

WATER DISTRIBUTION NETWORK RE-DESIGN FOR SVNIT SURAT CAMPUS

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Abstract: Main objective of paper is to design and evaluate the water distribution network due to revision in water demands at SVNIT Surat's campus. SVNIT's water distribution work has been chosen to help for further designing of an optimum pipe network that will be capable of satisfying the future water requirements. In performing the complete work, Arc-GIS 4.2 was used to identify the locations, element and joints while WaterGems software has been used in order to attain perfection in every aspect of the work. The water demands increased significantly due to new constructions to meet the needs of increasing population in the campus. Different kinds of pipes available in the market and their cost are referred from standard manual issued by government of Gujarat. Paper presents an output which is good, economical and well optimized in all aspects of a good water distribution network. The total study area has been divided into four different zones Academic, Residential, Administrative and Other zones to simplify the work. The two categories of network are Gravity network and Pressurized Network. The total network is divided into two categories based upon the fundamental whether the required head is more or less than the available head. The optimization of distribution network is done using WaterGems. The total cost of the water distribution network has been calculated.

1. INTRODUCTION

Water is a vital element in the living system and is an important component and also a key element for the socio-economic development of a country. A water distribution system is an essential infrastructure in the supply of water for

domestic as well as industrial uses. It connects consumers to sources of water, using hydraulic components, such as pipes, valves, pumps and tanks. The design of such systems is a multifarious task involving numerous interrelated factors, requiring careful consideration in the design process. Important design

parameters include water demand, minimum pressure requirements, topography; system reliability, economics, piping, pumping and energy use. The primary goal of all water distribution system engineers is the delivery of water to meet the demands on quantity and pressure. Unfortunately, as a water distribution system ages, its ability to transport water diminishes and the demands placed upon it typically increase. In addition to the unsatisfactory performance of a deteriorated network, there are direct economic impacts of a failing system.

WaterGems is a software which is being used for the whole work, it is useful in both designing, optimising and evaluating the water distribution network. There is a need for regular review on water distribution system because of the varying demands with time. There is a requirement of analysing the demands of various points of the network because of varying strengths. Due to increase in strength of students in SVNIT every year there are new buildings being built due to which the demands are getting revised and there is a requirement of new water distribution system. Taking above points into consideration, the work on designing water distribution network for revised water demands in SVNIT campus'. This work has been planned with following objectives: (a) Calculation of the revised demands for gravity and pressurised network, (b) Development of the pipe network for gravity and pressurised network depending upon demand at different locations, (c) Designing the water distribution network of the study area, (d) Calculation of optimised cost of the total work.

2. LITERATURE REVIEW

For the design of network there is a need for calibration of various parameters like discharge at nodes, height requirement to acquire the desired head etc. In addition to that it also requires the capacity of various structures, the daily demand of various buildings. The following are various sequential networking parameters that are to be calibrated.

2.1 Networking Parameters

Configuration-It involves the location of sites for various elements such as elevated service reservoirs, pumps, pipes, valves, and accessories. The configuration is decided by taking into consideration the existing pattern of streets and highways, existing and planned subdivisions, property right-of-ways, possible sites for elevated and ground service reservoirs, location and density of demand centres, and general topography.

Pipe Lengths-The pipe lengths are obtained from the known geometrical layout of the network. When nodes are connected by links consisting of pipes in series, in parallel, and in series-parallel combination, such pipes are usually replaced by equivalent pipes in network analysis.

Pipe Diameters-The pipe diameters are either known or calculated for equivalent pipes. They depend on demands so that the minimum and maximum velocities according to standards like CPHEEO manual can be satisfied.

Pipe Roughness coefficients-The pipe roughness coefficients such as Hazen-William coefficient CHW and Manning's coefficient N are considered known and

remains constant during the analysis. But Darcy-Weisbach friction factor f is a function of Reynolds number and therefore of pipe discharge, and thus must be re-evaluated when the pipe discharge changes.

Minor Appurtenances-The effect of minor appurtenances can be individually considered. However in network analysis, it is common practice to consider equivalent pipes and correspondingly increase the pipe length by 5-10% to account for the effect of minor appurtenances.

Demand Pattern-The demand fluctuate with time, days and seasons. But it is common practice to assume that demands remain constant in the analysis.

Hydraulic Gradient Levels-The hydraulic gradient levels or simply the heads are mostly unknown and obtained from the analysis.

2.2 Darcy-Weisbach's Equation

In fluid dynamics, the Darcy-Weisbach equation is a phenomenological equation, which relates the head loss or pressure loss — due to friction along a given length of pipe to the average velocity of the fluid flow. The equation is named after Henry Darcy and Julius Weisbach. It is of two types Pressure loss form:

$$\Delta p = f \cdot \frac{L}{D} \cdot \frac{\rho V^2}{2} \quad (1)$$

Head loss form:

$$h_f = f \cdot \frac{L}{D} \cdot \frac{V^2}{2g} \quad (2)$$

Where, h_f – head loss due to friction, L - length of pipe, D - hydraulic diameter of the pipe, V - average velocity of flow, g - acceleration due to gravity, f - dimensionless constant, darcy's friction coefficient. The calibrations in many software is done by using three main hydraulic equations named Darcy-Weisbach equation, Newton-Raphson method and Manning's equation.

2.3 Newton-Raphson Method

In numerical analysis, Newton's method (also known as the Newton–Raphson method), named after Issac Newton and Joseph Raphson, is a method for finding successively better approximations to the roots (or zeroes) of a real -valued function. The algorithm is first in the class of Householder's method succeeded by Halley's method. The method can also be extended to complex functions and to systems of equations.

Given a function f defined over the real x , and its derivative f' , we begin with a first guess x_0 for a root of the function f . Provided the function is reasonably well-behaved a better approximation x_1 is,

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} \quad (3)$$

Geometrically, $(x_1, 0)$ is the intersection with the x -axis of a line tangent to f at $(x_0, f(x_0))$. The process is repeated as,

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \quad (4)$$

until a sufficiently accurate value is reached. The idea of the method is as follows: one starts with an initial guess which is reasonably close to the true root, then the function is approximated by its tangent line (which can be computed using the tools of calculus), and one computes the x -intercept of this tangent line (which is easily done with elementary algebra). This x -intercept will typically be a better

approximation to the function's root than the original guess, and the method can be iterated.

2.4 Hazen-William's Equation

The Hazen–Williams equation is an empirical formula which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction. It is used in the design of water pipe systems such as fire sprinkler systems, water supply networks, and irrigation systems. It is named after Allen Hazen and Gardner Stewart Williams. The Hazen–Williams equation has the advantage that the coefficient C is not a function of the Reynolds number, but it has the disadvantage that it is only valid for water. Also, it does not account for the temperature or viscosity of the water. A general form of the equation relates the mean velocity of water in a pipe with the geometric properties of the pipe and slope of the energy line.

$$V = kCR^{0.63}S^{0.54} \quad (5)$$

Where, V is velocity, k is a conversion factor for the unit system ($k = 1.318$ for US customary units, $k = 0.849$ for SI units), C is a roughness coefficient, R is the hydraulic radius.

2.5 Standards and Manual's Studied and Used

2.5.1 Manual of Water Supply and Treatment, third edition- revised and updated, prepared by The Expert Committee constituted by The Government Of India, also known as CPHEEO manual (Central Public Health and Environmental Engineering Organisation) from which the demands per person per day is referred which is helpful in calculating the total demand of SVNIT, the study area. The

demand varies according to various criteria. For eg. The demand for residence purposes in various areas is different due to its location and the demand for various hostels of different levels (seating capacity) varies accordingly.

2.5.2 Manual of Bentley Water CAD/ GEMS V8I, Water Distribution Design and modelling using ArcGIS, Intermediate and advanced Version V8i, from which the operating techniques of WaterGems are known. This manual is very useful for the completion of work by giving a good idea about operating the software in all aspects like giving input values like demands, coordinates, tank specifications etc. The manual is arranged in a manner that can be easily understood. It comprises of theory part initially which illustrates the techniques of parameter input and the general working of the software, then different kinds of problems are given along with the solution so that the way of solving problems on WaterGems can be easily done.

2.5.3 Analysis of Water Distribution Networks, P.R.Bhave and R.gupta, this book is helpful in getting the information about theory based equations and methods like Hazen-Williams equation, Darcy-Weisbach equation, Newton–Raphson's method etc. which the software use to calibrate the parameters and evaluate the work. A clear idea on the designing process and adapting things is given in the book which helped in execution of the work.

2.5.4 The manual by GWSSB containing the various kinds of pipe materials and their costs which is helpful in knowing the Cost of pipes of various materials.

2.5.5 Ductile Iron pipe vs PVC pipe, American Water Works Department, Denver, Colorado, a paper published by respective authority which gives a clear idea about the advantages and disadvantages of PVC and DI pipe in all aspects like bearable pressure, tensile pressure etc. This helped in judging the type of pipe satisfying the work's conditions.

3. STUDY AREA AND DETAILS

Sardar Vallabhbhai National Institute Of Technology (SVNIT) has been selected as study area, which is situated on Athwa-Dumas Road, Surat. The campus is opposite to the Ichchhanath Temple, Piplod. The campus is spread over 250 hectares of lush green forest, which is midway between the Surat Domestic Airport and Surat Railway station. The campus is around 10 km from the Surat Railway station. The total area of campus comprises of different kind of zones which are divided into different categories based on the purpose of work. The study area can be broadly divided into four types types : (a) Academic area, (b) Residential area, (c) Administrative building, (d) Other area.

3.1 Demands of Various Elements of Study area

The water demands of various building in various zones are calculated using standard references CENTRE PUBLIC HEALTH AND ENVIRONMENTAL ENGINEERING ORGANISATION (CPHEEO) manual and the strength of the buildings using records from estate section. In the code of basic requirements of water supply, drainage and sanitation (IS 1172.1983) as well as the national building code, a minimum of 135lpcd has been recommended for all residences provided with full flushing system for excreta disposal. Though the manual on Sewerage

and Sewage Treatment recommends a supply of 150lpcd wherever sewerage is existing, with a view to conserve water, a minimum of 135lpcd is now recommended. The following table gives a clear idea about demands of various buildings.

Table 1: Domestic Needs

Sr. No .	Classification of towns/cities	Recommended Maximum Water Supply Levels (lpcd)
1	Towns provided with piped water supply but without sewerage supply	70
2	Cities provided with piped water supply where sewerage system is existing/ contemplated	135
3	Metropolitan and mega cities provided with piped water supply where sewerage system is existing/ contemplated	150

Institutional Needs

The water requirements for institutions should be provided in addition to the provisions indicated above where required, if they are of considerable magnitude and not covered the provisions already made. The individual requirements would be as follows:

Table 2: Recommendations as per CPHEEO Manual

Sr. No .	Institutions	Litres per Head per day
1	Hospitals a) Number of beds exceeding 100 b) Number of beds	450(p er bed)

	not exceeding 100	340(per bed)
2	Hotels	135
3	Hostels	135
4	Nurses homes and medical quarters	135
5	Boarding schools/ colleges	135
6	Restaurants	70(per seat)
7	Airports and sea ports	70

system-wide temporal water use to calibrate the results. Simulation process:

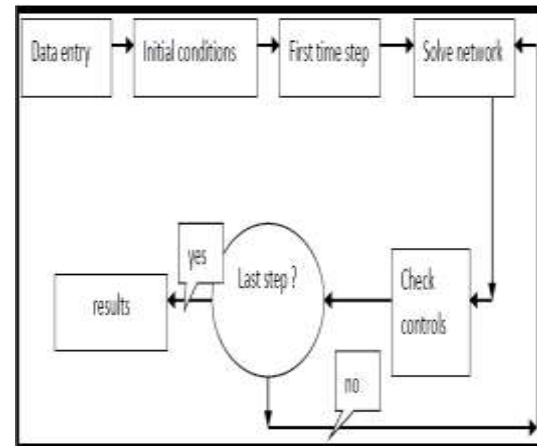


Figure 2: Flow Chart and Steps of Software Used



Figure 1: SVNIT, Surat's map using Arc-GIS 4.2 showing all locations

4. SOFTWARES USED

4.1 SELECTION OF SOFTWARE:-

Arc-GIS 10.2 is used for mapping and affixing the important locations-joints and co-ordinates. While the reason for selecting WaterGems, is its suitability towards the objective of the work.

4.2 GENERAL WORKING OF SOFTWARE:-

It can simulate Energy costs, Power outages, tank out of service, shutdown for rehab or connection, unusual demands, use your imagination. It uses the water use patterns, demand patterns, time scales,

4.3 CONTROLS: (a) Operational controls: (1) Property of a controlled element, (2) Limited to a single condition/action (b) Logical(rule based) controls: (1) Kept with logical alternatives and (2) Complex conditions/action

Operational rules: (a) Must tell mode how pumps and valves operate, (b) Status(digital): (1) Pipe: open or closed, (2) Pumps: on or off, (3) Valves: active, inactive, closed, (c) Setting(analog): (1)Pumps: relative speed factor and (2) Valves: pressure, flow or head loss coefficient. (d) Logical controls: (1) Controls made up of conditions and actions, (2) If(condition is true), (3) Then(action) and (d) Else(action).

4.4 COMPARISON BETWEEN PVC AND DI PIPES:-

With Ductile Iron pipe, there is no measurable relationship between applied tensile strength and time of failure. Thus, the strength for hydrostatic design of Ductile Iron Pipe is its minimum yield strength in tension, 42000psi. PVC responds to tensile stress by failing after a period of time inversely proportional to applied stress.

Thus, the strength used for hydrostatic design of PVC pipe is less than yield strength of the material as established in a short time test. The strength value used is called the long-term hydrostatic strength and is also referred to as the Hydrostatic Design Basis (HDB). The reason behind selecting PVC instead of any other available methods is its low cost. The water distribution network is best economical by using PVC pipes and the pressure that is obtained in various pipes of study area is considerably less than bearable pressure of PVC.

5. ANALYSIS, RESULTS AND DISCUSSION OF NETWORK

The total network to be designed in the study area can be broadly divided into two categories namely Gravity network and pressure network. The adoption of the type of network depends on whether the required head is satisfied or not. It depends on the elevation of building to which the water needs to be delivered.

5.1 GRAVITY NETWORK:-

This network comprises of buildings whose elevation is less than main tank elevation. There is no requirement of any pumps to pump the water to the target nodes, as the elevation of tank is more than elevation of individual buildings the water flows from tank to buildings by gravity action. Thus, this network is termed as gravity network. In general the buildings less than or equal to G+ 2 floors come under this category. The following buildings in study area come under gravity network. (a) Administrative building and drawing hall

,(b) Civil engineering department, (c) Applied mechanics department, (d) Applied sciences and humanities department, (e) Electronics engineering department, (f) Electrical engineering department, (g) Chemical engineering department, (h)

Mechanical engineering department, (i) Production engineering department., (j) Class room complex, (k) Old staff quarters, (l) Kasturibha bhavan, (m) Gandhi bhavan, (n) Sardar bhavan.

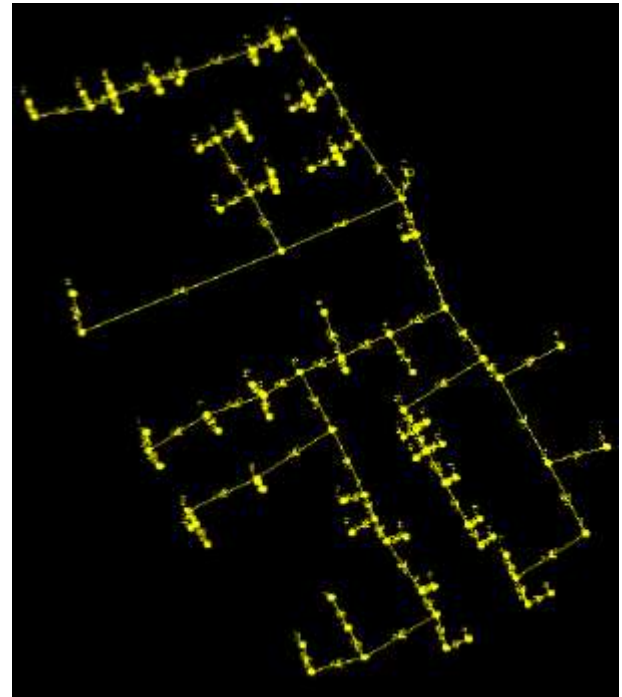


Figure 3: Layout of Gravity Network

5.2 PRESSURE NETWORK

The buildings whose elevation is more than the main tank height come under this category. In general the buildings having elevation more than G+2 come under this category of network. The following buildings of study area come under this category of network. (a) Bhabha bhavan, (b) Nehru bhavan, (c) PG boys hostel, (d) Raman bhavan, (e) Gajjar bhavan, (f) Mother Teresa bhavan, (g) Swami Vivekananda bhavan, (h) Sarojini bhavan and (i) New Staff quarters. (j) Staff club, (k) Student activity centre.

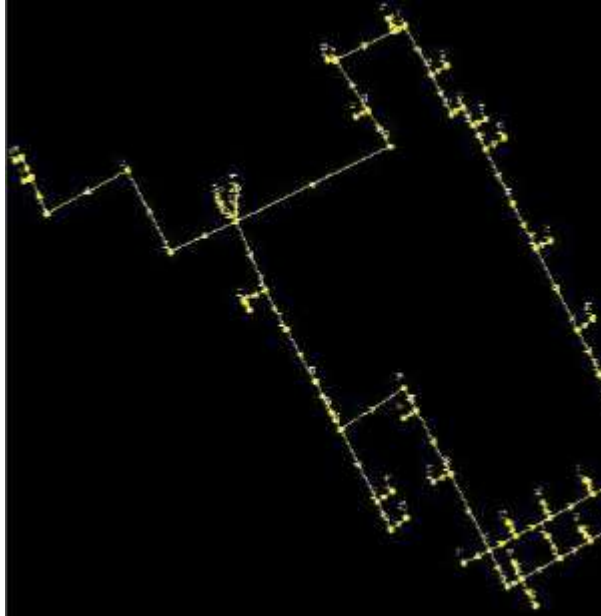


Figure 4: Layout of Pressure Network

5.3 RESULTS AND DISCUSSION

Various parameters of all the pipes in gravity network as well as in pressure network included in the designed network of study area. These parameters are written below to show the result formats in table 3. Similarly details of the junctions has been taken for both the systems i.e. gravity system and pressure system. The pattern of software output is shown In Table 4. The maximum velocities attained in Pressure and Gravity network are 0.81m/s and 0.85m/s respectively which are under the limit of standard maximum velocity of 1.5 m/s. The total head to be generated meets the needs of all the buildings. The total cost of gravity network calculated after optimizing the total pipe line of the network is around 3.03 lakhs and the total cost of the pressurized network after optimizing the network is around 11.4 lakhs.

Table 3: Various parameters of pipes under gravity and pressure system

ID	Label	Velocity (m/s)	Length (Scaled) (m)	Diameter (mm)	Start Node	Stop Node	Material	Hazen-Williams C
320		0.05	25.36	63	J-6	J-100	PVC	150
318		0.03	23.38	63	J-97	J-4	PVC	150
317		0.02	14.91	63	J-4	J-5	PVC	150
314		0.02	23.16	63	J-77	J-3	PVC	150
311		0.05	34.83	63	J-79	J-1	PVC	150
859		0.3	27.48	150	J-2	T-1	Ductile Iron	130
56	P-2	0.33	77.94	75	J-2	J-3	PVC	150
57	P-3	0.05	29.07	75	J-3	J-4	PVC	150
58	P-4	0.02	27.73	63	J-4	J-7	PVC	150
59	P-5	0.02	9.49	63	J-4	J-5	PVC	150
60	P-6	0.02	7.21	63	J-4	J-6	PVC	150
61	P-7	0.29	59.48	75	J-3	J-8	PVC	150
62	P-8	0.05	24.04	75	J-8	J-9	PVC	150
63	P-9	0.02	7.61	63	J-9	J-10	PVC	150
64	P-10	0.02	8.05	63	J-9	J-11	PVC	150
65	P-11	0.02	19.7	63	J-9	J-12	PVC	150
66	P-12	0.24	65.19	75	J-8	J-13	PVC	150
67	P-13	0.24	18.87	75	J-13	J-14	PVC	150

Table 4: Various parameters of Joints under gravity and pressure system

ID	Label	Elevation (m)	Hydraulic Grade (m)	Pressure (kg/cm ²)
310	J-1	7.12	17.21	1
26	J-2	7.82	18.96	1.1
313	J-3	8.05	17.25	0.9
27	J-3	7.6	18.84	1.1
315	J-4	7.4	17.88	1
28	J-4	8.05	18.84	1.1
316	J-5	7.36	17.88	1.1
29	J-5	8.05	18.84	1.1
30	J-6	8.05	18.84	1.1
319	J-6	6.97	17.85	1.1
31	J-7	7.5	18.84	1.1
32	J-8	7.61	18.77	1.1
33	J-9	7.99	18.77	1.1
34	J-10	7.86	18.76	1.1
35	J-11	7.66	18.76	1.1
36	J-12	7.55	18.76	1.1
37	J-13	7.61	18.71	1.1
38	J-14	7.75	18.69	1.1
39	J-15	7.75	18.69	1.1
40	J-16	7.75	18.69	1.1
41	J-17	7.75	18.67	1.1

5.3.1 COST OF PRESSURE NETWORK

The following table 5 indicates the cost of pressure network after optimising. The cost mainly includes the cost of PVC pipes. The cost is optimised used WaterGems which optimises the cost by reducing the diameters of the pipes where ever necessary. The cost of PVC pipes is referred from Gujarat Water Supply and Services Board, this body governs the cost of all types of pipes that are commercially available. The cost of the pipes taken, are with excise charge where the excise charge can be reduced with exemption certificate.

Table 5: Cost of Gravity and Pressure Network (Sample from Software)

PIPE	MATERIAL	HAZEN-WILLIAMS C	DIAMETER (MM)	COST(RS)
P-1	PVC	150	90	2059.2
P-2	PVC	150	63	5767.2
P-3	PVC	150	75	3061.8
P-4	PVC	150	63	2052
P-5	PVC	150	75	999
P-6	PVC	150	63	534.6
P-7	PVC	150	63	4401
P-8	PVC	150	63	1776.6
P-9	PVC	150	63	577.8
P-10	PVC	150	90	1193.8
P-11	PVC	150	63	1458
P-12	PVC	150	63	4822.2
P-13	PVC	150	63	1193.2
P-14	PVC	150	90	939.6
P-15	PVC	150	63	264.6

6. CONCLUSION

The newly built buildings in SVNIT (megahostell1, megahostell2, Vivekananda Bhavan, convocation hall, applied mathematics department, new building for estate section etc.) have increased the total water demand to 1.88 MLD. This work of designing a new water distribution network for revised demands succeeded in making the new network by taking PVC pipes due to their availability at low cost when compared to other pipes like DI and CI. The network is divided into two categories namely gravity, where there is no need of pumping water because of the sufficient available head and pressurized network, where there is a need to pump the water due to lack of availability of sufficient head. The standard water demand per day per person is considered from CPHEEO manual. The cost of PVC pipes is considered from GWSSB. All the work of the water distribution network is done using WaterGems, software also the velocities in various pipes laid in both gravity and pressurized network has been found.

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