FJ.Mock Method for Hydrological model in Water Reliability Study at Jatiluhur Estate, Purwakarta

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Abstract. Jatiluhur Estate is an area located in Purwakarta Regency and was developed for residential, industrial, and commercial areas. Therefore, it is important to determine the availability of water that will meet water needs, and to evaluate the water reliability in future. This study aimed to model the river discharge in determination of water availability of Jatiluhur Estate. The methods used in this study include observational discharge data, evapotranspiration, rainfall, and area of flow. To analyze the availability of water, F.J. Mock method was used, where the F.J. Mock method can show water balance analysis for monthly discharge. The results showed that the availability of water with mainstay discharge Q80% and Q90% met the water needs of the Jatiluhur Estate or showed a surplus condition for 30 years (2020-2050).

1. Introduction
Water resources are very important for life and the needs of water is very large for humans [1] Water resources are needed to meet several sectors such as water needs for domestic and urban, industrial, agricultural, fisheries, and livestock. Therefore, water is a vital resource for life [2]. The earth surface is covered by 80% of water. The water on earth consist of 96% sea water and 2.5% freshwater. In addition, ice at the poles makes up about 68.7% and the rest is groundwater about 31%. From total amount of water on earth, human only needs 0.8% [3]. The development of an area will cause an increase in water needs along with population growth. In general, problems that occur are due to unbalanced water availability and water needs. [4]. Based on the hydrological cycle, the volume of water in the world has a fixed amount. However, if the management of water resources is not carried out properly, there will be a water crisis or drought. Therefore, water resources must be managed properly so that the availability of water can be sufficient. Well-managed water resources can ensure the availability and sustainability of water in water source [5,6,7].

Jatiluhur Estate is a new area located in Purwakarta Regency, West Java which was built for residential, industrial, and commercial areas with an area of ± 1800 hectares. The water source used for the Jatiluhur Estate is obtained from the nearest water source of the Citarum Rivers. Therefore, an analysis of the water availability and water need should be determined to ensure the reliability of water in future.

F.J. Mock method is one of the methods used to show the water balance analysis of monthly discharge calculations based on monthly rainfall data, evapotranspiration, soil moisture, and groundwater. F.J. Mock method has a principle which states that the rain that falls on the catchment area will partly disappear due to evapotranspiration, some will become direct runoff, and some will enter the ground [8]. F.J. Mock method shows a relatively simple calculation method for various components based on the results of research on watersheds throughout Indonesia [9], hence, it was applied in this study. The objective of this study is to analyze the water availability, water needs, and reliability of Jatiluhur Regency Industrial Estate using FJ.Mock method.
2. Research Methodology

2.1. Study Area
Jatiluhur Estate is located in Babakancikao District, Purwakarta Regency, West Java. Jatiluhur Estate area stretches between 6°29'48.33" South Latitude and 107°25'09.47" East Longitude.

2.2. Data Collection and Methods
The data collected were rainfall data, observation river discharge data, actual evapotranspiration data, and population data. The Methodology of this study (Figure 1) consist of several steps such as, establishment of the FJ.Mock model, calibration of model based on objective function; and analyse water reliability using the water demand and water supply calculation result.

![Figure 1. Research Methodology, modified from [10]](image-url)
2.3. F.J.Mock Model
The hydrological model of F.J.Mock calculate rainfall and actual evapotranspiration data of the river basin. Calibration was carried out to compare the model discharge and observation discharge. At the calibration step, an assessment is carried out using correlation coefficient, Nash-Sutcliffe Efficiency (NSE), and Relative Volume Error (RVE). The water discharge result then utilized for water reliability analysis.

3. Result and Discussion
3.1. Water Availability Analysis
The data that will be used to F.J. Mock modelling is observation discharge data, rainfall data, evapotranspiration data, and area of flow data. Observation discharge data used are data from 2003-2006, while for rainfall data and evapotranspiration data are data from 2003-2015. The flow area data used has an area of 492.95 km². Table 1 illustrates a summary of the results of the discharge calculation using F.J. Mock method. F.J. Mock modelling calibration carried out when analyzing water availability. Table 2 shows the results of the F.J. Mock modelling calibration. The dependable flow used are Q80 and Q90. The dependable flow Q80 and Q90 are used because discharge with high probability is needed to meet water needs such as domestic, industrial, and commercial. The dependable flow analysis is determined using the Weibull method. Tabel 3 and 4 show the results of the Q80 and Q90 dependable flow calculation for average all years value from 2003 to 2015, and averaged monthly value (e.g.averaged value of January from 2003 – 2015).

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2003 | 3.36| 20.22| 14.30| 3.33| 8.10| 0.79| 0.72| 0.72| 3.69| 24.69| 4.19| 7.10|
| 2004 | 19.48| 42.46| 21.61| 9.33| 3.95| 4.31| 2.52| 2.06| 2.40| 2.68| 22.53| 17.81|
| 2005 | 29.06| 20.39| 30.66| 17.64| 6.80| 10.82| 5.65| 4.66| 4.43| 11.38| 22.79| 37.01|
| 2006 | 45.30| 35.57| 10.74| 24.00| 6.55| 5.49| 6.89| 4.85| 4.96| 6.73| 7.07| 41.63|
| 2007 | 8.95| 33.06| 22.19| 25.03| 12.95| 14.69| 5.98| 7.10| 7.22| 29.44| 31.41| 21.58|
| 2008 | 24.01| 18.52| 41.33| 22.45| 9.18| 7.89| 6.86| 8.17| 8.33| 8.48| 27.10| 18.42|
| 2009 | 40.16| 22.94| 12.40| 11.63| 8.97| 9.67| 7.15| 7.08| 9.31| 10.25| 16.91| 9.65|
| 2010 | 16.09| 40.95| 35.67| 10.20| 30.80| 15.61| 10.46| 17.44| 19.08| 22.63| 31.39| 22.81|
| 2011 | 9.96| 14.69| 10.65| 21.18| 10.17| 14.01| 8.71| 7.98| 8.46| 9.53| 31.28| 17.41|
| 2012 | 9.13| 16.63| 13.82| 22.52| 9.40| 10.52| 8.83| 8.38| 8.07| 8.76| 23.44| 18.43|
| 2013 | 43.15| 28.67| 27.00| 27.02| 8.63| 11.04| 11.59| 8.68| 8.82| 10.26| 19.08| 22.40|
| 2014 | 40.99| 22.28| 26.44| 19.72| 16.27| 20.24| 12.73| 9.12| 9.04| 9.85| 11.78| 20.30|
| 2015 | 13.00| 16.93| 16.37| 17.38| 9.77| 8.96| 9.37| 8.33| 8.57| 8.82| 12.71| 14.77|

| Objective function | Calibration Result | Interpretation |
|--------------------|--------------------|----------------|
| Correlation Coefficient | 0.75252 | Strong |
| NSE | 0.56434 | Satisfactory |
| RVE | 0.00593 | Good |

| Q | Discharge |
|---|-----------|
| 80% | 7.91 |
| 90% | 4.91 |
### Table 4. Monthly dependable Flow of Q80 and Q90 (m$^3$/s)

| Month   | Q80 | Q90 |
|---------|-----|-----|
| January | 9.63| 9   |
| February| 17.88| 16.72|
| March   | 13.25| 11.23|
| April   | 11.06| 9.59 |
| May     | 7.58 | 6.62 |
| June    | 6.93 | 4.67 |
| July    | 5.85 | 3.46 |
| August  | 4.77 | 2.84 |
| September | 4.75 | 3.91 |
| October | 8.65 | 7.26 |
| November| 12.34| 8.48 |
| December| 16.36| 11.19|

### 3.2. Population Projection Analysis

In the population projection analysis, the data used is population data of Babakancikao District, Purwakarta Regency. The population data from 2011 to 2020 was utilized to determine the population growth rate in Jatiluhur Estate. The results of the calculation of population growth rate was 2.24%. The correlation coefficient of Geometric, arithmetic and exponential methods were calculated and compared in order to determine the population projection method. All three methods had high correlation value, however arithmetic gave the highest correlation value. Therefore, the arithmetic method utilized to calculate population projection in 5, 10, 20 and 30 years (2025, 2030, 2040, and 2050, respectively), using the population growth rate of 2.24% (Table 5).

### Table 5. Result of Population Projection

| Year No. | Population (Person) | Total Projection |
|----------|---------------------|------------------|
| 0        | 270840              | 270840           |
| 1        | 276907              | 276907           |
| 5        | 301174              | 301174           |
| 10       | 331508              | 331508           |
| 20       | 392176              | 392176           |
| 30       | 452844              | 452844           |

### 3.3. Water Needs Analysis

The water needs analysis that calculated are domestic, industrial, and commercial water needs. The standard of water needs for domestic and industrial were 110 L/person/day and 0.448 L/s/ha, respectively [3], while the population used is the population of population projection analysis. In addition, the amount of water loss due to leakage in distribution system or other causes was assumed to be 20% of the water needs. The calculation result of domestic and industrial water needs which presented in Table 6 and 7, respectively.

### Table 6. Domestic Water Needs

| Year | Population (Person) | Water Needs (L/s) |
|------|---------------------|-------------------|
| 2020 | 270840              | 344.82            |
| 2021 | 276907              | 352.54            |
| 2025 | 301174              | 383.44            |
| 2030 | 331508              | 422.06            |
| 2040 | 392176              | 499.30            |
| 2050 | 452844              | 576.54            |
3.4. Water Reliability Analysis

Water reliability analysis is a comparison of water availability and water needs which serves to determine whether the water availability is sufficient for water needs.

Table 7. Industrial Water Needs

| Phase | Land Area  | Water Needs |
|-------|------------|-------------|
|       | (Hectare)  | (L/s)       |
| I     | 145.5245   | 65.19       |
| II    | 234.4612   | 105.04      |
| III   | 206.8674   | 92.68       |
| Total |            | **262.91**  |

Figure 2. Water Availability and Water Needs in year 2020-2050

Figure 3. Water Availability and Water Needs Monthly in year 2020
Figure 2 shows the water availability with dependable flow Q80 and Q90 fulfills water needs from 2020-2050. Q80 of water availability is 7.91 m$^3$/s and existing total water demand is 4.91 m$^3$/s. It shows that water source can meet the total demand from year 2020 up to 2050. However, there is a wide range of river discharge fluctuation between dry and rainy season. Therefore, the seasonal water availability should taken into consideration in the management of water supply and demand in the next 20 years (Figure 3). Beside water reliability with dependable flow Q80 and Q90 (overall), there is an analysis of water reliability with dependable flow Q80 and Q90 monthly. Where Q80 and Q90 monthly fulfills the water needs of Jatiluhur Estate from 2020-2050.

4. Conclusion

The following are the conclusions of the research:

a. Based on the calculations that have been carried out, the results of water availability with dependable flow Q80% is 7.91 m$^3$/s, while the availability of water with dependable flow Q90% is 4.91 m$^3$/s.

b. Based on the calculations that have been carried out, the results of water needs of domestic, industrial, and commercial for Jatiluhur Estate from 2020-2050 are obtained, namely: 2020 = 0.853 m$^3$/s; 2021 = 0.865 m$^3$/s; 2025 = 0.914 m$^3$/s; 2030 = 0.974 m$^3$/s; 2040 = 1.094 m$^3$/s; 2050 = 1.215 m$^3$/s.

c. Based on the calculations that have been made, the results of the water reliability analysis (overall) for Jatiluhur Estate are that the Q80% and Q90% discharges meet the water needs from 2020-2050.

d. Based on the calculations that have been made, the results of the water reliability analysis (monthly) for Jatiluhur Estate are that the Q80% and Q90% monthly discharges meet the water needs from 2020-2050.

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