The influence of regim’s river and run-off coefficient in the catchment areas of Sidutan and Reak: a correlation analysis

S C Noviadi* and A Rizki 
1Civil Engineering-Master Program, Universitas Mataram, Indonesia 
2Youth Professional Engineer, Mataram, Indonesia 
*E-mail: Satia.cahayanovember@gmail.com

Abstract. The annual runoff coefficient required a single hydrograph and hourly rainfall in a year. The relationship between the river regime coefficients and runoff coefficients will produce correlations in linear equations. The calculation results obtained the relationship of the River Regime Coefficient (KRS) with Runoff Coefficient in the Sidutan Watershed is proportional with the equation \( y = -2E-05x^2 + 0.0048x - 0.0539 \) with the coefficient of determination \( R^2 = 0.6796 \). KRS values obtained in 2011-2016 were respectively 67.69; 43.99; 188.92; 53.78; 45.01 which is included in the low to to high classification range. This indicates the watershed is in bad condition. Runoff coefficient (C) each 0.188; 0.101; 0.229; 0.163; 0.148 shows good classification, so that the watershed is in good condition. In the Reak River Basin, the relationship between KRS and C is proportional with the equation \( y = 0.0003x^2 - 0.011x + 0.1618 \) with a coefficient of determination \( R^2 = 0.7855 \). KRS values obtained in 2011-2016 are respectively 27.46; 29.80; 31.06; 16.96; 14.11 which are included in the very low to low classification range. This indicates the watershed is in good condition. Classification of good C values respectively 0.071; 0.106; 0.110; 0.074; 0.058, indicating that the watershed is in good condition.

1. Introduction

Direct flow or surface runoff is a part of rain water that falls in a watershed which then turns into flow in a river [1]. Runoff is all water that moves out of the outlet of the drainage area into the river through the route both above and underground before reaching the river [2]. Runoff coefficient (C) is a parameter used to see the infiltration and runoff values of rainwater falling on land with a ratio between surface flow volume and falling volume of rain. Finally, the value of C can also be used to determine the condition of the watershed. The greater the value of C indicates that the more rainwater becomes the surface flow. In calculating the value of C, many prefer to use the C values available in the table which are the results of previous studies because it can facilitate the calculation where the conditions of land use are quite regular. However, to see the value of C in the watershed area which is quite extensive, this will become more complicated, because the one that influences the calculation of the value of C is the type of land and land area, so that each change in land can affect the value of C. use the principle of water balance to calculate runoff or river discharge for a relatively long period of time.

Watershed conditions and their impact on the fluctuation of River Discharge aimed at the value of KRS (2.47) and MD (0.35 m3/s) for 1997-2003 and KRS (2.0) and Mean Deviation/MD (0.25 m3/sec) for the years 2004-2010 [3]. Whereas Ramza made observations of changes in the runoff coefficient (C) in the Ular watershed, South Sumatra, which obtained an average C value in 2000 was 0.46604 and the
2006 C average was 0.4775 [4]. Then Sarino conducted a study on Runoff Analysis in the Lematang Hulu Sub-watershed, South Sumatra, with the existing 10-year rainfall producing design rainfall for periods of 2.5 and 10 years of 83,607 mm, 131,806 mm and 161.07 mm. Then the runoff results of 679.8 m³/sec for the return period of 2 years [5].

Jangkok Watershed is changing in the land use of its upstream sub-watershed area. Therefore, it does not have a significant implication to the fluctuations in river discharge [6]. On the other study, Sunardi revealed that the watershed fluctuations during 15 years was classified as a ‘Good’ watershed. The Sidutan watershed and the Reak watershed have a water level recording station (AWLR) and rainfall data recording (ARR) so that with both data the actual C values for the watershed are reviewed [7].

In addition to the value of C, watershed conditions can also be identified by using the River Regime Coefficient (KRS), where the value of KRS is a number that states the ratio between daily maximum average discharge with minimum daily discharge in one hydrological year (rainy season), with the knowledge of river flow fluctuations, the watershed conditions in the area will also be seen.

2. Method

Four steps are taken in this study as follows:
1) Analysis of rainfall data includes test the consistency of rainfall data using the RAPS method (Rescaled Adjusted Partial Sums) [8] [9] [10] [11] and analysis of regional average rainfall volume.
2) Analysis of AWLR discharge data includes two stage: flood volume analysis, and River Regime Coefficient (KRS) Analysis [12].
3) Analysis of the value of the runoff coefficient (C) by using flood data that occurs due to the occurrence of rain at the same time.
4) Analysis of the relationship between KRS values and C values.

3. Result and Discussion

3.1 Study area

The research is located in the catchment area of the AWLR (Automatic Water Level Recorder) Santong (DAS 014 number), which is in the upstream part of the Sidutan watershed and the AWLR Driver (number DAS 041) located in the Reak watershed. The Santong AWLR catchment area has an area of 37.77 km² with the main river being the Sidutan River, while the AWLR Driver's catchment area has an area of 23.66 km² with Reak River being the main river which is administratively located in North Lombok Regency. Geographically the location of the Santong AWLR Station is at 8°19'44"LS and 116°17'47"BT, and the AWLR Station is located at 8°16’29"LS and 116°25’12"BT (figure 1).

![Figure 1](image1.png)

(a) Location map of the Sidutan watershed and Reak watershed, (b) Maps of the Santong AWLR area (Sidutan watershed) area, and (c) Sopak AWLR (Reak watershed)

3.2 River regime coefficient analysis (KRS)

KRS is the ratio between maximum discharge (Qmax) and minimum discharge (Qmin) in a watershed [13] [14]. The value of this KRS can show fluctuations between the rainy season and the dry season in several years of observation. Therefore, the KRS analysis is carried out at 1 period of the hydrological year, from the beginning of the rainy season to the end of the dry season. For example, the following data are used to calculate the KRS value in the year period, i.e. the beginning of the rainy season in 2011 until the end of the dry season in 2012. In Table 1 and Table 2, you can see the hourly discharge data for October 1, 2011 at AWLR Station Santong and AWLR Station Sopak.
The amount of water loss is greatly influenced by various causes such as the type and density of plants (vegetal cover), soil type, soil surface conditions and so on [15]. In addition, the presence of PLTMH also affects water loss in rivers. The Santong PLTMH located near the AWLR station began operations in mid-2014 assuming that construction work was carried out since 2013. In Table 3, it can be seen that the fluctuations in river flow in each year are large enough to indicate watershed conditions are not good. This can be seen from the value of the resulting KRS classified as low (20 < KRS < 50) to very high (KRS > 110). These conditions indicate that the soil absorbing power is less able to hold and store water during the rainy season so that runoff water becomes high (figure 2).

| Table 1. AWLR Santong hourly discharge data (BWS NT I) |
|--------------------------------------------------------|
| Time (Hour) | Discharge (m$^3$) | Time (Hour) | Discharge (m$^3$) |
|-------------|------------------|-------------|------------------|
| 10/01/2011 0:00 | 1.50 | 10/01/2011 12:00 | 1.50 |
| 10/01/2011 2:00 | 1.50 | 10/01/2011 14:00 | 1.50 |
| 10/01/2011 4:00 | 1.50 | 10/01/2011 16:00 | 1.50 |
| 10/01/2011 6:00 | 1.50 | 10/01/2011 18:00 | 1.50 |
| 10/01/2011 8:00 | 1.50 | 10/01/2011 20:00 | 1.50 |
| 10/01/2011 10:00 | 1.50 | 10/01/2011 22:00 | 1.50 |

| Table 2. AWLR Sopak hourly discharge data (BWS NT I) |
|-----------------------------------------------------|
| Time (Hour) | Discharge (m$^3$) | Time (Hour) | Discharge (m$^3$) |
|-------------|------------------|-------------|------------------|
| 10/01/2011 0:00 | 0.27 | 10/01/2011 12:00 | 0.27 |
| 10/01/2011 2:00 | 0.27 | 10/01/2011 14:00 | 0.27 |
| 10/01/2011 4:00 | 0.27 | 10/01/2011 16:00 | 0.27 |
| 10/01/2011 6:00 | 0.27 | 10/01/2011 18:00 | 0.27 |
| 10/01/2011 8:00 | 0.27 | 10/01/2011 20:00 | 0.27 |
| 10/01/2011 10:00 | 0.27 | 10/01/2011 22:00 | 0.27 |

| Table 3. Daily average discharge data and calculation results of KRS (yearly) - Santong AWLR |
|------------------------------------------------------------------------------------------------|
| Year                | Daily discharge average | KRS | Category |
|                     | Maximum | Date             | Minimum | Date            | |
| Oct 2011-Sep 2012  | 51.44    | 16/03/2012       | 0.76    | 05/09/2012      | 67.69 | Medium |
| Oct 2012-Sep 2013  | 10.56    | 01/03/2013       | 0.24    | 31/10/2012      | 43.99 | Low    |
| Oct 2013-Sep 2014  | 54.79    | 21/01/2014       | 0.29    | 04/11/2013      | 188.92 | Very High |
| Oct 2014-Sep 2015  | 12.91    | 12/03/2015       | 0.24    | 25/07/2015      | 53.78 | Medium |
| Oct 2015-Sep 2016  | 10.80    | 19/12/2016       | 0.24    | 01/10/2016      | 45.01 | Low    |

Figure 2. KRS values for each Santong AWLR Station
Figure 3. KRS value for each year at Sopak AWLR Station

In the period 2013-2014, the yielded KRS value was 188.92, where the value indicated that the ratio between the maximum daily average discharge and the minimum daily average discharge at that period
was high. This is probably due to the evasion of river flows during the construction of MHP buildings that occurred during that period.

While the condition of the Reak watershed in terms of the results of the KRS analysis is still in good condition each year which can be seen in table 4 and Figure 3. It is seen from the average value of KRS that is equal to 23.88 in the low range (20 < KRS < 50), therefore, the fluctuations in the river discharge are not too large during the rainy and dry seasons.

### Table 4. Recap of daily average discharge data and KRS calculation results for AWLR Sopak Station

| Year            | Daily discharge average | Daily discharge average | KRS | Category |
|-----------------|-------------------------|-------------------------|-----|----------|
|                 | Maximum | Date       | Minimum | Date       |          |
| Oct 2011-Sep 2012 | 7.49    | 3/02/2012  | 0.27    | 01/10/2012 | 27.46    | Low |
| Oct 2012-Sep 2013 | 8.13    | 11/12/2012 | 0.27    | 06/11/2013 | 29.80    | Low |
| Oct 2013-Sep 2014 | 8.39    | 01/06/2015 | 0.27    | 04/10/2014 | 16.96    | Very Low |
| Oct 2014-Sep 2015 | 4.58    | 07/10/2015 | 0.27    | 01/10/2015 | 14.11    | Very Low |

Analysis of the runoff coefficient value (C) resulted the C Value of Sidutan Watershed (Flood Volume / Rain Volume) was 0.050 and the C Value of Reak Watershed (Flood Volume / Rain Volume) was 0.069. In one year, the flood hydrograph analyzed produces different values of C. To make it easier to analyze the relationship of the KRS value with the value C, then the average value of C is obtained from each hydrograph, therefore, one value of C is obtained for one year period. In analyzing the value of C, different flood durations are obtained with different C values. Thus, an effort to analyze the value of C with an interval of 6 hours was carried out. The aim was to see the value of C resulting from the same duration of flood for each hydrograph analyzed. The calculation results is available in Table 5 and figure 4.

### Table 5. The average value of C for Sidutan watershed

| Year            | C Value Average |
|-----------------|-----------------|
| Oct 2011-Sep 2012 | 0.188           |
| Oct 2012-Sep 2013 | 0.101           |
| Oct 2013-Sep 2014 | 0.229           |
| Oct 2014-Sep 2015 | 0.163           |
| Oct 2015-Sep 2016 | 0.148           |

From the results of the C value data analysis in the Reak watershed, it was found that the watershed conditions were still in good each year. This is indicated by the average value of C every year which is in the range below 0.12 (<0.25), where this indicates that less than 12% of rainwater is runoff and about 88% of rainfall occur in the area, which will infiltrate into the soil. Thus the condition of the watershed is still in good, because the amount of infiltrated water is higher than the amount of rainwater that overflows.

From the results of the C value data analysis in the Reak watershed, it was found that the watershed conditions were still in good condition each year. This can be seen from the average value of C every year which is in the range below 0.12 (<0.25), where this indicates that less than 12% of rainwater is runoff and about 88% of rainfall occur in the area, which will infiltrate into the soil. Thus the condition of the watershed is still in good, because the amount of infiltrated water is higher than the amount of rainwater that overflows (table 6 and figure 5).
Table 6. Average value of C for each Reak watershed

| Year                | C Value Average |
|---------------------|-----------------|
| Oct 2011-Sep 2012   | 0.071           |
| Oct 2012-Sep 2013   | 0.106           |
| Oct 2013-Sep 2014   | 0.110           |
| Oct 2014-Sep 2015   | 0.074           |
| Oct 2015-Sep 2016   | 0.058           |

Figure 5. The annual runoff coefficient value of the Reak watershed

3.3 Analysis of the relationship between KRS value and C value

Within one year there is one KRS value, but there are many C values because many flood events are analyzed. One flood event produces one C value. The value of C in these two watersheds varies in each flood event. To get a C value that represents an event in one year, a standard for all C values in one year was taken (hydrological year). The annual C results and KRS for each watershed are presented in Table 7, Table 8, Figure 6, and Figure 8. Furthermore, the relationship between the KRS values and C values is available in Figure 7 and Figure 9.

Table 7. Average recapitulation of KRS and C values of Sidutan watershed

| Year                | Daily discharge average | KRS | C value average |
|---------------------|-------------------------|-----|----------------|
|                     | Maximum | Minimum |       |               |
| Oct 2011-Sep 2012   | 61.43    | 0.76    | 67.69 | 0.188         |
| Oct 2012-Sep 2013   | 11.83    | 0.24    | 43.99 | 0.101         |
| Oct 2013-Sep 2014   | 71.53    | 0.29    | 188.92| 0.229         |
| Oct 2014-Sep 2015   | 20.98    | 0.24    | 53.78 | 0.163         |
| Oct 2015-Sep 2016   | 12.34    | 0.24    | 45.01 | 0.148         |

Figure 6. KRS and C value (Sidutan watershed) yearly

Based on the results of the analysis shown in Table 7 and Figure 6 it can be seen that almost all KRS values and C values have the same trend, where in the year where the C is high, the KRS value will also be high. In Figure 7, it can be seen that the KRS value and the value of C have a fairly strong relationship when viewed from the coefficient of determination (R2) which is equal to 0.8836. This number is close to 1.

Table 8. Recapitulation of KRS values and C mean of Reak watershed each year

| Year                | Daily Discharge Average | KRS | C Value Average |
|---------------------|-------------------------|-----|----------------|
|                     | Maximum | Minimum |       |               |
| Oct 2011-Sep 2012   | 7.49     | 0.27    | 27.46 | 0.071         |
| Oct 2012-Sep 2013   | 8.13     | 0.27    | 29.80 | 0.106         |
| Oct 2013-Sep 2014   | 8.39     | 0.27    | 31.06 | 0.110         |
| Oct 2014-Sep 2015   | 4.58     | 0.27    | 16.96 | 0.074         |
| Oct 2015-Sep 2016   | 3.81     | 0.27    | 14.11 | 0.058         |
Figure 7. KRS value and C value of Reak watershed every year

Figure 8. Relationship between KRS and C value (Sidutan watershed)

Figure 9. Relationship between KRS value and C value of Reak watershed

It can be seen that the value of C and KRS in the Reak watershed also has the same trend, where in the year where the C value is high, the KRS value will also be high. Figure 9 shows that the value of C and KRS in the Reak watershed has a fairly strong relationship which is revealed by the value of the produced coefficient of determination (R2) of 0.7855, which is close to 1.

4. Conclusion
Based on the data analysis, some conclusions were found associated with the River Regime Coefficient (KRS) and the Runoff Coefficient (C value). The relationship between the value of the River Regime Coefficient (KRS) and the Runoff Coefficient (C) value in the Sidutan watershed is presented in the equation $y = -2E-05x^2 + 0.0048x - 0.0539$ with the coefficient of determination (R2) = 0.8836 while the equation for the relationship between the KRS value and the C value in the Reak watershed is $y = 0.0003x^2 - 0.011x + 0.1618$ with the coefficient of determination (R2) = 0.7855.

The KRS value in the Sidutan watershed shows that the watershed is in poor condition every year. This can be seen from the value of the KRS generated in the amount of 67.69; 43.99; 188.92; 53.78; 45.01, which is in the low to very high classification range. The value of C produced shows that the watershed is in good condition every year, where the value of C is 0.188; 0.101; 0.229; 0.163; 0.148. The KRS value generated in the Reak watershed every year is 27.46; 29.80; 31.06; 16.96; 14.11. These numbers are in the very low to low category, indicating that the watershed is in good condition. The value of C produced every year in a row is 0.071; 0.106; 0.110; 0.074; 0.058 also shows that the watershed is still in good condition. The condition of the Sidutan watershed and the Reak watershed based on the C value affect the fluctuations of the river discharge as seen from the value of C and KRS which have the same trend; in the year there the C value is high, the KRS value will also high. The high value of KRS indicates that there was a large fluctuation in the flow of the year.

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