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Chapter 1 INTRODUCTION 1.1 GENERAL Water distribution networks are the integral part of the cities to accomplish the water supply needs of people at all times. Water is a precious natural resource and one of the most essential requirements of all living beings. The perception of water availability and its quality is commonly discussed, studied and evaluated by the hydraulic researchers over the past decade. It is believed to be modest owing to various hydraulic, environmental controllable and uncontrollable factors. Many issues are thus apprehended pertaining to the capability, capacity and reliability of these water distribution networks. There are many areas, large and small, with high population growth rate which are not able to access water both in terms of quantity (average demand per capita) and hydraulic head (water Head at the consumer's end). The optimal design, operation and maintenance of WDN is of utmost importance in present times to prevent overexploitation of water resources. In the Delhi state,

> Delhi Jal Board (DJB), constituted under Delhi Jal Board Act 1998, is responsible for production and distribution of drinking water as well as for collection, treatment, and disposal of domestic sewage in
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Delhi. Water supply distribution network has been developed

> to cover both planned and unplanned areas. The water supply in
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most cities of developing countries like India is generally intermittent and erratic, leading to dissatisfaction among the consumers. A reliable supply of water to the residents constitutes an essential component of civic infrastructure of a city.

> At the launch of the international drinking water supply and sanitation decade (November 1980), Dr H.T.Mahler, Director Â General of the World Health Organisation, stated that: 1 "... the number of water taps per 1000 population is a much better indicator of a country's health status than the number of hospital beds" (Development Forum, 1987). As the population of Delhi is
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increasing, and is projected to reach 190 Lakhs by 2017, it is important that there be an adequate water system to support the increasing demand of water. The DJB is working to increase the water supply and expand the distribution networks by laying new water pipelines, construction of new water treatment plants (Dwarka and Okhla) and construction of UGRs. The water treatment and supply capacity for Delhi has increased steadily from 1956. It was raised from 66 MGD in 1956 to 437 MGD in 1990 and 855 MGD in 2012. Looking to the future, this increasing trend needs to continue in order to support growth and development of Delhi.

> Providing a water supply for a community involves tapping the most suitable source of water, ensuring that is safe for domestic consumption and then supplying it in adequate quantities. Upgrading the existing water distribution network
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is the next step towards supporting the imminent growth in demand for water. The

World Health Organization (WHO Study Group, 1987) defines safe water as "... water that does not contain harmful chemical substances or micro-organisms in concentrations that cause illness in any form". It defines adequate water supply as "... one that provides safe water in quantities sufficient for drinking, and for culinary, domestic, and other household purposes so as to make possible the personal hygiene of member of the household. A sufficient quantity should be available on a reliable, year-round basis near to, or within the household where the water is to be used". According to the 1

2011 census, 81% of the 3.41 lakhs of households in Delhi were provided water through piped water 2 supply system. The demand for water per capita is estimated to be 60GPCD. This includes both domestic requirement and non-domestic requirement. The total water demand, for the projected population of 190 Lakhs would be 1140 MGD. In the duration of two years, 2010-2012, water production by DJB was 845 MGD. The sources of water for DJB include the river Yamuna, Bhakra storage, underground water resources, as well as the Upper Ganga Canal. Given the adequate supply of water from the numerous water sources, Delhi has a water supply network that is about 11350 kilometers. However, the network is approximately 40 Â 50 years old and is prone to leakages at several nodes. According to the estimates of DJB, the total distribution losses are nearly 40 percent of the total water supplied. This is quite significant as majority of the water being supplied is unable to reach the consumer. Action is being taken by DJB to solve this problem. They have setup Leak Detection and Investigation (LDI) cell that has replaced 1200 km of old, damaged pipeline with new and sturdy pipelines. This effort needs to continue to ensure minimal loss of scarce water resource. Therefore, the board is currently working towards bringing down the losses to 20 percent of the total water supplied. The board is also investing resources in recycling of backwash water. This resulted in an additional 45 MGD of water from four water treatment plants, without the need of extra water sources. The combined effort will result in more water reaching the consumers. Given that there is adequate supply of water, however, the consumers still don't get water at adequate heads. Hence, it is essential to improve the water distribution network and make it reliable in order to reduce wastage of water and support the growth of the Delhi. 3 Reliability of the water distribution networks is of paramount importance considering the growing number of urban consumers and growing demand for piped water to meet their everyday need. The water distributing agencies are, therefore continuously working towards upgrading the existing networks and optimizing the design to a great extent to achieve the highest efficiency at the minimum installation and overall maintenance cost of the water distribution network. A system failure occurs when all the consumer demands are not met. In developing countries like India, the cities are growing at a fast pace with increasing population. The existing WDNs have become old and are not able to meet their requirement. So, it is essential to investigate, establish and upgrade existing network which satisfies the following conditions (McGhee, 1991): 1) Maintain water quality standard in distribution pipes; 2) establish economic design and layout; 3) deliver adequate quantity of water; 4) maintain required hydraulic pressure; 5) Assure reliability of supply during any period. A case study of one typical water distribution network is selected for study. 1.2 OBJECTIVES The present study of urban residential water distribution network under the control of Delhi Jal Board involves the appraisal, analysis for its capacity and reliability estimation to fulfill the water demands at various nodes by applying the EPANET hydraulic simulation software. The main objectives are: To check the inadequacies of design of water supply schemes To test the strength of network in terms of head and quantity of water the network delivers by varying demand 4 To study the implication of growing population on the network To determine reliability of WDN for head at nodes and quantity of water reaching the consumer To suggest possible modifications in the network to improve its reliability 1.3 SCOPE To extend the study to other networks in the country To incorporate latest technology and IT sector to make WDN advanced and responsive, making WDN smart To develop methods for more accurate estimation of demands at nodes To develop more advanced techno-economical solution for a reliable water distribution network 1.4 METHODOLOGY 1. Study location : WDN Pradhan enclave Burari Delhi. 2. Data collection on WDN of selected area includes network layout, age of network, supply duration, basic water demand at the nodes, number of pumps, parameters of installed pumps, pipe type, population etc. 3. Water distribution network reconstructed in EPANET. 4. Obtained pump curve by feeding pump parameters in EPANET. 5. Reliability calculation procedure is established for the study with main focus on head and quantity of water satisfaction for the consumer. Population is also assessed based on geometric incremental method for four decades. 5 6. Basic demand of 0.219 LPS at each node is given and simulation is run. Then demand is increased till there is negative pressure at any node in the network. Reliability is calculated for each incremental demand. 7. The network is studied for the two cases, 2 pumps/3 pumps running. 8. Based on the result obtained from the study of the network a modification of the network with 24X7 is suggested to increase the reliability of water reaching consumers. 1.4 ASSUMPTIONS The project assumes that the various fittings in the network function properly, and there is adequate

occupants in the residential area. In general, a daily per capita water consumption of at least 135 litres and 8 persons per plot is taken as design figure to calculate the domestic water needs. A residual head of 20 m at least is taken at the consumer tap at the highest/farthest outlet in the building. The study also assumes that the topology of the entire area under study as flat with normal conditions which may affect the performance of the network. There is no seismic activity which may deteriorate the performance of fittings in the piped network. There is also no corrosion, water leakages or pipe blocks which may have detrimental affect on the performance of the water distribution network. 6 CHAPTER 3 STUDY AREA 3.1 LOCATION An urban residential WDN of Delhi Jal board is taken for study. The network is situated in Burari area which is near Yamuna Biodiversity Park and flood plains of river Yamuna, Northern part of Delhi as shown in the fig 3.1.1 and fig 3.1.2. The residential area is named as Pradhan enclave. The size of this area is 24 hectares. For suppling water to this area, water is first received in an underground reservoir (UGR) from Wazirabad water treatment plant which is approximately 7.0 kms away from the residential area. The UGR is connected to Wazirabad water treatment plant by a pipeline of 700mm diameter. The topography of the overall area is flat with slope in between 1% to 2%. The area Pradhan Enclave is situated at longitude 77Â°12'22.9"E and latitude 28Â°46'08.4" N. Fig 3.1.3 shows satellite view of Pradhan Enclave. The climate of the area is humid subtropical. The area experiences high humidity during the rainy season with heavy rainfall. There is high variation between summer and winter temperatures. The average maximum and minimum temperature and total precipitation of the residential area is shown the fig. 3.1.4. FIGURE 3.1.1 LOCATION OF BURARI AREA IN NORTHERN DELHI 25 F FIGURE 3.1.2 LOCATION OF PRADHAN ENCLAVE IN BURARI AREA FIGURE 3.1.3 REMOTE SENSING IMAGE: SATELLITE VIEW OF PRADHAN ENCLAVE AVERAGE MAX. & MIN. TEMPERATURES IN Â°C PRECIPITATION IN MM FIGURE 3.1.4 CLIMATE CHART OF BURARI (DELHI) 26 3.2 SALIENT DATA The WDN under study is a dead end system. The salient data of the network are:- ITEM VALUE AREA 24 Hectares NO. OF PUMPS 3 DISCHARGE AND HEAD OF PUMP 2 MGD and 28 m HORSE POWER OF PUMP 100-150 HP NO. OF OVER HEAD TANK Nil NO. OF UNDER GROUND RESERVOIR (UGR) 1 SIZE/VOLUME OF UGR 10 Million Liters NO. OF CURRENT CONSUMERS 15480 approx. NO. OF PIPES 233 MATERIAL OF PIPE Ductile Iron (DI) DIAMETER OF THE PIPELINE 100, 200 and 250 mm AGE OF THE WATER SUPPLY NETWORK Less than 5 years DESIGN PERIOD OF THE NETWORK 40 Years NO. OF NODES 215 NO. OF PLOTS 1935 MAXIMUM HEIGHT ALLOWED TO BE 15 Meters CONSTRUCTED 27 CHAPTER 4 BURARI WATER DISTRIBUTION NETWORK Â A CASE STUDY 4.1 GENERAL A

water distribution system consists of network of pipes, reservoirs, pumps, valves and other hydraulic elements. 5

To analyze the inter-relationship among various components, a water distribution system is transformed into a network representation called water distribution network (WDN) Yang et al... 1996. 5

Its purpose is to supply adequate quantity of water to customers within adequate pressure levels under varying demand conditions. The 8

improvement and augmentation of water supply for Delhi is one of the sub- mission for urban infrastructure of cities focused under Jawaharlal Nehru National Renewal Mission (JNNURM), city development plan, department of urban development, Govt. of Delhi; 2006 since inadequacy of water supply has been identified as one of the weak area. 4.2 EPANET - WATER DISTRIBUTION MODELING TOOL The present study employs EPANET hydraulic simulation software, which

is a free software developed by USEPA, for analyzing the water distribution 11

network. EPANET assists

for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. EPANET provides a fully equipped and extended period of hydraulic analysis that can handle large systems. 2

It

also supports the simulation of temporarily varying water demand, constant or variable speed pumps, and the minor head losses for bends and fittings. The modeling provides information such as flows in pipes, pressures at junctions, propagation 2 of a contaminant, chlorine concentration, water age, and even alternative scenario analysis. This helps to compute pumping energy 28 and cost and then model various types of valves, including shutoffs, check pressure regulating and flow control. EPANET

uses the "Gradient Method" to solve the network hydraulics. The results obtained from EPANET are used to check the performance of the network based on its reliability. For analysis in this report Hazen William formula is used. Ductile Iron pipes are used in the network, hence C = 140 is taken for the pipes. 4.3 RELIABILITY In this study, network reliability is calculated for water head at nodes and quantity of water reaching to our consumers. If it is satisfied that reliability of quantity of water with adequate head is reaching consumers, then their belief in the system will increase. To calculate reliability in the network under study two ways have been adopted: 1. Head reliability of the network: The head of the network is divided into five slabs as shown in fig 4.3.1 FIG 4.3.1 Â HEAD SCALE To calculate head reliability of the system, nodes in each slab of head are counted for the result obtained from EPANET. Reliability of head in the network is calculated as: ++++ = ... 4.3.1 The formula is used when the demand in the network is assumed constant during the hour of supply. If the demand is varying during the hour of supply then reliability is 29 calculated for demand of each period separately and then average of the reliability of WDN is calculated. 2. Reliability of water demand: According to BIS 135 LPCD to 255 LPCD is the water demand for one person in a day. According to CPHEEO 227LPD was the requirement of water in India during 2011. The economic survey of Delhi 2012 has presented the current water demand at 172 LPCD and 180 LPCD by 2021. For network analysis 172 LPCD is taken i.e. water that should be made available to a consumer having metered supply. Hence, Reliability of quantity of water is calculated as: = 4.4 POPULATION The present population of an area can be determined by conducting an official enumeration "census". These official surveys are carried out at intervals of 10 years. This data help planners of WDN to calculate future population of the area under study. There are a number of ways to forecast population. Geometric increase method is adopted in the present study. Accordingly, = (+) .....4.4.1 Where, 0 = Initial population = Future population r = assumed rate of growth n = number of decade 30 The rate of growth is calculated based on the old population data of the country. The census of year 2011 is referred (Table 4.4.1). It gives us the population increase in India for the previous six decades. CENSUS S.NO. POPULATION % CHANGE YEAR 1 1951 361,088,000 2 1961 439,235,000 21.6 3 1971 548,160,000 24.8 4 1981 638,329,000 24.7 5 1991 846,387,888 23.9 6 2001 1,028,737,436 21.5 7 2011 1,210,726,932 17.7 TABLE 4.4.1 Â CENSUS OF INDIA Constant `r' is calculated by two methods: 1. Empirical relation t P2 r= -1 P1 Where 1 = 2= t = number of decades between 1 2 From the table 4.5.1: 1 = 1,028,737,436 2 = 1,210,726,932 31 t=1 1 1,210,726,932 r= - 1 = 1.1769 - 1 = 0.1769 1,028,737,436 r = 17.69% 2. Average of rate of increase: 1+2+3+ = 21.6 + 24.8 + 24.7 + 23.9 + 21.5 + 17.7 = = 22.37 6 `r' value calculated in empirical method matches the data given in table 4.4.1. So `r' value is taken as 17.69% and population for next 40 years is estimated. Population is than divided evenly on 1935 plots of Pradhan Enclave as shown in Table 4.4.2 New People Per Decade Population % Increase Population Plot 1 15480 17.69 18218 9 2 18218 17.69 25234 13 3 25234 17.69 41135 21 4 41135 17.69 78916 41 TABLE 4.4.2 Â Projected Growth of population with `r' constant In census data, it is observed that there is a constant decline in the `r' value hence a calculation more suitable to actual census data is shown in table 4.4.3. The constant for rate of growth is therefore reduced by 3 percent every decade and results are shown in table 4.4.3. 32 New People Per Decade Population % Increase Population Plot 1 15480 17.69 18218 9 2 18218 15 24094 12 3 24094 12 33850 17 4 33850 9 47782 25 TABLE 4.4.3 Â Projected Growth of population with `r' changing 4.5 PUMPS The water in the WDN is pumped from a pump house.

Pump is a device that raises the hydraulic head of water. 3

Pump house contains 3 pumps of 2 MGD (87.63 LPS) capacity. The design head of the pump is 28 meters. Pump house has three pumps, 2 are operated at a time and third is a spare. In EPANET,

pumps are described with a pump characteristic curve or pump curve. Pump curve describes the additional head imparted to a fluid as a function of its discharge through the pump. In EPANET, 3

pumps act

as links of negligible length with specified upstream and downstream junction nodes. 3

For EPANET to design

a single point pump curve, a combination of head and flow that represents a pump's desired operating point is provided. EPANET fills the rest of the curve by assuming: 1. A shut off head at zero flow equal to 133% of the design head 2. A maximum flow at zero head equal to twice the design flow 3

FIG 4.5.1 gives the pump curve produced by EPANET for 2 MGD (87.63 LPS) flow and 28 meter head, which is the operating point of the pump. 33 FIGURE 4.5.1 Â Pump curve 4.6 DESIGN OF NETWORK IN EPANET The simulations are performed for current population of approximate 15480 people, living on 1935 plots. Each plot having 8 people if divided equally. There are 215 nodes, each node supplying to 9 plots in the study area to identify the critical nodes and thus zone for drop in Head values for various demand variations. The water network collected from DJB was originally designed in waterGEM. It is reconstructed in EPANET software. The layout PLAN of Pradhan Enclave WDN, Burari is first fed as INPUT PLAN (FIG 4.6.1) as under: VIEW BACKDROP LOAD Nodes at the junction of the roads are identified. These nodes are connected with pipes, taking diameter and length of the pipelines from waterGEM data. Roughness coefficient `C' is taken 140. A WDN "hydraulic model" is thus formed for EPANET. Then the background map is removed so that the network with pipe diameters is clearly visible FIG (4.6.2). The network has further been divided into four zones for the purpose of its appraisal as shown in (FIG 4.6.3). 34 FIGURE 4.6.1 Â Layout plan of Pradhan enclave, Burari FIGURE 4.6.2 - WDN of Pradhan Enclave, Burari FIGURE 4.6.3 Â Zones defined in WDN Pradhan Enclave, Burari 35 4.7 NETWORK APPRAISAL The given network is now tested for its strength in terms of head and quantity of water for the current operating conditions at Burari which is intermittent water supply from UGR. 4.7.1 PUMPING FROM UGR WITH INTERMITTENT WATER SUPPLY This is the case used at Pradhan enclave by DJB currently. The community is supplied water two times a day for 3 hours each (Morning 6:30 to 9:30 and evening 5:30 to 8:30). Pump (3 X 2MGD at 28m) are installed but 2 pumps are currently utilized to pump water through the pipe network. The calculations show that:- Demand at each node as given by DJB 0.219 L/S Water delivered at 1 node in 1 hour 0.219 X 3600 = 788.4 L Water delivered at 215 node in 1 hour 788.4 X 215 = 169506 L Total water in one day at 215 node 169506 X 6 = 1017036 L Quantity of water for one person 1017036/15480 = 65.7 L EPANET simulation is run for 0.219 LPS demand at each node as shown in FIG 4.7.1.1. Thus, reliability is calculated (refer to 4.3): 1. All 215 nodes are above 20m (21520) = (21520) 100 = 100% 2. Total available volume of water to a person in a day = 65.7 L Total required volume of water for a person in a day = 172 L (65.7) = = 38.2% (172) 36 The above calculations indicate that although head at all nodes is fulfilled yet the quantity of water reaching the consumers to fulfill their requirement is low. This would lead the consumers dissatisfied and search for other options to fulfill their water demands. Keeping the population constant, the water demand is now increased. The volume of water reaching one plot is increased in steps by 50 L and the demand generated at a node is fed in the WDN. The variation of head at nodes by varying demand is observed by EPANET and reliability of head of the network is calculated. Also reliability of quantity of water delivered to a person is calculated. Table 4.7.1 indicates how the network responds when the water demand at Nodes is increased with two pumps operating in parallel.

a plot there is considerable reduction in Head. Initially till 87.5L per person i.e. 700 L of water at a plot, the Head reliability is 100% but as the water demand is increased further there is reduction in Head reliability of the system and hence needed to be addressed. As the quantity of water demand is increased to 143.75 L per person, nodes of zone 4 have head less than 5m and at 162.5 L per person there is negative pressure in zone 4 as shown in figure 4.7.1.13. Thus we can derive from table 4.7.1.1 that in current scenario water consumers in zone 1 will always have water with adequate supply and consumers in zone 4 would be dissatisfied since the head of water in zone 4 would fall below 20 meters. Further, for each demand value at the nodes, the EPANET simulation is run and the results are shown in FIG 4.7.1.1 to 4.7.1.13. We observe that as the water demand at nodes increase, the water head at the nodes in zone 4 starts falling the effect is shown by increasing red nodes. Finally at water demand 0.542, there is negative head in zone 4. 37 Nodes Water Total with Water Demand Nodes with head per water head per at one below ZONE plot for above person node Affected (L) network 20 (L) (LPS) (L) (M) 5m 10m 15m 20m 525.6 65.7 1017036 0.219 0 0 0 0 215 100.00 38.20 550 68.75 1064250 0.229 0 0 0 0 215 100.00 39.97 600 75 1161000 0.250 0 0 0 0 215 100.00 43.60 650 81.25 1257750 0.271 0 0 0 0 215 100.00 47.24 700 87.5 1354500 0.292 0 0 0 0 215 100.00 50.87 750 93.75 1451250 0.313 0 0 0 8 207 99.07 54.51 4 800 100 1548000 0.333 0 0 0 30 185 96.51 58.14 4 850 106.25 1644750 0.354 0 0 0 39 176 95.47 61.77 4 900 112.5 1741500 0.375 0 0 6 37 172 94.30 65.41 4 950 118.75 1838250 0.396 0 0 29 38 148 88.84 69.04 3,4 1000 125 1935000 0.417 0 0 32 60 123 85.58 72.67 3,4 1050 131.25 2031750 0.438 0 16 25 63 111 81.28 76.31 3,4 1100 137.5 2128500 0.458 0 30 14 66 105 78.60 79.94 3,4 1150 143.75 2225250 0.479 8 24 38 63 82 71.74 83.58 2,3,4 1200 150 2322000 0.500 28 13 51 44 79 65.47 87.21 2,3,4 1250 156.25 2418750 0.521 31 13 58 38 75 63.14 90.84 2,3,4 1300 162.5 2515500 0.542 NEGATIVE PRESSURE TABLE 4.7.1.1 Â Effect on nodal heads due to varied water demand 38 To understand much better EPANET simulation for each demand is indicated next. This shows how network reacts under increasing demand and areas affected. Figure 4.7.1.1 EPANET simulated WDN for water demand 0.219 to 0.292 Figure 4. 7.1.2 EPANET simulated WDN for water demand 0.313 Figure 4.7.1.3 EPANET simulated WDN for water demand 0.333 39 Figure 4.7.1.4 EPANET simulated WDN for water demand 0.354 Figure 4.7.1.5 EPANET simulated WDN for water demand 0.375 Figure 4.7.1.6 EPANET simulated WDN for water demand 0.396 40 Figure 4.7.1.7 EPANET simulated WDN for water demand 0.417 Figure 4.7.1.8 EPANET simulated WDN for water demand 0.438 Figure 4.7.1.9 EPANET simulated WDN for water demand 0.458 41 Figure 4.7.1.10

EPANET simulated WDN for water demand 0.479 Figure 4.7.1.11 EPANET simulated WDN for water demand 0.500 Figure 4.7.1.12 EPANET simulated WDN for water demand 0.521 42 Figure 4.7.1.13 EPANET simulated WDN for water demand 0.542 Now RH and RQ are plotted as calculated in table 4.7.1.1. The figure 4.7.1.14 shows variation of reliability when demand is increased. It shows that as the consumer starts to get adequate amount of water, head at nodes in the network starts to fall i.e. as RQ increases RH decreases. 120 100 Reliability (percentage) 80 RH 60 RQ 40 20 0 Water Per Person (L) Figure 4.7.1.14 Â Variation of reliability with increasing water demand 43 Figure 4.7.1.15 shows the relationship between the head of water at the first node and farthest node in the WDN. The difference in both head is increasing as the water consumption per person per day is increased. 35 30 25 20 Head (M) 15 10 5 0 -5 Head at farthest point Water Per Person (L) Head at first point Figure Â 4.7.1.15 Â Variation of head with demand increase Figure 4.7.1.16 shows the flow through one pump when two pumps are operational in parallel. Also the head created by the pump is shown. The figure shows that the pumps capacity is sufficient since the head starts falling in WDN while there is enough discharge capacity of pump i.e. (87.63 58.27=29.36 LPS) is left. 70 Discharge (LPS) and Head (M) 60 50 40 30 20 10 0 Pump Discharge Water Per Person (L) Head created by pump Figure 4.7.1.16 Â Pump output 44 The network strength is again tested with all three pumps running in parallel to simply understand and show the results based on EPANET simulation software, how the head would vary if in future demand increases further and all the three pumps are run during 6 hours of supply to the network. The exercise done next is only to observe if it is possible to increase head and quantity of water reaching to consumers. Table 4.7.1.2 again shows the reliability of head and quantity of water with increasing demand with 3 pumps operational. Total Nodes Water Water Demand Nodes with head water with per per at one below ZONE for head plot person node Affected network above (L) (L) (LPS) (L) 5m 10m 15m 20m (M) 525.6 65.7 1017036 0.219 0 0 0 0 215 100.00 36.50 550 68.75 1064250 0.229 0 0 0 0 215 100.00 38.19 600 75 1161000 0.250 0 0 0 0 215 100.00 41.67 650 81.25 1257750 0.271 0 0 0 0 215 100.00 45.14 700 87.5 1354500 0.292 0 0 0 0 215 100.00 48.61 750 93.75 1451250 0.313 0 0 0 0 215 100.00 52.08 800 100 1548000 0.333 0 0 0 20 195 97.67 55.56 4 850 106.25 1644750 0.354 0 0 0 31 184 96.40 59.03 4 900 112.5 1741500 0.375 0 0 0 41 174 95.23 62.50 4 950 118.75 1838250 0.396 0 0 16 27 172 93.14 65.97 4 1000 125 1935000 0.417 0 0 29 36 150 89.07 69.44 3,4 1050 131.25 2031750 0.438 0 0 33 55 127 85.93 72.92 3,4 1100 137.5 2128500 0.458 0 20 21 59 115 81.28 76.39 3,4 1150 143.75 2225250 0.479 0 30 14 62 109 79.07 79.86 3,4 1200 150 2322000 0.500 8 24 33 57 93 73.60 83.33 2,3,4 1250 156.25 2418750 0.521 28 13 45 47 82 66.51 86.81 2,3,4 1300 162.5 2515500 0.542 31 12 55 38 79 64.19 90.28 2,3,4 1350 168.75 2612250 0.563 NEGATIVE PRESSURE TABLE 4.7.1.2 Â Effect on reliability due to varied water demand For EPANET simulation result for each demand in table 4.7.1.2 refer to APPENDIX 1. 45 Figure 4.7.1.17 shows the comparison of reliability of head RH and reliability of quantity of water RQ with 2 pumps and 3 pumps running. 120 100 80 Percentage 60 40 20 0 Water Per Person 3 Pump (Head) 2 Pump (Head) 3 Pump (Quantity of water) 2 Pump (Quantity of water) Figure 4.7.1.17 RH, RQ Variation for 2 and 3 pumps working 30 25 20 Head (M) 15 10 5 0 -5 Water Per Person (L) Head at farthest point (2 Pump) Head at farthest point (3 Pump) Figure 4.7.1.18 head variation at farthest node in WDN for 2 and 3 pumps working This indicates that even with 3 pumps operating the head at the farthest point on network does not change much indicating that adding pump will not solve the problem. 46 Pump Discharge Comparison 70 60 Discharge (LPS) 50 40 30 20 10 0 Water Per Person (L) 2 Pump Discharge 3 Pump Discharge Figure 4.7.1.19 Â Discharge per pump for 2 and 3 pumps working Figure 4.7.1.19 shows that only half of pump capacity is used at 168.75 LPS but the head in Zone four has fallen below 0 m i.e. negative pressure are obtained. This shows the installed capacity of pump is more than sufficient but the network is not supporting the pump. 4.7.2 DEMAND AS POPULATION INCREASE In section 4.7.1 demand was increased assuming population of the area is not changing. Now, the population in increased and new water demands are calculated. The population increment over four decade from present is studied taking the life of WDN as 40 years. Referring from section 4.5 population growth is calculated. Table 4.7.2.1 indicates population growth in next four decades. New People Per Decade Population Plot 1 18218 9 2 24094 12 3 33850 17 4 47782 25 TABLE 4.7.2.1: POPULATION GROWTH 47 As the population grows, the water demand at each node increases. In the first decade population growth is from 8 people per plot to 9 people per plot. Daily consumption as 180 LPCD Total quantity of water per plot 9X180 = 1620 L per day Water supplied at one node 1620 X 9 = 14580 L Water demand at node for 14580/ (6 X 3600) = 0.68 LPS 6 hours intermittent supply Table 4.7.2.2 further show the calculation for next 3 decades. Node Demand People per supply Total water per Total water at Decade 6 hrs plot LPCD plot one node (Intermittent supply) 1 9 180 1620 14580 0.68 2 12 180 2160 19440 0.90 3 17 180 3060 27540 1.28 4 23 180 4140 37260 1.73 TABLE 4.7.2.2 Effect on Population growth on nodal water demand From table 4.7.2.2 the node demand after first decade i.e. 0.68 LPS is much more the network can satisfy even when 3 pumps are running as shown in table 4.7.1.2 for 6 hours of water supply per day. Therefore, even if the WDN is sufficient to some extent today it would not fulfill the water requirement of future population. Figure 4.7.2.1 shows EPANET simulation of 0.68 LPS demand when all the three pumps are running. The figure 4.7.2.1 shows that Zone 1 and 2 consumer are satisfied with their need but zone 3 and 4 have no water at all. This shows the limitations of network. Similarly, for decade 2 and 3 conditions, the figure 4.7.2.2 and 4.7.2.3 show that the network is not able to supply water to the consumers for 6 hours of water supply per day. 48 Figure 4.7.2.1 EPANET simulated WDN for water demand 0.68 Figure 4.7.2.2 EPANET simulated WDN for water demand 0.9 Figure 4.7.2.3 EPANET simulated WDN for water demand 1.28 49 35 30 25 20 HEAD 15 10 5 0 0.68 0.9 1.28 Demand (LPS) FIRST NODE OF NETWORK PUMP HEAD Figure 4.7.2.4 Â Effect on head at first node due to increase of water demand The figure 4.7.2.4 shows the head variation between first node and last pump end when all three pumps are operating. It depicts that the pipe diameter between pump and first node is not sufficient. But as changing of pipe in the network is very costly and not a viable option it is not recommended. Instead it would be prudent to increase the present hours of water supply. 50 CHAPTER 5 MODIFICATION The strength to which the present network of Pradhan enclave could supply water to the consumer has so far been verified and analyzed. From the analysis done in section 4.7.1 and 4.7.2, it is evident that the modification to network is necessary in order to use the existing network to fulfill the current demand with higher reliability and to satisfy the demand of future growing population. Figure 5.1 shows how water demand vary if we increase the duration of water supply for 6 hours per day to 24 hours in the network. It shows that current 6 hours of supply will not be sufficient to supply 180 LPCD water to each individual in a day, since the table 4.7.1.2 indicates that any demand above 0.5 LPS will leave consumers in the area without water. 2.000 1.800 1.600 1.400 Demand (LPS) 1.200 1.000 0.800 0.600 0.400 0.200 0.000 Present

1 Decade 2 Decade 3 Decade 4 Decade Time 6 hour supply 8 hour supply 10

7

hours supply 12 hours supply 24 hour supply Figure 5.1- Demand based on duration of supply 51 From the interpretation of the figure 5.1 and table 4.7.1 it is suggested that if the duration of water supply to the network is increased to 24 hours supply than only the demand at nodes will decrease to the levels that the WDN could satisfy today as well as in future. Hence, for continuous supply to the network a time pattern for water demand is assumed for a day. Figure 5.2 shows the demand in 24 hours supply for present population. Demand Pattern During Day 0.350 0.300 0.250 Demand LPS 0.200 0.150 0.100 0.050 0.000 0:00 - 2:00 - 4:00 - 6:00 - 8:00 - 10:00 - 12:00 - 14:00 - 16:00 - 18:00 - 20:00 - 22:00 - 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 24:00 Time (Hours) Figure 5.2 Â Water Demand Pattern during day Demand at Total Supply each node for Time Population Water (LPCD) 24 hour Required supply (LPS) Present 15480 180 2786400 0.150 1 Decade 18218 180 3279240 0.177 2 Decade 24094 180 4336920 0.233 3 Decade 33850 180 6093000 0.328 4 Decade 47782 180 8600760 0.463 TABLE 5.1 Â Demand variation for continuous water supply 52 EPANET simulation is run with demand value 0.15 LPS as given in table 5.1 and water demand as per figure 5.2 is fed into the EPANET. The simulation is run. The network is able to supply water to all the nodes with head above 20 meters for complete duration of supply. Hence, reliability RH is 100% for current demands of the population. Also RQ is 100% as the consumers are supplied water throughout the day. If such a system is used then the belief of the consumer in the network will increase many folds and consumers will take special care to make sure water is not wasted. Also as the society under study is metered therefore water wastage will be less if supply is 24 hours. This would reduce the need for people to look for other sources of water such as tankers and bore wells which create large wastage of water and detrimental to environment. The water demand at each node for continuous supply is less than 0.542 LPS as depicted in table 5.1 and hence there shall not be any negative pressure in any of the four zones in the network. The effect of population on nodal reliability RH is shown in FIG 5.3. The average reliability of the network is above 90% up to 3 decades and remains above 70% in 4th decade as per the water demand pattern during day (FIG 5.2). Reliability for one day 120 100 80 Percentage 60 40 20 0 Today

1 Decade 2 Decade 3 Decade 4 Decade

Time Average Reliability for one day Figure 5.3 Â Effect of population on nodal reliability RH 53 CHAPTER 6 CONCLUSION The water distribution network of Pradhan Enclave, Burari has been studied for its capacity to supply water, capability to satisfy the consumers for their future water needs for four decades, effect of population increase as well as its reliability using EPANET simulation software. The literature review on the subject emphasized that the water distribution networks in the cities have been studied extensively by the researchers during the past two decades using the specialized simulation software's and has helped in developing more reliable and efficient water distribution networks of present times. Based on the study and discussion in this report, following is concluded:- 1. The existing water distribution network is being used as intermittent water distribution network. It is able to cater water demand up to 156.25 LPCD for all the four zones of the Pradhan Enclave, Burari. 2. The existing water distribution network can barely satisfy the water demand of 0.68 LPS at node for intermittent water supply one decade as per the present rate of increase of population and estimated water needs at the nodes in Pradhan Enclave. 3. The head reliability RH of the existing water distribution network is more than 90% for the water demand up to 112.5 LPCD for current population. 4. The existing water supply network is recommended for continuous water supply system so as to cater the existing water demand up to 180 PLCD and fulfill the water needs as per the population growth up to three decades. 5. The reliability of the existing water distribution network is above 90% up to three decades and remains above 70% in fourth decade as per the water demand at nodes. 6. In case the network is extended in the near future, it will not be able to supply water with sufficient head in zone 3 and 4. 54