Impact of Additional Water Capacity from Umbulan Spring to Water Distribution System of Central Gresik and South Gresik

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Abstract. The service area of drinking water in Gresik is divided into three zones: Central Gresik Zone, Central Gresik Zone, and South Gresik Zone. Gresik would receive an additional flow of 1,000 l/s from Umbulan Spring in 2021 to supply the demand of Central Gresik Zone. Legundi Water Treatment Plant (WTP) and Dewata WTP are two of several WTPs that supply Central Gresik Zone’s demand. Moreover, those two aforementioned WTPs also supply Central Gresik Zone’s demand. Once there is additional water capacity from Umbulan Spring, the water capacity of those two WTPs will be allocated to supply Central Gresik Zone’s demand. Central Gresik Zone is also supplied by Drupadi WTP which supplies South Gresik Zone’s demand. The rate of drinking water service in Central Gresik Zone and South Gresik Zone has not reached 100% especially in Benjeng sub-district and Balongpanggang sub-district. Therefore, the distribution pipeline network was planned to be developed in stages starting from 2015 until 2030. Analysis result of additional capacity to existing distribution pipeline network in 2021 showed incompatibility to design criteria.

1. Introduction

Drinking water service uses the 4K principle which consists of quality, quantity, continuity, and affordability. The meaning of quantity in this principle is that the supply of drinking water must meet the demand. Quantity often being the highly considered aspect due to the growth of population every year. So far, to fulfil the demand of drinking water in Gresik Regency, the Regional Water Utility Company (PDAM) of Gresik acquired raw water supply by buying bulk water and Surabaya River raw water from PDAM Surabaya. Besides buying raw water from PDAM Surabaya, deep wells were also used to supply consumers’ demand. The rate of drinking water service, both by PDAM Gresik and Drinking Water Consumer Association (HIPPAM), in 2017 was 46% from total demand.

This had not yet reached the government’s target of drinking water services, which is 100% access to drinking water divided into 60% of total demand distributed by piped networks and 40% of total demand distributed by protected non-piped networks. At this time, drinking water service zone is divided into 3 zones: Central Gresik Zone, Central Gresik Zone, and South Gresik Zone.

In 2017, The Provincial Government of East Java continued the Umbulan Spring Utilization project which was initiated in 1972. This project aims to distribute Umbulan Spring water to several areas that still lack drinking water supply, one of them being Gresik Regency. Gresik Regency would get 1,000 l/s drinking water supply from Umbulan Spring which would be distributed in 3 stages starting in 2019. The first stage would start in 2019 with a water capacity of 300 l/s. The second stage would start
in 2020 with a water capacity of 600 l/s. Gresik Zones would be fully supplied by Umbulan Spring and existing sources that previously only supplied Central Gresik Zone. With the additional capacity from Umbulan Spring, two water treatment plant that currently supply Central Gresik Zone and Central Gresik Zone’s demand, namely Legundi Water Treatment Plant and Dewata Water Treatment Plant, would only supply Central Gresik Zone’s demand. Central Gresik Zone is also supplied by Drupadi Water Treatment Plant that also supply South Gresik Zone’s demand. With the additional water capacity, it would be necessary to evaluate the existing water distribution system in Central Gresik Zone and South Gresik Zone for 2021.

2. Materials and Methods
Planning method is an important aspect in planning. A planning method contains the steps of planning implementation which will be explained in detail below.

2.1. Study of Literatures
Study of literatures aims to obtain theoretical basis to support the planning. Basic theories were obtained by journals, books, articles, previous final projects, and other sources (regulations, brochures, etc.)

2.2. Initial Preparation
Initial preparation was done by obtaining permits to acquire the actual data. Obtaining permits was done by creating a proposal and delivering introduction letters from the Environmental Engineering Department, Institut Teknologi Sepuluh Nopember to relevant stakeholders. The stakeholders included PDAM of Gresik Regency, Regional Development Planning Agency (Bappeda), Gresik Public Works Office, and National and Political Unity Agency (Bakesbangpol) of Gresik Regency.

2.3. Collection Data
Data were needed to serve as the basis for planning. Data can be classified into two types, namely primary data and secondary data. Primary data are data that can be obtained directly by field observation. Secondary data are data that can be obtained from other sources or stakeholders. The data needed in this plan are as follows:

- Primary Data
  - Topography of planning, particularly the elevation of planning area. This data could be obtained by measuring elevation at the end of each existing pipeline branch with GPS.
  - Road condition which included location of bridge, type of pavement, and width of the road.

- Secondary Data
  - Water demand per household (domestic) and public facilities (non domestic) in Gresik Regency to calculate domestic and non domestic water demand. Water demand per capita data were obtained from Gresik Regency Statistics.
  - Number of domestic and non domestic customers to calculate domestic and non domestic water demand. These data were obtained from PDAM of Gresik Regency. Data of customer needed were those of the years 2014-2018.
  - Total population for the calculation of population growth so growth of household can be calculated. These data were obtained from Gresik Regency Statistics. Data of population needed were those of the years 2009-2016.
  - Technical data of PDAM on the existing pipeline network, rate of pipe leakage, and production capacity for each water treatment plant, also the Water Supply System Master Plan (RISPAM) of Gresik Regency for 2010-2030 and company profile of Gresik Regency PDAM for 2017. These data were obtained from PDAM of Gresik Regency.
2.4. Data Processing

The distribution network analysis was focused on the primary distribution network with data processing stages as follows:

- Calculation of population projection rate considering the population projection method used.
- Projection of total domestic and non-domestic customers for 2021. Projection was made for each tapping point. The growth rate of total domestic customers follow that of the total population. If the rate of total domestic customer growth is rapid (exceeding the rate of total population growth), then the rate of total domestic customer growth would be equal to the rate of total population growth. The ratio of total non-domestic customer to total domestic customer would be considered the same so the growth of total non-domestic customer would follow the growth of domestic customers.
- Calculation of water demand for 2021 considering domestic water demand, non-domestic water demand, and water leakage. The value of peak hour demand factor would follow the value that had been set by PDAM of Gresik Regency in RISPAM of Gresik Regency.

2.5. Network Modelling

Network modelling was based on the existing pipeline network and data that had been obtained. EPANET 2.0 was used to create the network model. Modelling was done by inserting data of node, junction, reservoir, and pump. Data that had to be inserted into EPANET 2.0 are as follows:

- Data that must be inserted in pipe:
  - Name of pipe (Pipe ID), e.g. P1.
  - Pipe length (Length) was filled with value of length of existing pipeline in meter.
  - Roughness of pipe (Roughness) was filled with roughness value of existing pipe material.
  - Pipe diameter in mm.

- Data that must be inserted in junction:
  - Name of junction (junction ID), e.g. J1.
  - Elevation was filled in meter according to field condition.
  - Base demand was filled with the value of peak hour demand for each tapping of the block. The base demand value must be filled in litres/second.

- Data that must be inserted in reservoir:
  - Name of reservoir (Reservoir ID, e.g. R1.
  - Head total was filled with the elevation of existing reservoir in meter.

- Data that must be inserted in curve:
  - Add curve by clicking browser – data – curve – add curve (the icon is in the lower left of browser column).
  - Name of curve (Curve ID), e.g. curve1.
  - Head of existing pump in meter, e.g. 45 meter.
  - Flow of existing pump (Flow) was filled with peak hour demand in litres/second.

- Data that must be inserted in pump:
  - Name of pump (Pump ID) was filled according to the curve used, i.e. curve1.

3. Results and Discussion

3.1 Determination of total domestic customer growth rate

Population growth rate determination was done by using one of three methods: arithmetic, geometric, and least square. In this analysis, geometric method was used to project the population in accordance to RISPAM Gresik Regency. Geometric method assumed that the population growth rate was constant in every year. After the calculation, the average of Central Gresik and South Gresik population growth rate for 2009-2016 was found to be 1.5%. The calculation can be seen in Table 1.
Table 1. Population Growth Rate in Central Gresik and South Gresik

| Year | Total Population | People | % | Growth Ratio |
|------|------------------|--------|---|--------------|
| 2009 | 508,569          | -      | - | 0            |
| 2010 | 521,090          | 12,521 | 2.46 | 0.025        |
| 2011 | 529,713          | 8,623  | 1.65 | 0.017        |
| 2012 | 547,472          | 17,729 | 3.35 | 0.034        |
| 2013 | 560,311          | 12,839 | 2.35 | 0.023        |
| 2014 | 566,626          | 6,315  | 1.13 | 0.011        |
| 2015 | 566,858          | 232    | 0.04 | 0.000        |
| 2016 | 571,663          | 4,805  | 0.85 | 0.008        |

Average population growth rate per year: 0.015

Source: a Gresik statistics  
b Calculation result

3.2 Projection of total domestic customer growth rate

Total domestic customer projection was calculated based on the total domestic customer growth rate in 2014-2018 in the existing service area. From the data of total domestic customers, tapping points in the existing service area were plotted to determine domestic demand in the existing service area for every tapping point. Service development in Gresik Regency is divided into three stages which began in 2015 and would end in 2030. In 2018, the total domestic customers in South Gresik and Central Gresik were 19,089 and 44,929 units. The company target of domestic customers in each development stage can be seen in Table 2.

Table 2. Development Plan of Gresik PDAM in Central Gresik and South Gresik

| Development Stage | Target of Domestic Customers |
|-------------------|-------------------------------|
|                   | South Gresik | Central Gresik |
| Stage 1 (2015 – 2020) | 24,507      | 32,346         |
| Stage 2 (2021 – 2025) | 33,279      | 45,818         |
| Stage 3 (2025 – 2030) | 43,783      | 63,262         |

Source: PDAM of Gresik Regency

The projection of total domestic customer was started by projecting domestic customers for 2020. This was because based on the data of total domestic customers in 2018, South Gresik still needed to increase its number of domestic customers of 5,418 unit to meet 2020 target. Projection was done by assuming there would be no expansion of service area until 2020 so the additional domestic customers would be added in the existing service area. To obtain the total domestic customers that must be added in each region on existing service area, a percentage of domestic service for every region should be known. Then, total addition of domestic customer in each region could be determined by multiplying the percentage of domestic service for each region by the additional total domestic customers in South Gresik for 2020 target.

Domestic customer projection for 2021 had a different calculation from 2020 projection because 2021 would be in a different stage from 2020 so the total domestic customer was estimated to increase in new service area. Total domestic customers would certainly increase in existing service area but it was assumed that the growth rate of domestic customers (r) would be equal to the total population growth rate, i.e. 0.015. The base year of this projection was 2020. The result of total domestic customer projection in South Gresik was 24,894 units. Total domestic customer projection was
calculated with the following equation:

$$SR_n = SR_o (1 + r)^n$$  (1)

Where:
- $SR_n$ = total domestic customers in projection year (unit)
- $SR_o$ = total domestic customers in base projection year (unit)
- $r$ = average of total domestic customer growth rate

Afterwards, the total domestic customer was projected in Central Gresik’s existing service area. The calculation was different from South Gresik’s projection because in 2018 the total domestic customers in Central Gresik had exceeded 2020 target. Projection was determined by considering the total domestic customer growth rate in every region for 2014-2018. If a region has no increasing total domestic customers, then the ratio of total domestic customer growth rate is assumed to be 0. If the total domestic customer growth rate in a region is more than 0.015, then the domestic customer growth rate is equal to the total population growth rate, i.e. 0.015. This is because the growth rate of total domestic customer is considered as new service area in development stage 1 so the growth of domestic customer in that area is significant. If the total domestic customer growth rate in a region is less than 0.015, then that value is used as growth rate of total domestic rate. After determining the ratio of total domestic customer growth rate in each region, then projection was calculated in the same way as projection of total domestic customer in South Gresik’s existing service area for 2021 with 2018 as the base projection year. Result of total domestic customers calculation in Central Gresik for 2021 was 46,080 units.

3.3 Projection of total non-domestic customer growth rate

Non-domestic customers can be classified into 7 categories, i.e. social (S), government agencies (IP), small commerce (NK), big commerce (NB), small industry (IK), big industry (IB), and public social (SU). Classification is based on water tariffs classification of Gresik Regency PDAM. Classification of non-domestic customer can be seen in Table 3.

Table 3. Customer Classification of Gresik PDAM

| Customer Classification   | Public Facility                                                                 |
|--------------------------|-------------------------------------------------------------------------------|
| Public Social (SU)       | Public hydrants, public faucets/public terminal                               |
| Social (S)               | Public worship places, social foundations, orphanages, public schools, public toilets |
| Government Agencies (IP) | Government offices, army/police station, non-commercial institutions, government hostels, etc. |
| Small Commerce (NK)      | Small workshops, grocery stores, internet cafes, boarding houses, polyclinics, doctor/midwife’s clinic, pharmacies, offices, notarism offices, etc. |
| Big Commerce (NB)        | Restaurants, diners, supermarkets, gas stations, big showrooms, wholesalers, swimming pools, hotels, hospitals, warehouses, service bureaus, etc. |
| Big Industry (IB)        | Textile factories, garments, car body factories, timber, steel / concrete construction fabrication, ceramic factories, and other industries |
| Small Industry (IK)      | Home industry and other small industrial businesses                           |

Source: PDAM of Gresik Regency

Projection of non-domestic customer was calculated for each category for each region. The calculation
used the following equation:

\[ F_n = \frac{S_{Rn} \times F_0}{S_{Ro}} \]  

(2)

Where,

- \( F_n \) = total non-domestic customer in projection year (unit)
- \( F_0 \) = total non-domestic customer in base projection year (unit)

In this projection, public social was planned not to have any unit addition in the existing service area. The addition will be planned in the new service area. Results of non-domestic customer projection can be seen in Table 4.

**Table 4. Projection of Non-Domestic Customers for 2021**

| Customer Classification     | Total Unit | South Gresik | Central Gresik |
|-----------------------------|------------|--------------|----------------|
| Public Social (SU)          | 5          | 9            |
| Social (S)                  | 208        | 682          |
| Government Agencies (IP)    | 22         | 76           |
| Small Commerce (NK)         | 440        | 1,786        |
| Big Commerce (NB)           | 308        | 225          |
| Small Industry (IK)         | 18         | 140          |
| Big Industry (IB)           | 209        | 85           |

Source: Calculation Result

### 3.4 Water Demand for 2021

After knowing the total of domestic and non-domestic customers in 2021, water demand in 2021 could be calculated. Non-domestic water consumption for each category referred to water consumption for 2017 that was found in Gresik Statistics. Domestic water consumption in this calculation was 120 litres/people.day with each unit of domestic customer consisting of 5 people, so water consumption for each domestic customer was found to be 0.6 m³/day. Water consumption for each category of customers can be seen in Table 5.

**Table 5. Water Consumption for Each Customer Category in 2017**

| Customer Category            | Water Consumption |
|------------------------------|-------------------|
|                              | m³/day | Litres/second |
| Public Social (SU)          | 2.12   | 0.025         |
| Social (S)                  | 1.34   | 0.016         |
| Domestic Customer (R)\(^a\) | 0.60   | 0.007         |
| Government Agencies (IP)    | 1.52   | 0.018         |
| Small Commerce (NK)         | 0.80   | 0.009         |
| Big Commerce (NB)           | 1.49   | 0.017         |
| Small Industry (IK)         | 1.17   | 0.014         |
| Big Industry (IB)           | 41.65  | 0.482         |

Source: Gresik Statistics

\(^a\) RISPAM of Gresik Regency

After water consumption for each category was calculated, the water demand for each tapping point for 2021 could be calculated. Water demand for each tapping point was calculated using peak
hour demand with the value of peak factor \((f_p)\) being 1.75, based on RISPAM of Gresik Regency. Moreover, the calculation of water demand also considered water leakage. Percentage of water leakage used in this planning was 20.33\%, following the percentage of water leakage for 2017.

- Total water demand \((Q_t)\) = 678.94 litres/second
- Total water demand with water leakage \((Q_a)\) = \(Q_t / (100\% - \% \text{ water leakage})\)
  \[= 678.94 \text{ litres/second} / (100\% - 20.33\%)\]
  \[= 852.19 \text{ litres/second}\]
- Peak water demand \((Q_p)\) = \(Q_a \times f_p\) = 1,491.34 litres/second

Afterwards, the capacity of water treatment that supply Central Gresik and South Gresik Service Zone must be known. The capacity of the water treatments can be seen in Table 6.

**Table 6. Production Capacity of Water Treatment Plants Serving Central Gresik and South Gresik**

| Water Treatment Plant          | Production Capacity (Litres/second) |
|-------------------------------|------------------------------------|
| Legundi Water Treatment Plant | 430                                 |
| Perumnas Water Treatment Plant| 100                                 |
| Bulk Water – PT Dewata        | 200                                 |
| Bulk Water – PT Drupadi       | 168                                 |

Source: PDAM of Gresik Regency

The capacity of water treatment that supplied Central Gresik and South Gresik Service Zone was 878 litres/second. Compared with the 2021 water demand, the total capacity from those water treatment plants would exceed the demand for 2021. The excess capacity would be 45.75 l/s.

Then, the distribution pipeline network was analyzed with EPANET 2.0. Analysis results were then compared with the planning criteria. The planning criteria are as follows:
- Pressure = \((15-100)\) meter
- Velocity = \((0.3-2)\) meter/second
- Unit headloss = maximal 10 m/km

Analysis results showed that, in the 2021 distribution pipeline network, 82 of 142 pipes would have headloss that exceed the criteria. Excessive headloss would cause a lack of pressure so water would not be able to be distributed to the farthest point. The analysis also showed that 123 of 141 points would lack pressure and 2 of 141 points would have excessive pressure. Lack of pressure would result in small flow in the distribution of water in service area hence water would not be able to be distributed to the farthest point. Excessive pressure could cause ruptures in the distribution pipe. Lack of pressure can be overcome by reducing headloss and increasing pump pressure. Headloss can be reduced by replacing existing pipes with larger diameter ones or adding new pipes installed in parallel. Moreover, 58 of 142 pipes would have excessive velocity and 7 of 142 pipes would have velocity less than the minimal criteria. Excessive velocity would cause high headloss and make pipes break faster. This can be reduced by replacing existing pipes with larger diameter ones. Water velocity that is less than minimal criteria can cause sedimentation in pipes. This can be overcome by replacing existing pipes with smaller diameter ones. Network modelling for 2021 can be seen in Figure 1.

The cause of the large number of tapping points and pipes that would not meet the planning criteria is the inadequate pump capacity in meeting 2021 water demand. Inadequate pump capacity would result in small pressure released by the pump.
4 Conclusions
Analysis results of the existing distribution pipeline network for 2021 showed that 123 distribution points would have pressure less than 15 meters and 2 distribution points would have pressure more than 100 meters. 58 pipes would have velocity more than 2 m/s and 7 pipes would have velocity less than 0.3 m/s. 82 pipes would have unit headloss more than 10 m/km. These could cause irregular distribution of water from the reservoir to customer and could also cause damage to distribution pipes. The existing production capacity would exceed the water demand of Central Gresik and South Gresik Service Zone with an excess of 45.81 l/s.

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