A Study of Drinking Water Supply and Demand in Surabaya in the Year 2039

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Abstract. This study of supply and demand of water in Surabaya City evaluates the equilibrium of domestic and non-domestic water demand with the existing supply so that the source flow rate can be prepared for the demand in the following 20 years. PDAM Surabaya has reached water service area of 96.67% and will increase to 100 percent in the following year as targeted by the Central Government. The method used was water balance of PDAM Surabaya planned for every five years until 2039. The result of this study showed the potential of raw water from Umbulan with 1,000 L/s and from Kali Brantas with 1,000 L/s. Projection for water demand for the first water balance in year 2024 resulted 15,037 L/s and there was a deficit of 3,062 L/s. The result of water balance in 2019-2039 showed that the supply would not fulfill the water demand.

Keywords: raw water potential, supply and demand, water demand, water balance

1. Introduction
Water demand increases along with population growth. Water is a human need that must be fulfilled by the government [4]. The city of Surabaya is the second largest metropolitan city in Indonesia, which is experiencing growth in trade, economy, settlement, service, companies and industries that are quite rapid [2]. In addition, Surabaya is also a place to work or study for people coming from other regions.

The Regional Water Company (PDAM) Surabaya has worked continuously to provide the best quality service to people. In 2018, PDAM Surabaya reached water service area of 96.67%. This has made the central government target to reach 100% water service area based on Rencana Pembangunan Jangka Menengah Nasional (RPJMN) for year 2015-2019 about 100-0-100. Thus, PDAM efforts to improve services will increasingly become a challenge for the demands or supply.

PDAM Surabaya uses surface water from Kali Surabaya and Kali Brantas by 97% or at 10.5 m³/s and Umbulan and Pandaan springs by 3% or at 0.33 m³/s to serve water needs [3]. But along with increasing population and the development of industries, water demand will rise so that the company will be required to look into potential raw water to fulfill the demands of water in Surabaya in the future.

2. Materials and Methods
The method used in this study was water balance by calculating population projections and water needs for 20 years from 2018-2039. Population projection in this study was done using arithmetic,
geometric and least squares that have the value of r close to 1, which aimed to achieve near perfect data. Supporting data in projections include existing number of citizens, number of customers, water consumption, water loss, water potential data, and existing supply data. Water demand that was calculated included domestic, non-domestic, water loses, and water demand for fire. The results of this study aimed to determine whether the water production capacity to serve Surabaya residents would experience a deficit or surplus for the next few years.

3. Results and Discussion

3.1. Existing Water Resources of PDAM
In serving Surabaya residents, PDAM Surabaya utilizes two types of raw water sources, namely surface water and spring water. Raw water used by PDAM Surabaya is obtained from Perum Jasa Tirta I, which comes from Surabaya River with supply percentage of 97% and Umbulan and Pandra springs with supply percentage of 3%.

The water is taken from 17 sources, mostly from Pandaan, Pasuruan including Umbulan, Government I, Government II, Government III, Toyo Arang, Jambangan, Mermaid Bulak, Bumbungan, Lamer, Winong, Kalong, Kesambi, Klampok I, Klampok I II, Klampok III, Duren Sewu, and Karang Jati.

There are four PDAM Surabaya Water Treatment Plants (WTP/IPA), including Ngagel I WTP, Ngagel II WTP, Ngagel III WTP, Karangpilang I WTP, Karangpilang WTP II, Karangpilang WTP III. The service coverage of PDAM Surabaya in 2018 was 96.67% and it supplies water with a pipe interconnection system.

3.2. Alternative Sources of Drinking Water for PDAM Kota Surabaya
Based on secondary data, there are several alternative water sources that can be used as PDAM Surabaya water sources as follows.

| No. | Source of Raw Water     | Discharge |
|-----|-------------------------|-----------|
| 1   | Umbulan                 | 1000 l/s  |
| 2   | Brantas River           | 4000 l/s  |
| 3   | Bengawan Solo River     | 4000 l/s  |
| 4   | Surabaya River          | 1200 l/s  |
| 5   | Boezem Morokrembangan   | 0.96 l/s  |

Based on the results of the analysis, the source of raw water that is suitable and can be used as an alternative for the City of Surabaya is the Umbulan spring which would be realized in two phases, phase I (2019) with a discharge capacity of 500 L/s and phase II in 2020 with 500 L/s. In addition, Brantas River water can be taken at 1000 L/s from the existing 4000 L/s production discharge through the DAM Mlirip for the City of Surabaya based on the existing financial capacity to meet water needs in the next 20 years. Both of these raw water sources were used as a reference in the calculation of the water balance.

3.3. Population Projection
In this study, the projection of the population of Surabaya City was calculated for 20 years from 2018 to 2039 by comparing the three methods: arithmetic, geometric, and least square methods. Statistical testing methods were done to find the smallest standard deviation and the correlation coefficient value closest to 1 (linear). Based on the calculation, the least square method was chosen with a correlation value (r) of 0.0475 and a standard deviation of 3363.97. Therefore, the least square method was then carried out in the projection of population of Surabaya in each district.
Based on the calculation of population projections, the East Surabaya area was the region with the highest population, amounting to 813,013 people in 2018 and is estimated to experience the largest population growth to 1,177,462 people in 2039. The most populous area in 2018 was Simokerto Subdistrict with a density of 38,820 people/km² and a population of 100,545 people, while the most populous sub-district in 2039 is projected to be Tambaksari Subdistrict with a density of 4557 people/km².

3.4. Domestic and Non-Domestic Water Needs
The calculation of the projected domestic and non-domestic water needs of the City of Surabaya in this study was done for a period of 20 years from 2019 to 2039. In the calculation, the percentage of service planned in 2019 used in calculations was 100%, which is in accordance with the plan of PDAM Surabaya and the 2015-2019 RPJMN which targets Surabaya residents to be served by PDAM pipes.

In determining the water usage / domestic consumption unit of Surabaya City, calculations were done using secondary data from PDAM in the form of the amount of water sold and house connections. The number of house connections referred to the Ministry of Public Works standards of 5 people in 1 (one) SR, so it was assumed that there would be 5 people in one house connection in the next 20 years in the City of Surabaya. The results of the calculation of the consumption unit of the City of Surabaya in 2018 amounted to 190 L/person/day.

Non-domestic water needs were calculated based on the types of customers of PDAM Surya Sembada including public social, special social, government, trade, industry, and ports.

3.5. Fire Water Supply
Based on SNI 03-1735-2000, water supply for a city hydrant (yard) must be at least 2400 liters/minute and be able to drain water for at least 45 minutes. According to [1], fire incidents in Surabaya in 2017 occurred as many as 321 times in 196 fire points. Among them were 82 housing estates, 14 factories, and the remaining 225 were reeds on vacant land or open areas.

For the calculation, it was assumed that the City of Surabaya had experienced major fires that required handling from the fire fighters (PMK), according to data in 2017 there were 82 houses and 14 factories which were assumed to have four fires, so it was assumed that in one year there were 24 fires. Therefore, the minimum additional discharge needed to meet the fire needs is 960 L/s.

3.6. Water Losses
In 2018, Surabaya PDAM experienced water losses at 30.66%. This figure is classified as high and might be due to technical factors such as pipe leakage, old pipelines, damaged customer meters and those that were more than 5 years old, as well as meters found in deposits, submerged and opaque. These conditions resulted in non-physical water loss such as mishandling of data due to inaccuracies in water meters. However, the highest water losses occurred due to leakage of pipes from excavation projects on the highway.

For the level of water loss in the projection year, the plan to reduce the percentage of PDAM water loss was assumed to be ±1% per five years provided that the causes of water loss in the City of Surabaya could be resolved each year. The amount of water loss in 2018 was 3364.9 L/s and in the projected year of 2039 (27.66%) it would be 4396 L/s.

3.7. Water Balance
The water balance calculation was done for every 5 years, which is the PDAM's existing water balance, the first 5-year water balance, the second 5-year water balance, the third 5-year water balance and the fourth 5 years, which referred to the PDAM service plan that was planned per five years so that the calculation of projections would be in line with the results of PDAM projections. The addition of water sources included Umbulan (1000 L/s) and Kali Brantas (1000 L/s) planned for 2030 in this study.
Table 2. Existing Water Balance of PDAM Year 2018

| Demand in Year 2018 | Supply in Year 2018 |
|---------------------|---------------------|
| **Sources**         | **Discharge (Liter/sec)** | **Sources** | **Installed (Liter/sec)** | **Production (Liter/sec)** |
| Domestic            | 5535                | Surabaya River | 11500                      | 10645                      |
| Non Domestikc       |                     | Pandaan Spring | 220                        | 220                        |
| 1. General Social   | 146.76              | Umbulan        | 110                        | 110                        |
| 2. Sosial Special   | 389.80              |                |                            |                            |
| 3. Government Agencies | 206.70           |                |                            |                            |
| 4. Trading          | 1240.66             |                |                            |                            |
| 5. Industry         | 69.84               |                |                            |                            |
| 6. Port             | 21.99               |                |                            |                            |
| **Total Non domestic** | **2076**         |                |                            |                            |
| **Total domestic + non domestic** | **7611** |                |                            |                            |
| **Water losses**    | 3365                |                |                            |                            |
| **Jumlah**          | 10975               |                | **Total**                  | **11830**                  |
|                     |                     |                |                            | **10975**                  |

In 2018, the PDAM repaired 4 pumps with a capacity of up to 1000 L/s. This would increase the installed capacity from 10,500 L/s in 2017 to 11,500 L/s in 2018. The total existing demand of customers was 7611 L/s and the capacity produced by PDAM was 10,975 L/s.

Table 3. First Years Water Balance of PDAM in 2024

| Demand in Year 2024 | Supply in Year 2024 |
|---------------------|---------------------|
| **Sources**         | **Discharge (L/s)** | **Sources** | **Installed (L/s)** | **Production (L/s)** |
| Domestic            | 6990                | Surabaya River | 11500                      | 10645                      |
| Non Domestikc       |                     | Pandaan Spring | 220                        | 220                        |
| 1. General Social   | 139.81              | Umbulan        | 1110                       | 1110                       |
| 2. Sosial Special   | 489.32              |                |                            |                            |
| 3. Government Agencies | 209.71           |                |                            |                            |
| 4. Trading          | 1537.86             |                |                            |                            |
| 5. Industry         | 69.90               |                |                            |                            |
| 6. Port             | 30.01               |                |                            |                            |
| **Total Non domestic** | **2477**         |                |                            |                            |
| Fire Water Need     | 960                 |                |                            |                            |
| **Total domestic + non+domestic + Fire** | **10426** |                |                            |                            |
| Water Losses        | 4610                |                |                            |                            |
| **Total**           | 15037               |                | **Total**                  | **12830**                  |
|                     |                     |                |                            | **11975**                  |
|                     |                     |                |                            | **(3062)**                 |

Clean water supply would also be supplied from the addition of Umbulan discharge capacity through the Umbulan KSP project of 500 L/s both in 2019 and 2020. The total requirement of 10,426 L/s with a water loss of 30.66% would be 4610 L/s. While the existing supply was 11975. Therefore, in 2019 there was a deficit of 3062 L/s.
Table 4. Second Year’s Water Balance of PDAM Year 2029

| Demand Year 2024 | Supply Year 2024 |
|------------------|------------------|
| Sources | Discharge (L/s) | Sources | Installed (L/s) | Production (L/s) |
| Domestic | 7265 | Kali Surabaya | 11500 | 10645 |
| Non Domestic | | | | |
| 1. General Social | 14530 | Sumber Air Pandaan | 220 | 220 |
| 2. Social Special | 508.55 | 3. Government Agencies | 217.95 | 217.95 |
| 4. Trading | 1598.31 | 5. Industry | 72.65 | 72.65 |
| 6. Port | 31.19 | Total Non domestic | 2574 | 2574 |
| Fire Water Need | 960 | Total domestic + non+domestic + Fire Water Need | 10798 | 10798 |
| Water Losses | 4553 | Total | 12830 | 12830 |
| Total | 14947 | Deficit | (3376) | (3376) |

In the second 5-year water balance, namely in 2029, there would be no increase in the discharge capacity of any source from the previous 5 years. Table 5 shows that total domestic and non-domestic discharges would be 9839 L/s, water loss would be 4553 L/s with a percentage of leakage at 29.66%.

Table 5. Third Year’s Water Balance of PDAM Year 2034

| Demand Year 2024 | Supply Year 2024 |
|------------------|------------------|
| Sources | Discharge (L/s) | Sources | Installed (L/s) | Production (L/s) |
| Domestic | 7542 | Surabaya River | 11500 | 10645 |
| Non Domestic | | | | |
| 1. General Social | 150.85 | Pandaan Spring | 220 | 220 |
| 2. Social Special | 527.96 | Umbulan | 1110 | 1110 |
| 3. Government Agencies | 226.27 | Brantas (DAM Milirip) | 1000 | 1000 |
| 4. Trading | 1659.30 | | | |
| 5. Industry | 75.42 | | | |
| 6. Port | 32.38 | | | |
| Total Non domestic | 2672 | Fire Water Need | 960 | 960 |
| Total | 9407 | Total domestic + non+domestic + Fire Water Need | 11174 | 11174 |
| Water Losses | 4489 | Total | 13830 | 13830 |
| Total | 15278 | Deficit | (2688) | (2688) |

The total needs would be 11174 L/s. Water loss would be 4489 L/s with a percentage of leakage at 28.66%, while the existing supply would be 12975 L/s. In 2030, based on the results of the workshop, it was planned that there would be an increase in installed discharge capacity for the City of Surabaya...
through Mlirip DAM, Mojokerto from Brantas River. This addition could be accompanied by the construction of a new IPA in Surabaya which would be built three years before the water could be distributed to customers.

Table 6. Fourth Year’s Water Balance of PDAM in Year 2039

| Demand in Year 2029 | Supply in Year 2029 |
|---------------------|---------------------|
| **Sources**         | **Discharge (L/s)** | **Sources** | **Discharge (L/s)** | **Sources** |
| Domestic            | 7782                | Kali Surabaya | 11500             | 10645       |
| Non Domestic        |                     | Sumber Air Pandaan | 220          | 220         |
| 1. General Social   | 155.63              | Sumber Air Umbulan | 1110         | 1110        |
| 2. Sosial Special   | 544.72              | Kali Brantas (DAM Mlirip) | 1000    | 1000        |
| 3. Government Agencies | 233.45           |                     |                |             |
| 4. Trading          | 1711.97             |                     |                |             |
| 5. Industry         | 77.82               |                     |                |             |
| 6. Port             | 33.40               |                     |                |             |
| **Total Non domestic** | 2757               |                     |                |             |
| Fire Water Need     | 960                 |                     |                |             |
| **Total domestik + non domestik + Kebakaran** | 11499 |                     |                |             |
| kehilangan air      | 4396                |                     |                |             |
| **Jumlah**          | 15528               | **Total**          | 13830           | 12975       |
|                     |                     | **Deficit**        | (2920)          |             |

Total domestic and non-domestic needs + fires would be 11499 L/s, while the existing supply would be 12975 L/s, in the fourth year it would also experience a deficit of 2920 L/s. Therefore, PDAM Surabaya would require the addition of an installed source of discharge water or an reduction in water loss figures to meet the drinking water needs of Surabaya City residents.

![Figure 1. Water Balance of Surabaya Year 2039](image)

The result of water balance for the period of 2019-2039 was that the supply would not be able to fulfil the water demand so that the water consumption was corrected and it would need other alternatives to fullfill the demand.
3.8. Correction of Domestic Drinking Water Consumption

The amount of consumption of drinking water for each person and every day can actually be calculated accurately if there is a record from PDAMs about water usage and the number of people per unit of its customers [4]. PDAMs generally have records of water usage for each customer, but records of the number of people in each customer are not available, because PDAM only has an interest in the amount of water that is distributed to customers or the amount of revenue from the sale of water. Therefore it was necessary to make corrections to the consumption of domestic use in Surabaya.

Surabaya as a metropolitan city experiences symptoms of migration. In this study, it was identified that the migration that occurred was circular migration. These migrating residents routinely go to their destination and return to their residence within a weekly or monthly period by crossing the administrative boundary of Surabaya City. These residents occupy residences in Surabaya such as boarding houses and rented houses, or they live with relatives for a certain period of time. This circular population consists of high school students, college students, and workers.

Table 7. Results of Analysis of the Number of Circular Populations in Surabaya

| Year | Number of Students | Number of Workers | Total |
|------|--------------------|-------------------|-------|
| 2015 | 129666             | 17603             | 147269|
| 2016 | 145798             | 17743             | 163541|
| 2017 | 161930             | 18134             | 180064|

Then, the domestic consumption unit was calculated based on the total number of Surabaya residents registered and the circular population with water sold (billed) and the result was 150 L/person/day. After calculating the need for clean water using a consumption unit of 150 L/person/day, the available water supply was found to be insufficient for meeting water demand.

3.9. Scenario of Water Balance in Surabaya

From the results of the analysis, the balance sheet in the first year i.e. 2024 would experience a deficit even though there would have been additional supply from new water sources such as Umbulan amounting to 1000 L/s with a total demand of 14,418 L/s. Therefore, this should be an early warning for the city of Surabaya in the next five years.

To meet the water needs of the next 20 years, a scenario was made to cover the deficit rate. This would reduce the rate of water loss by 25%, which is in line with the commitment of PDAM Surabaya that plans to reduce the percentage of leakage with a number of programs implemented such as the formation of a special team related to leakage of pipes in Surabaya, the formation of DMA-DMA batru each year, and the replacement of water meters of citizens for free.

In addition, the water consumption unit used was 150 L/person/day in accordance with the correction analysis of the consumption unit. In the following years, the decline in water usage of Surabaya residents per person would need to be encouraged early on by providing education to residents related to water conservation / water saving. In addition, it could also be done by increasing PDAM water tariffs in the hope that residents will be more efficient in using water.

The rate of water service coverage increased gradually from 96.06% in 2017, 96.67% in 2018 to 100% in 2019 in accordance with the rate of drinking water needs of the City of Surabaya and the target of the RPJMN to provide 100% access to clean water where SPAM West Surabaya began operating phase I in 2019 (500 L/s) and phase II in 2020 (500 L/s). The source of raw water that could potentially be used is Brantas River, with 1000 L/s can be used for Surabaya of the total 4000 L/s of existing potential.
High effort is needed to achieve this target which of course involves various parties from PDAM, Ciptakarya Office, PEMDA, residents and other agencies. If the target to reduce water loss by 25% in the next five years is not achieved then it is estimated that there will be a deficit. It is possible that in the future there might be additional water supply from other alternative sources that require community participation such as wastewater recycling, rainwater harvesting, and sea water utilization.

Figure 2. Scenario of Water Balance Surabaya Year 2039

4. Conclusions
The results of this study show potential water sources from Umbulan of 1,000 L/s which would be realized at 2019 and DAM Mlrip Mojokerto from Brantas River of 1,000 L/s. Water balance of the existing water demand in 2018 was 7610 L/s with the existing supply of 10,975 L/s. In 2024, the total demand was calculated to be 15,037 L/s and there would be a deficit of 3,062 L/s, in 2029 the total demand would be 14,947 L/s and there would be a deficit of 3,376 L/s, in 2034 the total demand would be 15,278 L/s and there would be a deficit of 2,688 L/s and in 2039 the total demand would be 15,528 L/s and there would be a deficit of 2,920 L/s.

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