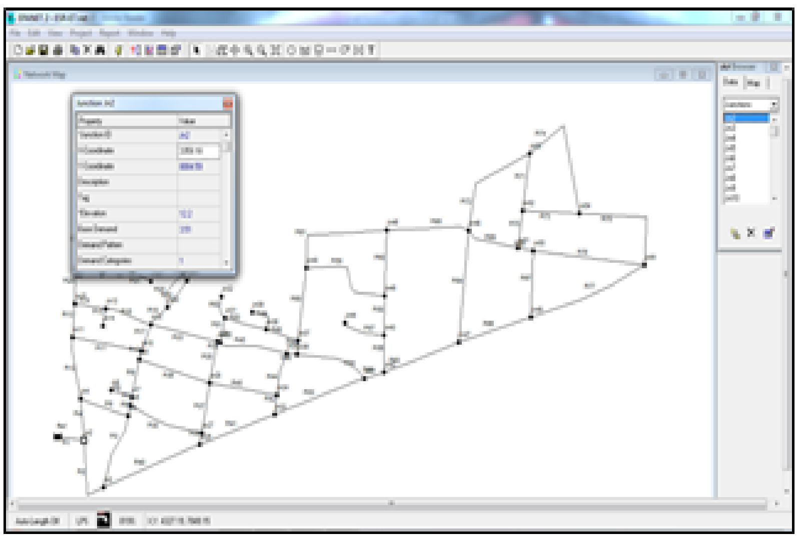

Fig. 5: Property editor for Junction

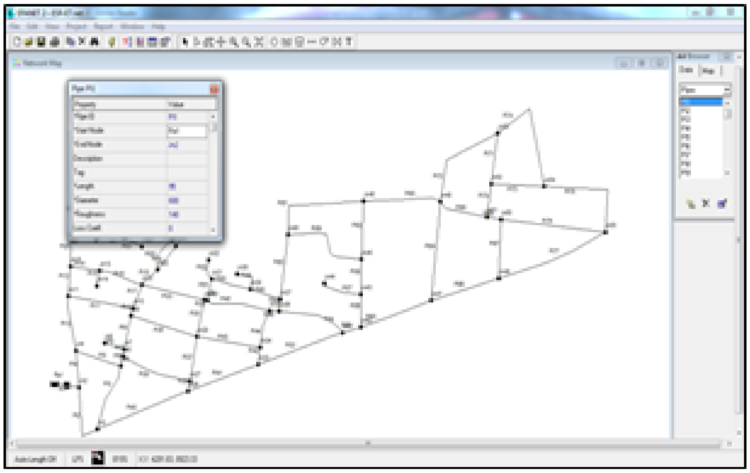

Fig. 6: Selection of type of Analysis

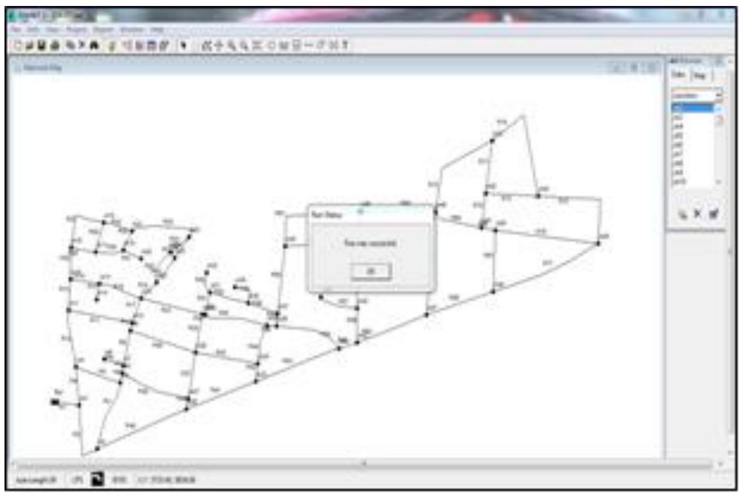

Fig. 7: Running of Analysis

A. WDS ESR E10

The network diagram of WDS ESR E10 drawn in EPANET is shown in figure 7.

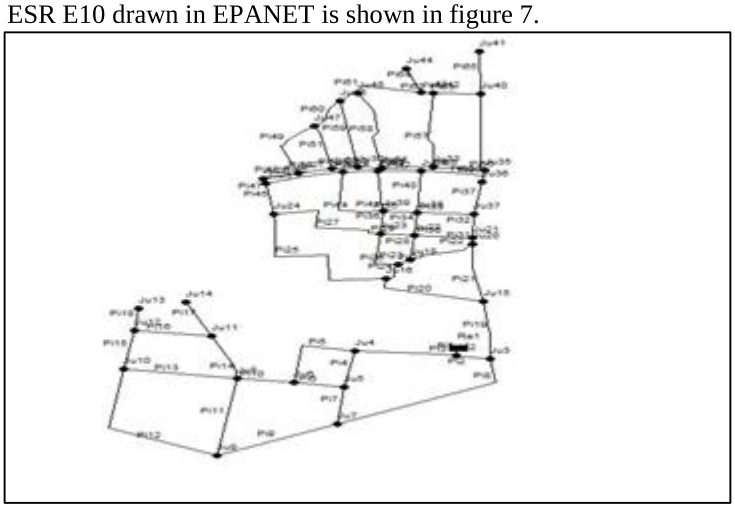

Fig. 8: Network Diagram of WDS ESR E10

B. Junction Report (WDS ESR E10)

It includes 47 junctions. The result obtained using EPANET is presented in table. The error between actual pressure and pressure computed by EPANET is also shown in table. Pressure profile for WDS ESR E10 is shown in below table.

Network Table - Nodes

Node ID	Elevation m	Demand LPS	Pressure m
Junc Ju2	12.5	0.81	23.97
Junc Ju3	12.2	3.69	23.95
Junc Ju4	11.7	6.06	23.74
Junc Ju5	12.7	4.29	21.69
Junc Ju6	12.8	11.73	20.88
Junc Ju7	14	19.80	19.65
Junc Ju8	12.1	3.87	20.57
Junc Ju9	12.7	18.27	19.90
Junc Ju10	13.8	22.71	17.41
Junc Ju11	11.8	5.40	19.62
Junc Ju12	12.5	9.87	18.63
Junc Ju13	11.6	2.70	19.51
Junc Ju14	12.1	4.32	19.24
Junc Ju15	11.7	6.63	23.59
Junc Ju16	11.4	9.04	21.42
Junc Ju17	11.2	2.33	21.62
Junc Ju18	11	1.26	21.97
Junc Ju20	10.75	13.00	23.84
Junc Ju21	10.75	0.91	23.78
Junc Ju22	10.85	7.97	21.99
Junc Ju23	10.9	7.91	21.50
Junc Ju24	12.83	27.87	18.37

Network Table - Nodes

Node ID	Elevation m	Demand LPS	Pressure m
Junc Ju25	11.1	10.31	20.15
Junc Ju26	11.1	0.74	20.15
Junc Ju27	11.7	2.79	19.58
Junc Ju28	12.4	2.62	19.06
Junc Ju29	12.4	11.31	19.38
Junc Ju30	12.4	2.04	19.57
Junc Ju31	12.5	5.74	19.78
Junc Ju32	12.5	8.72	19.60
Junc Ju33	12.75	4.15	19.96
Junc Ju34	12.75	10.57	19.81
Junc Ju35	12.74	0.78	20.79
Junc Ju36	12.74	5.09	20.93
Junc Ju37	10.68	3.01	23.59
Junc Ju38	10.67	7.55	22.06
Junc Ju39	10.8	5.38	21.52
Junc Ju40	12.69	10.11	19.39
Junc Ju41	11.38	5.64	20.56
Junc Ju42	12.3	13.94	19.15
Junc Ju43	12.25	7.97	19.07
Junc Ju44	11.2	3.18	20.09
Junc Ju45	11.1	10.28	20.41
Junc Ju46	11.1	12.74	20.13
Junc Ju47	11.2	13.29	20.01

Table 3: Junction Report for WDS E3 ESR 10

C. Pipe Report (WDS ESR E10)

Pipe report of WDS ESR-E10 includes 77 pipes. The result obtained using EPANET software for WDS ESR-E10 is presented in table. The error between actual flow and flow computed using EPANET software is shown in table. The error between actual head loss & head loss computed EPANET software is also shown in below figure.

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s	Unit Headloss m/km
Pipe P1	[illegible]	700	140	348.39	0.91	0.91
Pipe P2	126	500	140	253.49	1.29	2.61
Pipe P3	206	300	140	94.09	1.33	5.00
Pipe P4	146	250	140	70.81	1.44	7.18
Pipe P5	279	150	140	17.22	0.97	6.31
Pipe P6	121	200	140	35.31	1.12	5.87
Pipe P7	159	200	140	31.21	0.99	4.67
Pipe P8	515	150	140	14.93	0.85	4.04
Pipe P9	308	200	140	26.35	0.84	3.41
Pipe P10	132	200	140	40.79	1.30	7.67
Pipe P11	314	150	140	-2.87	0.16	0.23
Pipe P12	511	150	140	10.94	0.62	2.72
Pipe P13	263	150	140	16.09	0.91	5.56
Pipe P14	184	150	140	17.97	1.02	6.82
Pipe P15	159	150	140	4.32	0.24	0.49
Pipe P16	177	150	140	8.25	0.47	1.61
Pipe P17	147	150	140	4.32	0.24	0.49
Pipe P18	92	150	140	2.70	0.15	0.20
Pipe P19	226	450	140	234.07	1.48	3.78
Pipe P20	279	150	140	20.67	1.17	8.84
Pipe P21	232	450	140	207.57	1.31	3.01
Pipe P22	169	150	140	21.63	1.22	9.62

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s	Unit Headloss m/km
Pipe P23	39	150	140	12.90	0.73	3.69
Pipe P24	72	150	140	0.12	0.01	0.00
Pipe P25	521	150	140	11.75	0.67	3.11
Pipe P26	168	150	140	10.45	0.59	2.50
Pipe P27	339	150	140	12.61	0.71	3.54
Pipe P28	98	150	140	7.47	0.42	1.34
Pipe P29	76	150	140	16.29	0.92	5.69
Pipe P30	149	150	140	23.79	1.35	11.47
Pipe P31	28	450	140	172.94	1.09	2.14
Pipe P32	93	400	140	149.24	1.18	2.86
Pipe P33	144	150	140	22.88	1.29	10.68
Pipe P34	89	150	140	7.00	0.40	1.19
Pipe P35	76	150	140	15.88	0.90	5.43
Pipe P36	90	150	140	6.22	0.35	0.96
Pipe P37	157	350	140	122.35	1.27	3.84
Pipe P38	24	300	140	98.75	1.40	5.47
Pipe P39	154	150	140	18.51	1.05	7.21
Pipe P40	172	150	140	6.44	0.36	1.02
Pipe P41	168	150	140	7.36	0.42	1.31
Pipe P42	101	150	140	14.38	0.81	4.52
Pipe P43	85	150	140	13.02	0.74	3.76
Pipe P44	264	150	140	9.37	0.53	2.04

Table 4: Pipe Report for WDS E3 ESR 10

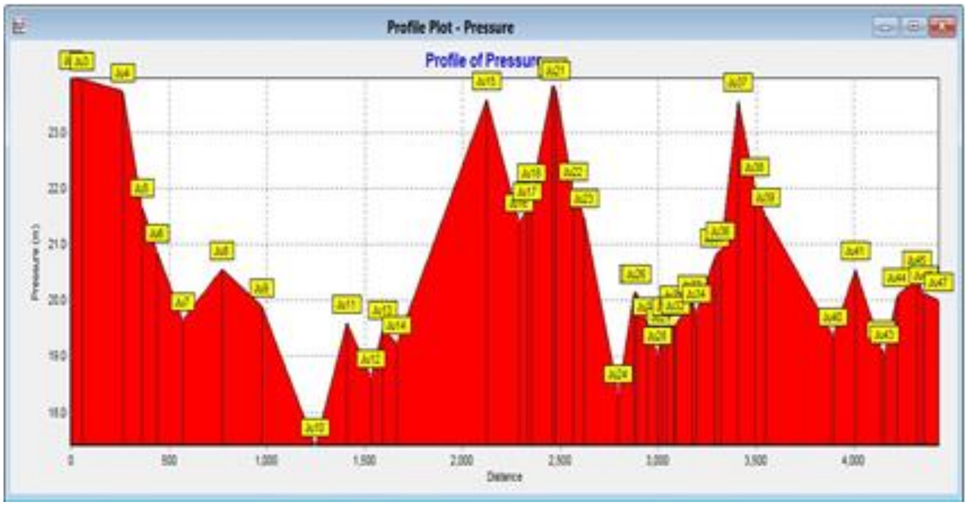

Fig. 9: Pressure Profile of WDS ESR E10

Following are some finding of above study

- The total numbers of junction are 47.
- The pressure is computed using Hazen-William approach.
- For WDS-ESR-E10 jn-2,jn-3,jn-4,jn-5,jn-6,jn-7,jn-8,jn-9,jn-11,jn-12,jn-15,jn-17,jn-18,jn-20,jn-21,jn-22,jn-27,jn-30,jn-31,jn-32,jn-33,jn-34,jn-35,jn-36,jn-37,jn-41 junction gives negative pressure.
- There is fluctuation in the pressure head.

D. *Result Analysis of Junction Report*

Label	*Pressure (m)*		*% Error*
	Actual	*EPANET*	
Jn2	*24*	*23.97*	*-0.0003*
Jn3	*24*	*23.95*	*-0.0005*
Jn4	*24*	*23.74*	*-0.0026*
-	-	-	-
-	-	-	-
Jn17	*22*	*21.62*	*-0.0038*
Jn18	*22*	*21.97*	*-0.0003*
Jn20	*24*	*23.84*	*-0.0016*
Jn21	*24*	*23.78*	*-0.0022*
-	-	-	-
-	-	-	-
Jn44	*20*	*20.09*	*0.0009*
Jn45	*20*	*20.41*	*0.0041*

Table 5: Junction Report

E. Result Analysis of Pipe Report

Labal	*Flow(L/s)*		*Velocity(m/s)*		*Head loss Gradient(m/km)*	
	Actual	*EPANET*	*Actual*	*EPANET*	*Actual*	*EPANET*
Pi1	*348.4*	*348.39*	*0.91*	*0.91*	*0.912*	*0.91*
Pi2	*253.5*	*253.49*	*1.29*	*1.29*	*2.606*	*2.61*
-	-	-	-	-	-	-
-	-	-	-	-	-	-
Pi16	*8.25*	*8.25*	*0.47*	*0.47*	*1.616*	*1.61*
Pi17	*4.32*	*4.32*	*0.24*	*0.24*	*0.487*	*0.49*
-	-	-	-	-	-	-
-	-	-	-	-	-	-
Pi50	*9.68*	*9.69*	*0.55*	*0.55*	*2.168*	*2.18*
Pi51	*-7.55*	*7.57*	*0.43*	*0.43*	*1.37*	*1.38*

-	-	-	-	-	-	-
-	-	-	-	-	-	-
Pi63	*15.41*	*15.39*	*0.87*	*0.87*	*5.134*	*5.12*
Pi64	*3.18*	*3.18*	*0.18*	*0.18*	*0.276*	*0.28*

Table 6: Pipe Report

VI. CONCLUSIONS

The main focused of study is to analyze the water distribution network and identify deficiencies in its analysis, implementation and its usage. At the end of the analysis it was found that the resulting pressure at all junction and the flows with their velocities at all pipes are adequate enough to provide water to study area. This study would help the water supply engineers in saving time as it this process is fast and less tedious. Discharge should be increase to achieve the base demand.

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