

Water Distribution Network Analysis for Vellore Town Panchayat Using GIS and EPANET

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Abstract.Water distribution system serves many purposes in addition to the provision of water for the human consumption and hence it is an important component in the development of an area. Due to urbanization, the population of city is increasing drastically and hence the distribution system should be designed in such a way that it should satisfy the consumers demand at adequate pressure. Analysis of water distribution system involves determining the quantities of flow, head loss in various pipes sections and resulting residual pressure. The study area chosen for the project is Vellore town panchayat of Coimbatore district. The main source of water supply to the area is from Athikadavu. The present distribution system consists of 7 overhead tanks which is inefficient to meet the future demands. The feasibility of increasing the tank in the study area was identified. New tank location is placed foreseeing the future population expansion of the area. The topographic map of the study area is obtained from Google earth. Spatially bound network model for the newly determined capacity is created by using polyline theme in ArcView GIS software. The network created is based on the road pattern of the area. The network model generated is georeferenced to real world features. The georeferenced network from ArcView GIS is imported into the EPANET by using interchange tool. Nodal elevation is taken from digital elevation map. Manual calculation is carried out for determining the effective size of the pipes using Hazen-William's nomogram. Elevation and demand as a nodal input and pipe sizes and length as link input hydraulic simulation of the model is carried out using EPANET software. The result from the EPANET shows that the pressure at each node is within the limits.

Keywords: Water Distribution, Population, Capacity, ArcView GIS, EPANET, Network.

1 Introduction

Water supply network plays a vital role in infrastructure projects of the city. The basic function of water supply system is to transport water from treatment facility to the consumer. The distribution system also provides storage facilities and required flow and pressure for fire protection. The major issues prevailing in the distribution system is distributing water with adequate pressure and at the same time quality of water arriving at the consumer ends should be within the prescribed limits. GIS is a tool that collect, stores, analyze and display geographically referenced data. In this project GIS is used as a mapping tool for distribution utilities and it also offers extensive functions such as spatial analysis and data management. Water supply system based on GIS, makes the process easy, efficiency and exact. Design and analysis of water distribution system is a complex process and involves various steps and

consumption of time. The work performed by Arunkumar and Nethaji mariappan(2011), highlights the process involved in the design of water supply system for the area named Kathgarh.

2 Objective

The objective of the project is

1. To develop water distribution network line for the future demand using ArcView GIS for the study area.
2. To determine the effective sizes of the pipes using Hazen-Williams formula by manual method
3. To determine the various parameters such as head, velocity and pressure of water distribution network using EPANET.

3 Study area

The study area selected is vellalore town panchayat is shown in fig 1. It is located 12 Km towards south from district headquarters Coimbatore. Its location is at 77o01'39"E and 10o58'40"N. It has a population of 24,872 as per census of 2011. It comes under Madukkarai taluk. It has an area of about 16.64Km2 with 15wards. The main source of water to the study area is from Athikadavu.

4 Methodology

The methodology adopted for this project is forecasting of population for the design period using suitable method. The water demand for various purposes such as industrial, commercial and domestic purposes are known and average percapita consumption of water is calculated as per the codal provisions. The capacity of the reservoir is calculated using manual method. The new network to be proposed for the study area is drawn using polyline theme in ArcView GIS and analysis is carried out using EPANET.

5 Population Forecasting

The population forecasting is an important factor in planning an network when the project has to serve the community for the certain design period. The design period for the distribution system is 30 years. The population at the end of the design period can be predicted by using various forecasting methods. Since it is a growing town geometric method is used keeping 2018 as a base year as shown in table 1.

6 Water Demand

The Water demand for the town is divided into various purposes such as domestic, institutional, commercial and industrial use. According to central public Health Environmental Engineering Organization manual, the average water demand, for the town is 135lpcd excluding water losses in pipes which accounts for 15%.

7 Storage capacity of tank

The present system is inefficient to cater the future demands since the design period of the system is over. The storage capacity of tank is calculated for forecasted population. The pumping is done for 8hrs from 5am-9am and 5pm-9pm. The system is designed for continuous supply of water rather than intermittent supply. The design of storage capacity of tank is shown in table 2

$$\begin{aligned}\text{Quantity of water estimated} &= 33658 * 135 * 1.15 \\ &= 5225404 \text{ litres}\end{aligned}$$

$$\begin{aligned}\text{Capacity of tank} &= \text{maximum of surplus} + \text{maximum of deficit} \\ &= 156800 \text{ litres}\end{aligned}$$

8 ArcView GIS

ArcView GIS was developed by Environmental System Research Institute (ESRI) which is a geographic information system software product that allow the user to visualize, analyze, query, map and organize geographic information. The extension that will be validated in this test plan and report are spatial analyst, geoprocessing, data query etc. It has high level generic geographic data model for representing spatial information such as features, raster and other spatial types. In this project, ArcView GIS is used to create the network using polyline theme which is shown in fig 2.

9 Interchange Method

Interchange method involves batch process approach to interchange data between a GIS and a computer model. In this method, there is no direct link between GIS and model. Both run separately and independently. The GIS database is processed to extract model input parameters which are manually copied into a model input file. Similarly, model output file are manually copied in a GIS as a new spatial layer for representation of map.

10 Determination of Pipe size

The effective sizes of the pipes are calculated by using Hazen-Williams formula by assuming pipe size which involves various trials. This process is cumbersome and time consuming. In order to make the process easy Hazen William's nomogram has been used. In this chart a straight edge is placed in the known values of flow and assumed pipe diameter, the unknown value head loss can be found. The pipe materials used is Cast Iron. The manual calculation carried out is shown in table 3 and table 4.

Table 1: Population forecasting for vellore

Design year	Forecasted population
2028	28580
2038	31016
2048	33658

Table 2: Storage capacity of tank

Time	Percent of average consumption	Demand	Cumulative demand	Inflow	Cumulative inflow	Deficit	surplus
5am-9am	40	2090162	2090162	2612702	2612702	-	522542
9am-5pm	30	1567621	3657783	-	2612702	1045079	-
5pm-9pm	25	1306351	4964134	2612702	5225404	-	261270
9pm-5am	5	261270	5225404	-	5225404	-	-

Table 3: Manual calculation of pipe size

Pipe section	Population at end node	Population at start node	Total population	Maximum demand (lps)
qr	199	487	686	3.33
pq	785	72	857	4.15
op	1000	105	1105	3.36
no	1689	263	1952	9.47
mn	2198	605	2803	13.59
lm	2967	67	3034	14.72
kl	3121	90	3211	15.57
jk	3343	42	3385	16.42
ij	3465	84	3549	17.21
hi	4326	74	4310	20.90
gh	4645	83	4728	22.93
fg	4871	80	4951	24.01
ef	5033	78	5111	24.78

de	5282	132	5414	26.25
cd	5608	71	5679	27.54
bc	6419	88	6507	31.55
ab	6803	105	6935	33.63
o'a	7234	87	7321	35.51



Fig 1: Map of study Area- Vellore

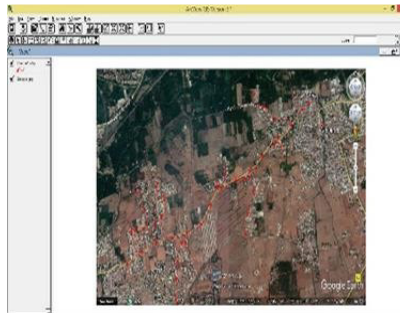


Fig 2: Creation of Water Distribution Network using ArcView

Table 4: calculation of head

Pipe section	Assumed pipe diameter(mm)	Head loss in m/1000m	Length(m)	Actual head loss(m)	Hydraulic level (m)	Ground level(m)	Net head(m)
qr	100	3.5	682	2.38	400	386	14
pq	100	5.5	101	0.55	403.25	386	17.25
op	100	8.5	368	1.24	403.80	386	17.8
no	150	3.3	847	1.21	405.04	388	17.04
m	200	1.52	93.9	1.28	406.25	388	18.25
n							
lm	200	1.28	123	0.12	407.53	389	18.53
kl	200	2.4	60	0.30	407.65	391	16.65
jk	200	2.5	118	0.15	407.95	393	18.53
ij	200	2.7	104	0.31	408.10	394	14.95
hi	200	3.2	117	0.33	408.41	394	14.10

gh	200	0.4	112	0.468	408.74	397	14.41
fg	300	0.75	110	0.084	409.20	397	11.74
ef	300	0.7	185	0.07	409.29	397	12.20
de	300	0.8	100	0.148	409.36	397	12.29
cd	300	0.75	85	0.075	409.51	398	11.51
bc	300	1	124	0.124	409.58	400	9.58
ab	300	1.1	147	0.16	409.71	401	8.71
o'	300	1.4	96	0.13	409.87	401	8.87

11 EPANET

The work carried out by Suraniand Dihora (2015) reports EPANET is a public domain software which model water distribution piping system. 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. The input parameters given in the nodal points are elevation and base demand. In the pipe sections length, diameter, roughness coefficients are entered manually. The hydraulic simulation of the network is carried out. Kakadiyashital et al, (2017)

11.1 Input details

The following table consists of the parameters to be given as an input for the nodal junctions. After the manual entry of inputs single period hydraulic simulation work is carried out for the imported network. The parameters to be given as input is shown in table 5.

12 Results and Discussions

The network drawn consists of 36 nodes, 36 links and 1 tank. The hydraulic simulation of the network is carried out considering the status of the pipes as open and the following results are obtained. The head loss between the start and end nodes of the pipe is computed using Hazen -Williams's formula. The link results are tabulated in the table 7 and nodal results are given the table 6 below. The study area consists mostly of single storey buildings the minimum pressure adopted is 7m. EPANET results shows that the pressure at each junction point are found to be greater than 7m hence the flow can takes place easily. The assumed diameter of each pipe is sufficient enough to withstand the pressure in the entire network. No negative pressure node is identified from the results which show that there is no change in direction of water flow. The entire network has a uniform flow and velocity and there is enough pressure at each node and there is no deficiency in demand. The head loss from simulation results are in correlation with the manually calculated head loss. The results shows that the pressure obtained are satisfy enough to provide water to the study area

Table 5: Input the parameter in to the network

NODE	DEMAND (lps)	EPANET INPUT	ELEVATION(m)
O'	35.51	-	410

a	0.42	35.09	401
1	1.45	33.64	399
b	0.50	33.13	401
2	1.58	31.55	404
c	0.43	31.12	400
3	3.59	27.53	403
d	0.34	27.19	398
4	0.95	26.24	397
e	0.64	25.60	397
5	0.83	24.77	394
f	0.38	24.39	397
6	0.40	23.99	394
g	0.38	23.61	397
7	0.69	22.92	394
h	0.40	22.52	394
8	1.62	22.12	393
i	0.35	20.50	394
9	3.33	20.14	390
j	0.41	16.81	394
10	0.38	16.40	392
k	0.20	16.01	393
11	0.64	15.81	390
l	0.44	15.17	391
12	0.42	14.74	391
m	0.32	14.32	389
13	0.80	14.00	388
n	2.93	13.21	388
14	1.19	10.28	385
o	1.27	9.09	388
15	2.84	7.82	384
p	0.51	4.98	386
16	0.69	4.47	383
q	0.35	3.78	386
17	0.48	3.43	383
r	2.36	0.97	386
18	0.97	0.0	384

Table 6: Nodal results

Node	Demand (lps)	Head (m)	Pressure (m)
a	0.42	419.85	18.85
b	0.51	419.65	18.65
c	0.43	419.50	19.50
d	0.34	419.40	21.04
e	0.64	419.24	21.24
f	0.38	419.15	20.15

g	0.38	419.07	20.07
h	1.62	418.50	14.50
i	0.36	418.07	14.07
j	0.41	417.72	13.72
k	0.20	417.57	14.57
l	0.44	417.26	16.26
m	0.32	417.06	18.06
n	2.93	415.48	17.48
o	1.27	415.13	17.17
p	0.51	413.69	17.69
q	0.35	413.07	17.07
r	2.36	410.32	14.32
1	1.45	419.49	10.49
2	1.58	419.19	15.19
3	3.59	414.68	11.68
4	0.95	419.29	22.21
5	0.83	419.17	15.17
6	0.40	419.14	15.14
7	0.69	419.03	12.0
8	0.35	418.47	15.47
9	3.33	414.18	14.18
10	0.39	417.72	15.72
11	0.64	417.53	17.53
12	0.42	417.25	16.25
13	0.80	416.99	18.99
14	1.19	415.27	10.27
15	2.84	412.67	18.67
16	0.69	413.65	10.65
17	0.48	413.06	10.06
18	0.97	410.20	16.02
O'	35.46	420.00	10

Table 7: Link results

Node	Flow (lps)	Velocity (m/s)	Unit head loss (m)
a	35.46	0.50	1.53
b	33.59	0.48	1.39
c	31.50	0.45	1.23
d	27.48	0.39	0.96
e	26.19	0.37	0.87
f	24.72	0.35	0.79
g	23.94	0.34	0.74
h	22.87	0.73	4.90
i	20.90	0.67	4.15
j	17.21	0.55	2.89

k	16.41	0.52	2.65
l	15.57	0.50	2.40
m	14.71	0.47	2.16
n	13.59	0.43	1.87
o	9.47	0.30	0.96
p	5.36	0.68	9.76
q	4.16	0.53	6.10
r	3.33	0.42	4.04
1	1.45	0.18	0.87
2	1.58	0.20	1.02
3	3.59	0.46	4.65
4	0.95	0.12	0.40
5	0.83	0.11	0.31
6	0.40	0.05	0.08
7	0.69	0.09	0.22
8	0.35	0.04	0.06
9	3.33	0.42	4.04
10	0.39	0.05	0.08
11	0.64	0.08	0.19
12	0.42	0.05	0.09
13	0.80	0.10	0.29
14	1.19	0.15	0.60
15	2.84	0.36	3.01
16	0.69	0.09	0.22
17	0.48	0.06	0.11
18	0.97	0.12	0.41

13 Conclusion

Geo referenced network model created using ArcView GIS can be directly interchanged into EPANET input file. This reduces the work of modeling in EPANET and provides more accurate data. The design period of the existing system has been over. Analysis of demand with the collection of preliminary data shows that there is a requirement of additional water supply source for the study area. The feasibility of increasing the number of tanks in the study area was identified. The new tank was proposed at 10°58'03"N and 77°0'04" E and considering the maintenance and cost of tanks, single tank of 3.68 lakh litre was suggested. The new network has been proposed based on the road pattern and this will meet the future demand. The dead end type of distribution system has been adopted placing tank at a higher elevation. Thus the recommendation is made to the existing system for the improvement of study area for the future demands.

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