Analysis of Water Distribution Network At Humchadakatte Village Using EPANET Software

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Abstract- *This study presents the use of EPANET Software in the design of the N.D.A water distribution network. A network consists of pipes, nodes (pipe junctions). pumps. valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network. EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. In this paper it EPANET used to carry out the hydraulic analysis of the distribution network in the study area. The results obtained verified that the pressures at all junctions and the flows with their velocities at all pipes are feasible enough to provide adequate water to the distribution network*

Keywords- Water Distribution Network, Water Quality, EPANET, Water Distribution Analysis

I. INTRODUCTION

Water is not only a resource, is a life source. Life exists around numerous uses of water which makes important for survival and luxury. It is a part of our biosphere that should not be overused, ignored or taken for granted because of this, water should be conserved to sustain our domestic needs for the future.

Water supply is an inevitable part of the urban infrastructure. Municipal water systems provide portable water to a wide array of commercial property and domestic use including apartments, condominiums, duplex housing and single-family dwellings through a distribution network. The water distribution system is a large-scale network system with complex topological structure. Its functions are designed to convey volumes of water to customers under adequate pressure and acceptable quality. The main elements of the water distribution system are pipe systems, pumping stations, storage facilities, fire hydrants, house service connections, meters and other appurtenances. The piping systems have nodes and links(pipes).

The performance of water distribution systems is one of the most important issues in ensuring public water security and continuous operation of urban functions. Such functions include water supply, infrastructure construction and industrial development. The operational practices of large-scale water scale networks still continue to be a major engineering challenge. The performance of a distribution network does not depend only on supply and demand gap. The performance depends on how far systems is reliable and satisfying the demand with minimal loss. The system should also be capable of meeting the demand at all times and at satisfactory pressure. There are many causes for the poor performance of water distribution system. Some of the important causes are pipe failures, low pressure and flow rate in pipes, shortage of pumping stations, value and appurtenances. Failures of any pipe system can occur when the strength, toughness or chemical resistance capabilities of the pipe are exceeded. Structural failures of large diameter metallic water mains are usually occurring, when pipes get deteriorated due to excessive internal and (or) external loadings. Low pressure and flow rate is due to absence of booster in break rates and loss of carrying capacity and the deterioration of water quality in aging water distribution infrastructure, many studies were conducted in order to analysis failure patterns and attempt to evaluate and predict the performance of water distribution systems.

Simulation models are employed to estimate the distribution of hydraulic parameters, flow rates in pipes and pressure (residual heads) at nodes concerning some sets of particular loading and operating conditions. The hydraulic simulation models help in evaluating water distribution piping systems. With the help of hydraulic models, it is easy to predict the overall performance of a water distribution system. Therefore, to perform a comprehensive performance assessment a well proposed methodology is needed

1.1 DISTRIBUTION OF WATER

Water distribution systems are ordinary designed to adequately satisfy the water requirements for a combination of domestic, commercial, industrial and firefighting purpose. The performance of a distribution system can be judged on this basis of pressure available in the system for a specific rate of flow. The distribution system consists of a network of pipes with appurtenances, for transporting water from the purification plant to the consumers tap. A good distribution system should satisfy the following requirements:

- The system should be capable of supplying water at consumers tap at reasonable pressure head. Also, the head should not be excessive.
- It should be capable of meeting the fire demand simultaneously.
- It should maintain the degree of purity. The distribution system should be completely watertight.
- It should be easy to operate and maintain.
- Water should be available even during breakdown period.
- It should be so laid during repairs, it does not cause obstruction to traffic.
- The initial cost of the distribution should be as low as possible. network does not depend only on supply and demand gap. The performance depends on how far systems is reliable and satisfying the demand with minimal loss. The system should also be capable of meeting the demand at all times and at satisfactory pressure.

There are many causes for the poor performance of water distribution system. Some of the important causes are pipe failures, low pressure and flow rate in pipes, shortage of pumping stations, value and appurtenances. Failures of any pipe system can occur when the strength, toughness or chemical resistance capabilities of the pipe are exceeded. Structural failures of large diameter metallic water mains are usually occurring, when pipes get deteriorated due to excessive internal and (or) external loadings. Low pressure and flow rate is due to absence of booster in break rates and loss of carrying capacity and the deterioration of water quality in

1.2 DRINKING WATER STANDARDS

Table -1: IS-19500 Drinkingwater specification

Sl. No.	**Parameter**	**Requirement Desirable limit**	**Remarks**
1	Cukor	5	May be extended up to 50 fi toxic
2	Turbidity	10	May be relaxed up to 25 in the absence of alternate
3	pH	6.5 -8.5	May be relaxed up to 9.2 in the absence
4	Total Hardness	300	May be extended up to 600
5	Calcium as Ca	75	May be extended up to 200
6	Magnesium as Mg	30	May be extended up to 100
7	Copper as Ca	0.05	May be extended up to 1.5
8	Iron	0.3	May be extended up to 1
9	Manganese	0.1	May be extended up to 0.5
10	Chlorides	250	May be extended up to 1000
11	Sulphates	150	May be extended up to 400
12	Nitrates	45	No Reaction
13	Fluoride	0.6 to12	If the limit is below 0.6 water should be rejected, Max Limit is extended to 1.5
14	Phenols	0.001	May be relaxed up to 0.002
15	Mercury	0.001	No relaxation
16	Cadmium	0.01	No relaxation
17	Selenium	0.01	No relaxation
18	Arsenic	0.05	No relaxation
19	Cyanide	0.05	No relaxation
20	Lead	0.1	No relaxation
21	Zinc	5.0	May be extended up to 10.0
22	Anionic detergents (MBAS)	0.2	May be relaxed up to 1
23	Chromium as Cr	0.05	No relaxation

24	Poly nuclear aromatic Hydrocarbons		-
25	Poly nuclear aromatic Hydrocarbons	-	May be relaxed up to 0.03
26	Mineral oil	0.01	Applicable only when water is Chlorinated
27	Residual free chlorine	0.2	-
28	Pesticides	Absent	-
29	Radio active	-	

1.3 ANALYSIS OF DISTRIBUTION NETWORK USING EPANET

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. Sampling program design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment are some examples. EPANET can help assess alternative management strategies for improving water quality throughout a system.

These can include:

- Altering source utilization within multiple source systems,
- Altering pumping and tank filling/emptying schedules,
- Use of satellite treatment, such as re-chlorination at storage tanks,
- Targeted pipe cleaning and replacement.
- Running under Windows, 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. These include color-coded network maps, data tables, time series graphs, and contour plots.
- EPANET tracks:
- The flow of water in each pipe.
- The pressure at each node.
- The height of chemical concentration throughout the network during a stimulation period.
- Water age.
- Source and tracing.

EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

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HYDRAULIC MODELING 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:

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

WATER QUALITY MODELING CAPABILITIES

In addition to hydraulic modeling, EPANET provides the following water quality modeling capabilities:

- Models the movement of a non-reactive tracer material through the network over time
- Models the movement and fate of a reactive material as it grows (e.g., a disinfection by-product) or decays (e.g., chlorine residual) with time
- Models the age of water throughout a network
- Tracks the percent of flow from a given node reaching all other nodes over time
- Models reactions both in the bulk flow and at the pipe wall
- Uses nth order kinetics to model reactions in the bulk flow
- Uses zero or first order kinetics to model reactions at the pipe wall
- Accounts for mass transfer limitations when modeling pipe wall reactions
- Allows growth or decay reactions to proceed up to a limiting concentration
- Employs global reaction rate coefficients that can be modified on a pipe-by-pipe basis
- Allows wall reaction rate coefficients to be correlated to pipe roughness
- Allows for time-varying concentration or mass inputs at any location in the network
- Models storage tanks as being either complete mix, plug flow, or two-compartment reactors.

By employing these features, EPANET can study such water quality phenomena as:

- Blending water from different sources
- Age of water throughout a system
- Loss of chlorine residuals
- Growth of disinfection by-products
- Tracking contaminant propagation events.

APPLICATIONS

EPANET helps water utilities maintain and improve the quality of the water delivered to consumers. It can be used to:

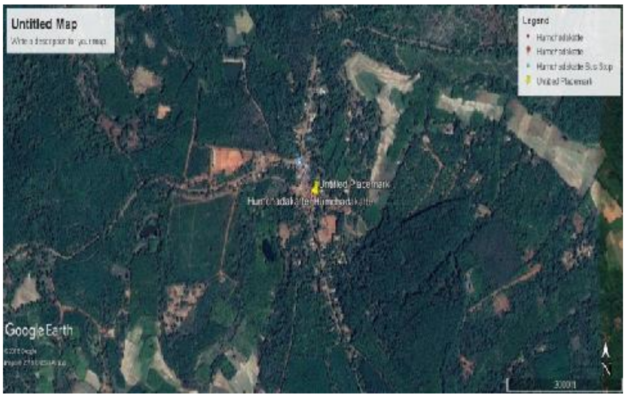
Design sampling programs.

- Modify pumping and tank filling/emptying schedules to reduce water age.
- Plan and improve a system's hydraulic performance.
- Assist with pipe, pump, and valve placement and sizing.
- Fire flow analysis and Vulnerability studies.

II. MATERIAL AND METHODOLOGY

2.1 STUDY AREA

The study area chosen is Humchadakatte, a medium size village located in Tirthahalli Taluka of Shimoga district, Karnataka with total 118 families residing. The Humchadakatte village has population of 503 as per population census 2011. Humchadakatte village has higher literacy rate compared to Karnataka.



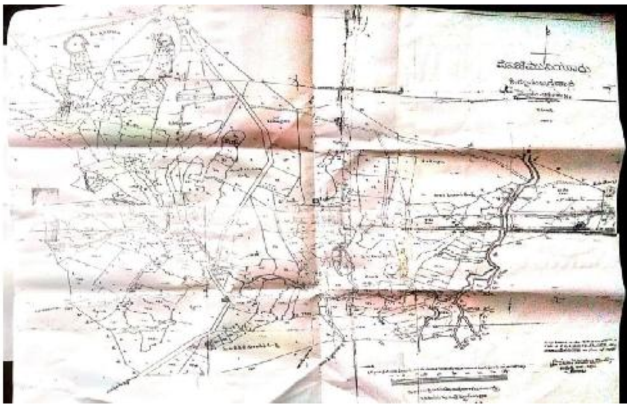


Fig -1: Humchadakatte village

2.2 STEPS FOLLOWED IN DATA COLLECTION

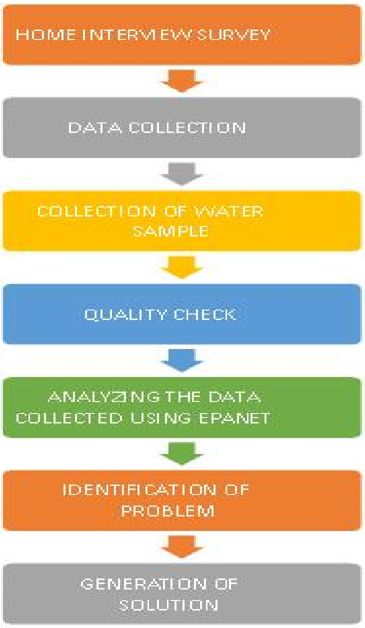


Fig -2: Steps data collection & generation of solution

2.3 HOME INTERVIEW SURVEY

•Home-interview survey is one of the most reliable type of surveys for collection of the required data.
•This is also very convenient method to know the problem faced by the household which is related to water supply.

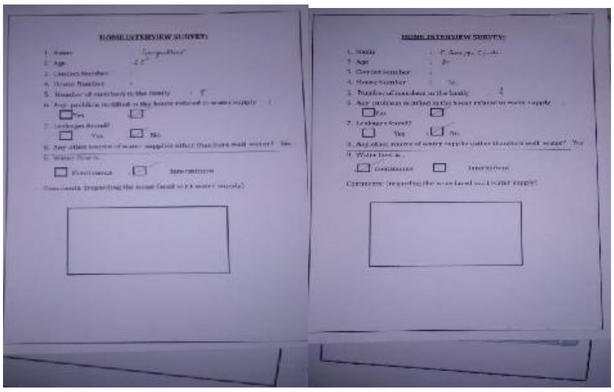
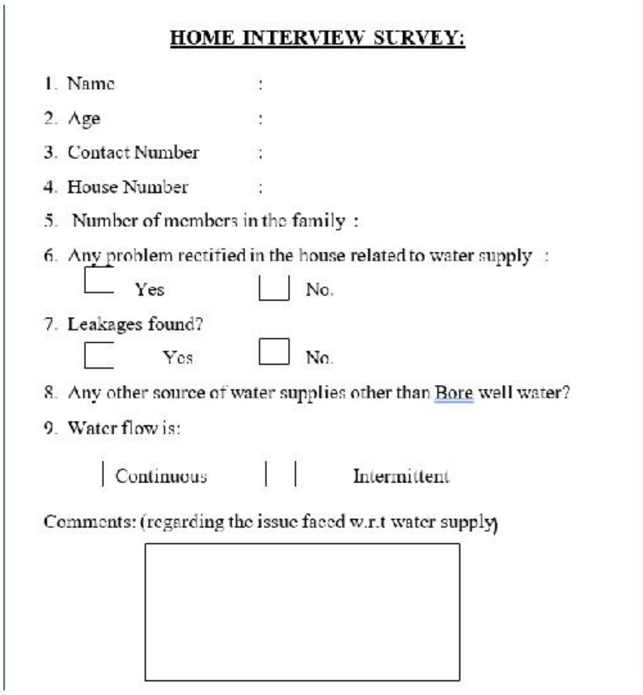


Fig -3: Home interview survey samples



HOME INTERVIEW SURVEY:

1. Name :
2. Age :
3. Contact Number :
4. House Number :
5. Number of members in the family :
6. Any problem rectified in the house related to water supply :
   ☐ Yes ☐ No.
7. Leakages found?
   ☐ Yes ☐ No.
8. Any other source of water supplies other than Bore well water?
9. Water flow is:
   ☐ Continuous ☐ Intermittent

Comments: (regarding the issue faced w.r.t water supply)

Fig -4: Home interview survey Sheet

2.4 DATA COLLECTION

- Source of water supply
- Pipe material
- Roughness coefficient
- Types of valves
- Existing drawing

2.5 SOURCE OF WATER SUPPLY

Humchadakatte village the sources of water is Bore-well water

2.6 PIPE MATERIAL

Cast iron -150mm & 200mm

Fig -5 Cast Iron & Ductile Iron

2.7 ROUGHNESS COEFFICIENT

• Hydraulic roughness is the measure of the amount of frictional resistance water experiences when passing over land and channel features.
• Roughness co-efficient:130-140

2.7 TYPES OF VALVES

- Sluice valves
- Butterfly valves
- Air valves

Fig -6 Sluice valves , Butterfly valves & Air valves

2.8 Collection of water sample

The sample are collected, grab sampling method is used

Fig -7 All source of Sample collected at Humchadakatte village

2.9 Test Conducted during the Study period

The test conducted are pH, Alkalinity, Hardness,Chlorides

2.10 EPANET ANALYSIS

The following steps are used in EPANET to model a water distribution system:

1.Draw a network representation of distribution system or import a basic description of the network placed text file.
2.Edit the properties of the objects that make up the system.
3.Describe how the system is operated.
4.Select a set of analysis options (Demand Adjusted EPANET Analysis).
5.Run a hydraulic/water quality analysis.
6.View the results of the analysis.

III. RESULTS AND DISCUSSIONS

- The study area is imported to AUTOCAD

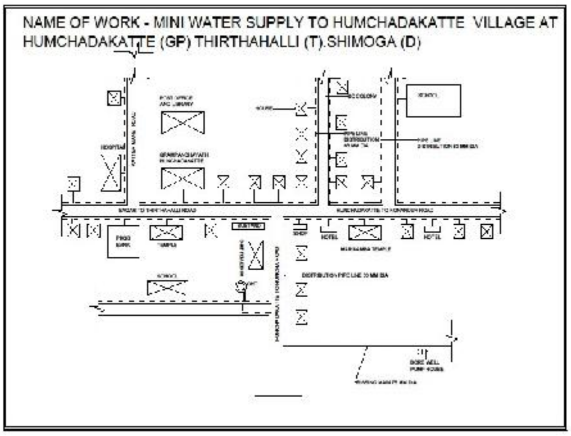


Fig -8 The study area is imported to AUTOCAD

- Assigning nodes, pipes and tank

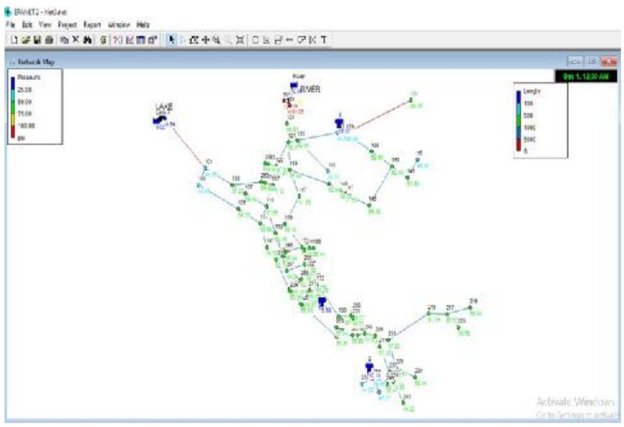


Fig -9 Assigning nodes, pipes and tank

- Assigning the value of elevation and base demand for nodes

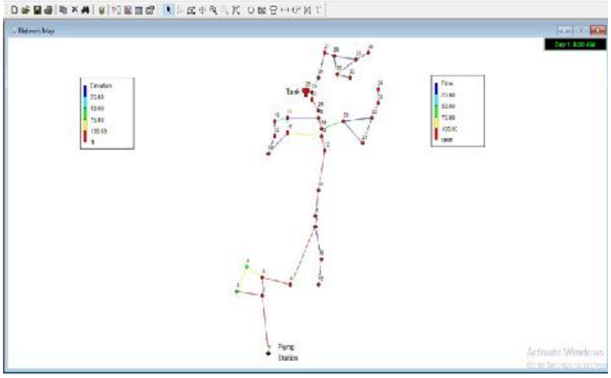


Fig -10 Input junction node details

- Assigning the value length and diameter for pipes

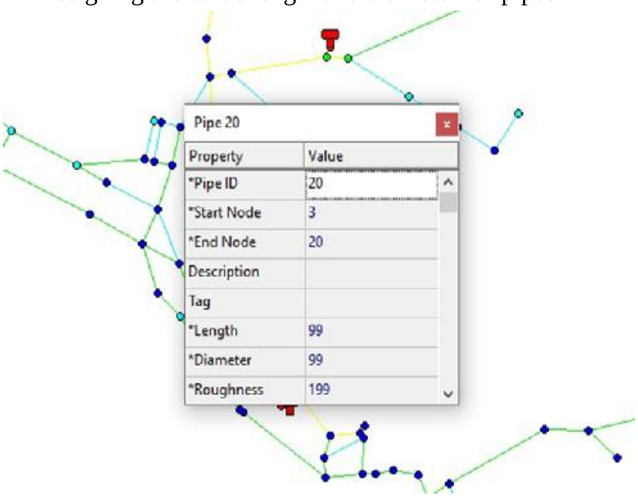


Fig -11 Length & diameter of the pipe

- Pattern of demand:

Fig -12 Water flow demand pattern graph

Enter the multiplier values 0.5, 1.3, 1.0, 1.2 for the time periods 1 to 4 that will give our pattern a duration of 24 hours

Pressure at node

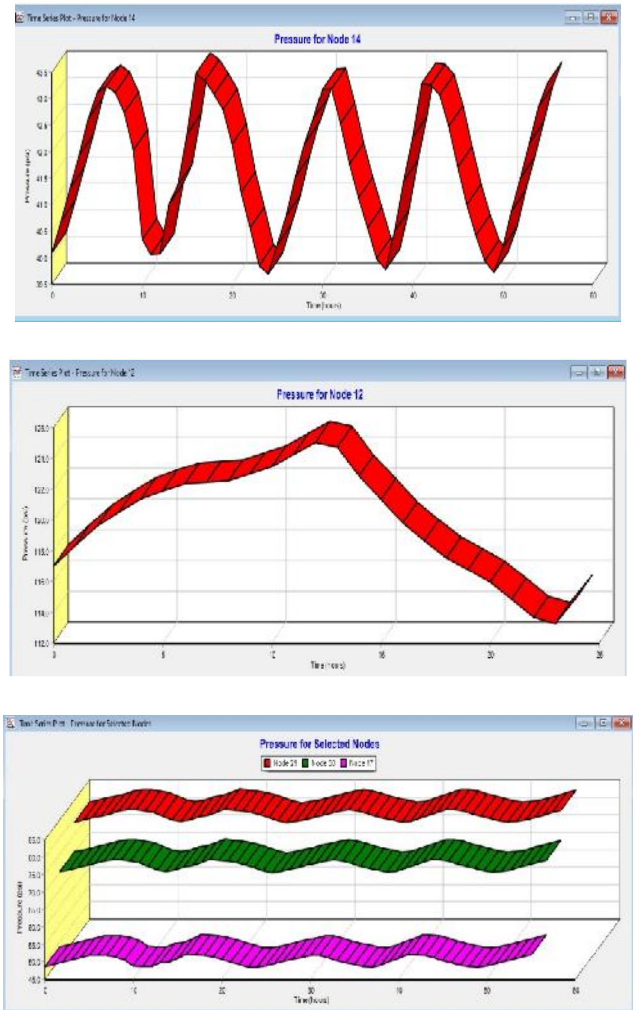


Fig -13 Pressure distribution graph

Note the periodic behavior of the water elevation in the tank over time

- <u>Analysis:</u>

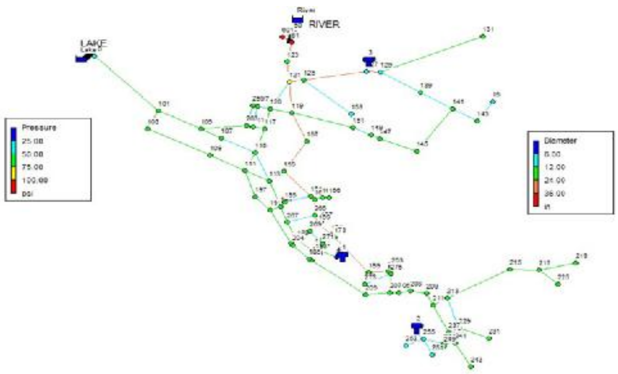


Fig -14 Warning for analysis

Status Report

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Page 1                                   Sun Aug 09 22:16:09 2020

******************************************************************
*                        E P A N E T                             *
*              Hydraulic and Water Quality                       *
*              Analysis for Pipe Networks                        *
*                    Version 2.00.12                             *
******************************************************************

Analysis begun Sun Aug 09 22:16:09 2020

Hydraulic Status:
-----------------------------------------------------------------------
  0:00:00: Balanced after 5 trials
  0:00:00: Reservoir River is emptying
  0:00:00: Reservoir Lake is closed
  0:00:00: Tank 1 is filling at 13.10 ft
  0:00:00: Tank 2 is emptying at 23.50 ft
  0:00:00: Tank 3 is filling at 29.00 ft

  1:00:00: Pump 10 changed by timer control
  1:00:00: Balanced after 7 trials
  1:00:00: Reservoir Lake is emptying
  1:00:00: Pump 10 changed from closed to open

  2:00:00: Balanced after 3 trials
```

Fig -15 Generation of warnings

➢ LABORATORY TEST PERFORMED:

Indian Standard for Drinking Water-Specification IS 10500:1991

Table -2: Laboratory Test Results

Sl no	Parameter	Result	Unit	Methods	IS 10500:2012	
					Acceptable limits	**Permissible limits**
1	pH	7.63	NA	IS 3025 (Part 11)	6.5 - 8.5	No relaxation
2	Total Alkalinity expressed as CaCO3	51	mg/l	IS 3025 (Part 23)	200	600
3	Chloride as Cl	5	mg/l	IS 3025 (Part 32)	250	1000
4	Total Hardness expressed as CaCO3	117	mg/l	IS 3025 (Part 21)	200	600
5	Calcium hardness expressed as Ca	31	mg/l	IS 3025 (Part 10)	75	200
6	Magnesium Hardness as Mg	10	mg/l	IS 3025 (Part 46)	30	100

Table -3: Junction report

EPANET 2 - Net3.net

Network Table - Nodes at 0:00 Hrs

Node ID	Elevation ft	Base Demand GPM	Initial Quality percent	Demand GPM	Head ft	Pressure psi
Junc 10	147	0	0	0.00	145.52	-0.64
Junc 15	32	1	0	620.00	125.81	40.65
Junc 20	129	0	0	0.00	158.00	12.57
Junc 35	12.5	1	0	1637.00	145.74	57.73
Junc 40	131.9	0	0	0.00	145.00	5.68
Junc 50	116.5	0	0	0.00	140.00	10.18
Junc 60	0	0	0	0.00	209.01	90.56
Junc 601	0	0	0	0.00	302.45	131.05
Junc 61	0	0	0	0.00	302.45	131.05
Junc 101	42	189.95	0	254.53	145.52	44.86
Junc 103	43	133.2	0	178.49	145.49	44.41
Junc 105	28.5	135.37	0	181.40	146.83	51.27
Junc 107	22	54.64	0	73.22	146.82	54.09
Junc 109	20.3	231.4	0	310.08	145.49	54.25

EPANET 2 - Net3.net

Network Table - Nodes at 0:00 Hrs

Node ID	Elevation ft	Base Demand GPM	Initial Quality percent	Demand GPM	Head ft	Pressure psi
Junc 109	20.3	231.4	0	310.08	145.49	54.25
Junc 111	10	141.94	0	190.20	146.11	58.98
Junc 113	2	20.01	0	26.81	146.15	62.46
Junc 115	14	52.1	0	69.81	146.92	57.59
Junc 117	13.6	117.71	0	157.73	150.03	59.12
Junc 119	2	176.13	0	236.01	157.55	67.40
Junc 120	0	0	0	0.00	155.12	67.21
Junc 121	-2	41.63	0	55.78	161.01	70.63
Junc 123	11	1	0	0.00	165.47	66.93
Junc 125	11	45.6	0	61.10	160.43	64.75
Junc 127	56	17.66	0	23.66	158.74	44.52
Junc 129	51	0	0	0.00	158.73	46.68
Junc 131	6	42.75	0	57.28	158.71	66.17
Junc 139	31	5.89	0	7.89	153.08	52.90

PIPE REPORT

Pipe report of Humuchadakatte consists of 333 pipes From the above study it is observed that the head loss is very less at various pipes which is essential for continuous pressure required for continues water supply.

Table -4: Pipe junction

EPANET 2 - Net3.net

Network Table - Links at 4:00 Hrs

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Reaction Rate mg/L/d	Trace Lake percent	Status
Pipe 20	-4501.38	0.19	0.00	0.009	0.00	0.00	Open
Pipe 40	-1600.38	0.07	0.00	0.000	0.00	5.15	Open
Pipe 50	-569.30	0.02	0.00	0.000	0.00	0.00	Open
Pipe 60	12789.79	9.07	8.47	0.013	0.00	0.00	Open
Pipe 101	3130.84	3.96	3.99	0.025	0.00	100.00	Open
Pipe 103	1673.92	2.67	1.62	0.020	0.00	100.00	Open
Pipe 105	1321.56	3.75	4.25	0.019	0.00	100.00	Open
Pipe 107	405.13	1.15	0.48	0.023	0.00	100.00	Open
Pipe 109	1572.68	2.51	1.44	0.020	0.00	100.00	Open
Pipe 111	1396.82	3.96	4.71	0.019	0.00	100.00	Open
Pipe 112	307.79	0.87	0.29	0.024	0.00	91.61	Open
Pipe 113	771.15	2.19	1.57	0.021	0.00	97.83	Open
Pipe 114	257.60	1.64	1.48	0.024	0.00	91.61	Open
Pipe 115	363.60	2.32	2.80	0.022	0.00	100.00	Open

EPANET 2 - Net3.net

Network Table - Links at 4:00 Hrs

Link ID	Flow GPM	Velocity fps	Unit Headloss ft/Kft	Friction Factor	Reaction Rate mg/l/d	Trace Lake percent	Status
Pipe 115	363.60	2.32	2.80	0.022	0.00	100.00	Open
Pipe 116	1013.54	2.88	2.60	0.020	0.00	95.43	Open
Pipe 117	-813.55	2.31	1.73	0.021	0.00	100.00	Open
Pipe 119	-241.38	0.68	0.18	0.025	0.00	85.32	Open
Pipe 120	-648.27	1.84	1.14	0.022	0.00	25.70	Open
Pipe 121	-261.84	0.74	0.21	0.025	0.00	5.19	Open
Pipe 122	165.55	1.06	0.65	0.025	0.00	0.00	Open
Pipe 123	7634.33	3.47	1.00	0.015	0.00	0.00	Open
Pipe 125	12789.78	5.81	2.82	0.013	0.00	0.00	Open
Pipe 129	4958.27	3.52	1.68	0.018	0.00	0.00	Open
Pipe 131	4771.01	3.38	1.56	0.018	0.00	0.00	Open
Pipe 133	-4501.38	4.60	3.41	0.017	0.00	0.00	Open
Pipe 135	256.21	0.18	0.01	0.027	0.00	0.00	Open
Pipe 137	32.49	0.05	0.00	0.035	0.00	0.00	Open

Note that flows with negative signs means that the flow is in the opposite direction to the direction in which the pipe was drawn initially.

- The quality of water in distribution network is tested at different point at consumer outlets.
- Suitable recommendation is made and implemented to improve the quality of the water
- Distribution pipe network is studied in detail including pipe diameter, length. material. pressure and roughness co-efficient.
- Problem was identified in the distribution network by the software and it has been Rectified

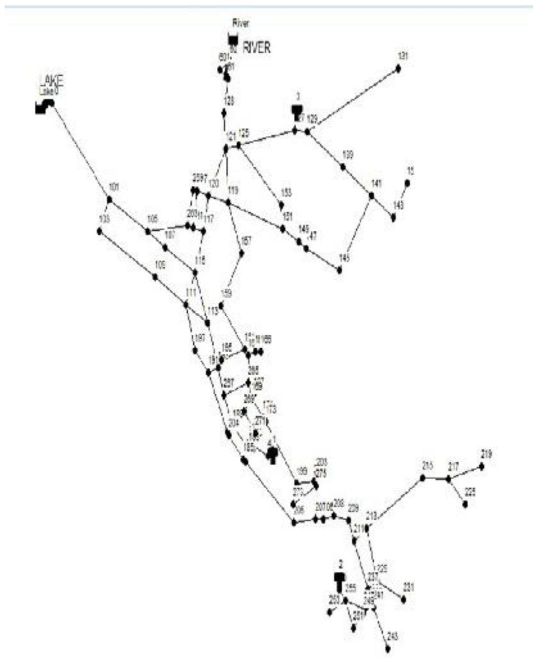

Fig -16 (a) Water distribution network using EPANET

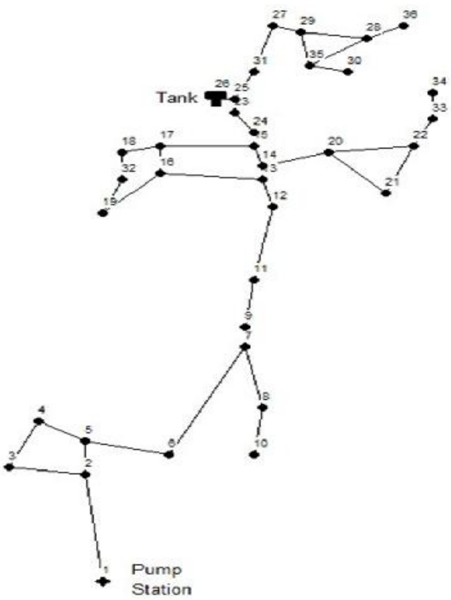

Fig -16 (b) Water distribution network using EPANET

IV. CONCLUSIONS

After analysis, Tabulations, Results and Discussions of water distribution network of Humchadakatte village, Following conclusions are drawn:

- EPANET used to carry out the hydraulic analysis of the distribution network in the study area. The results obtained verified that the pressures at all junctions and the flows with their velocities at all pipes are feasible enough to provide adequate water to the distribution network
- Pipe report of Humuchadakatte consists of 333 pipes
- From the above study it is observed that the head loss is very less at various pipes which is essential for continuous pressure required for continues water supply.
- The flow & velocity of the water supplied to this zone is appropriate and there is no problem in the flow & supply of water.
- Test on bore well water and RO plant water was conducted and it is found that drinking water and bore well water both are safe for drinking

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