Analysis of meteorological water availability and water demand in Semarang Regency

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Abstract. Population growths are increasing the demand for water. This can cause an imbalance of water availability to fulfill domestic water demand. Therefore, it is necessary to analyze the water availability and water demand so that water resources are maintained and can fulfill the community needs in the present and future. This research aims to analyze the water availability and domestic water demand in Semarang Regency. The methods consist of calculating monthly rainfall, calculating water balance using F. J Mock model, calculating the water demand regarding to the water availability, and calculating how much water can be obtained from rain harvesting. The results show the highest annual water availability in Semarang Regency is Pringapus district 48,559,764.55 m³/year, while the lowest is Kaliwungu district 17,352,024.13 m³/year. The highest domestic water demand are in West Ungaran district, East Ungaran district, and Bergas district, while the lowest are in Bancak and Kaliwungu district. The total water demand is 6% of the total water availability, means there is no water deficit in Semarang Regency. The total volume of rainwater harvested is 120,163,412 m³/year which means the volume of rainwater harvested in one year can fulfill the domestic water demand in Semarang Regency.

Keyword: water balance, water availability, water demand

1. Background

Water resources are one of the renewable resources, but the availability of water can be reduced due to excessive human usage of water. One of the factors that threaten water resources is the increase in population growth [3]. These can affect the increase in daily needs too. The increase of daily needs results for the needs of water. The increase in population that is not in accordance with the availability of water will cause conflicts in the future [10]. Analysis of water availability and water demand is needed so that water resources are maintained and can fulfill the needs of the community.

Semarang Regency has a large groundwater recharge due to its urban area with a high population. Semarang Regency has a population of 1,053,786 people with a population growth rate of 1.26% in 2019 [5]. Population growth that continues to increase has the potential to deplete groundwater and threatened the availability of water. The problem of inequality in water demand and water availability in Semarang Regency needs to be resolved by managing water resources properly. An assessment of water availability and water demand in Semarang Regency is needed in order to achieve a balance water demand and water availability in the future by examining their components [23].

The availability of water is divided into the availability of rainwater, surface, and groundwater [23]. The availability of rainwater water is based on the rain that falls in an area. The rain will go through a hydrological cycle which will partially evaporate again and some will become surface water runoff which will enter the river or be absorbed into the soil and become a groundwater recharge. The
availability of water is influenced by various factors including climatic factors, geology, geomorphology, hydrology, land cover, and land use [18]. The availability of water can be analyzed using the water balance. The water balance based in the form of water input and output at a location on a certain period which is used to determine the value of water surplus and water deficit [12].

Semarang Regency’s Rainfall is around 1000-2000 mm per year which can be used as an alternative for water availability [5]. Utilization of rainwater to fulfill water demand can be done by harvesting rainwater and used it for daily needs [24]. Utilization of rainwater is an effort to conserve water resources because the use of water through rainwater harvesting can reduce the exploitation of groundwater availability [21]. Harvesting rainwater is one of the things that can increase the availability of existing water [20].

The demand of water can be divided into various kind of usage such as agricultural, domestical, and industrial. The analyzed water demands are domestic water demand because the population level in Semarang Regency is high, around 1,053,786 people in 2019 [5]. The population of Semarang Regency is included in a metropolitan city, which has a population of more than 1 million people [19]. A high population with high water demand increases groundwater abatement and has the potential to reduce water availability in Semarang Regency. Knowing that, an analysis of water resources in Semarang Regency need research, in order to create a balance between water demand and water availability to be maintained and can be sustainable in the future.

2. Methods and materials

There are four steps of method to gain the results of this research. The first one is calculating the values of monthly rainfall, the second is calculating the water balance model, the third is calculating the water demand regarding to the water availability and the last one is calculating how much water can be obtained from rain harvesting.

2.1. Values of monthly rainfall

The daily rainfall data obtained from the BMKG and CHIRPS data was converted into monthly rainfall data from 1991 to 2020. The rainfall was then validated against the nearest BMKG monthly rainfall station, the Tanjung Mas Maritime Meteorological Station. The analysis of water availability is followed by frequency analysis with a probability of 80% of all rain data for each CHIRPS point. Statistical analysis used for validation is Pearson correlation as outlined by the following equations:

Pearson correlation

\[ r = \frac{\left( \sum_{i=1}^{n} (c_i - \bar{c})(o_i - \bar{o}) \right)}{\left( \sqrt{\sum_{i=1}^{n} (c_i - \bar{c})^2} \sqrt{\sum_{i=1}^{n} (o_i - \bar{o})^2} \right)} \]

\[ C_i = \text{CHIRPS monthly rainfall (mm)} \]
\[ O_i = \text{BMKG monthly rainfall (mm)} \]

2.2. Water balance model

The water balance calculation method used is the water balance method by F. J. Mock. This method assumes that some of the rain that falls will be lost as evapotranspiration, while the remaining part will directly become surface runoff and enter the soil. The calculation of the water balance using the F. J. Mock method is divided into three stages.
a. Actual evapotranspiration
The actual evapotranspiration was calculated from the Penman Evaporation Potential Method (ETo). The relationship between potential evaporation and actual evapotranspiration is calculated by the following formula:

\[ E_a = E_{To} - \Delta E \rightarrow (E_a = E_t) \]
\[ \Delta E = E_{To} \times (m/20) \times (18 - n) \rightarrow (E = \Delta E) \]

\[ E_a = \text{actual evapotranspiration (mm/day)} \]
\[ E_t = \text{limited evapotranspiration (mm/day)} \]
\[ M = \text{percentage of land that is not covered by plants by land use} \]

b. Water balance on the soil surface
Calculation of the amount of rainfall that reaches the ground can be calculated by the following equation:

\[ D_s = P - E_t \]
\[ D_s = \text{rainfall that reaches the ground (mm/day)} \]
\[ P = \text{rainfall (mm/day)} \]
\[ E_t = \text{limited evapotranspiration (mm/day)} \]

c. Runoff and storage of groundwater
Calculation of the storage of groundwater can be calculated by the following formula:

\[ V_n = k \cdot V_{n-1} + \frac{1}{2} \cdot (1 + k) \cdot I_n \]
\[ D V_n = V_n - V_{n-1} \]
\[ V_n = \text{groundwater volume of the n-month} \]
\[ V_{n-1} = \text{groundwater volume of the (n - 1) month} \]
\[ K = \frac{q_t}{q_o} = \text{groundwater flow recession factor} \]
\[ I_n = \text{infiltration of the n-month} \]
\[ D V_{n-1} = \text{groundwater flow volume change} \]

2.3. Water demand
The calculation of water demand in Semarang Regency is only focused on water demand for domestic purposes. The calculation of water demand for domestic purposes is based on the Indonesian National Standard (SNI) 6728.1: 2015 concerning the Preparation of the Spatial Balance of Natural Resources Part 1: Water Resources, and the formula for water demand by Triatmodjo (2010) in Cahyadi, et al (2015). The equation used is as follows:

\[ K_{Ad} = 365 \times ((q_u / 1000) \times P_d) \]
\[ K_{Ad} = \text{domestic water demand (m}^3/\text{year)} \]
\[ q_u = \text{average water consumption (liter/person/day)} \]
\[ P_d = \text{total population} \]

2.4. Rain harvesting
Rain harvesting using the roof is one of the efforts to take advantage of the availability of rainfall which can be implemented in Semarang Regency. The data used for this calculation consist of roof area based
on Inageoportal data, rainfall data, and runoff coefficient. The equation used to determine the amount of rainfall that can be harvested is:

\[
RWH = A \times P \times Cr
\]

- **RWH** = rain water harvesting (liter)
- **A** = roof area (dm²)
- **P** = average rainfall (dm/year)
- **Cr** = runoff coefficient (%)

### 3. Result and Discussion

#### 3.1. Semarang Regency Rainfall

The availability of water in an area can be determined from the input of water resources. One of these water sources is meteorological water, or what is known as rainfall. The calculation of rainfall in Semarang Regency begins with determining five grids of daily rain measurement sourced from CHIRPS data. The five grids used are determined based on the diversity of geographical conditions in the form of topography and land use. The five rainfall measurement points and the districts they represent can be seen in Table 3.1 below.

| Location | Coordinate X | Coordinate Y | Districts                                      |
|----------|--------------|--------------|------------------------------------------------|
| 1        | 430985       | 9212386      | Ungaran Barat, Ungaran Timur                   |
| 2        | 436513       | 9206865      | Bergas, Bawen, Bandungan, Sumowono             |
| 3        | 453080       | 9201356      | Bringin, Bancak, Pringapus                     |
| 4        | 453096       | 9184773      | Suruh, Tengaran, Susukan, Kaliwungu, Pabelan   |
| 5        | 436527       | 9195810      | Ambarawa, Jambu, Banyubiru, Tuntang, Getasan  |

(Source: CHIRPS grid data processing results, 2021)

The CHIRPS daily data used based on these measurement points has a total of 30 years, as the minimum data length to determine normal rainfall in an area [17]. The CHIRPS daily data is then converted into monthly rainfall data for 30 years, for later validation and frequency analysis with a probability of 80%. Rainfall data validation was carried out by calculating the correlation values (r) from monthly rainfall data from 1991 to 2020 at the five CHIRPS grids and the BMKG using the Pearson correlation method. Monthly rainfall data correlation value chirps with BMKG shows the value of R² of 0.5382. This shows that the monthly rainfall data patterns contained in the two data tend to be the same, thus showing a fairly good R²-value. The results of the calculation of rainfall data validation can be seen in Figure 3.1 below.
Figure 3.1. CHIRPS and BMKG monthly rainfall correlation graph

Frequency analysis was carried out using monthly rainfall data for each CHIRPS point in the range from 1991 to 2020. The calculation method of frequency analysis consisted of four distributions, namely Normal distributions, Log-Normal, Gumbel, and Log Pearson III. The determination of rainfall is then continued by selecting the best distribution so that the statistical estimate for determining the frequency at 80% probability can be minimized [13]. The amount of rainfall calculated from the frequency analysis is presented in Table 3.2.

Table 3.2. Monthly rainfall in Semarang Regency

| Loc. | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sept | Oct  | Nov  | Dec  |
|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1    | 318.195 | 350.062 | 332.910 | 218.889 | 100.083 | 42.336 | 22.663 | 20.392 | 28.269 | 80.090 | 236.753 | 322.892 |
| 2    | 301.399 | 312.852 | 295.183 | 223.283 | 87.471 | 40.187 | 18.235 | 20.427 | 25.724 | 70.252 | 242.957 | 321.776 |
| 3    | 278.467 | 292.115 | 275.025 | 189.559 | 85.560 | 37.221 | 17.703 | 16.151 | 29.485 | 77.316 | 248.396 | 298.821 |
| 4    | 286.478 | 309.601 | 305.927 | 216.811 | 98.920 | 37.543 | 19.197 | 19.581 | 27.300 | 73.006 | 241.612 | 316.246 |
| 5    | 290.667 | 318.379 | 319.050 | 207.751 | 93.860 | 38.466 | 21.534 | 15.511 | 34.214 | 59.323 | 228.786 | 302.176 |

(Source: CHIRPS monthly rainfall data analysis 1991-2020, 2021)

Spatial analysis of the amount of monthly rainfall for each point from the results of the frequency analysis is poured into the form of an isohyet map. The isohyet map is made using IDW interpolation because it has a relatively lower error value compared to other interpolations. The isohyet map of monthly rainfall in Semarang Regency can be seen in Figure 3.2 and Figure 3.3., which shown that the highest rainfall in Semarang Regency occurs from November to April, while the lowest rainfall occurs in June to September. Points 1, 2, and 5 have relatively more rainfall compared to points 3 and 4. This is caused by the location of points 1, 2, and 5 which are located around the plains at the foothills of the mountains, so that orographic rain often occurs due to rising water vapor and moist air to mountainous areas, especially Mount Ungaran in Semarang Regency [15].
Figure 3.2. Monthly rainfall map of Semarang Regency (January - June)
3.2. Water Balance

The water balance is a calculation of the amount of input (inflow) and output (outflow) in a review of a certain time in a hydrological sub-system [9]. There are several models for calculating the water balance, one of them is the F.J. Mock water balance method. The analysis of the water balance in Semarang Regency is not only calculated based on regional rainfall, but also on the spatial conditions of the water balance parameters from 5 different areas to represent the conditions of each district in Semarang Regency as shown in Table 3.3. The water balance graphs for each area are described in Figure 3.4.
Figure 3.4. Water Balance in Semarang Regency by Area

Table 3.3. Mock’s Water Balance in Semarang Regency by Area

| Parameter         | Location | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sep  | Oct  | Nov | Dec |
|-------------------|----------|------|------|------|------|------|------|------|------|------|------|-----|-----|
| **Rainfall**       | Area 1   | 318.2 | 350.1 | 332.9 | 218.9 | 100.1 | 42.3 | 22.7 | 20.4 | 28.3 | 80.1 | 236.8 | 322.9 |
|                   | Area 2   | 301.4 | 312.9 | 295.2 | 223.3 | 87.5  | 40.2 | 18.2 | 20.4 | 25.7 | 70.3 | 243.0 | 321.8 |
|                   | Area 3   | 287.5 | 292.1 | 275.0 | 189.6 | 85.6  | 37.2 | 17.7 | 16.2 | 29.5 | 77.3 | 248.4 | 298.8 |
|                   | Area 4   | 286.5 | 309.6 | 305.9 | 216.8 | 98.9  | 37.5 | 19.2 | 19.6 | 27.3 | 73.0 | 241.6 | 316.3 |
|                   | Area 5   | 290.7 | 318.4 | 319.1 | 207.8 | 93.9  | 38.5 | 21.5 | 15.5 | 34.2 | 59.3 | 228.8 | 302.2 |
| **Potential**      | Area 1   | 114.7 | 102.2 | 119.0 | 117.9 | 125.2 | 115.5 | 130.5 | 153.8 | 148.8 | 144.2 | 128.7 | 110.4 |
|                   | Area 2   | 115.3 | 102.8 | 119.7 | 118.2 | 125.9 | 116.1 | 131.1 | 154.4 | 149.4 | 144.8 | 129.0 | 111.0 |
|                   | Area 3   | 121.5 | 108.4 | 125.9 | 124.8 | 133.3 | 123.0 | 139.2 | 163.4 | 158.1 | 152.5 | 135.9 | 116.6 |
|                   | Area 4   | 115.9 | 103.3 | 120.3 | 119.1 | 126.8 | 116.7 | 132.1 | 155.3 | 150.3 | 145.4 | 129.9 | 111.6 |
|                   | Area 5   | 114.1 | 101.6 | 118.4 | 117.0 | 124.6 | 114.6 | 129.6 | 152.8 | 147.9 | 143.2 | 127.8 | 109.7 |
| **Groundwater**    | Area 1   | 116.8 | 79.9  | 69.0  | 17.9  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 35.1  | 86.1 |
|                   | Area 2   | 112.6 | 68.2  | 55.9  | 20.0  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 39.1  | 88.4 |
|                   | Area 3   | 100.0 | 62.4  | 49.6  | 10.1  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 43.3  | 82.9 |
|                   | Area 4   | 106.3 | 66.6  | 59.9  | 19.7  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 38.3  | 86.2 |
|                   | Area 5   | 105.1 | 72.4  | 66.3  | 18.4  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 33.4  | 81.1 |
| **Surplus**        | Area 1   | 86.7  | 168.0 | 144.9 | 83.1  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 72.9  | 126.4 |
|                   | Area 2   | 73.5  | 141.9 | 119.6 | 85.1  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 74.8  | 122.4 |
|                   | Area 3   | 57.0  | 121.3 | 99.5  | 54.7  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 69.2  | 99.3 |
|                   | Area 4   | 64.3  | 139.7 | 125.8 | 78.0  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 73.4  | 118.5 |
|                   | Area 5   | 71.5  | 144.3 | 134.3 | 72.4  | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 67.6  | 111.4 |
| **Deficit**        | Area 1   | 0.0   | 0.0   | 0.0   | 0.0   | 8.2   | 49.1  | 76.1  | 94.1  | 87.2  | 48.7  | 0.0   | 0.0  |
a. Evapotranspiration
The calculation of evapotranspiration in Semarang Regency was carried out with the help of CROPWAT 8.0 software. CROPWAT is a software developed by FAO (Food and Agriculture Organization) to estimate evapotranspiration using the Penman-Monteith method. Input data used to calculate potential evapotranspiration are temperature, wind speed, humidity, and sunshine duration [7]. Calculation of evapotranspiration at each station uses the assumption that air humidity, solar radiation duration, and wind speed have the same value, so the data used is the temperature at each station area. In addition, the calculation of evapotranspiration using CROPWAT software also considers the elevation of the station area. Table 3.3 shows that area 3 has the highest amount of evapotranspiration of 1602.48 mm, while area 5 has the lowest of 1501.43 mm. Area 3 has the highest temperature compared to other station areas, considering that area 3 has the lowest elevation.

b. Groundwater Storage
Groundwater storage is the amount or volume of groundwater in the aquifer affected by groundwater flow recession factors [1]. The groundwater recession factor is affected by the geological characteristics of a watershed [1] and topographical conditions. The groundwater recession factor (k) is 0 – 1.0, which a high value of k will give a slow recession as in the geological conditions of the very permeable subsoil [16]. This study uses a groundwater recession factor of 0.6. This value is chosen based on previous research that used a recession factor of 0.7 for the Mock water balance study in the Krengseng watershed whose a flatter topography and a more porous layer [22]. In addition, the value of 0.6 is also a recession factor that is used in mountainous topography [8]. The amount of groundwater storage obtained in Semarang Regency is shown in Table 3.3. The highest groundwater storage is occurred in January, while in the months with deficit occurs there is no groundwater storage, specifically from May to October.

West Ungaran and East Ungaran districts have an average groundwater storage value of 116.79 mm in January. As a recharge area, these districts have big potential in storing groundwater. Meanwhile, the Bergas, Bawen, Bandungan, and Sumowono districts have the highest groundwater reservoir of 112.6 mm in the same month. Bringin, Bancak, and Pringapus districts have the highest mean groundwater storage of 99.97 mm. The Suruh, Tengaran, Susukan, Kaliwungu, and Pabelan districts have the highest storage value in January of 106.28 mm. This condition is not much different from the Ambarawa, Jambu, Banyubiru, Tuntang, and Getasan districts whose highest groundwater storage is 105.14 in the same month. The amount of groundwater storage in each district is affected by the presence of different hydrogeological conditions.

c. Surplus dan Deficit
The surplus and deficit conditions were analysed by the presence of the runoff from Mock’s water balance method. The highest runoff in West Ungaran and East Ungaran districts was in February of 168 mm. Meanwhile, in the Bergas, Bawen, Bandungan, and Sumowono districts, the highest value was 141.86 mm. West Ungaran and East Ungaran districts have the highest runoff values because they are
affected by high rainfall and topography. Semarang regency also has deficit period instead of the excess water condition. Table 3.3 shows that area 3 which includes Bringin, Bancak, and Pringapus Districts has the highest deficit during the dry months. These areas experienced the highest deficit due to the small rainfall and regional landuse condition. Furthermore, management with some techniques are required such as rainwater harvesting to support water availability during the dry months.

3.3. Water Availability
Water availability in Semarang Regency is quite large based on the calculation using five water balances and interpolation of the runoff. The five water balance points were selected by spatial variations of land use and topography. The water availability value obtained can approach the results in the field. Based on the five water balances, the water availability is obtained by multiplying the amount of runoff by the area of Semarang Regency and districts in Semarang Regency. The value of runoff in Semarang Regency can be seen in Table 3.4 below.

Table 3.4. Runoff in Semarang Regency

| Loc. | Run Off (mm) |
|------|-------------|
|      | Jan | Feb | Mar | Apr | Mei | Jun | Jul | Aug | Sep | Okt | Nov | Dec |
| 1    | 86.70| 168.00| 144.87| 83.06| 0.00| 0.00| 0.00| 0.00| 0.00| 72.91| 126.41 |
| 2    | 73.48| 141.86| 119.60| 85.08| 0.00| 0.00| 0.00| 0.00| 0.00| 74.83| 122.38 |
| 3    | 56.98| 121.32| 99.54| 54.70| 0.00| 0.00| 0.00| 0.00| 0.00| 69.18| 99.35  |
| 4    | 64.26| 139.69| 125.78| 77.99| 0.00| 0.00| 0.00| 0.00| 0.00| 73.41| 118.47 |
| 5    | 71.45| 144.35| 134.30| 72.37| 0.00| 0.00| 0.00| 0.00| 0.00| 67.62| 111.39 |

The monthly water availability of Semarang Regency can be seen in Figure 3.5. Based on the figure, the water is available from November to April in Semarang Regency. From May to October, the water availability is 0 due to the lower rainfall compared to the higher evapotranspiration. The lower rainfall value compared to evapotranspiration results in a water deficit. The highest water availability in Semarang Regency is 141,555,448.85 m3 in February. High water availability is due to the high runoff value, they are at point 1 of 168 mm, at point 2 of 141.86 mm, at point 3 of 121.32, at point 4 of 139.69 mm, and point 5 of 144.35 mm.

Figure 3.5. Monthly Water Availability in Semarang Regency

Semarang Regency is divided into 19 districts. The calculation of water availability by district used the interpolated value of the five water balances in Figure 3.6. Based on the figure, the highest runoff is in
the northern area, around the West Ungaran, East Ungaran, Bergas, and Suwono, and Bandungan districts. The amount of runoff in these five districts is about 613-681 mm/year which is higher than other districts in Semarang Regency. The districts that have the lowest runoff are in Bringin and Bancak districts due to the lower rainfall than other areas in Semarang Regency. In addition, the hydrogeological condition in the eastern area of Semarang Regency has a low productivity aquifer and a scarce groundwater flow area. This is affected by the ecoregion in the east of Semarang Regency consists of a folded structural hill with geological conditions in the form of limestone and marl. It is also affected by the aquifer gap or nesting [6].

Water availability per district in Semarang Regency is available in Figure 3.7 below. Based on the figure, the highest annual water availability is in the Pringapus district, while the lowest is in the Ambarawa district. The annual water availability value in Pringapus district is 48,559,764.55 m³/year, while the annual water availability in the Kaliwungu district is 17,352,024.13 m³/year. The Pringapus district has the highest annual water availability and the Kaliwungu district has the lowest annual water availability due to the area size difference. Pringapus is the largest district (80.986 km²), while Kaliwungu is the smallest district in Semarang (28.939 km²).
3.4. Water Demand

Domestic water demand in Semarang Regency is the total consumption of water demand each year for household purposes such as bathing, washing, and cooking in Semarang Regency. Domestic water demand in Semarang Regency is obtained by calculating the number of residents in each district, and multiplied by the average water consumption per district. The average amount of water consumed by residents of Semarang Regency for household purposes is 100 liters/day following the IKK standard system [4]. This domestic water demand is calculated based on each district in Semarang Regency which can be seen in Table 3.5 below.

Table 3.5. Annual Domestic Water Demand for Each District in Semarang Regency

| District     | Total Population (people) | Water Demand (m³/year) |
|--------------|----------------------------|------------------------|
| Getasan      | 52932                      | 1,932,018.00           |
| Tengaran     | 71966                      | 2,889,434.90           |
| Susukan      | 49545                      | 1,808,392.50           |
| Kaliwungu    | 30311                      | 1,106,351.50           |
| Suruh        | 70088                      | 2,814,033.20           |
| Pabelan      | 44457                      | 1,622,680.50           |
| Tuntang      | 68700                      | 2,758,305.00           |
| Banyubiru    | 44294                      | 1,616,731.00           |
| Jambu        | 40642                      | 1,483,433.00           |
| Sunomowono   | 33967                      | 1,239,795.50           |
| Ambarawa     | 63753                      | 2,559,682.95           |
| Bandungan    | 58799                      | 2,146,163.50           |
| Bawen        | 59675                      | 2,178,137.50           |
| Bringin      | 46441                      | 1,695,096.50           |
| Bancak       | 23888                      | 784,720.80             |
| Pringapus    | 56885                      | 2,076,302.50           |
| Bergas       | 75910                      | 3,047,786.50           |
| Ungaran Barat| 81074                     | 3,255,121.10           |
| Ungaran Timur| 79767                     | 3,202,645.05           |

Based on the calculation of the table above, it can be seen that the highest demand for domestic water demand is in West Ungaran district and followed by East Ungaran district and Bergas district. This could be due to the large population in the three districts. Meanwhile, the least amount of water demand was found in Bancak district and followed by Kaliwungu district. The size of the water demand is influenced...
by the population density in the area. The total high and low total domestic water demand for each district in Semarang Regency can be seen in Figure 3.8 below.

![Figure 3.8. Graph of Domestic Water Demand in Semarang Regency](image)

3.5. Comparison of Water Demand and Water Availability

Overall, water consumption in each year, total water use with water availability in Semarang Regency, in all districts is included in the very safe category at 80% probability, because there is no water deficit. If seen through the graphic above, the contribution of water demand and water availability of Semarang Regency for each district can be described as shown in Figure 3.9 below.

![Figure 3.9. Comparison of Total Water Demand and Water Availability in Semarang Regency by District](image)

The graphic of the comparison of water demand and water availability above, directly shows that the water demand of Semarang Regency are smaller than the water availability in each year. When seen in the graphic above, even with the lowest water availability condition in Kaliwungu district, this value far exceeds the amount of water demand which has a smaller value. If further analyzed the highest total amount of water availability is in Pringapus district, where this shows that there is a dynamic difference between water demand and availability, because the highest amount of water demand is in West Ungaran district. However, this can be caused by the area and the total population density in the related area which affects the water conditions in the area.
3.6. Rain Water Harvesting
Conservation of water resources means an effort to save and reuse water to avoid the negative impact of changes in water availability [11]. One of the efforts to conserve water resources is rainwater harvesting. The rainwater harvesting technique is a way to collect rainwater that can be utilized to supply water demand when rainfall is low [25]. Rainwater harvesting is divided into two methods [2]. First, rainwater harvesting with a roof (rooftop rainwater harvesting method) and the second method is rainwater harvesting through the ground surface (land surface catchment areas method).
Semarang regency has soil characteristics dominated by clay that has a low level of permeability, is a cohesive, high capillary rise, and has high levels of shrinkage [26]. Therefore, the method of rainwater harvesting that is considered suitable to be applied in Semarang Regency is rainwater harvesting with a roof, which then streamed and stored in a rainwater reservoir. The calculation of rainwater harvesting is by assuming the type of roof tile made of clay and considered to have good conditions, so that the coefficient of roof runoff used 0.31 [14]. The potential amount of rainwater volume that can be harvested for one year in Semarang Regency then compared with the domestic water demand to find out the quantity of rainwater as a fulfillment of domestic water demand are presented in Figure 3.10 below.

Figure 3.10. Comparison of Rainwater Harvested Volume with Domestic Water Demand of Each District in Semarang Regency

Based on the graph, it can be known that the volume of rainwater harvesting shows a higher graph compared to domestic water demand in all districts, so that rainwater harvesting can supply domestic water demand and can still be utilized for another demand. The use of rainwater as one of the alternative sources of water for domestic demand needs to be optimized because is very potential to be applied in Indonesia considering that Indonesia is a tropical country that has a high rainfall [21]. Rainwater harvesting can serve as a clean water supply, reduce water use for daily activities, especially domestic activities from other sources such as PDAM and groundwater, reduce surface runoff that has the potential to cause flooding, save water use costs, low operational costs and protect the availability of water as an effort to mitigate water problems [21].

4. Conclusion
1. The result of the F.J. Mock water balance method shows the water is available from November to April. From May to October, the water availability is 0 due to the lower rainfall compared to the higher evapotranspiration. The highest annual water availability is in the Pringapus district, while the
lowest is in the Kaliwungu district. The annual water availability value in Pringapus district is 48,559,764.55 m³/year, while the annual water availability in the Kaliwungu district is 17,352,024.13 m³/year.

2. The highest domestic water demand are in West Ungaran district, East Ungaran district, and Bergas district, due to the high populations. The lowest water demand are in Bancak and Kaliwungu district. One alternative to fulfill domestic water demand is by harvesting rainwater. Based on the calculation, the largest rainwater harvested volume in Semarang Regency is in Tengaran district about 9,218,421 m³/year, while the lowest volume is in Bancak district. The total volume of rainwater harvested is 116,829,175 m³/year. Compared to the total domestic water demand for one year in all district, it can be concluded that the volume of rainwater harvested in one year can fulfill domestic water demand in Semarang Regency.

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