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Case Report JoRSG

A Smart Design of Domestic Water Supply Network Using EPANET 2.0 Software for Chityala, Nandigudem, Vadalakunta and Bhimolu Villages in West Godavari District of Andhra Pradesh State

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Abstract

Prevalence of a proper Domestic Water Supply Network could be coined as a fundamental requirement for any borough for its proper functioning and survival. Even today, many villages including Chityala, Nandigudem, Vadalakunta, Bhimolu, and Saggonda in Andhra Pradesh State are suffering adversely by the absence of this network. So, the Government of Andhra Pradesh is considerate to provide a suitable Domestic Water Supply Network for all these villages, to put forth this issue, through Andhra Pradesh Water Supply Scheme. Therefore, this study aims to design a simple and economical water supply network, with a high end precision and simplicity, in Chityala, Nandigudem, Vadalakunta and Bhimolu villages using EPANET 2.0 Software based on their Digital Global Positioning System (DGPS) Survey Data and Population Data. The designs are proposed based on the hydraulic parameters that are enumerated using the same software. Also, by calculating the minimum volume of water lost as head loss using Hazen-William's Equation. This study is worked intensively in designing the networks to suit the needs and criteria of Government of Andhra Pradesh. It is also intended to surpass the disastrous situation facing by the citizens of those villages, as a small contribution towards the scheme.

Keywords: Andhra Pradesh Water Supply Scheme, EPANET 2.0, Hazen-William's Equation, head loss, population and DGPS survey data, water supply network

INTRODUCTION

Occurrence of a proper water supply network in a village, town or any other locality is an essential requirement for the functioning of domestic, agricultural, industrial or any other activities. Having this supply network enables the following advantages:

- Resistance towards inconsistency of quantity of water in case of Surface and Subsurface Sources.
- Disables the spread of water borne diseases like Amoebiasis, Dysentery, Fluorosis, etc. particularly from tanks, rivers, etc. [1].
- Saves time for manual transport of water from the sources.

Even today, under prodigious development in the standards of living of mankind and extremely rapid development in terms of science and technology around the globe, where water is one of the basic resources for survival, and having all the resources near our finger tips, it was throbbing to learn that, there are many remote villages in our country India,

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particularly in our adjacent state Andhra Pradesh, actually lack proper water supply networks, and the citizens living there are actually being suffered with this.

To overcome this problem, Government of Andhra Pradesh have come up with a proposal called "Andhra Pradesh Water Supply Scheme", which aims to provide clean and potable water to every house [2].

After an intensive survey made for this study, few villages called Chityala, Nandigudem, Vadalakunta and Bhimolu from West Godavari District, which are really remote by nature, are observed having no sort of water supply network or a consistent and a safe water source, and the people there are actually suffering due to this. The people in these villages are depending on adjacent small lakes for water and carrying them to their places manually, also consuming them without proper treatment. It is indeed that these sources cannot feed the village in hard summers and particularly in coming times.

Water supply network can be designed and analyzed using manual calculations and other methods, which are tedious, elaborative and time eaters. Whereas, EPANET [3] is a new-age software that can be used for this purpose, that enables the following advantages and have got the following applications:

- Design of a shiny new water supply network for a locality [4].
- Analysis of hydraulic parameters and remodeling of an existing water supply network [5].
- Estimation of losses during flow of a network [6].
- Determination of effects of water age spots in the quality of water [7].
- Determination of defects and errors in an existing network [8].
- Simulation of hydraulic parameters [9].
- Study of transport of contaminants in a pipe network [10].

Therefore, this study aims to design the water supply network using this new-age software called EPANET (Environment Protection Agency Network) in the most economical way possible and analyze the hydraulic parameters in *Chityala, Nandigudem, Vadalakunta and Bhimolu* villages, as a small contribution towards AP Water Supply Scheme.

OBJECTIVES

- To present a smart, simple and economical design of a Domestic Water Supply Network for Chityala, Nandigudem, Vadalakunta, Bhimolu villages which are actually in an immediate need of it.
- To design the water supply networks using EPANET 2.0 software for these villages with minimal losses.
- To enumerate all the hydraulic parameters for the designed network using EPANET Software.
- To determine the quantity of water lost as unit head loss using Hazen-William's Equation.

LITERATURE REVIEW

Ramana and Birhaun [5] have made a case study on "Task of EPANET Analysis of Existing Water Distribution System" and have chosen DIRE DAWA CITY, ETHIOPIA as their subject and discussed their results as follows:

The residual pressure at all nodes is found to be greater than 3 m. Hence, the flow can take place easily to all nodes without any disturbance. The assumed internal diameter of 132.40 mm is insufficient for all the links in the network. Hence, based on the elevation at nodes, base demand diameter of pipes can be fixed for the network. Various hydrological parameters like base demand, pressure head, head of water and friction factor, etc. can be easily observed even for a large or complex network.

Gisha et al. [6] have made an analysis on the concept of "Water Distribution Network Analysis by EPANET" and have chosen Bodditi Town as a case study and explained the results as under:

Out of 141 junctions analyzed in the distribution system, 9% of the junctions have above the maximum operating pressure (70 m) and 2% of the junctions have below the minimum operating pressure (15 m). In the distribution system of the town, 30% of pipes (6165 m) have head loss gradient greater than 15 m/km and their ages were greater than 16–40 years.

In the distribution link analysis, 11% mainline pipes (1549 m) and 4% of submain pipes (200 m) have less diameters than the minimum design criteria. As a result, their head loss gradients become greater 15 m/km.

Patel and Parmar [11] have made a case study on "Water Distribution Network using EPANET: A Case Study of Olpad Village" and have vividly presented their results as follows:

The analysis was found that the resulting pressures at all the junctions and the flows with their velocities at all pipes are enough to provide water to the study area. This study would help the water supply engineers in saving time as this process is fast and less difficult. Discharge should be increased to achieve the base demand. The method of distribution used here is pumping system. Water supply in the pipe is through Variav Water Treatment Plant. The distribution layout used here is tree system or dead-end system which is according to the layout of the Olpad village.

STUDY AREA

Here is a brief description about the villages for which the domestic water supply networks are proposed to be designed.

Chityala

Chityala Village is situated in Gopalapuram Mandal of West Godavari District in Andhra Pradesh State. This village falls in 17.090662° N and 81.5966462° E on the Earth. This village is located at an altitude of 22 m from Mean Sea Level (MSL). This village is bounded with Gopavaram Village on the North, Cherukumilli Village on South, Venkatayapalem Village on East and Gopalapuram and Vadalakunta Villages on West. This village has an extent of 1271 hectares. This village holds a population of 1176 citizens as per 2011 census. The Figure 1 represents Chityala Village in satellite view attained from Google Earth.

Figure 1. Satellite Image of Chityala Village from Google Earth.

Nandigudem

Nandigudem village is a small and secluded village situated in Gopalapuram Mandal of West Godavari District in Andhra Pradesh State. This village falls in 17.1357369° N and 81.4575104° E on

the Earth. This village is located at an altitude of 22 m from Mean Sea Level (MSL). This village is bounded with Kovvurupadu Village on the North, Chinnayagudem Village on South, Gopalapuram Village on East and Dippakayalapadu Village on West. This village has an extent of 1786 hectares. This village holds a population of 1036 citizens as per 2011 census. The Figure 2 represents Nandigudem Village in satellite view attained from Google Earth.

Vadalakunta

Vadalakunta village is situated in Gopalapuram Mandal of West Godavari District in Andhra Pradesh State. This village falls in 17.0859° N and 81.5185° E on the Earth. This village is located at an altitude of 22 m from Mean Sea Level (MSL). This village is bounded with Guddigudem Village on the North, Devarapalli Village on South, Venkatayapalem Village on East and Yadavolu Village on West. This village has an extent of 921 hectares. This village holds a population of 3303 citizens as per 2011 census. The Figure 3 represents Nandigudem Village in satellite view attained from Google Earth.

Figure 2. Satellite Image of Nandigudem Village from Google Earth.

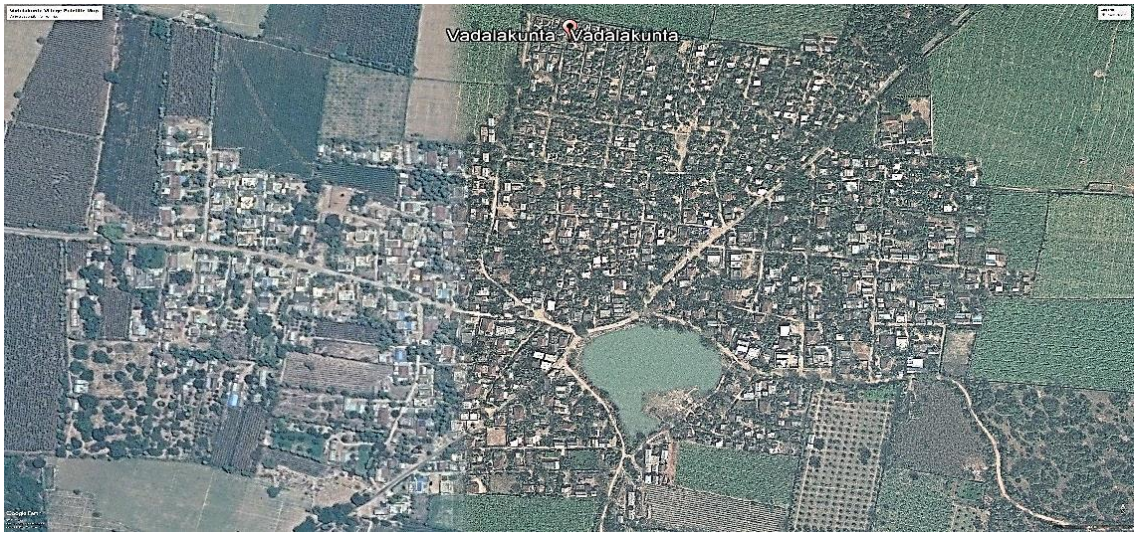


Figure 3. Satellite Image of Vadalakunta Village from Google Earth.

Bhimolu Village

Bhimoulu village is situated in Gopalapuram Mandal of West Godavari District in Andhra Pradesh State. This village falls in 17.1454° N, 81.5747° E on the Earth. This village is located at an altitude

of 22 m from Mean Sea Level (MSL). This village is bounded with Gopavaram Village on the North, Chityala Village on South, Gajjaram Village on East and Gopalapuram and Vadalakunta Villages on the West. This village has an extent of 2240 hectares. This village holds a population of 2844 citizens as per 2011 census. The Figure 4 represents Nandigudem Village in satellite view attained from Google Earth.

Figure 4. Satellite Image of Bhimolu Village from Google Earth.

METHODOLOGY

- To begin with, the primary motive of this study is to provide the drinking water supply network using EPANET 2.0 Software. For that, the villages actually lack them are selected. For the designing of the network in EPANET 2.0, 2 essentials are needed, i.e., Survey Report and Population Report of the village.
- Therefore, the village has to be surveyed or collect the surveyed data at the latest. It is preferred to use Digital Global Positioning System (DGPS) as survey equipment to attain high end accuracy and ease [12], and the data are exported as (.dxf) file, that could be explored in AutoCAD Software.
- On the other hand, the population data shown also to be in hand. It can be attained from Census Department or Andhra Pradesh Drinking Water Supply Corporation. This population would for the year 2011, since the latest population statistics are not taken from then.
- This (.dxf) file is fed into EPACAD Software, where this file gets converted into (.NET) format, where this file can be opened and developed in EPANET Software. This (.NET) file is fed in EPANET Software and kept on hold.
- On the other hand, the population data are to be analyzed. Initially the population of the village by the end of design period (30 years) is forecasted by Incremental Increase Method (IIM) (∵ This method can be applied for slow growing cities and villages, while the other methods like Arithmetic and Geometric Increase Methods does not fit for this kind of villages).
- Then the demand for water, by the end of Design Period based on Per Water Capita Demand with respect to IS: 1172-1993 is calculated [13].
- Then coming back to EPANET, this quantity of water required or the ultimate demand is used to design the OHDR tanks. It should be seen that the tank is situated at a possible higher elevation, to enable greater flow due to gravity.
- The diameters of pipes, size of tanks and other hydraulic data are fed into EPANET.
- Then, the file applied to "Run" and the errors and losses are observed and minimized. This is a trial and error process, and the network is continuously re-designed, by altering the hydraulic parameters at required stages. Then if the Run is observed to be successful, then proceed to further stages like unit head loss calculation.
- Before that do not forget to generate the full network report with all the hydraulic parameters of the network from EPANET.

- Determine the amount of water lost as head loss using Hazen William's Equation.

RESULTS AND DISCUSSIONS

As stated in the methodology, there are series of steps that lead towards the design of water supply network for Chityala, Nandigudem, Vadalakunta and Bhimolu Villages. But the Steps 1, 3 and 4 are presented below for only Nandigudem Village (as the calculation part is same for all the villages), but the results for all the parameters are presented at the end.

Step 1

Population and Demand Analysis:

Initially, the population and demand analysis is done based on 2011 Census. The water supply network should be capable of functioning for at least 30 years therefore, the ultimate year is 2050.

Population Analysis

- Population as per APDWSC census from 2011 = 1096 Citizens (Base Year)
- Adopting Incremental Increase Method (IIM), for Population Forecasting
- Assuming the growth factor = 1%
- According to IIM

Population at the end of "n" years = Population at the end of Base year* 1.011^n

- Population in the village by the end of 2020 = $1096*1.011^9$ = 1210 citizens (Base Year for the Design)
- Since, water supply network has to serve for a life period of 30 years.
- Population of Nandigudem by the end of 2050 = $1210* 1.011^{30}$ = 1680 citizens.
- Similarly, the population estimated by the end of 2050 in the remaining villages is presented in Table 1.

Based on this population, the demand for water is calculated in the next step

Water Demand Analysis

Assuming the per capita demand in the village as 75 lpcd [13]

∴ Ultimate Demand of water by the end of 2050 = 1680* 75 = 1,25,000 liters per day = 125.00 m^3 = 125.00 KL

In the next step, the village is designed with the water supply network using EPANET and every individual layer is presented clearly.

Table 1. Population Analysis in the remaining Villages (Chityala, Vadalakunta and Bhimolu).

Population/Village	Chityala	Vadalakunta	Bhimolu
In 2011 (as per APDWSC Statistics)	1176 citizens	3303 citizens	3138 citizens
Growth Factor	1%	1%	1%
By end of 2020 (Base Year)	1298 citizens	3645 citizens	3138 citizens
By end of 2050 (Ultimate Year)	1803 citizens	5061 citizens	4357 citizens

Table 2. Ultimate Water Demand in the remaining Villages (Chityala, Vadalakunta and Bhimolu) by 2050.

Demand/Village	Chityala	Vadalakunta	Bhimolu
Ultimate Population by 2050	1803 citizens	5061 citizens	4357 citizens
Estimated per capita demand	75 lpcd	75 lpcd	75 lpcd
Ultimate Demand of water by the end of 2050	135.23 KL	379.575 KL	326.803 KL

Step 2

Surveying and EPANET Analysis:

DGPS Survey Report

The entire Chityala, Nandigudem, Vadalakunta, Bhimolu villages, particularly Road Networks are properly surveyed using DGPS [12] and fed is explored AutoCAD Software. Figure 5–8 represent the Survey Report of all the villages in AutoCAD.

EPANET Layers

This CAD file is converted into .NET file using EPACAD and is opened in EPANET Software. Figures 9–12 represent the initial water supply network of all the villages in EPANET.

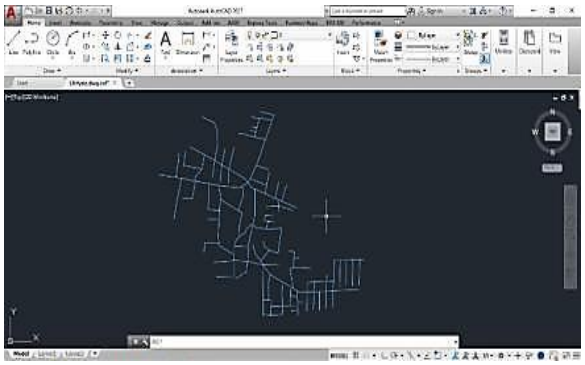


Figure 5. Survey Report of Chityala Village.

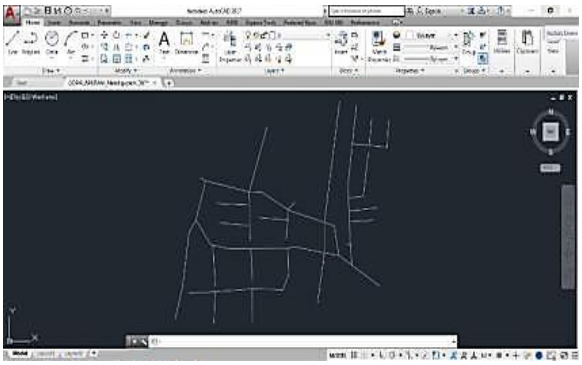


Figure 6. Survey Report of Nandigudem Village.

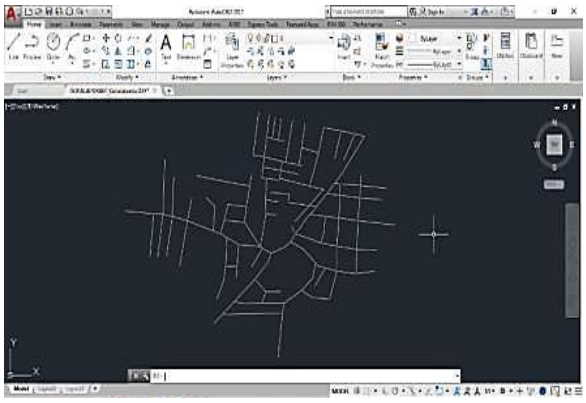


Figure 7. Survey Report of Vadalakunta Village.

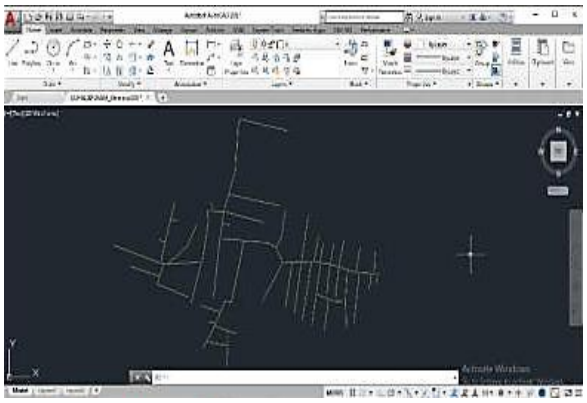


Figure 8. Survey Report of Bhimolu Village.

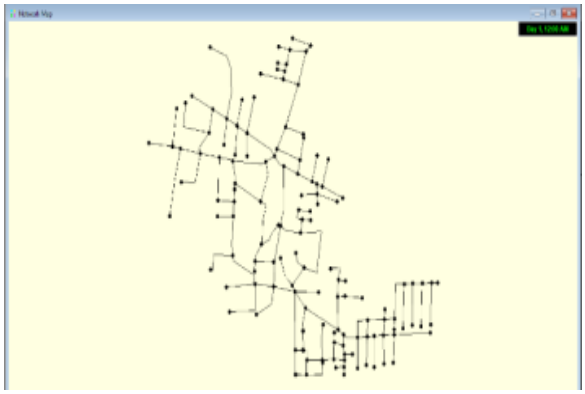


Figure 9. Chityala Village Network in EPANET.

Figure 10. Nandigudem Village Network in EPANET.

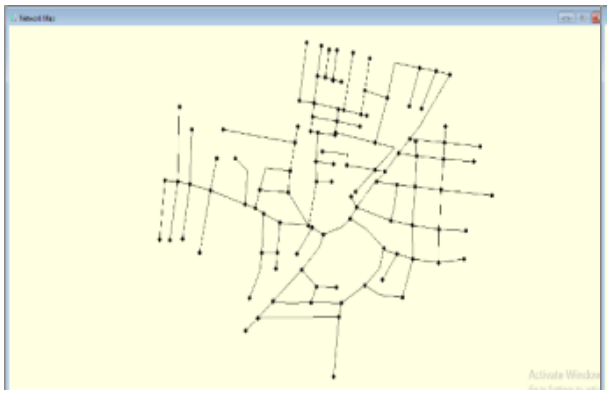


Figure 11. Nandigudem Village Network in EPANET.

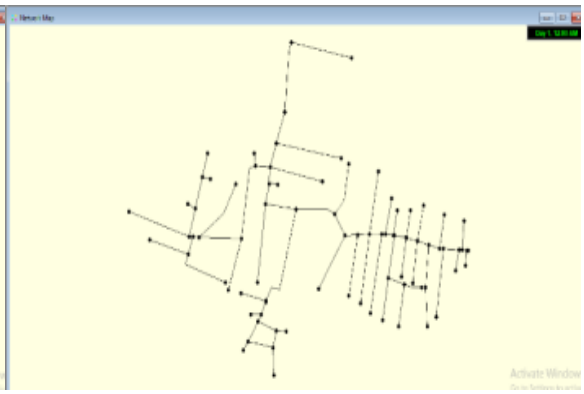
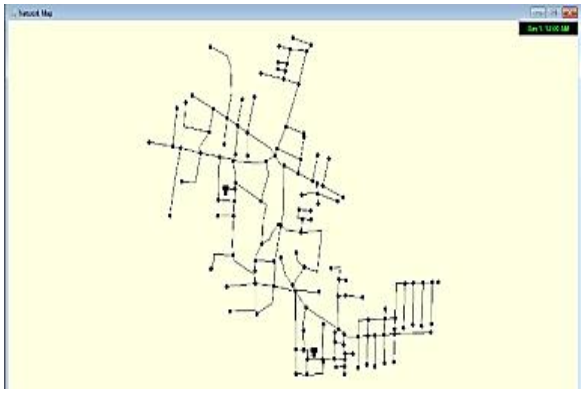
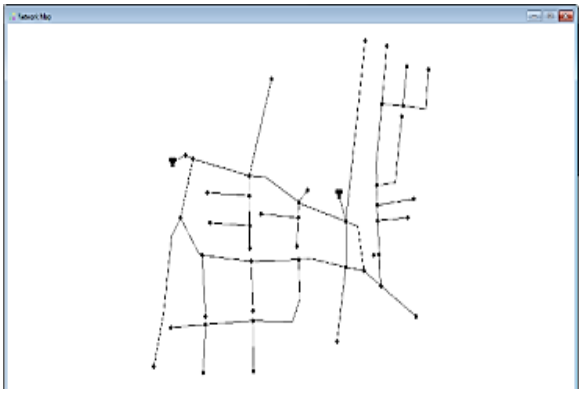


Figure 12. Bhimolu Village Network in EPANET.



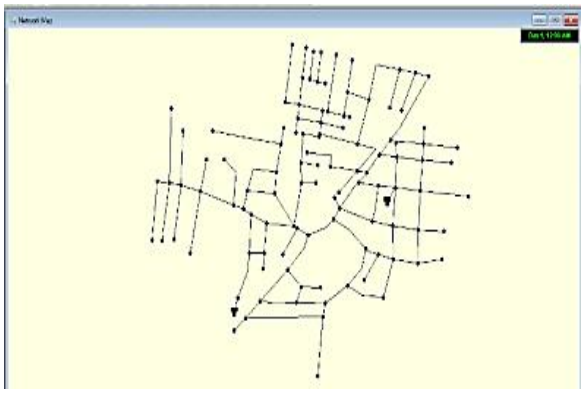
Note: Dia of each Tank = 5.1 m

Figure 13. Chityala Village Network with in EPANET with Designed OHDR Tanks.



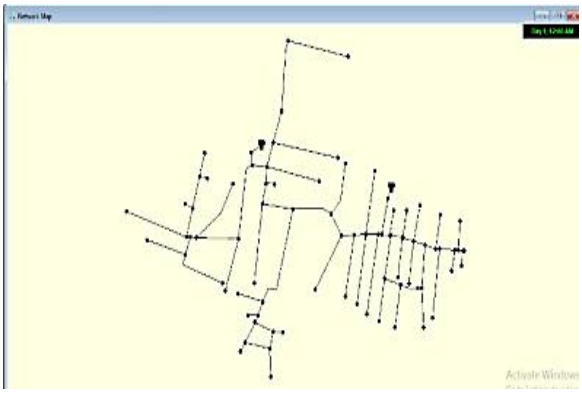
Note: Dia of each Tank = 5.0 m

Figure 14. Nandigudem Village Network with in EPANET with Designed OHDR Tanks.



Note: Dia of each Tank= 8.5 m

Figure 15. Vadalakunta Village Network with in EPANET with Designed OHDR Tanks.



Note: Dia of each Tank= 8.25 m

Figure 16. Bhimolu Village Network with in EPANET with Designed OHDR Tanks.

Based on the demand calculated in Step 1, 2 identical circular OHDR tanks are designed for every village at suitable locations with 3.4 m height. The bottom of the tank is 9 m from Ground Level. Then, the networks, after providing those tanks in all the villages would look, as presented in Figures 13–16.

All the nodes Ids in the network of all the villages are displayed in Figures 17–20.

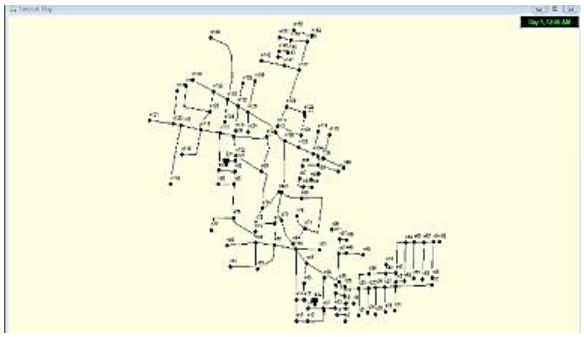


Figure 17. Chityala Village Network with Node Ids.

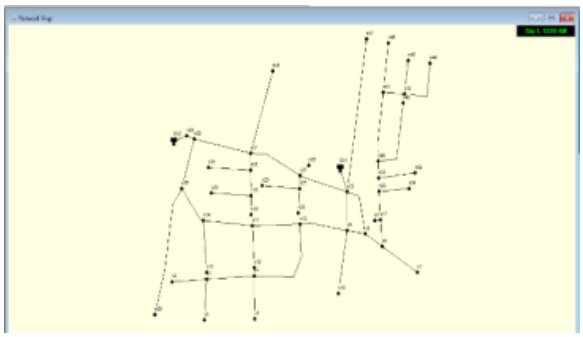


Figure 18. Nandigudem Village Network with Node Ids.

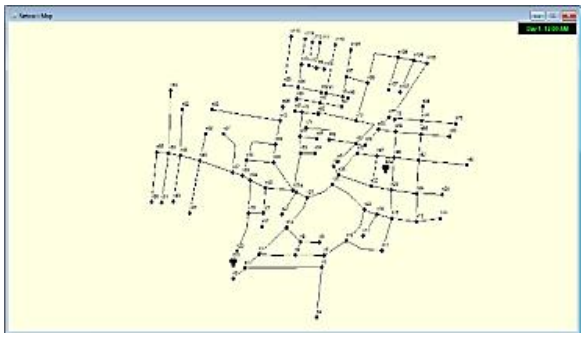


Figure 19. Vadalakunta Village Network with Node Id's.

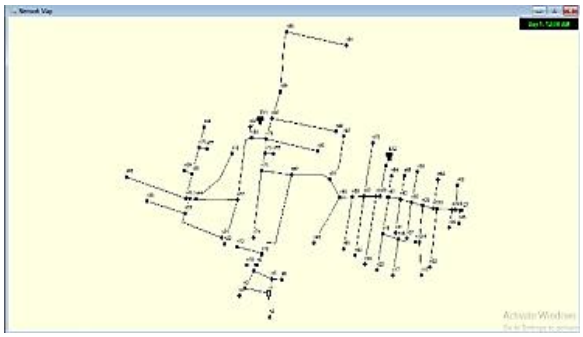


Figure 20. Bhimolu Village Network with Node Id's.

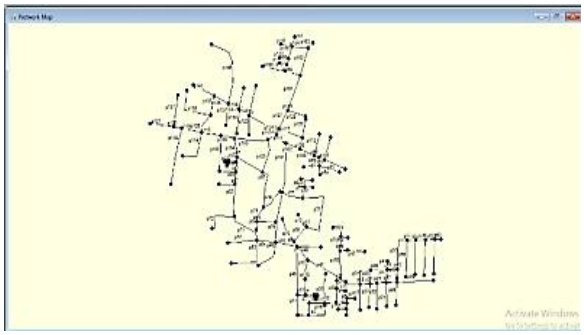


Figure 21. Chityala Village Network with Link Id's.

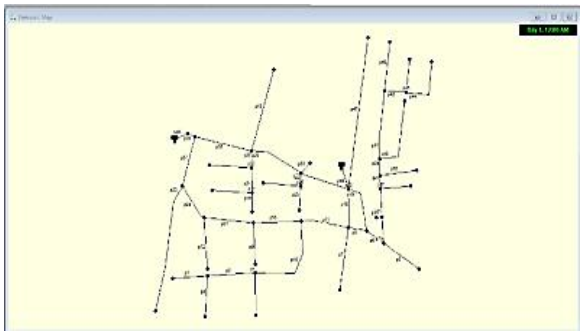


Figure 22. Nandigudem Village Network with Link Id's.

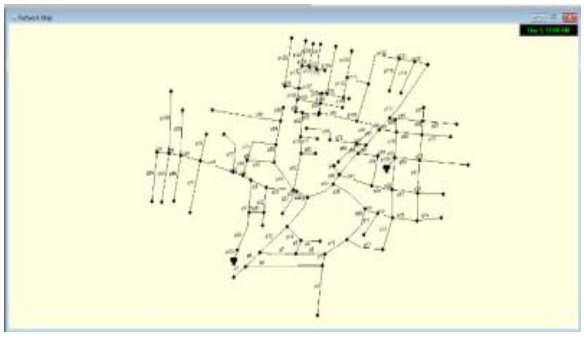


Figure 23. Vadalakunta Village Network with Link Id's.

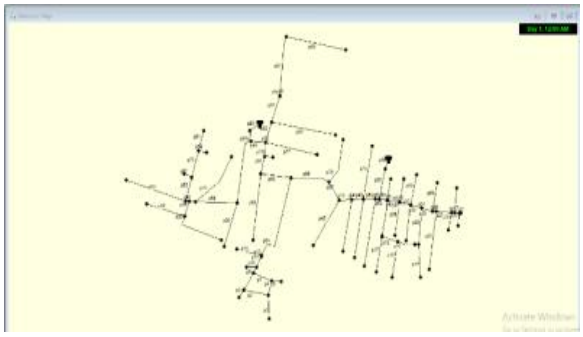


Figure 24. Bhimolu Village Network with Link Id's.

The Ids of links in all the villages are presented below in Figures 21–24.

From here, all data related to links or pipes will be presented. Firstly, the lengths of all the pipes are presented below in Figures 25–28.

The diameter of water in mm for all the pipes in the network is shown in Figures 29–32 (two types of pipes are used across the networks with 100 and 56.2 mm, respectively).

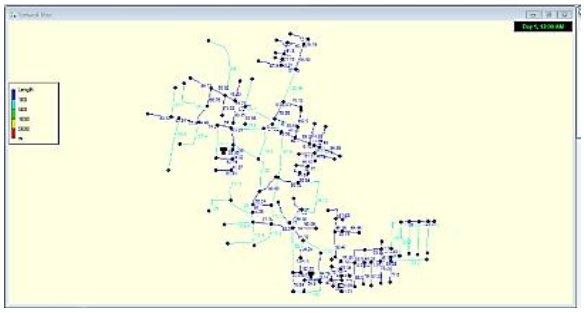


Figure 25. Lengths of all the Pipes of Chityala Village.

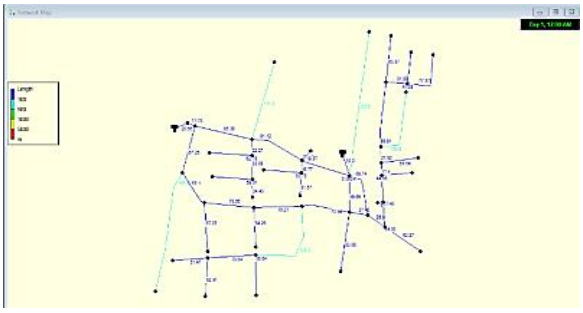


Figure 26. Lengths of all the Pipes of Nandigudem Village.

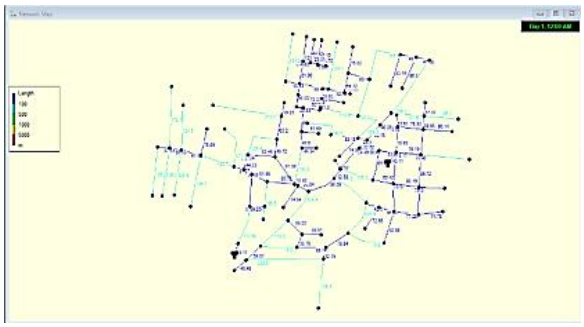


Figure 27. Lengths of all the Pipes of Vadalakunta Village.

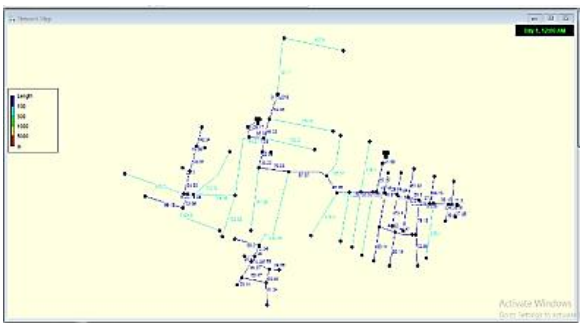


Figure 28. Lengths of all the Pipes of Bhimolu Village.

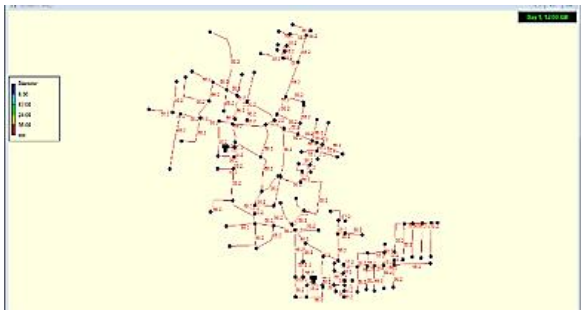


Figure 29. Diameters of all the Pipes of Chityala Village.

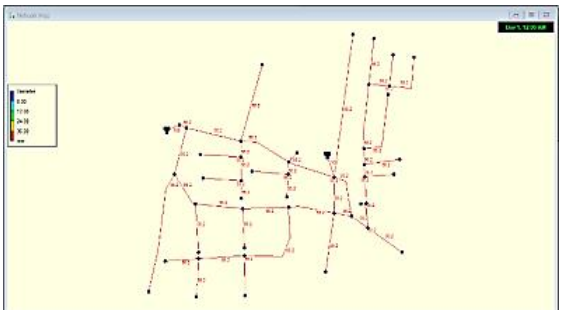


Figure 30. Diameters of all the Pipes of Nandigudem Village.

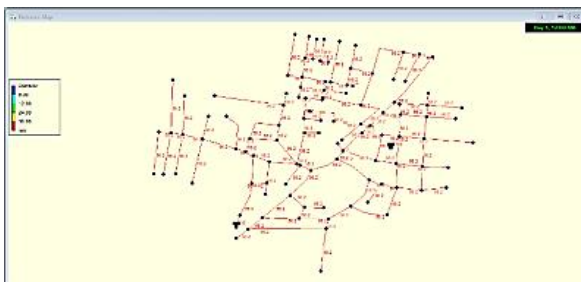


Figure 31. Diameters of all the Pipes of Vadalakunta Village.

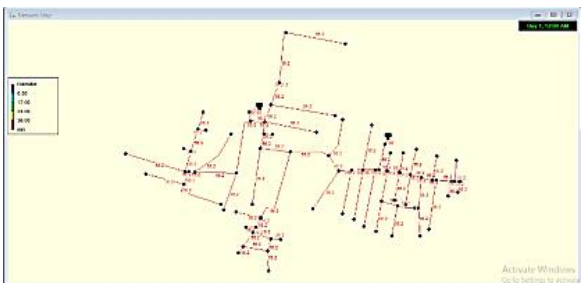


Figure 32. Diameters of all the Pipes of Bhimolu Village.

The unit head loss of water, in m/km for all the pipes in the network in all the villages are shown in Figures 33–36.

Figures 36–40 illustrate the direction of Flow of Water in every pipe in all the villages, respectively.

Figure 33. Unit Head Loss of all the Pipes of Chityala Village.

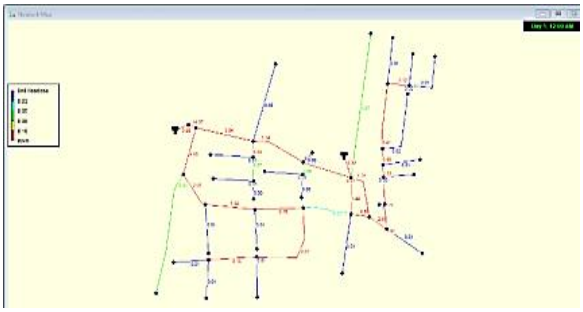


Figure 34. Unit Head Loss of all the Pipes of Nandigudem Village.

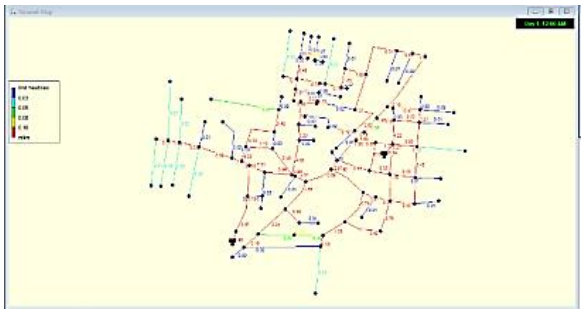


Figure 35. Unit Head Loss of all the Pipes of Vadalakunta Village.

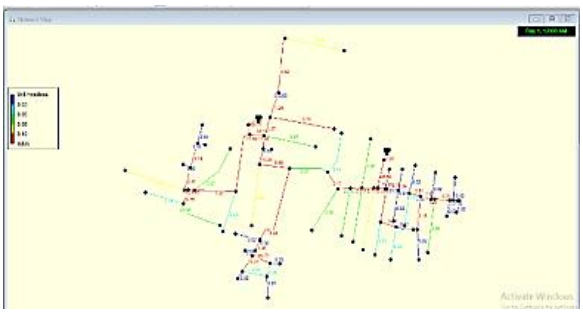


Figure 36. Unit Head Loss of all the Pipes of Bhimolu Village.

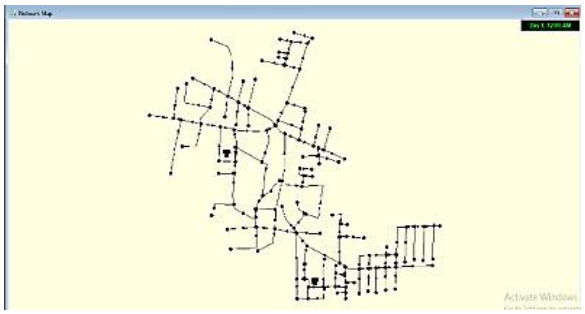


Figure 37. Flow of Water in the Entire Network of Chityala Village.

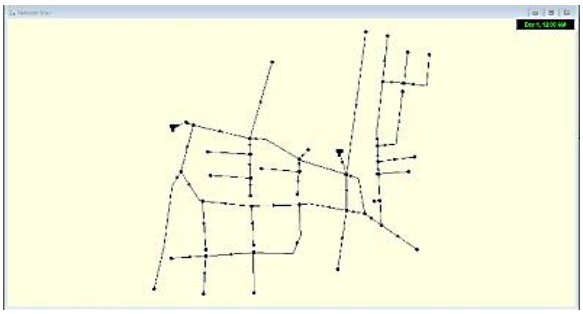


Figure 38. Flow of Water in the Entire Network of Nandigudem Village.

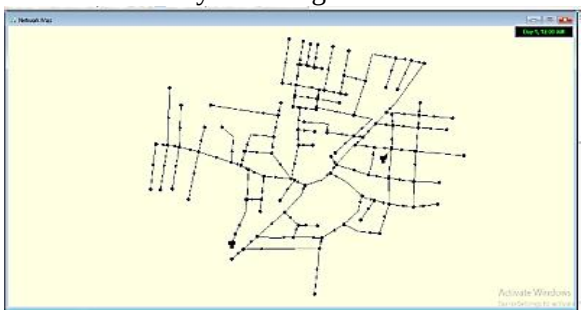


Figure 39. Flow of Water in the Entire Network of Vadalakunta Village.

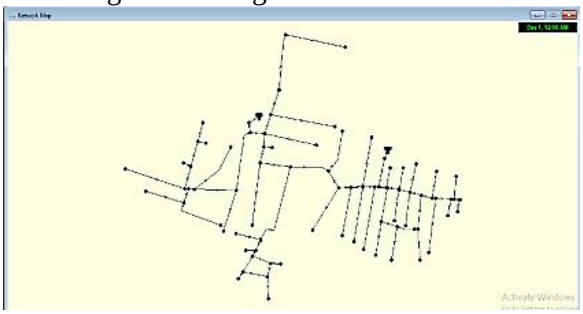


Figure 40. Flow of Water in the Entire Network of Bhimolu Village.

Step: 3
Hydraulic parameters of the network:

The Layers Attained from EPANET are Presented in the Step: 2

Table 3 presents the results of the network and properties in individual pipe attained from EPANET report for Nandigudem Village.

Table 3. Hydraulic Parameters of Nandigudem Village Water Supply Network.

Link ID	Length (m)	Diameter (mm)	Flow (LPM)	Velocity (m/s)	Unit Head Loss (m/km)	Friction Factor
p1	51.47	56.2	1.76	0.01	0.01	0.044
p2	52.91	56.2	1.81	0.01	0.01	0.043
p3	70.64	56.2	9.55	0.06	0.13	0.034
p4	55.64	56.2	1.9	0.01	0.01	0.044
p5	62.27	56.2	2.13	0.01	0.01	0.043
p6	29.8	56.2	48.09	0.32	2.57	0.027
p7	83.08	56.2	2.84	0.02	0.01	0.041
p8	27.42	56.2	19.95	0.13	0.5	0.031
p9	54.26	56.2	1.85	0.01	0.01	0.044
p10	129.2	56.2	20.18	0.14	0.51	0.031
p11	70.94	56.2	4.47	0.03	0.03	0.039
p12	67.23	56.2	2.3	0.02	0.01	0.043
p14	8.527	56.2	0.29	0.00	0.00	0.00
p15	34.03	56.2	41.65	0.28	1.97	0.028
p16	24.45	56.2	0.84	0.01	0	0.04
p17	59.01	56.2	2.02	0.01	0.01	0.043
p18	49.66	56.2	35.15	0.24	1.44	0.028
p19	68.74	56.2	32.44	0.22	1.24	0.029
p20	0.050	56.2	13.73	0.09	0.37	0.048
p21	37.45	56.2	38.62	0.26	1.71	0.028
p22	44.66	56.2	1.53	0.01	0	0.046
p23	169.8	56.2	5.8	0.04	0.05	0.037
p24	53.1	56.2	42.5	0.29	2.04	0.028
p25	31.57	56.2	1.08	0.01	0	0.043
p26	55.75	56.2	1.91	0.01	0.01	0.044
p27	17.4	56.2	33.7	0.23	1.33	0.029
p28	16.77	56.2	6.54	0.04	0.06	0.036
p29	73.18	56.2	17.35	0.12	0.39	0.032
p30	54.54	56.2	1.86	0.01	0.01	0.044
p31	33.09	56.2	6.84	0.05	0.07	0.036
p32	62.78	56.2	2.15	0.01	0.01	0.043
p33	18.37	56.2	0.63	0	0	0.031
p34	21.92	56.2	28.63	0.19	0.98	0.029
p35	22.27	56.2	13.02	0.09	0.23	0.033
p36	81.12	56.2	30.99	0.21	1.14	0.029
p37	67.25	56.2	58.22	0.39	3.66	0.026
p38	85.39	56.2	58.06	0.39	3.64	0.026
p39	11.78	56.2	121.9	0.82	14.37	0.024
p40	100.8	56.2	3.44	0.02	0.02	0.04
p41	89.81	56.2	17.92	0.12	0.41	0.031
p42	31.88	56.2	9.39	0.06	0.12	0.035
p43	111.3	56.2	3.8	0.03	0.02	0.04
p44	77.37	56.2	2.64	0.02	0.01	0.042
p45	44.08	56.2	1.51	0.01	0	0.045
p46	63.97	56.2	2.19	0.01	0.01	0.043
p47	200.9	56.2	6.86	0.05	0.07	0.036
p48	20.56	100	123.0	0.26	0.88	0.025
p49	32.2	100	71.62	0.15	0.32	0.028
p50	70.21	56.2	24.95	0.17	0.76	0.03
p51	73.66	56.2	33.58	0.23	1.32	0.029

Table 4. Summary of all the Hydraulic Parameters of all the Villages.

Parameter		Village			
		Chtiyala	***Nandigudem***	***Vadalakunta***	***Bhimolu***
No. of Nodes		155	47	115	91
No. of Links		170	51	121	95
Tanks Proposed	Numbers	2	2	2	2
	Diameter of Tank	5.10 m	5.00 m	8.50 m	8.25 m
	Height of Tank	3.40 m	3.40 m	3.40 m	3.40 m
Total Length of Pipe Network		10,610.99 m	2,874.257 m	9,723.628 m	5,242.41m
Diameter of Pipes		56.2 and 100 mm	56.2 and 100 mm	56.2 and 100 mm	56.2 and 100 mm
Type of the Distribution Network		Dead End System	Dead End System	Dead End and Grid System	Dead End System
Total Unit Head Loss		110.62 m/km	42.48 m/km	156.02 m/km	137.45 m/km

Summary of all Hydraulic Parameters of all the Villages

The Table 4 represents the summary of all the hydraulic parameters of all the villages.

Step 4

Friction Losses calculation**:**

For Nandigudem village, from the above Table 3 and Figure 34, using Hazen William's Equation [14]

Unit Head Loss (H_f) = $10.65*((Q^{1.85})*L) / (C^{1.85})*d^{4.87})$

where, Q is the Flow or Discharge (LPM)

L is the Length of Pipe (m)

C is the Roughness Factor = 140

d is the Diameter of Pipe (mm)

it is found that,

Total Unit Head Loss in the entire network = 42.48 m/km

Total Unit Head Loss in 100 mm diameter pipes = 0.88 + 0.32 = 1.20 m/km

Total Unit Head Loss in 56.2 mm diameter pipes = 110.62-1.47 = 41.28 m/km

The Table 5 presents a model calculation of the amount of water lost as head loss calculation in the individual pipe section. Since, only two diameters of pipes are used in the entire network, (i.e., 100 and 56.2 mm) the amount of the water lost as head loss in the entire network is calculated.

Table 5. Model Calculation of the Amount of Water Lost as Head Loss Calculation in the Individual Pipe Section.

100 mm Diameter Pipe	**56.2 mm Diameter Pipe**
Height of the Water Lost = Unit Head Loss in a pipe Length of the Pipe*	
E.g.,: Pipe 48: Unit Head Loss = 0.88 m/km Length of Pipe = 20.56 m = 0.02056 km ∴ Height of Water Lost = 0.88* 0.02056 = 0.018 m	E.g.,: Pipe 8: Unit Head Loss = 0.5 m/km Length of Pipe = 27.42 m = 0.02742 km ∴ Height of Water Lost = 0.5* 0.02742 = 0.01371m
Similarly, Total Height of Water lost in 100 mm pipe network = 0.0283 m	Similarly, Total Height of Water lost in 100 mm pipe network = 1.690 m
Volume of Water Lost (Q) = Area Height*	
Area of Pipe = $(\pi/4)*0.1^2 = 7.85*10^{-3}$ m^2	Area of Pipe = $(\pi/4)*0.0562^2 = 2.48*10^{-3}$ m^2
Q_1 = A* 0.0283= $2.22*10^{-4}$ m^3	Q_2 = A* 1.690= $4.19*10^{-3}$ m^3

Table 6. Summary of Head Loss of the other Villages (Chityala, Vadalakunta and Bhimolu).

	Village		
	Chityala	***Vadalakunta***	***Bhimolu***
Total Unit Head Loss	110.62 m/km	155.94 m/km	308.25 m/km
Amount of Water Lost as Head Loss (per day)	14.5 liters	25.78 liters	32.5 liters
% of Water Lost as Head Loss	0.01%	0.0067%	0.009%

Q_1 and Q_2 present the total quantity of water lost as head loss cumulatively in 100 and 56.2 mm pipes in the entire Nandigudem Village.

Therefore, Total Volume of Water lost = $Q_1 + Q_2 = 2.22*10^{-4} + 4.19* 10^{-3} = 4.412*10^{-3}$ m^3 = 4.412 liters

That is, 4.412 liters of water per day is lost in the form of head loss in the entire village's water supply network.

% of Water Lost as Head Loss per day = (Quantity of Water Lost/Quantity of Water Supplied to the Network) * 100

= (4.412/1,25,000) *100 = 0.00352%

So, out of 125 KL of water fed into the tanks, during the distribution process, 4.412 liters of water is lost as head loss, which is equal to 0.00352% which is almost negligible. Therefore, 99.996% of the water provided in the tanks, is distributed for the village. This loss is constant up to the ultimate design life of the network that is 2050. Till this time, the head losses would be equal to or below 0.00352% but under cases like leakages or thefts, this value could be exceeded.

Similarly, for the other villages (Chityala, Vadalakunta and Bhimolu) the calculation for the amount of water lost as Unit Head Loss is presented below in Table 6.

From the above Table 6, the ultimate head losses in the designed Domestic Water supply network and the ultimate % of water lost is presented, since all the results are lesser than 0.01%, and the quantities are almost negligible therefore, the networks could be understood as economical and simple in all the villages.

CONCLUSIONS OF THE STUDY

From this study, there are various outcomes, which are discussed below:

Achievements of Objectives

- Firstly, the villages are completely explored and presented in study area.
- EPANET Software was thoroughly studied and explored before beginning this study.
- Using the Survey Report and Population Reports, the villages are designed with the water supply networks.
- Under trial and error process, the losses and errors in the network are rectified and the finely polished networks of every are presented in results topic.
- Every hydraulic parameter is presented clearly shown in the layers and reports presented in the same topic.
- Using Hazen William's Equation, the amount of Unit Head Loss in the village are determined and the amount of water lost as losses is also calculated and presented.

Summary of the Village Networks

Chityala Village

- As stated in the study area, this village has an extent of 1271 hectares.
- The population as per 2011 census was recorded as 1176 citizens. It was forecasted using IIM that, the population by the end of the design period in this village would be 1803 citizens.
- With respect to IS 1172:1993 [13], the per capita demand was assumed as 75lpcd per day and the ultimate demand by the end of the design period is found to be 135.23 KL.
- With respect to the demand, two identical OHDR tanks of 5.10 m dia and 3.40 m height are designed at elevated locations.

- The entire network is attained with 155 nodes and 170 links/pipes.
- This village has achieved the pipe network of length 10,610.99 m, with 56.2 and 100 mm diameter pipes used depending on the situation.
- The network is proposed to use DI pipes of K9 Grade. Roughness Constant for all the pipes is given as 140.
- The network is completely Dead End System [15].
- It is also observed that the total Unit Head Loss in the network is 110.62 m/km. By which it is determined that a maximum of 0.01% of the water supplied to the village is lost in the form of head losses. That is about 14.5 liters per day. This value is really negligible.
- Finally, by estimation based on various items of work and quantities, the cost of construction of this network is found to be ₹.1,97,86,852.68/-. Based on Standards Schedule of rates [16]. Also, the construction could be completed within 4 months and 15 days.

Nandigudem Village

- As stated in study area, this village has an extent of 1786 hectares.
- Where the population as per 2011 census was 1096 citizens. It was forecasted using IIM that, the population by the end of the design period in this village would be 1680 citizens.
- With respect to IS 1172:1993 [13], the per capita demand was assumed as 75lpcd per day and the ultimate demand by the end of the design period is found to be 125.00 KL.
- With respect to the demand, two identical OHDR tanks of 5.00 m dia and 3.40 m height are designed at elevated locations.
- The entire network is attained with 47 nodes and 51 links/pipes
- This village has achieved the pipe network of length 2,874.257 m, with 56.2 and 100 mm diameter pipes used depending on the situation.
- The network is proposed to use DI pipes of K9 Grade. Roughness Constant for all the pipes is given as 140.
- The network is completely Dead End System [15].
- It is also observed that the total Unit Head Loss in the network is 42.48 m/km. By which it is determined that a maximum 0.00352% of the water supplied to the village is lost in the form of head losses. That is about 4.412 liters per day. This value is really negligible.
- Finally, by estimation based on various items of work and quantities, the cost of construction of this network is found to be ₹.1,03,04,522/-. Based on Standards Schedule of rates [16]. Also, the construction could be completed within 4 months and 15 days.

Vadalakunta Village

- As, stated in the study area, this village has an extent of 921 hectares.
- The population as per 2011 census was recorded as 3303 citizens. It was forecasted using IIM that, the population by the end of the design period in this village would be 5061 citizens.
- With respect to IS 1172:1993 [13], the per capita demand was assumed as 75lpcd per day and the ultimate demand by the end of the design period is found to be 379.575 KL.
- With respect to the demand, two identical OHDR tanks of 8.50 m dia and 3.40 m height are designed at elevated locations.
- The entire network is attained with 115 nodes and 121 links/pipes
- This village has achieved the pipe network of length 9,723.628 m, with 56.2 and 100 mm diameter pipes used depending on the situation.
- The network is proposed to use DI pipes of K9 Grade. Roughness Constant for all the pipes is given as 140.
- The network is made of Dead End and Grid Systems [15].
- It is also observed that the total Unit Head Loss in the network is 156.02 m/km. By which we have determined that a maximum of 0.0067% of the water supplied to the village is lost in the form of head losses. That is about 25.78 liters per day.

- Finally, by estimation based on various items of work and quantities, the cost of construction of this network is found to be ₹.3,08,14,743.35/-. Based on Standard Schedule of Rates [16]. Also, the construction could be completed within 5 months and 15 days.

Bhimolu Village

- As stated in the study area, this village has an extent of 2240 hectares.
- The population as per 2011 census was recorded as 2844 citizens. It was forecasted using IIM that, the population by the end of the design period in this village would be 4357 citizens.
- With respect to IS 1172:1993 [13], the per capita demand was assumed as 75lpcd per day and the ultimate demand by the end of the design period is found to be 326.803 KL.
- With respect to the demand, two identical OHDR tanks of 8.25 m dia and 3.40 m height are designed at elevated locations.
- The entire network is attained with 91 nodes and 95 links/pipes.
- This village has achieved the pipe network of length 5,242.41 m, with 56.2 and 100 mm diameter pipes used depending on the situation.
- The network is proposed to use DI pipes of K9 Grade. Roughness Constant for all the pipes is given as 140.
- The network is designed as a complete Dead End System [15].
- It is also observed that the total Unit Head Loss in the network is 137.45 m/km. By which it is determined that a maximum of 0.009% of the water supplied to the village is lost in the form of head losses, which implies 32.5 liters of water per day.
- Finally, by estimation based on various items of work and quantities, the cost of construction of this network is found to be ₹.2,44,69,212.24/-. Based on Standard Schedule of Rates [16]. Also, the construction could be completed within 5 months and 15 days.

CONCLUSIONS OF THE STUDY

- EPANET Software is found to be really simple software, with its own simplicity and limitations.
- Every village has got its own definite amount of pipe lengths, demands, and all of them are clearly explained in Results and Conclusions topic.
- It was also understood that there is a definite relationship between Time, Budget, Quality and the Quantity of Resources needed for completion of a project through this study.
- Simple, Economical and Optimistic Domestic Water Supply Networks are designed in Chityala, Nandigudem, Vadalakunta and Bhimolu Villages in a smart approach using EPANET 2.0 Software, as a small and elegant contribution concerning to Andhra Pradesh Water Supply Scheme.
- Finally, all these networks are efficient to match the requirements and criteria from Government of Andhra Pradesh for Andhra Pradesh Water Supply Scheme. Also, this work is intended to totally surpass the catastrophic situation being faced by the people dwelling over there and bring a smile on their faces assuring them pure and safe water till 2050.

RECOMMENDATIONS AND SCOPE FOR FUTURE STUDIES

- These water supply networks could also be fed into few other advanced software including WaterGEMS for further level analysis and precision.
- Using software like MS Project, Primavera, etc. the project management and resource allocation could be done with greater level of accuracy.
- Based on the series of activities, a proper network diagram for project management and tracking could also be designed.
- Finally, after a certain period of time, again the network of this village could be analyzed using EPANET or any other similar software available for that time and present them [5, 11].

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