

# Design of Water Supply Distribution System for Thayet Downtown Area by EPANET 2.0

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**Abstract**—Thayet downtown area has eight quarters and now only six quarters are available municipal water supply. By comparing six quarters that available municipal water supply with two quarter that have no municipal water supply, the remaining two quarter is as wide as the six quarter. So, about half of thayet downtown area is not available municipal water supply. This paper represents to design the required water supply system to distribute to the whole of Thayet downtown area. In this paper source of supply is Ayeyarwady river because Thayet downtown area is located on the right bank of Ayeyarwady river. The water is pumped from the source to the treatment plant and pumped from the treatment plant to the elevated tank and then is delivered to the consumers. The gravity system is used for the supply. The methods of layout of distribution system used in this paper are Dead-End system and Grid-Iron system. Distribution system is designed by using EPANET 2.0 software and the results are checked by Hardy Cross method. The distribution pressure is controlled between seven to twenty-two meters range.

**Keywords**—Water Supply Distribution; Ayeyarwady River; Gravity System; EPANET 2.0 Software; Distribution Pressure

## I. INTRODUCTION

Water, a precious natural resource, is vital for physiological processes of all organisms. Water is one of the most abundant compounds found in nature, covering approximately three-fourths of the surface of the earth. Moreover, water also has a social and economic value for human beings, and on the other hand, population growth and economic development put constant pressure on the ecosystems of water resources. The provision of safe and adequate drinking water to the increasing population continues to be one of the major challenging tasks. Beside, the distribution system with adequate pressure is also one of the important things.

### A. Location of Study Area

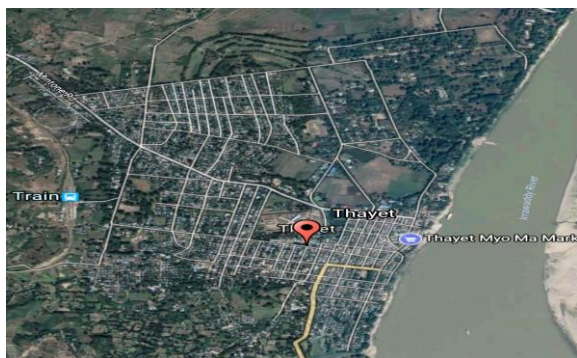


Figure 1. Aerial Photo of the study location Source: Google map

Thayet is a city in Thayet District of Magway Region in central Myanmar. It is a part on the right bank of the Ayeyarwady River, across and just south of Aunglanmyo,

between Pyay and Magway. It is located between 19° 34' 60" and 19° 10' 10" of North latitude and 95°12' 44" and 94° 51' 42" of East Longitude. Thayet downtown area is contributed eight quarters and nowadays, only six quarters are available municipal water supply. The existing distribution system is not a systematic. Therefore, available water is often inadequate for use. So, a systematic and suitable water supply distribution is required for Thayet downtown area. In this study, a primary water supply system is designed to use in Thayet. Ayeyarwady river water is selected as the source because it is a plentiful supply of water.

### B. Objectives of the study

The objectives of the study are;

- (1) To provide adequate water supply to the whole town for domestic purposes.
- (2) To provide adequate pressures and flows for fire protection.
- (3) To access the present and future capacity of the Thayet downtown area water supply.

## II. METHODOLOGY

### A. Water Demand Projection

According to Raju 1997, stated that a minimum of 180 liters per capita per day should be assured to take care of basic hygiene needs and basic food hygiene including fire-fighting demand. The present population of Thayet downtown area is 18261 at the year of 2017. Percentage of growth rate is taken as 1.7% per year (According to "Report from Thayet's City Development Project"). The water demand for institutional need is considered as 20 % of the demand based on per capita consumption. Design period is 30 years (from 2017 to 2047). Population forecasting is calculated by Geometrical Increase Method. [1]

$$P_n = P \left( 1 + \frac{I_g}{100} \right)^n \quad (1)$$

### B. Design Calculation for Elevated Tank

In this study, per capita consumption of Thayet Downtown area is assumed as 180 lpcd. [2] By considering the water demand for institutional need as 20 % of the demand based on per capita consumption. The operating time from the river is assumed as 8 hours and the water supply system is assumed as 8 hours. The maximum daily consumption is taken to be 1.5 times the average daily consumption and maximum hourly consumption to be 3 times the average hourly consumption. [3] Design population and demands of each quarter are shown in Table I. The calculation for the capacity of elevated tank is described in Table II. Then, cumulative demand and cumulative supply curve is drawn as shown in Figure 2.

Table 1: Design Population and Demands of each Quarter

No	Design	Daily Demand	Others add 20%	Daily average	Hourly average	Daily maximum	Hourly Maximum
	Population	(m <sup>3</sup> /d)	(m <sup>3</sup> /d)	(m <sup>3</sup> /d)	(m <sup>3</sup> /hr)	(m <sup>3</sup> /d)	(m <sup>3</sup> /hr)
1	1824	328.32	65.66	393.98	49.25	590.97	147.74
2	1652	297.36	59.47	356.83	44.6	535.25	133.81
3	1370	246.6	49.32	295.92	36.99	443.88	110.97
4	1428	257.04	51.41	308.45	38.56	462.68	115.67
5	6439	1159.02	231.8	1390.82	173.85	2086.23	521.56
6	4485	807.3	161.46	968.76	121.1	1453.14	363.29
7	5124	922.32	184.46	1106.78	138.35	1660.17	415.04
8	7959	1432.62	286.52	1719.14	214.89	2578.71	644.68
Total	30281	5450.4	1090.06	6540.46	817.59	9811.02	2452.76

Table 2: Calculation for the Capacity of Distribution Tank

Period	Average Hourly	Hourly Demand	Cumulative	Hourly	Cumulative	Cumulative
hr	Factor	(m <sup>3</sup> )	Hourly Demand (m <sup>3</sup> )	Supply (m <sup>3</sup> )	Hourly Supply (m <sup>3</sup> )	Surplus (m <sup>3</sup> )
06-Jul	1	817.5×1.0×1=817.50	817.5	1226.4	1226.4	408.9
07-Aug	2	817.5×2.0×1=1635.00	2452.5	1226.4	2452.8	0.3
08-Sep	1.5	817.5×1.5×1=1226.25	3678.75	1226.4	3679.2	0.5
09-Oct	1.5	817.5×1.5×1=1226.25	4905	1226.4	4905.6	0.6
10-Nov			4905		4905.6	0.6
11-Dec			4905		4905.6	0.6
Dec-13			4905		4905.6	0.6
13-14			4905		4905.6	0.6
14-15			4905		4905.6	0.6
15-16			4905		4905.6	0.6
16-17	1	817.5×1.0×1=817.50	5722.5	1226.4	6132	359.5
17-18	2	817.5×2.0×1=1635.00	7357.5	1226.4	7358.4	0.9
18-19	1.5	817.5×1.5×1=1226.25	8583.75	1226.4	8584.8	1.1
19-20	1.5	817.5×1.5×1=1226.25	9810	1226.4	9811.2	1.2

From Table I,

Pumping hours = 8 hrs

Total daily maximum demand = 9811 m<sup>3</sup>

Pumping rate =  $\frac{\text{Total daily maximum demand}}{\text{Pumping hours}}$

$$= \frac{9811}{8} = 1226.4 \text{ m}^3/\text{hr}$$

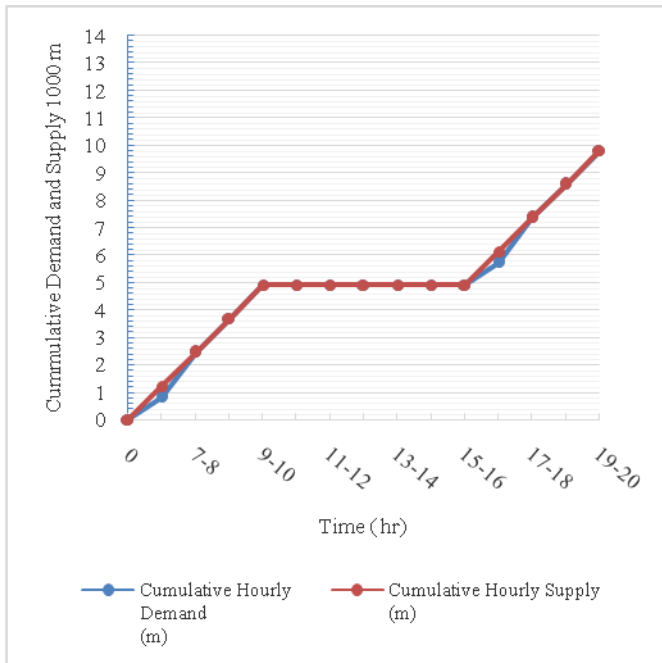


Figure 2. Cumulative Demand and Supply Curve for Elevated Tank

From Figure 2, the maximum vertical intercepted ordinate is 0.41 cm and the capacity of elevated tank including fire-fighting demand is  $0.41 \times 1000 = 410 \text{ m}^3$ . (1 cm = 1000  $\text{m}^3$ )

The maximum vertical distance between cumulative demand and cumulative supply curve is the capacity of elevated tank including fire-fighting demand. So, the dimension of proposed elevated tank is length 12m, width 7m and depth 5m. The capacity of elevated tank is  $420 \text{ m}^3$ .

### B. Algorithm for Pipe Network Analysis

A basic equation which is associated between quantity of water flow, average velocity and cross-sectional area of flow is given by following equation,

$$Q = AV \quad (2)$$

$$\therefore V = \frac{Q}{A} \quad (3)$$

Where, Q = quantity of water flow,  $\text{m}^3/\text{s}$   
A = cross-sectional area of flow,  $\text{m}^2$   
V = velocity of flow, m/s

$$h_f = \frac{fLV^2}{2gd} \quad (4)$$

Where,  $h_f$  = friction head loss, m  
f = friction factor  
L = length of pipe, m  
V = velocity of water, m/s  
d = diameter of pipe, m  
g = acceleration due to gravity,  $\text{m/s}^2$

$$h_v = \frac{V^2}{2g} \quad (5)$$

Where,  $h_v$  = velocity head loss, m

$$\text{Power}(Hp) = \frac{Q\omega H}{75\eta} \quad (6)$$

Where,  $\omega$  = specific weight of water  
H = total dynamic head, m  
 $\eta$  = efficiency of pumping machineries

The most common pipe flow formula used in the design and evaluation of the water distribution system is the Hazen Williams shown in equation (7) and (8):

$$V = 0.849 C R^{0.63} S^{0.54} \quad (7)$$

Where, V = velocity of water, m/s  
C = coefficient that depends on the material and age of conduit  
R = hydraulic radius, m  
S = slope of the hydraulic gradient, m/m

$$Q = 0.278 Cd^{0.63} S^{0.54} \quad (8)$$

Where, Q = quantity of water flow,  $\text{m}^3/\text{s}$   
d = diameter of pipe, m

The results of pipe networks are checked by the following formula,

$$\Delta Q = -\frac{\sum h_L}{1.85 \sum (h_L/Q)} \quad (9)$$

Where,  $\Delta Q$  = flow correction

$\sum h_L$  = sum of head losses

$\sum h_L/Q$  = sum of  $h_L/Q$  ratios for each pipeline in a loop

Q = discharge,  $\text{m}^3/\text{s}$

$$h_L = \frac{10.74LQ^{1.85}}{C^{1.85}D^{4.87}} \quad (10)$$

Where,  $h_L$  = friction loss, m  
D = diameter of pipe  
L = length of pipe, m

### C. Computer Modeling of Pipe Network Analysis

Mathematical models of distribution networks are now created and analyzed with computers. In this study, EPANET 2.0 network modeling program is used to analyze the distribution networks for Thayet down town area water supply system. EPANET 2.0 is a computer program that models and stimulates hydraulic and water-quality conditions within pressurized water distribution networks. It models a water distribution system as a collection of links connected to nodes.

The links represented pipes, pumps and controlled valves. The nodes represent junctions, tanks and reservoirs. A network consists of pipes, nodes, pumps, valves and storage tank or reservoirs. EPANET 2.0 tracks the flow of water in each pipe, the pressure at each node and the height of water in each tank.

EPANET 2.0 contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

1. Places no limit on the size of network that can be analyzed.
2. Computes friction headloss using either Hazen-Williams, Darcy-Weisbach, or Chezy-Manning equations.
3. Includes minor headloss for bends, fittings, etc.
4. Models constant or variable-speed pumps.
5. Allows storage tanks to have any shape. (i.e. diameter can vary with height)
6. Considers multiple demand categories at nodes, each with its own pattern of time variation. [4]

### III. RESULTS

#### A. Pumping main between the source and treatment plant

The Calculation of required pump size from source to treatment plant is as follow;

- Design flow = 0.34 m<sup>3</sup>/s
- Design diameter = 0.6 m = 600 mm
- By equation (3), calculated design velocity,  $V = 1.2$  m/s
- Suction head = 42 – 27 = 15 m
- Static head = 52 – 42 = 10 m
- Distance between source to treatment plant,  $L = 705$  m
- Acceleration due to gravity,  $g = 9.81$  m/s<sup>2</sup>

$$f = 0.016$$

- By equation (4), calculated friction head loss,  $h_f = 1.38$  m
- By equation (5), calculated velocity head loss,  $h_v = 0.073$  m
- Total head loss,  $H = 15 + 10 + 1.38 + 0.073 = 26.5$  m
- Assume efficiency of machinery as 80 %,  $\eta = 0.8$
- By equation (6), Required horse power,  $H.P = 150$  H.P (112 kW)

Therefore, the required pump capacity to pump the water from source to treatment plant is 150 H.P.

#### B. Pumping main between the treatment plant and elevated tank

The Calculation of required pump size from source to treatment plant is as follow;

- Design flow = 0.34 m<sup>3</sup>/s
- Design diameter = 0.6 m = 600 mm
- By equation (3), calculated design velocity,  $V = 1.2$  m/s
- Suction head = 1 m
- Static head = 61 – 58 = 3 m
- Distance between source to treatment plant,  $L = 1869$  m
- Acceleration due to gravity,  $g = 9.81$  m/s<sup>2</sup>

$$f = 0.016$$

- By equation (4), calculated friction head loss,  $h_f = 3.66$  m
- By equation (5), calculated velocity head loss,  $h_v = 0.073$  m
- Total head loss,  $H = 1 + 3 + 3.66 + 0.073 = 8$  m
- Assume efficiency of machinery as 80 %,  $\eta = 0.8$
- By equation (6), Required horse power,  $H.P = 45$  H.P (34kW)

Therefore, the required pump capacity to pump the water from source to treatment plant is 45 H.P.

#### C. Design of Distribution Pipes for Supply System

In using EPANET software, the first step is to draw a network representation of distribution system. The nodes are connected with links. The nodes represent junctions, tanks and reservoirs. The links represent pipes, pumps and controlled valves. Length, diameter and roughness coefficient are required as input data for pipes. And elevation and base demand are also required for nodes. Input data for tank is elevation and diameter. Demand multiplier factor is considered as 3. Then, a hydraulic and water quality analysis is run. The distribution pressure is controlled between seven to twenty-two meters range.

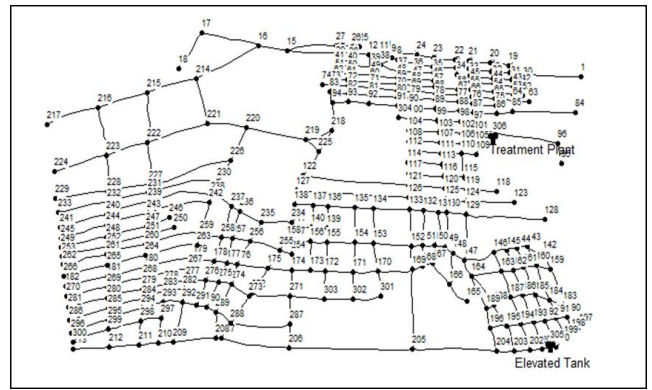


Figure 3. Proposed Pipe Network Plan of Thayet Downtown Area (Node ID is shown)

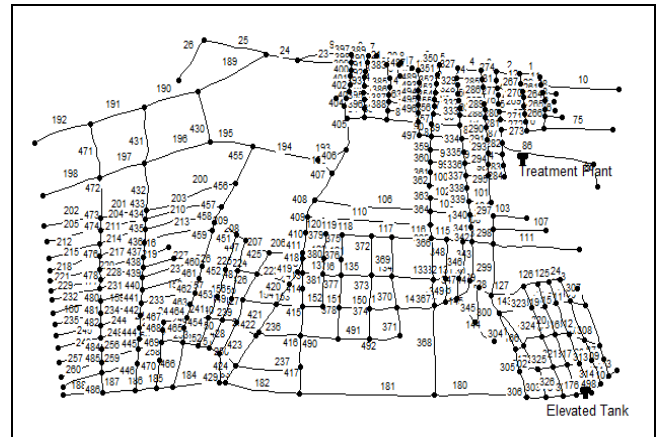


Figure 4. Proposed Pipe Network Plan of Thayet Downtown Area (Link ID is shown)

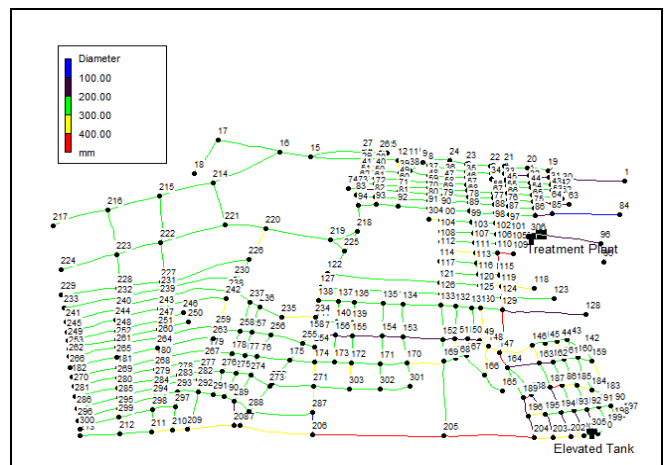


Figure 5. Proposed Pipe Network Plan for Thayet Downtown Area Water Supply



Figure 6. Location Map of Thayet Downtown Area's Water Supply Pipe Network System

Node and link ID are shown in Figures 3 and 4. Detail results of distribution system is shown in Figure 5. Figure 6 is the location map of water supply pipe network system of Thayet downtown area. Table III shows the design distribution pipe sizes and length of proposal water supply system.

Table 3: Result of Pipes Size and Length of Proposed Water Supply System

Item	Size of Pipe (mm)	Length of pipe (m)
1	50 mm φ	1143
2	100 mm φ	6972
3	150 mm φ	4670
4	200 mm φ	24678.5
5	250 mm φ	7701
6	300 mm φ	3169
7	350 mm φ	2108
8	400 mm φ	828
9	450 mm φ	90
Total Length		51359.5

**D. Check for Selected Pipe Network by Hardy-Cross Method**

Some of the output results of EPANET 2.0 Software can be checked by the Hardy-Cross Method using equation (11). Checking for loops is shown in Table IV. In general, if the errors are less than five percent of total inflow around a loop, these errors can be negligible.

$$\Delta Q = - \frac{\sum h_L}{1.85 \times \sum (h_L/Q)} \quad (11)$$

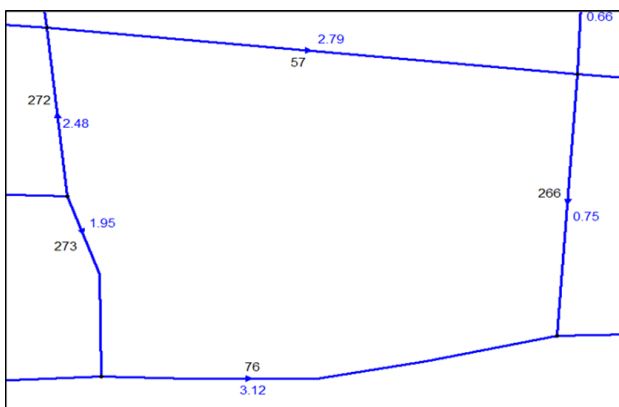


Figure 7. Pipe Network Plan for Loop (1) in Taung Min Tae Quarter

Table 4: Check for Selected Loop

Pipe No	Diameter (mm)	Length (m)	Flow (lps)	Total $h_L$ (m) $h_L = \frac{10.7L(Q)^{1.85}}{C^{1.85} D^{4.87}}$	$\frac{h_L}{Q}$
266	100	68	0.75	0.0178	0.0237
76	100	84	- 3.12	- 0.3075	0.0986
273	100	47	- 1.95	- 0.0721	0.0370
272	100	39	2.48	0.0934	0.0377
57	100	90	2.79	0.2679	0.0960
Sum			11.09	0.0421	0.2930

After checking by the Hardy- Cross Method, all of the errors within the loops are negligible. Therefore, output results of EPANET 2.0 Software can be acceptable.

**DISCUSSION AND CONCLUSION**

In my study, Geometrical Increase method is used to estimate the design population. The design period is considered for 30 years from the year of 2017 to 2047. In my study, water supply system is intermittent system. Water is distributed from 6:00 AM to 10:00 AM in the morning and from 4:00 PM to 8:00 PM in the evening. The dimension of distribution tank is (12 m × 7 m × 5m). Gravity and combined systems are used in this study. Death-End and Grid-iron system are used as a method of layout of distribution system. The material of transmission pipes is considered as G.I and that of distribution pipes are U. P.V.C. The total length of transmission pipe from source to treatment plant is 705 m with diameter of 600 mm. The total length of distribution pipe is 51.36km with diameter varying from 50 mm to 450 mm. The network model consists of 304 junctions, 498 pipe lines and one elevated tank. EPANET 2.0 software is used in designing the water distribution process. It is designed to supply safe water that is easily enough for the growing population. It is found that, adequate portable water can be distributed to the whole of Thayet downtown area by using the proposed treatment system and distribution system. According to the proposed system, people lived in Thayet downtown area can achieve happiness and healthy life.

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