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SIMULATION OF SPRING WATER DISTRIBUTION SYSTEM USING EPANET

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Abstract

A water distribution system carried potable water with such an adequate flow and pressure from a point source to the consumers. It is important to design the system accurately to make sure that every consumer should get the same quality and quantity of water. In Universiti Pertahanan Nasional Malaysia (UPNM), the demand of water has increased since the community in UPNM increased. Also, UPNM has an excessive water come from spring water that located at the hillside of UPNM. The Environmental Protection Agency NETwork (EPANET) was used to simulate the spring water distribution system to address the water demand. The aim behind the study was to model distribution system of spring water and to evaluate the effectiveness by calibrate the model. Three designs are proposed with different pipe length, pipe diameter and location of the tank. Results showed that the most optimal design is the second design as it has fulfilled the requirements needed which all the residual pressure value above 4.5 m and velocity within 0.5 to 2.6 m/s. As conclusion, spring water simulation for distribution in system successfully carried out for determining the optimum design to supply the water to UPNM communities.

Keywords: EPANET, Water demand, Water distribution system, Spring water, UPNM.

1. Introduction

Water is the most basic essential for all living things and plays a crucial role for us to survive and required for almost all kinds of activities [1]. It took a lot of effort and advances in technology and science to make the water distribution systems nowadays inexpensive and reliable. Planning and constructing a water supply scheme that suitable is essential with a well designated distribution system to ensure the sufficient quantity and quality of water available in the community that fulfil their requirements and demand [2].

A distribution system consists of pipelines that has different sizes to transport water to the streets; flow control valves, service links to the individual homes, distribution reservoirs to store the water to be fed into the distribution pipes. Depending on distribution methods, the distribution system can be classified to gravity system, pumping system and combined gravity and pumping system. There are generally four distinct distribution systems that are used in practice which are tree system or dead end, radial system, grid iron system and circular system [3].

There are two fundamental requirements for a water system. It must, first and foremost, transport enough water to satisfy usage requirements. Additionally, the water framework should be sturdy, and the required amount of water should be available 24 hours per day [2]. Excellent developments have recently been made in various areas of water distribution and supply. Another important factor in the evolution of human societies is the appropriate allocation of water resources. Despite the methods to effectively manage the distribution of water system is by using a model. An expert can administer, preserve and evolve the local water supply system with the aid of a water distribution system model. A model assists the authority determine when improvements are needed to the current water distribution system and what changes should be done to meet the needs of the people [3].

Environmental Protection Agency NETwork (EPANET) can analyse the pipes and tanks in multiple number [4]. It developed by USA Environmental. It performs the hydraulic simulation in extended time and the behavior of water quality within the networks of pressurized pipe. EPANET monitors the water flow in each pipe, the pressure at each node, the concentration of chemical species across the network, and the water level in each tank [5]. The aim of the study is to simulate spring water distribution system using EPANET model and to evaluate the efficiency of water distribution system by calibrate the model.

2. Methods

2.1. Water demand

The water demand is the requested volume of water by consumers to satisfy their need. For this study, the calculation of water demand is determining by the number of students in Jebat and Kasturi building. The number of students is calculated by room which has 8 students. The total number of rooms in Jebat is 96 rooms. For Research Laboratory, the water demand is calculated based on Selangor Water Supply Company guideline. The demand is 1000/100 m^2 and the area of the Research Laboratory is approximately 4014 m^2.

2.2. Hazen William equation

In designing the water distribution system, Hazen-Williams equation is used in EPANET software. Hazen-Williams equation is given by Eq. (1) [6].

$$V = 0.852 C_H R^{0.68} S^{0.54} \quad (1)$$

where C_H is Hazen-Williams coefficient of pipe, S denotes as slope of hydraulic gradient line (m/m) and R as hydraulic mean depth as unit in m.

2.3. Bernoulli's equation

EPANET software uses Bernoulli's equation to track the pressure in nodes and water flow in pipes. There are three main heads used for analyzing the flow in pipes which are pressure head, $P_1/\rho g$, velocity head, $v_1^2/2g$ and static head, z and the ΣhL is a total head loss as shown in Eq. (2) below [7, 8].

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + \Sigma h_L \quad (2)$$

2.4. Proposed design

For the first design, the pipe is designated along the side of the road. The length of pipe is longer according to the side of the road. The water tank will be located at a higher level to perform the gravity system. The elevation the tank is determined to be 123 m and according to the demand, the size for the tank is 8 × 8 m. The design proposed is shown in Fig. 1. The pipeline will supply the water from the hill at 150 m elevation, went through the side of the road and crossing the road to the side of the developed hill and ended at the three buildings which are Jebat, Kasturi and Research Laboratory buildings. The total length of the pipeline is determined to be 586 m.

Fig. 1. First proposed design.

In the second design, the pipeline designated through the slope as shown in Fig. 2. The tank with the same size as the previous design, was located at 136 m elevation. The pipeline is drawn to supply the water from the reservoir to the tank, crossing the slope and crossing the slope again to the sideway road then crossing the slope and ending to the three buildings. The total length of the pipeline is estimated to be 452 m.

Fig. 2. Second proposed design.

The third design, the pipeline also designates through the slope and the location of the tank at elevation 123 m. The tank also has the same area as the previous design which is 8 × 8 m. In this design, the pipeline is drawn from the reservoir to the tank, crossing the hill or slope, to the side of the road and cross again the hill before it ended to the three buildings to supply the water. The path before it ended to Jebat buildings is the same as second design. The total length of the pipeline is determined to be 428 m. The design proposed is shown in Fig. 3.

Fig. 3. Third proposed design.

The initial diameter used with roughness coefficient of 120 High Ductile Polyethylene (HDPE) pipe. The design will first be run in a steady state at a single instant in time as make sure the design is run smoothly and next run for an extended period of 24 hours to simulate a real situation [9].

3. Results and Discussion

3.1. First design

The first design is drawn and labelled in EPANET as shown in Fig. 4. The pressure at each node in Table 1 shows that at J2 have a higher value pressure which is 46.5 m. This is because the water is flowing from the higher level to a lower level gave a high pressure in the nodes [10]. According to Table 2, velocity in pipe 1 with 90 mm diameter is 3.3 m/s which is higher than the recommended. During the calibration, when the diameter is set to 75 mm, the velocity is decreased however at the end of the nodes, the negative pressure occurred which water cannot be supplied. The pipe size, which in term of length and diameter influence head loss [10].

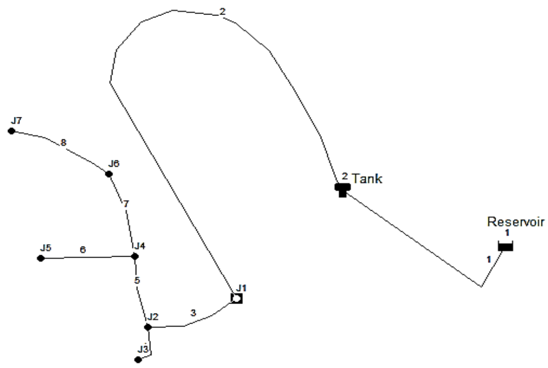

Fig. 4. First design in EPANET.

Table 1. The output data from nodes.

Network Table - Nodes at 0:00 Hrs				
Node ID	Elevation	Demand	Head	Pressure
	m	l/s	m	m
J1	79	0.0	116.5	37.5
J3	70	1.2	114.2	44.2
J2	68	0.0	114.5	46.5
J4	73	0.0	113.0	40.0
J5	103	5.1	112.0	9.0
J6	69	0.0	111.9	42.9
J7	104	5.1	110.8	6.8
R1	150	-10.3	150.0	0.0
Tank 2	123	-1.0	129.2	6.2

Table 2. The output data from links.

Network Table - Links at 0:00 Hrs						
Link	Length	Diameter	Roughness	Flow	Velocity	Head loss
	m	mm		l/s	m/s	m/km
P1	92.9	63	120	10.3	3.3	224
P2	275.0	90	120	11.3	1.8	46.3
P3	39.9	90	120	11.3	1.8	49.0
P4	19.0	50	120	1.2	0.6	14.7
P5	33.2	90	120	10.1	1.6	44.5
P6	38.5	75	120	5.1	1.1	28.4
P7	39.6	75	120	5.1	1.1	28.3
P8	45.2	75	120	5.1	1.1	25.3

The head of water in pipes is plotted over distance as shown in Fig. 5 shows that the head in pipe 1 from the reservoir has a big value. This is because, the reservoir is at the highest level in the water distribution system. The head of water is then decreased over the distance as the elevation decreased [11]. The head of water from pipe 3 to pipe 8 gave a most similar value. This might be because the pressure is nearly the same between the nodes.

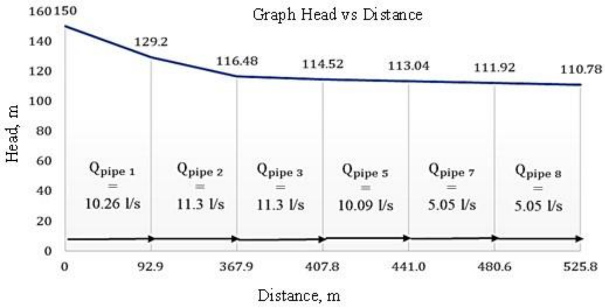

Fig. 5. The head in pipes.

3.2. Second design

The second design is drawn and labelled in EPANET as shown in Fig. 6. The pressure at J5 have a higher value pressure which is 68.1 m shown in Table 3. This is because the water is flowing from the higher level to a lower level gave a high pressure in the nodes [12].

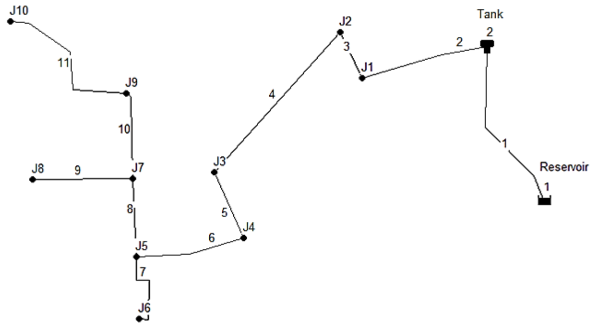

Fig. 6. Second design in EPANET.

Table 3. Output data from nodes.

Network Table - Nodes at 0:00 Hrs				
Node ID	**Elevation**	**Demand**	**Head**	**Pressure**
	m	**l/s**	**m**	**m**
J1	120	0.0	141.3	21.3
J2	122	0.0	140.9	18.9
J3	87	0.0	137.5	50.5
J4	78	0.0	136.2	58.2
J5	66	0.0	134.1	68.1
J6	70	1.2	130.2	60.2
J8	103	5.1	131.7	28.7
J10	104	5.1	130.1	26.1
J7	69	0.0	132.8	63.8
J9	69	0.0	131.8	62.8
R1	150	-11.2	150.0	0.0
Tank 2	136	-0.1	142.2	6.2

Based on Table 4, in pipe 1, the velocity of the pipe with 75 mm diameter is 2.5 m/s which is within the recommendation. During the calibration, when the diameter is set to 50 mm, the velocity is decreased however at the end of the nodes, the negative pressure occurred which water cannot be supplied [13]. In pipe for link 7, the flow value is lower than the other pipes. This is because, the water demand at Research Laboratory building is smaller than other building which is 1.21 l/s approximately 104 544 l/d.

The head of water in pipes is plotted over distance as shown in Fig. 7. The pipe 1 is showing that the head in the pipe has a higher value. This is because, the reservoir is at the highest level in the water distribution system. The head of water is then decreased over the distance as the elevation decreased [14]. The head of water from pipe 5 to pipe 11 gave a most similar value. This might be because the pressure is nearly the same between the nodes [15].

Table 4. The output data from links.

Network Table - Links at 0:00 Hrs						
Link	**Length**	**Diameter**	**Roughness**	**Flow**	**Velocity**	**Head loss**
	m	**mm**		**l/s**	**m/s**	**m/km**
P1	69.3	75	120	11.3	2.5	113.0
P2	49.5	110	120	11.3	1.2	18.4
P3	19.9	110	120	11.3	1.2	17.4
P4	73.0	90	120	11.3	1.8	47.1
P5	28.0	90	120	11.3	1.8	48.4
P6	42.2	90	120	11.3	1.8	47.7
P7	33.1	32	120	1.21	1.5	119.1
P8	30.6	90	120	10.1	1.6	45.1
P9	38.6	75	120	5.05	1.1	28.4
P10	34.2	75	120	5.05	1.1	28.8
P11	61.9	75	120	5.05	1.1	27.2

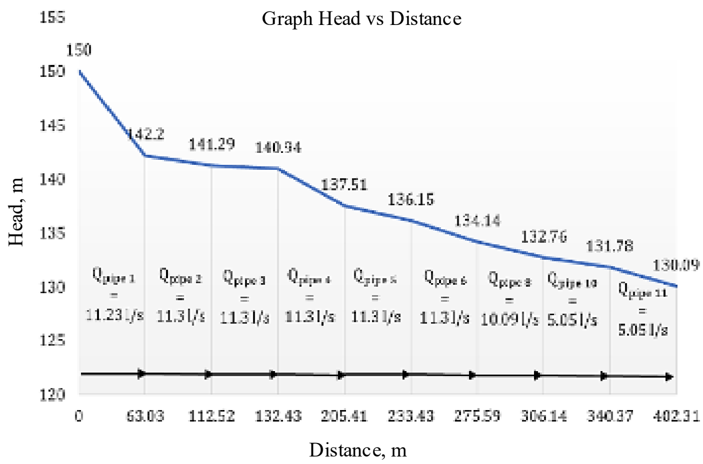

Fig. 7. The head in pipes.

3.3. Third design

The third design is drawn in EPANET according to the proposed design before and labelled as shown in Fig. 8. The output data is shown in Tables 5 and 6 below. The pressure at each node in Table 5 shows that at J4 have a higher value pressure which is 55.5 m. This is because the water is flowing from the higher level to a lower level gave a high pressure in the nodes [10].

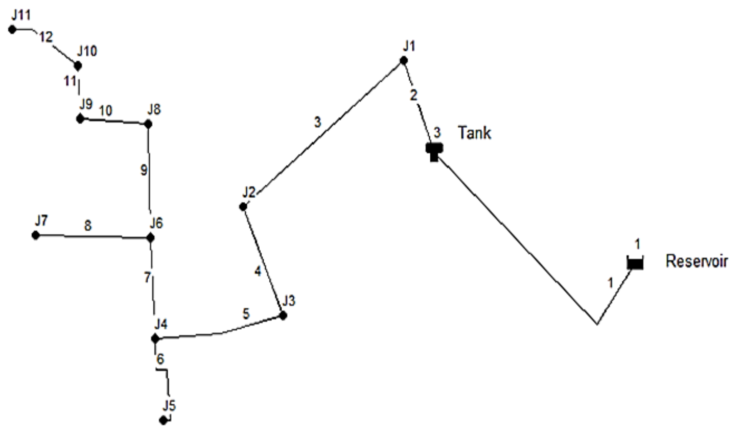

Fig. 8. Third design in EPANET.

Table 5. Output data from nodes.

Network Table - Nodes at 0:00 Hrs				
Node ID	Elevation	Demand	Head	Pressure
	m	l/s	m	m
J1	118	0.0	128.0	10.0
J2	85	0.0	125.0	40.0
J3	78	0.0	123.4	45.4
J4	66	0.0	121.5	55.5
J5	70	1.2	118.3	48.3
J6	69	0.0	120.3	51.3
J7	103	5.1	119.8	16.8
J8	69	0.0	119.8	50.9
J9	68	0.0	119.3	51.3
J10	72	0.0	118.9	46.9
J11	104	5.1	118.3	14.3
R1	150	-10.6	150.0	0.0
Tank 3	123	-0.7	129.2	6.2

According to Table 6, the velocity in pipe 1 in with 63 mm diameter is 3.4 m/s which is above the recommended. During the calibration, when the diameter is set to 50 mm, the velocity is decreased however at the end of the nodes, the negative pressure occurred which water cannot be supplied. The design is then run for 24 hours extended period to supply the water to show a real time situation [6].

Moreover, the flow in pipe shows a constant value in 24 hours for a several pipe. However, in pipe 1, the flow value is gradually increasing. This is maybe because the effect of the pipe diameter and the length of the pipe. For pipe 1, the length is 87.9 m with 10.6 l/s flow while for pipe 12, the length is 22.8 m with 5.1 l/s flow. Hence, the increase of pipe length will increase the pipe flow.

Table 6. The output data from links.

Network Table - Links at 0:00 Hrs						
Link	**Length**	**Diameter**	**Roughness**	**Flow**	**Velocity**	**Head loss**
	m	**mm**		**l/s**	**m/s**	**m/km**
P2	26.5	90	120	11.3	1.8	46.3
P3	62.5	90	120	11.3	1.8	47.2
P4	32.0	90	120	11.3	1.8	49.7
P5	39.2	90	120	11.3	1.8	49.1
P7	27.6	90	120	10.1	1.6	45.9
P8	34.5	90	120	5.1	0.8	12.1
P9	31.0	90	120	5.1	0.8	12.3
P10	20.3	75	120	5.1	1.1	27.5
P11	14.2	75	120	5.1	1.1	28.5
P1	87.9	63	120	10.6	3.4	236.7
P6	27.6	32	120	1.2	1.5	115.8
P12	22.8	75	120	5.1	1.1	26.4

The head of water in pipes is plotted over distance as shown in Fig. 9. At pipe 1 shows that the head in pipe has a higher value than the rest. This is because, the reservoir is on the highest level in the water distribution system which is 150 m. The head of water is then decreased over the distance as the elevation decreased [16, 17]. The value head of water from pipe 2 to pipe 12 decreased gradually. This might be because the pressure is nearly the same between the nodes.

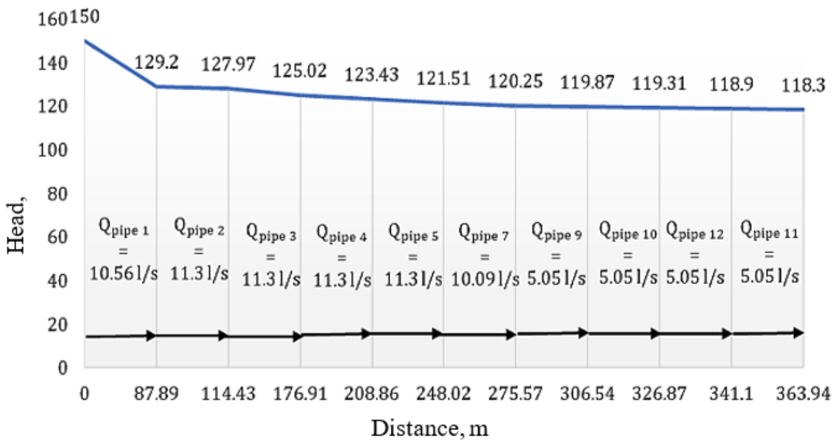

Fig. 9. The head in pipes.

3.4. Optimal design

There are several things need to be considered. First, the pressure of the pipe must be within 10 m to 30 m [18]. However, the range of pressure obtained from the EPANET output data from the three designs was above 30 m and in second design it reaches about 70 m. The calculated pressure and head of water were sufficient to distribute the actual demand for 24 hours at all the junctions [19-20]. To overcome the high pressure in pipe, HDPE pipe PN 10 PE100 will be used. This type of pipe can withstand minimal pressure is up to 10 bar or 100 m [20, 21]. Hence, with HDPE can cater the pressure in the design.

Next, the ought to be within 0.5 to 2.0 m/s. But, in Malaysian Water Associated (MWA) guideline, the maximum velocity is taken 2.6 m/s. In design 1 and 3, the maximum velocity is 3.04 and 3.39 m/s respectively. In design 2, the maximum velocity is 2.54 m/s which it is follow the limitation given [22].

Residual head is a pressure that resides in the system when flowing in the condition of the actual flow and should be greater than 4.5 m. In design 1 and 3, the residual pressure from the reservoir and tank was below 4.5 m hence it is not sufficient for the water supply. In design 2, all the residual pressure value was above 4.5 m hence it is the most sufficient design from the rest.

For the piping cost, in design 1 it cost about RM 9 500, while design 2 is RM7 500 and design 3 is RM 6 900. Design 1 is pricier than the other designs as it has about 586 m pipe length which it is the longest pipe than the rest of the design. Design 3 is cheaper because it has shortest pipe which is 428 m pipe length. Design 2 is in between that being not too pricy. The price difference between design 2 and design 3 was about RM 600 but design 2 is the most optimal design as it fulfils the requirements [23, 24].

4. Conclusions

In conclusion, the simulation of spring water distribution system using EPANET are achieved as the three designs that drawn and simulated has run successfully. Moreover, the evaluation of the efficiency of water distribution system by calibrate the model also succeed by calibrating the diameter of the pipe till it can withstand the smaller pipe without failed.

The efficiency of the design is determined by several things which are pressure, velocity, and residual pressure. Design 2 is chosen as the most optimal design between the three designs simulated and fulfilled most of the requirements which is the velocity is within the limit, sufficient residual head, and the cost is about RM 7 500. The value with the manual calculation seems closed. The design also fulfils the demand of 375 624 l/d.

For recommendation, the diameter and length of the pipeline need to be calibrated till the output data is within the requirements. The design should give an adequate pressure head for water to ensure the distribution system is good at all locations. Lastly, to avoid a very high pressure at the node, a pressure reducing valve shall be installed to reduce the pressure at node. The valve can be expensive to install but to make sure the water distribution system can be operated smoothly.

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