A discharge estimation model using a spatial correlation method in Cipanunjang-Cileunca Reservoir, Bandung District, West Java Province

Mariana Marselina* and Arwin Sabar

* Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia

Abstract. Cipanunjang-Cileunca reservoir is one of the raw water sources for the Drinking Water Supply System of Bandung City and Bandung District. The total raw water need for both area is 1.66 m$^3$/s. It is known that discharge data estimation is essential for the successful management of the reservoir. This study estimate the future discharge of the Cipanunjang-Cileunca Reservoir using a spatial correlation method, also known as the continuous method. Before the discharge was estimated, the mainstay discharge was first calculated in each reservoir. We found that the mainstay discharge for the raw water in Cipanunjang Reservoir was 0.86 m$^3$/s, while in Cileunca Reservoir was 0.34 m$^3$/s. This study also calculated the sufficient reservoir volume using discharge data from 2000 to 2017, and found that there was a decrease of reservoir volume: from 22 million m$^3$ to 18.7 million m$^3$ at Cipanunjang Reservoir, and from 11 million m$^3$ to 9.5 million m$^3$ at Cileunca Reservoir. Discharge estimation using a continuous method showed a correlation between historic discharges, which was 0.87 for Cipanunjang Reservoir and 0.83 for Cileunca Reservoir. This shows that the discharge estimation model using a continuous method, which had a value close to 1, could estimate future discharge.

1. Introduction

Water resources can be updated through the hydrology cycle and affected by weather, forming a hydrology regime where the components are random and stochastic. The most essential component in water resource management is rainfall, which is the sole input of Drainage Basin (DAS), which has the characteristics of being random and tends to be stochastic [1,2]. The hydrology component, which is directly related to mainstay raw water, is the discharge in which its amount depends on the rainfall and land cover in DAS. The company for raw water supply for the downstream sector, such as Hydroelectric Power Plant (PLTA), irrigation, and Drinking Water Supply Water (SPAM), can be performed by identifying the characteristics of the discharge; one of the methods is the continuous model.

Utari [3] investigated the comparison of discharge model in DAS of Cikapundung and found that the continuous model gave the best correlation value and relatively smaller error with historic discharge value since the continuous model calculated rainfall and discharge value (P, Q) in the previous period to predict the discharge in the future. Cipanunjang-Cileunca reservoir used a discrete Markov method to develop its correlation value to approach 1, which means that the discharge
estimation, when done conceptually, approaches the real condition (actual/historic discharge) [4]. The SPAM of Bandung City and District of West Java Province is sourced from Cikalong Intake from the Cipanunjang-Cileunca Reservoir series. There are three hydroelectric power plants between the intake and reservoir: Plengan, Lamajan, and Cikalong. Those three PLTA also supply electricity to the Bandung community. This becomes problematic since both raw water and electricity are essential needs for daily life. At the Cipanunjang and Cileunca Reservoir series, water is often wasted through the spillway during the raining season, while there is a lack of water supply during the dry season. The performance of PLTA Plengan-Lamajan-Cikalong and SPAM of Bandung City and District is disrupted. Due to limited source (reservoir series) and downstream need (electricity and drinking water) that must be fulfilled, the optimum reservoir operational pattern must be designed so that the need can be fulfilled at any time of the year.

This research focuses on estimating future input discharge to assist reservoir managers in planning a reservoir guideline pathway and achieving optimal reservoir management. Basically, the popular methods for estimating input discharge are the FJ Mock and NRECA methods [5,6,7]. Therefore, in this research, discharge forecasting is carried out by applying a regression model of the rainfall and discharge relationships in a river basin (Spatial Correlation Model).

2. Method
Cipanunjang-Cileunca reservoirs series are administratively located in Warnasari Village, Pengalengan Sub-District, West Java Province. The water source for both of these reservoirs is the Cilaki River, which is included in Cisangkuy and Citarum DAS (Figure 1). This research consisted of two main sections: completing the empty data using the spatial correlation method; and developing discharge using a continuous method. The required hydrology components were daily or monthly data of rainfall and discharged from 1997 to 2017. Rainfall data were taken from six rain observation points, of which four of them are in Cisangkuy DAS, while the other two are outside DAS. Discharge data for the Cipanunjang-Cileunca Reservoirs system were owned by PLTA Plengan as the reservoir management.

![Figure 1. Research location map.](image)
2.1. Completing the empty data
Rainfall (P) and discharge (Q) data sometimes experience emptiness due to various factors, such as the absence of an observer, problematic measurement tool, or the loss of the record. Celleri [8] stated that missing data could be filled through simple linear regression and multiple linear regression. The rainfall data was developed by considering the relationships between rainfall observer stations (P-P). The station with the most significant correlation value was chosen to fulfill the data using simple linear regression. The relationship between rain observer stations can be seen in Table 1. The historic input discharge data is the calculation result of the reservoir mass balance method. Discharge value during t is the difference between reservoir volume at time t+1 and t added by discharge output at t. Historic input discharge data was equipped by considering the relationship between the rain observer station and discharge observer station (P-Q). Multiple linear regression was applied in which the Q value at t is built using the Q value at t-1 and P value at t.

| Value | P₁ | P₂ | P₃ | P₄ | Pₙ |
|-------|----|----|----|----|----|
| P₁    | 1  |    |    |    | ρ₁n|
| P₂    | ρ₂₁| 1  |    |    | ρ₂n|
| P₃    | ρ₃₁| ρ₃₂| 1  |    | ρ₃n|
| P₄    | ρ₄₁| ρ₄₂| ρ₄₃| 1  | ρ₄n|
| …     | …  | …  | …  | …  | …  |
| Pₘ    | ρₘ₁| ρₘ₂| ρₘ₃| ρₘ₄| ρₘₙ|

2.2. Calendar Correction
The number of day for each month in each year is different, so that calendar correction needed to be performed. The amount of correction factor (fk) is as follows:

\[
\text{Monthly rain data } f_k = \frac{30.4157}{\text{number of days in a month}}
\]

2.3. Determination of mainstay discharge and year estimation
The reliability of data can be calculated using the Weibull reliability formula. This formula showed a higher probability value (after being sorted from the highest to the lowest) of the incident compared to the value [9].

Weibull Probability Formula:

\[
P(X \geq x) = \frac{m_x}{n + 1}
\]

In which P(X ≥ x) = incident probability value of all incidents (X), which is higher or the same as data x; mₓ = ranking data x, after being sorted from the highest to the lowest; n = number of total data.
The average discharge was then calculated, obtaining the value of average dischargeable to meet the downstream water need, referred to as the mainstay discharge.

2.4. The model of future discharge estimation through spatial correlation of rainfall-discharge (continuous)

Uncertainty of the hydrology system makes the present inflow parameter to be determined by using several estimation methods [9]. Model of discharge estimation through spatial correlation can be done by correlating between Rain (P) and discharge (Q) or between discharges, with several explanatory variables, two binary explanatory variables, three ternary explanatory variables, and four quartered variables. Then, the highest determination coefficient ($R^2$) is chosen. If the determination coefficient value approaches one, then the discharge estimation model is more approaching the actual discharge value (Figure 2). This model has been proven to estimate future discharge reasonably [10,11].

![Figure 3](image)

**Figure 3.** A continuous model of future discharge estimation [6].

2.5. Statistical Test for Data Validation

A statistical test was used to determine the most representative model in which the dependable discharge is compared with the measured discharge through comparison of three values:

1. Correlation
   The comparison was made by considering the correlation value of each model simulation. The best model is a model with a correlation level approaching 1.

2. Relative Absolute Error (RAE)
   To determine the extent of the hydrograph approach of the model simulation result with the historical data, the relative absolute error (RAE) test was done.

   $$KAR = \frac{1}{n} \sum_{i=1}^{n} \frac{Q_{obs} - Q_{mod}}{Q_{obs}}$$  \hspace{1cm} (3)

3. Root Mean Square Error (RMSE)
   The accuracy level of each model was determined based on Root Mean Square Error.

   $$RMS = \left( \frac{1}{n} \sum_{i=1}^{n} \left( \frac{Q_{obs} - Q_{mod}}{Q_{obs}} \right)^2 \right)^{1/2}$$  \hspace{1cm} (4)
3. Results and discussion

3.1. Completing empty data

Daily rainfall data were obtained from six stations: Cileunca Station (P1), Cipanas-Pengalengan Station (P2), Kertamanah Station (P3), Ciherang Station (P4), Cibereum Station (P5), and Cisondari Station (P6). Figure 4 shows the rain post location map.

![Rainfall post location map (P).](image)

Daily rainfall data were then converted into monthly data by summing the daily rainfall recorded. The rainfall data were then grouped based on the month. An example of the regression equation used to fulfill Ciherang Station (P4) from 2000 to 2017 is presented in Table 2.

| Month   | Equation                                                                 |
|---------|--------------------------------------------------------------------------|
| January | P4 = 119.04764 + 0.25485 * P1 + 0.17643 * P3 + 0.14437 * P2               |
| February| P4 = 28.74098 + 0.84161 * P1 - 0.317 * P2 + 0.42596 * P5                 |
| March   | P4 = -51.79186 + 1.2772 * P1 - 0.35603 * P5 + 0.34546 * P2               |
| April   | P4 = 28.84696 + 1.0502 * P3 - 0.07021 * P1 - 0.16137 * P2                |
| May     | P4 = 50.52435 + 0.35416 * P5 - 0.04637 * P3 + 0.37767 * P1               |
| June    | P4 = 31.52703 + 0.41287 * P5 + 0.05926 * P2 + 0.05297 * P3               |
| July    | P4 = 12.81426 + 0.64176 * P3 + 0.29976 * P2 + 0.06295 * P1               |
| August  | P4 = 15.55961 + 1.04945 * P3 - 0.33619 * P5 + 0.0081 * P2                |
| September| P4 = 23.21752 + 0.57252 * P5 + 0.54984 * P3 - 0.3383 * P1               |
| October | P4 = 9.90956 + 0.63121 * P3 + 0.04208 * P5 + 0.15958 * P2                |
| November| P4 = 31.22437 + 1.63083 * P1 + 0.45078 * P5 - 0.88777 * P3               |
| December| P4 = -30.72637 + 0.67812 * P1 + 0.40221 * P2 - 0.04976 * P3              |

Based on Table 2, it is seen that Ciherang Station (P4) had a weak correlation with Cisondari Station (P6), and the relationship between the four stations is varied for each month. This indicates the random characteristics of the hydrology component.
3.2. Reliability of raw water
The historical input data of the Cipanunjang Reservoir, which had been previously completed, was then calculated in terms of its reliability by using the historic statistical method through the Weibull probability equation, thereby determining the reliability probability. In this stage, the historic input discharge was also divided into five classes using the Discrete Markov Method: very dry, dry, regular, wet, and very wet. Table 3 is the classification of historical input discharge into three classes.

| Table 3. Classification of historical input discharge of Cipanunjang Dam into three classes (wt, normal and dry year) using discrete Markov method (m3/s). |
| % | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wet | 4.55 | 5.27 | 5.33 | 5.14 | 5.43 | 3.64 | 3.39 | 2.27 | 1.9 | 3.52 | 3.54 | 6.1 | 5.72 | 4.27 |
| 9.09 | 5.17 | 5.19 | 4.42 | 4.55 | 2.67 | 2.93 | 1.35 | 1.88 | 2.28 | 3 | 3.65 | 4.75 | 3.49 |
| 13.6 | 4.91 | 4.81 | 4.19 | 4.35 | 2.44 | 1.83 | 1.22 | 1.41 | 2.02 | 2.66 | 3.58 | 3.88 | 3.11 |
| 18.1 | 4.03 | 4.75 | 4 | 3.78 | 2.19 | 1.64 | 1.16 | 1.36 | 1.9 | 2.58 | 3.5 | 3.83 | 2.89 |
| 22.7 | 3.96 | 4.71 | 3.86 | 3.77 | 2.13 | 1.49 | 1 | 1.21 | 1.65 | 2.50 | 3.27 | 3.79 | 2.78 |
| 27.2 | 3.86 | 4.69 | 3.81 | 3.68 | 2.06 | 1.4 | 0.85 | 1.19 | 1.38 | 2.38 | 2.99 | 3.77 | 2.67 |
| 31.2 | 3.66 | 4.55 | 3.79 | 3.58 | 1.93 | 0.9 | 0.75 | 1.01 | 1.36 | 2.16 | 2.67 | 3.77 | 2.51 |
| Normal | 36.3 | 3.43 | 4.37 | 3.77 | 3.28 | 1.89 | 0.86 | 0.74 | 0.9 | 1.15 | 1.69 | 2.51 | 3.66 | 2.35 |
| 40.9 | 3.39 | 4.19 | 3.66 | 2.95 | 1.86 | 0.82 | 0.71 | 0.79 | 1.07 | 1.48 | 2.08 | 3.56 | 2.21 |
| 45.4 | 3.12 | 4.18 | 3.63 | 2.88 | 1.69 | 0.81 | 0.69 | 0.79 | 1.05 | 1.43 | 2.03 | 2.79 | 2.09 |
| 50.0 | 2.84 | 3.61 | 3.61 | 2.85 | 1.49 | 0.77 | 0.68 | 0.77 | 1.03 | 1.24 | 1.91 | 2.62 | 1.95 |
| 54.5 | 2.78 | 3.45 | 2.58 | 2.83 | 1.34 | 0.75 | 0.44 | 0.75 | 1 | 1.09 | 1.68 | 2.37 | 1.76 |
| 59.0 | 2.68 | 3.35 | 2.56 | 2.03 | 1.16 | 0.74 | 0.38 | 0.68 | 0.87 | 0.99 | 1.35 | 2.35 | 1.60 |
| 63.6 | 2.63 | 3.02 | 2.51 | 1.8 | 1.08 | 0.74 | 0.37 | 0.53 | 0.86 | 0.79 | 1.28 | 2.14 | 1.48 |
| Dry | 68.1 | 2.26 | 2.01 | 1.95 | 1.72 | 1.06 | 0.44 | 0.31 | 0.3 | 0.47 | 0.47 | 1.27 | 2.09 | 1.20 |
| 72.7 | 1.89 | 1.98 | 1.84 | 1.36 | 0.9 | 0.34 | 0.3 | 0.21 | 0.29 | 0.45 | 1.06 | 2.07 | 1.06 |
| 77.2 | 1.75 | 1.78 | 1.52 | 3.2 | 0.88 | 0.33 | 0.18 | 0.1 | 0.23 | 0.42 | 0.85 | 1.99 | 0.95 |
| 81.8 | 1.75 | 1.76 | 1.32 | 1.31 | 0.66 | 0.24 | 0.08 | 0.08 | 0.11 | 0.15 | 0.59 | 1.68 | 0.81 |
| 86.3 | 1.58 | 1.4 | 1.31 | 1.19 | 0.53 | 0.19 | 0.05 | 0 | 0.05 | 0.07 | 0.4 | 1.66 | 0.70 |
| 90.9 | 1.36 | 1.2 | 1.24 | 1.05 | 0.3 | 0 | 0.04 | 0 | 0.03 | 0.02 | 0.22 | 0.86 | 0.53 |
| 95.4 | 1.25 | 0.85 | 0.66 | 1 | 0.09 | 0 | 0 | 0.02 | 0 | 0.16 | 0.15 | 0.35 |
| R20 Wet | 5 | 5.26 | 5.32 | 5.07 | 5.34 | 3.54 | 3.34 | 2.18 | 1.9 | 3.40 | 3.49 | 5.86 | 5.62 | 4.19 |
| R10 Wet | 10 | 5.12 | 5.11 | 4.37 | 4.51 | 2.62 | 2.71 | 1.32 | 1.79 | 2.23 | 2.93 | 3.64 | 4.58 | 3.41 |
| R5 Wet | 20 | 4.00 | 4.73 | 3.94 | 3.78 | 2.17 | 1.58 | 1.10 | 1.30 | 1.80 | 2.55 | 3.41 | 3.82 | 2.85 |
| R2 Normal | 50 | 2.84 | 3.61 | 3.61 | 2.85 | 1.49 | 0.77 | 0.68 | 0.77 | 1.03 | 1.24 | 1.91 | 2.62 | 1.95 |
| R5 Dry | 80 | 1.75 | 1.77 | 1.4 | 1.31 | 0.75 | 0.28 | 0.12 | 0.09 | 0.16 | 0.26 | 0.69 | 1.80 | 0.86 |
| R10 Dry | 90 | 1.40 | 1.24 | 1.25 | 1.08 | 0.35 | 0.04 | 0.04 | 0.00 | 0.03 | 0.03 | 0.26 | 1.02 | 0.56 |
| R20 Dry | 95 | 1.26 | 0.89 | 0.72 | 1.01 | 0.11 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.17 | 0.22 | 0.37 |

Based on the calculation result presented in Table 3, we obtained the reliability of historical input discharge of the Cipanunjang Reservoir by interpolating the discharge value above and determined its mean. The raw water, which became the operational guidelines of the Cipanunjang Reservoir, was 0.86 m3/s or around 860 liters/s. Meanwhile, Cileunca Reservoir had a reliability of 1.21 m3/s obtained by adding the dry R5 reliability of the Cipanunjang Reservoir with the dry R5 reliability of Cilaki Beet of 0.34 m3/s. This was performed because Cileunca Reservoir has two different hydrology systems as the input those are Cipanunjang output and Cilaki Beet. The calculation result of the historical input discharge classification of the Cileunca Reservoir can be seen in Table 4.
Based on the data from Municipal Waterworks (PDAM) of Bandung City and District, the Bandung region's water need is about 1.66 m$^3$/s. There was a difference between the water need and raw water discharge reliability, so that in a specific time, the raw water need cannot be fulfilled.

Table 4. Classification of historical input discharge of Cileunca Reservoir into three classes (very wet, wet, normal, dry, arid year) using the discrete method (m$^3$/s).

| %     | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | mean |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 4.55  | 4.20| 6.02| 4.76| 6.37| 4.47| 4.74| 7.48| 4.05| 4.27| 3.43| 5.18| 4.39| 4.95 |
| 9.09  | 3.97| 5.64| 4.54| 4.53| 4.23| 3.22| 3.99| 3.79| 4.08| 3.37| 4.72| 3.64| 4.14 |
| 13.64 | 3.92| 5.53| 4.31| 4.36| 4.21| 3.14| 3.58| 2.96| 4.00| 3.29| 4.46| 3.61| 3.95 |
| 18.18 | 3.77| 5.01| 4.09| 4.20| 3.92| 2.85| 3.26| 2.80| 3.11| 2.82| 4.35| 3.42| 3.63 |
| 22.73 | 3.87| 4.77| 3.94| 3.52| 3.63| 2.84| 2.45| 2.61| 3.02| 2.55| 4.31| 3.40| 3.39 |
| 27.27 | 3.55| 4.34| 3.58| 3.26| 3.40| 2.83| 2.33| 2.37| 2.99| 2.53| 4.06| 3.25| 3.21 |
| 31.82 | 3.43| 4.17| 3.41| 3.25| 3.31| 2.64| 2.15| 2.35| 2.78| 2.50| 4.01| 2.97| 3.08 |

Wet

| %     | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | mean |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 36.36 | 3.41| 3.96| 3.05| 3.23| 3.17| 2.36| 2.12| 2.18| 2.30| 2.34| 2.58| 2.96| 2.80 |
| 40.91 | 3.37| 3.18| 2.93| 3.01| 2.90| 2.26| 2.07| 2.13| 2.27| 2.19| 2.24| 2.60| 2.59 |
| 45.45 | 3.20| 2.26| 2.89| 2.92| 2.38| 1.82| 2.05| 2.03| 2.01| 1.99| 2.54| 2.35 |
| 50.00 | 3.15| 1.72| 2.55| 2.82| 2.36| 1.64| 1.80| 1.96| 1.98| 2.00| 1.96| 2.33| 2.19 |
| 54.55 | 3.08| 1.63| 2.34| 2.39| 1.84| 1.57| 1.73| 1.73| 1.98| 1.68| 2.14| 1.98 |
| 59.09 | 2.95| 1.63| 1.84| 1.65| 1.54| 1.52| 1.48| 1.65| 1.92| 1.49| 2.01| 1.78 |
| 63.64 | 1.63| 1.50| 1.79| 1.65| 1.44| 1.48| 1.42| 1.73| 1.34| 1.41| 1.74| 1.55 |

Normal

| %     | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | mean |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 68.18 | 1.62| 1.44| 1.51| 1.57| 1.43| 1.47| 1.38| 1.34| 1.72| 1.22| 1.37| 1.53| 1.47 |
| 72.73 | 1.44| 1.43| 1.51| 1.55| 1.42| 1.37| 1.34| 1.34| 1.16| 1.19| 1.44| 1.38 |
| 77.27 | 1.34| 1.43| 1.49| 1.37| 1.37| 1.34| 1.34| 1.27| 1.10| 1.08| 1.39| 1.33 |

Dry

| %     | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | mean |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 81.82 | 1.34| 1.43| 1.43| 1.37| 1.37| 1.34| 1.29| 1.12| 1.06| 1.02| 1.34| 1.29 |
| 86.36 | 1.34| 1.40| 1.38| 1.36| 1.37| 1.34| 1.17| 1.07| 0.94| 0.97| 1.11| 1.24 |
| 90.91 | 1.34| 1.40| 1.34| 0.87| 1.34| 1.33| 1.29| 1.04| 1.02| 0.94| 0.97| 0.84| 0.15 |
| 95.45 | 0.84| 1.40| 1.34| 0.87| 0.84| 0.87| 1.29| 1.03| 0.97| 0.84| 0.87| 0.84| 1.00 |

3.3 Model of Future Discharge Estimation

The spatial correlation method of the hydrology component (also known as the continuous model method) can predict future discharge. Discharge at t+1 was developed by the discharge and rainfall at t using multiple linear regression. Table 7 is the equation of multiple linear regression of four variables to predict the input discharge of the Cipanunjang Reservoir.

Table 5. Equation of linear regressions to estimate the future discharge of the Cipanunjang Reservoir.

|     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|
| Qian| 1.967| 0.435| Qdec| + | 0.002| P5| + | -0.0045| P6 |
| Qfleb| -0.265| + | 0.616| Qian| + | 0.003| P6| + | 0.0045| P1 |
| Qmar| 0.522| + | 0.584| Qfleb| + | 0.003| P6| + | -0.0005| P4 |
| Qapr| 0.996| + | 1.014| Qmar| + | -0.001| P5| + | -0.00445| P6 |
| Qmay| -0.079| + | 0.437| Qapr| + | 0.001| P4| + | 0.0002| P6 |
| Qijn| -0.136| + | 0.005| P3| + | 0.001| P2| + | 0.19| Qmay |
| Qjul| 0.1345| + | 0.462| Qjum| + | 0.002| P6| + | -0.0012| P4 |
Qaug = 0.213 + 0.8976 Qjul + -2.2E-6 P2 + -0.0007 P3
Qsep = 0.0513 + 1.065 Qaug + 0.001 P5 + 0.005 P6 + 0.118 Qsep
Qoct = -0.014 + 0.74 Qjul + 0.004 P3 + 0.002 P5
Qnov = 1.85 + 0.309 Qoct + 0.001 P4 + 0.0004 P3
Qdec = 0.0513 + 1.065 Qaug + 0.001 P5 + 0.005 P6 + 0.118 Qsep

Based on the table above, the discharge estimation for February was developed by historical input discharge in January (Qjan), rainfall in Cisondaru Station (P6), and Cileunca station (P1). Figures 4 and 5 compare historical discharge and estimated discharge; respectively, for Cipanunjang Reservoir and Cileunca Reservoir (Cilaki Beet) based on the statistical test between historical discharge and estimated discharge, the correlation value reached 0.87 and 0.83. Then, the determination coefficient values were 0.76 and 0.7. This shows that the spatial correlation method could be employed to estimate future discharge proven by the correlation value between the historical discharge and estimated discharge, which approached 1. The result of the statistical result can be seen in Table 8.

**Table 6.** Comparison of RAE and RMSE of Cipanunjang and Cileunca Reservoirs.

| Statistical Parameter                  | Cipanunjang Reservoir | Cileunca Reservoir |
|---------------------------------------|-----------------------|--------------------|
| Relative Absolute Error (RAE)         | 0.004                 | 0.004              |
| Root Mean Square Error (RMSE)         | 0.064                 | 0.063              |

**Figure 5.** Comparison between historical discharge and estimated discharge of the Cipanunjang Reservoir.

**Figure 6.** Comparison of historical discharge and estimated discharge of the Cileunca Reservoir.
The popular models in estimating the input debit are the FJ Mock and NRECA models [3, 12, 13]. In this research, discharge forecasting was carried out by applying a regression model to a watershed to better understand how the regression model was performed in rainfall and discharge modeling.

The Spatial Correlation Model, which is also called the Continuous Model (Continuous Model-Spatial Correlation) in this study, can be simulated using the four-variable multiple regression method, which consists of the rain and discharge variables. In previous studies, the Continuous Model-Spatial Correlation has shown that the four-variable multiple regression equation provides a correlation value that is significantly better than the two and three variables. Meanwhile, the multiple regression equations of five or more produce a slightly better correlation value than the four variables, and is not worth the additional effort required.

Based on previous work [14], the Continuous-Spatial Correlation and Discrete Chain Markov models were used to estimate the inflow discharge in overcoming the most challenging problems of exploiting excess discharge and optimizing reservoir management to anticipate the amount of water discharge in the future.

4. Conclusion
A continuous method – also called a spatial correlation method – of the hydrological component was used to fill missing data points and estimate discharge and year. The dependable discharge for water need (dry R5) in the Cipanunjang-Cileunca reservoir series is 1.2 m$^3$/s, while the raw water need of SPAM of Bandung City and District is 1.66 m$^3$/s, which cannot be guaranteed at any time, especially during the dry season. The determination of sufficient reservoir volume shows that the two reservoirs experience a decrease: from 22 million m$^3$ to 18.7 million m$^3$ in Cipanunjang; and from 11 million m$^3$ to 9.5 million m$^3$ at Cileunca. The estimation of future discharge using the continuous method shows a correlation between historical discharge and continuous model, which is 0.87 for Cipanunjang Reservoir, and 0.93 for Cileunca Reservoir.

In reservoir operation, the estimation of discharge input is essential to anticipate the occurrence of the lack of water when the discharge input is smaller than the discharge output planned. Thus, the reservoir management needs to calculate the type of year (dry, normal, or wet) and the future discharge, thereby determining the future discharge.

As a recommendation, this study needs to be compared with other discharge estimation methods such as the FJ Mock method, NRECA and ARIMA.

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