WATERSHED MORPHOMETRIC CLASSIFICATION ANALYSIS USING GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT: One of the important physical characteristics of watersheds is morphometry. Watershed shape is one the earth surface morphometric features. The watershed shape has a strong relation with the characteristic peak discharge and land erosion. Therefore, the watershed shape due to the strong relation between watershed shape and peak discharge and land erosion must be classified. Watershed shape can be classified based on morphometric analysis from the perspective of linear, areal, and relief aspects. In this paper the watershed located at Serayu-Bogowonto river basin was classified into four categories based on areal aspect. The areal aspects used to classify the watershed included Gravelius’s index, form factor, shape index, shape factor, circulation ratio, elongation ratio, and compactness coefficient. Four categories of watershed shapes (circular, oval, semi-oval, and elongated) were applied in this research. Seventeen watersheds at Serayu-Bogowonto river basin were selected as samples in the classification process. The Geographical Information System (GIS) technique was applied to generate watershed geometric properties such as, river length, watershed perimeter, area, diameter, and watershed length. Based on the analysis process, watersheds with broad and wide shape were difficult to classify. Such watersheds can be classified as circular, oval, semi-oval, and elongated. Finally, these watersheds can be classified under one category based on morphometric analysis results combined with the watershed figure. From the 17 watersheds, 5 were classified as circular, 3 as oval, 5 as semi-oval, and 4 as elongated shapes. GIS is a powerful tool for the analysis relating to watershed morphometric parameters.

Keywords: Morphometric, Elongation ratio, Form factor, Shape factor, Circularity ratio

1. INTRODUCTION

The drainage basin or watershed physical characteristic analysis is important in any hydrological investigation, such as assessment of soil erosion, runoff discharge, and land critical analysis. Morphometry is one of the important physical characteristics [1]. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth’s surface, shape, and dimension of its landform [2-5]. With this definition, watershed shape is considered one the earth’s surface morphometric properties. A watershed is an area whose major surface runoff is conveyed to a single outlet and is the appropriate unit to study land surface processes [6]. In general, watersheds can be classified based on morphometric analysis of the following aspects: linear (one dimension), areal (two dimensions), and relief (three dimensions) aspects. Watershed parameters for linear aspect include stream length, watershed length (Lb), watershed area (A), and watershed perimeter (P). The parameters for areal aspect or shape parameters comprise form factor (Rf), elongation ratio (Re), circulation ratio (Rc), and compactness coefficient (Cc). Finally, the parameters for relief aspect include watershed relief and relief ratio [7]. Various important hydrologic variables, such as the size, shape, slope, drainage density, size and length of the tributaries can be correlated with the morphometric characteristics of watersheds [4,8]. The shape of watersheds has a strong relation with their characteristic peak discharge and land erosion. In this paper, watershed shape was analyzed based on areal aspects, i.e., Gravelius’s index (KG), Rf, shape index (Sw), shape factor (Rs), Rc, Re, and Cc. The physical data used to analyze the watershed shape were length, perimeter, diameter, and watershed area.

On the basis of the general shape of watersheds, watersheds in the study area were classified into four shapes categories, i.e., circular, oval, semi-oval, and elongated. A total of 17 watersheds were selected in the study area. On the basis of areal aspect, the 17 watersheds were classified into four watershed shape categories. Given that watershed is the basic unit in hydrology, morphometric analysis at the watershed scale is an important parameter and preferable than individual channels. The interrelationship between morphometric parameters differs from that of one watershed to another under varied topographical and climatic conditions. Hence, fluvial geomorphology is connected with watershed geometry and its channel network [9].

Morphometric analysis provides a good alternative to understanding the underlying factors
controlling the hydrological behavior [10]. With the use of conventional techniques, morphometric characterization of various watersheds in different parts of the globe has been carried out [11,12]. With the advancement in geospatial and computer technology, the assessment of watershed morphometry has shown good accuracy and precision. In GIS technique, various terrain and morphometric parameters of drainage basins are evaluated with ease and accuracy. In the present study, morphometric characterization of 17 watersheds of the Serayu-Bogowonto river basin area was performed in GIS environment.

2. MATERIALS AND METHODS

2.1 Materials

The study area is Serayu-Bogowonto river basin. The river basin is located at Java Island, Indonesia and occupies two provinces, i.e., Middle Java province and Special Region of Yogyakarta. Geographically, Serayu-Bogowonto river basin is located between 07°54′16″S and 07°10′04″S and 108°56′56″E and 110°08′47″E. The topographic map used in this research was in the scale of 1:25,000 with a contour interval of 12.5 m. Fifty sheets were used in this research. Fig. 1 shows the location of Serayu-Bogowonto river basin.

The total area of the Serayu-Bogowonto river basin is 7,354.631 km², and its perimeter is equal to 430.333 km.

![Fig.1 Serayu-Bogowonto river basin area](image)

2.2 Methods

The following steps were followed to analyze the parameters for areal aspect or shape parameters of watershed. ArcGIS 10.6.1 was used for analyzing the watershed shape.

1. Create the shapefile for river network, contour line, stream order, and administrative boundaries;
2. Create a Digital Elevation Model (DEM) with a grid size of 25 × 25 m²;
3. Analyze the river basin and watershed boundaries;
4. Select watershed as samples;
5. Calculate the watershed shape parameters;
6. Classify the watershed shapes.

From the topographic map the DEM was generated in GIS environment. No distinction was observed between the water-filled stream channels and land surface in the DEM. The DEM was constructed based on the contour line. From the contour line the Triangular Irregular Network (TIN) was developed. Finally, the DEM with grid size 25 × 25 m² was developed by transforming the TIN to DEM. To draw the watershed boundary, the river network generated from the topographical map which are proposed to be defined as the watershed boundary was overlapped with DEM. By using the basin menu in the ArcGIS environment, the boundaries of each watershed of the study area were developed. The watershed area was evaluated by calculating the geometry of the derived watershed polygons, and the \( L_b \) was calculated by summing the length of the main stream channel and the distance from the top of the main channel to the watershed boundary. By summing the lengths of all the streams in each watershed, the total stream length was calculated.

As mentioned above, in this research the morphometric was analyzed by classifying the watershed shape based on areal aspect. Among the areal aspects, \( KG, R_f, Sw, Rs, Rc, Re, \) and \(Cc\) were analyzed. The formula for each areal aspect can be described as follows.

1. **\( KG \)**

\[
KG = \frac{P}{2\sqrt{\pi A}}
\]

Based on the \( KG \) values, the watershed shape can be classified into four categories, i.e., \( KG \) equal to 1.6, 1.3, 1.2, and 1.1 denoted elongated, semi-oval, oval, and circular shaped watersheds, respectively [13].

2. **\( R_f \)**

\[
R_f = \frac{A}{L_b^2}
\]

\( R_f \) is defined as the ratio of the basin area to the square of the basin length. The values between
0.13 and 0.26 show that the watershed shape is elongated [14,15].

\[ Sw = \frac{Lb^2}{A} \]  

(3)

The \( Sw \) values for watershed area show that the larger value, the more elongated is the watershed [4].

3. \( Rs \)

\[ Rs = \frac{Pu}{P} \]  

(4)

The \( Rs \) has a similar interpretation to \( Rc \), \( Re \), and \( Rf \) [4].

4. \( Rc \)

\[ Rc = \frac{4\pi A}{P^2} \]  

(5)

\[ Rc = \frac{A}{Al} \]  

(6)

Values ranging from 0.53 to 0.62 indicate that the watershed is elongated, whereas those less than 0.53 indicate that the watershed shape is oval [4].

5. \( Re \)

\[ Re = \frac{2}{Lb} \sqrt{\frac{A}{\pi}} \]  

(7)

\[ Re = \frac{D}{Lb} \]  

(8)

The values can be grouped into five categories, namely, circular (0.9–1.0), oval (0.8–0.9), less elongated (0.7–0.8), elongated (0.5–0.7), and more elongated (< 0.5) [9].

6. \( Cc \)

\[ Cc = \frac{P}{Pu} \]  

(9)

This parameter has a similar interpretation to \( Rc \), \( Re \), and \( Rf \). This variable gives an idea about the circular character of the basin [4].

Here \( P \) = watershed perimeter (km); \( A \) = watershed area (km\(^2\)); \( Al \) = area of circle having the same circumference as the perimeter of the watershed (km); \( \pi \) = pi, that is, 3.142; \( Lb \) = watershed length (km); \( D \) = diameter of a circle of the same area as the watershed area (km); \( Pu \) = circumference of watershed area (km). \( Lb \) can be defined in several ways: Eq. (1) the greatest straight-line distance between any two points on the perimeter; Eq. (2) the greatest distance between the outlet and any point on the perimeter; Eq. (3) the length of the main stream from its source (projected to the perimeter) to the outlet [16]. In this research, \( Lb \) were measured in two ways; Eq. (1) as the greatest straight-line distance between any two points on the perimeter and namely maximum of watershed length (\( Lbm \)), Eq. (2) the length of the main stream from its source to the outlet and namely river of watershed length (\( Lbr \)). The \( Lbr \) will use especially in case of ambiguous watershed shapes.

3. RESULTS AND DISCUSSION

The analysis was started by collecting the topographic map of the Serayu-Bogowonto river basin. Fifty sheets covering the river basin were selected. The river network, road network, contour lines, and administrative boundaries layers were selected. The layers were analyzed based on the GIS environment using ArcGIS 10.6.1. Finally, the shapefiles of the layers were created. The DEM has been obtained with a pixel size of 25 \( \times \) 25 m\(^2\) and an area of 12,600 km\(^2\). The DEM is shown in Fig. 2. Based on the DEM data, the boundaries of the Serayu-Bogowonto river basin and the watershed inside the river basin were analyzed. On the basis of the availability of an automatic water level recorder (AWLR), 17 rivers networks were selected. The availability of AWLR is very important, because in the future the research will continue to analyze the relationship between each watershed shape type and hydrological characteristics (time to peak, peak discharge, and hydrograph shape). By overlapping the selected rivers network and DEM, the 17 watersheds as samples in this research were developed and shown in Fig. 3. The geometry of the 17 watersheds was analyzed using GIS environment. Based on the watershed area, the largest watershed is Serayu watershed with an area equal to 714.004 km\(^2\) (WS13), and the smallest is Merden watershed with an area equal to 19.028 km\(^2\) (WS10). Table 1 shows the names and geometric data of the 17 watersheds.
Table 2 Watershed shape parameters

| No. | Watershed names   | P [km] | A [km] | Lb [km] | Al [km] | Pu [km] | D [km] |
|-----|-------------------|--------|--------|---------|---------|---------|--------|
|     |                   |        |        | Lbm     | Lbr     |         |        |
| WS 1| Badegolan         | 97.805 | 219.431| 27.110  | 26.803  | 761.228 | 52.511 | 16.712 |
| WS 2| Banjarnegeara     | 125.278| 688.553| 39.384  | 30.854  | 1248.938| 93.019 | 29.603 |
| WS 3| Bendung Dagan     | 25.501 | 31.173 | 8.190   | 7.084   | 51.750  | 19.792 | 6.299  |
| WS 4| Clangap Mrawu     | 75.804 | 229.739| 24.814  | 21.873  | 457.265 | 53.731 | 17.100 |
| WS 5| Kali Gending      | 76.340 | 252.085| 20.465  | 15.287  | 463.764 | 56.283 | 17.912 |
| WS 6| Kedung Gupit      | 47.117 | 70.904 | 17.212  | 16.648  | 176.664 | 29.850 | 9.500  |
| WS 7| Kober             | 45.435 | 50.950 | 19.211  | 17.572  | 164.274 | 25.303 | 8.053  |
| WS 8| Krasak Begaluh    | 71.083 | 183.585| 22.795  | 18.959  | 402.094 | 48.031 | 15.286 |
| WS 9| Madurejo          | 105.585| 312.325| 32.524  | 29.570  | 887.147 | 62.648 | 19.938 |
| WS 10| Merden           | 23.373 | 19.028 | 8.167   | 7.591   | 43.473  | 15.463 | 4.921  |
| WS 11| Pesucen          | 55.188 | 114.923| 18.216  | 18.194  | 242.367 | 38.002 | 12.094 |
| WS 12| Pungangan        | 103.852| 355.699| 36.052  | 28.349  | 858.265 | 66.857 | 21.277 |
| WS 13| Serayu           | 145.398| 714.004| 42.679  | 33.729  | 1,682.313| 94.723 | 30.145 |
| WS 14| Slinga S Klawing | 148.978| 566.371| 31.060  | 22.015  | 1,766.178| 84.364 | 26.848 |
| WS 15| Telomoyo         | 34.073 | 44.147 | 8.348   | 6.623   | 92.387  | 23.554 | 7.496  |
| WS 16| Tipar Kidul      | 77.861 | 181.294| 21.726  | 17.301  | 482.425 | 47.731 | 15.190 |
| WS 17| Winong           | 76.232 | 125.889| 28.929  | 27.218  | 462.450 | 39.774 | 12.658 |

Table 3 Watershed areal aspect values with Lbm

| No. | Watershed names   | KG | Rf | Sw | Rs | Rc | Re | Cc |
|-----|-------------------|----|----|----|----|----|----|----|
| WS 1| Badegolan         | 1.9| 0.3| 3.3| 0.5| 0.3| 0.6| 1.9|
| WS 2| Banjarnegeara     | 1.3| 0.4| 2.3| 0.7| 0.6| 0.8| 1.3|
| WS 3| Bendung Dagan     | 1.3| 0.5| 2.2| 0.8| 0.6| 0.8| 1.3|
| WS 4| Clangap Mrawu     | 1.4| 0.4| 2.7| 0.7| 0.5| 0.7| 1.4|

3.1 Kg

Musy (2001) classified watersheds into four categories: circular ($KG = 1.1$), oval ($KG = 1.2$), semi-oval ($KG = 1.3$), and elongated ($KG = 1.5$). On the basis of $KG$ value (Table 2), the 17 watersheds at Serayu-Bogowonto river basin were classified as follows. No watershed was classified as circular. One watershed was classified as oval (WS3), four watersheds were classified as semi-oval (WS2, 4, 5, 15), and the remaining watersheds as elongated (WS1, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17).

3.2 Rf

For $Rf$, the values between 0.13 and 0.26 show that the watershed shape is elongated [15]. Based on the $Rf$ spread values and the watershed figures, in this research, classification was conducted as follows. If $Rf ≥ 0.754$, then the watershed was classified as circular; $0.5 ≤ Rf < 0.754$, oval; $0.3 ≤ Rf < 0.4$, semi-oval; $Rf < 0.3$, elongated. The classification results show zero circular watersheds,
four oval watersheds (WS3, 5, 14, and 15), ten semi-oval watersheds (WS1, 2, 4, 8, 9, 10, 11, 12, 13, and 16), and three elongated watersheds (WS6, 7, and 17). Based on the figures of WS5, 14, and 15, the watershed shapes are near and exhibit circular shapes. To ensure clarity, \( Lbr \) will measured base on \( Lbr \) analysis and will be discussed later.

### 3.3 \( Sw \)

As previously mentioned [4], the larger the value of watershed shape, the more elongated it is. Table 2 shows that the highest value of \( Sw \) is 7.2, and the smallest is 1.6. Based on the spread values and watershed figures, the watershed shapes were classified in accordance with the following method. If \( 1.6 \leq Sw \leq 1.7 \), the watershed was classified as circular; \( 2.2 \leq Sw < 2.3 \), oval; \( 2.6 \leq Sw \leq 3.0 \), semi-oval; \( Sw > 3.0 \), elongated. The classification results revealed three circular (WS5, 14, and 15), two oval (WS2, and 3), five semi-oval (WS4, 8, 11, 13, and 16), and seven elongated watersheds (WS1, 6, 7, 9, 10, 12, and 17).

### 3.4 \( Rs \)

As mentioned above, \( Rs \) is interpreted similarly with \( Rf \), \( Rc \), and \( Re \). Consequently, the largest \( Rs \) can be predicted as circular watershed, whereas small \( Rs \) indicates an elongated shape. Based on the spread values of \( Rs \), in this research, the watershed shape was classified based on the following categories. If \( Rs = 0.8 \), the watershed was classified as circular; \( Rs = 0.7 \), oval; \( Rs = 0.6 \), semi-oval; and \( Rs = 0.5 \), elongated. The classification results revealed one watershed classified as circular (WS3), eight oval (WS2, 4, 5, 8, 10, 11, 13, and 15), six semi-oval (WS6, 7, 9, 12, 14, and 16), and two elongated watersheds (WS1 and 17).

### 3.5 \( Re \)

Altaf A., Meraj G., and Romshoo S. A., (2013) mentioned that \( Re \) with range values from 0.53 to 0.62 indicate that the watershed is elongated, and values less than 0.53 denote that an oval shape. Based on the spread values of \( Re \) (0.3–0.6), in this research, the watershed shape was classified based on the following categories. If \( Re = 0.6 \), the watershed was classified as circular; \( Re = 0.5 \), oval; \( Re = 0.4 \), semi-oval; \( Re = 0.3 \), elongated. The classification results indicated two circular (WS2, and 3), five oval (WS4, 5, 8, 11, and 15), six semi-oval (WS6, 9, 10, 12, 13, and 16), and four elongated watersheds (WS1, 7, 14, and 17).

### 3.6 \( Re \)

Rai P. K., Chandel R. S., Mishra V. N., and Singh P. (2018) mentioned that \( Re \) can be classified into five categories, namely, circular (0.9–1.0), oval (0.8–0.9), less elongated (0.7–0.8), elongated (0.5–0.7), and more elongated (<0.5). Classification using similar categories, namely, circular (0.9 \( \leq Re \leq 1.0 \)), oval (0.8 \( \leq Re \leq 0.9 \)), semi-oval (0.7 \( \leq Re \leq 0.8 \)), elongated (\( Re < 0.7 \)), was conducted in this research. The classification results identified three circular (WS5, 14, and 15), two oval (WS2, and 3), five semi-oval (WS4, 8, 11, 13, and 16), and seven elongated watersheds (WS1, 6, 7, 9, 10, 12, and 17). These results are the same with the findings obtained using \( Sw \).

### 3.7 \( Cc \)

Altaf A., Meraj G., and Romshoo S. A., (2013) mentioned that this watershed shape parameter gives an idea about the circular character of basins. In Table 2, the values in the \( Cc \) column were the same as those of \( KG \). Therefore, this classification method was conducted in the same manner as \( KG \) classification. The classification results showed zero circular, one oval (WS3), two semi-oval (WS4 and 15), and fourteen elongated watersheds.

Table 3 shows all the classification results. The table reveals that WS1 was classified as semi-oval based on the \( Rf \) and elongated based on \( KG \), \( Sw \), \( Rs \), \( Re \), and \( Cc \). Consequently, WS1 could be classified as an elongated watershed shape.

| Par | Watershed shape categories |
|-----|---------------------------|
|     | Cir. | Oval | Semi oval | Elongated |
| \( KG \) | None | WS3 | WS2, 5 | WS1, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 |
| \( Rf \) | None | WS3, 5, 14, 15 | WS1, 2, 4, 8, 9, 10, 11, 12, 13, 16 | WS6, 7, 17 |
| \( Sw \) | WS5, 14, 15 | WS2, 3 | WS4, 8, 11, 13, 16 | WS1, 6, 7, 9, 10, 12, 17 |
| \( Rs \) | WS3 | WS2, 4, 5, 8, 10, 11, 13, 15 | WS6, 7, 9, 12, 14, 16 | WS1, 17 |
| \( Re \) | WS2, 3 | WS4, 5, 8, 11, 15 | WS6, 9, 10, 12, 13, 16 | WS1, 7, 14, 17 |
| \( Cc \) | None | WS3 | WS2, 5 | WS1, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 |
WS2 was classified as circular based on Rc; oval based on Sw, Rs, and Re; semi-oval based on KG, Rf, and Cc. Therefore, WS2 could be classified as an oval watershed shape.

WS3 was classified as circular based on Rs and Rc; oval based on Rf, Sw, and Re; semi-oval based on KG, Rf, and Cc. Therefore, WS3 could be classified as an oval watershed shape.

WS4 was classified as oval based on Rs, and Rc; semi-oval based on KG, Rf, Sw, Re, and Cc. Therefore, WS4 could be classified as a semi-oval watershed shape.

WS5 was classified as circular based on Sw and Re, oval based on Rf, Rs, and Rc; semi-oval based on KG and Cc. Therefore, WS5 could be classified as an oval watershed shape.

WS6 was classified as semi-oval based on Rs and Rc; elongated based on KG, Rf, Sw, Re, and Cc. Therefore, WS6 could be classified as an elongated watershed shape.

WS7 was classified as semi-oval based on Rs and elongated based on KG, Rf, Sw, Re, and Cc. Therefore, WS7 could be classified as an elongated watershed shape.

WS8 was classified as oval based on Rs and Rc; semi-oval based on Rf, Sw, and Re; elongated based on KG and Cc. Therefore, WS8 could be classified as a semi-oval watershed shape.

WS9 was classified as semi-oval based on Rf, Rs, and Rc; and elongated based on KG, Sw, Re, and Cc. Therefore, WS9 could be classified as an elongated watershed shape.

WS10 was classified as oval based on Rs; semi-oval based on Rf and Rc; elongated based on KG, Sw, Re, and Cc. Therefore, WS10 could be classified as an elongated watershed shape.

WS11 was classified as oval based on Rs and Rc; semi-oval based on Rf, Sw, and Re; elongated based on KG and Cc. Therefore, WS11 could be classified as a semi-oval watershed shape.

WS12 was classified as semi-oval based on Rf, Rs, Rc, and elongated based on KG, Sw, Re, Cc. Therefore, WS12 could be classified as an elongated watershed shape.

WS13 was classified as oval based on Rs; semi-oval based on Rf, Sw, Re, and Re; elongated based on KG, and Cc. Therefore, WS13 could be classified as semi-oval watershed shape.

WS14 was classified as circular based on Sw and Re; oval based on Rf; semi-oval base on Rs; elongated based on KG, Rc, and Cc. Therefore, WS14 could be classified as an elongated watershed shape.

WS15 was classified as circular based on Sw, and Re; oval based on Rf, Rs and Rc; semi-oval based on KG; elongated based on Cc. Therefore, WS15 could be classified as an oval watershed shape.

WS16 was classified as semi-oval based on Rf, Sw, Rs, Re, and Re and elongated based on KG and Cc. Therefore, WS16 could be classified as a semi-oval watershed shape.

WS17 was classified as elongated based on KG, Rf, Sw, Rs, Re, and Cc. Therefore, WS17 could be classified as an elongated watershed shape.

In summary, the classification results for each category of watershed shape at the Serayu-Bogowonto river basin are shown in Table 4. Based on the data as shown in Table 3 and given the related figures, there are some mistook classification. For example, the WS5 and WS14 can be interpreted were mistook classification. Based on the relating figures, WS5 and WS14 is near to circular shape, but the result was classified to oval and elongated. The reason is how to define the watershed length. If the watershed length defined as Lbm, the angle to view the watershed shape is different from view based on Lbr. For illustration, both views are shown in Fig.4. From this figure it is clear that WS5 and WS14 are near with oval and elongated if the angle view base Lbm. But if the angle of view based on Lbr, both watersheds are near with circular shape. To clarify this case, the watershed classification was done based on Lbr watershed distance. The watershed shape parameters base on Lbr is shown in Table 5. The classification was done in the same ways with the classification based on Lbm as described above. The classification was summarized in Table 6 and represented in Fig.5.

| Watershed shapes | Watershed No. |
|------------------|---------------|
| Circular         | None          |
| Oval             | WS2, 3, 5, 15 |
| Semi-oval        | WS4, 8, 11, 13, 16 |
| Elongated        | WS1, 6, 7, 9, 10, 12, 14, 17 |

Table 4 Watershed shapes classification with Lbm

Fig.4 Watershed shapes with Lbm and Lbr (a)
Due to the river as the main view for watershed shape classification, classification using $L_{br}$ is better than using $L_{bm}$. From river the watershed area can be defined. Watershed is the basic area for analyzing hydrological characteristics. Therefore, classification based on $L_{br}$ is closed related to the hydrological characteristic analysis. All the analysis of the watershed geometries was analyzed using GIS environment and was done smoothly.

Table 5 Watersheds shape parameters based on $L_{br}$

| No. | Watersheds shape factors values |
|-----|---------------------------------|
|     | $KG$   | $R_{f}$ | $S_{w}$ | $R_{s}$ | $R_{e}$ | $R_{c}$ | $C_{c}$ |
| WS 1 | 1.9    | 0.3     | 3.3     | 0.5     | 0.3     | 0.6     | 1.9     |
| WS 2 | 1.3    | 0.7     | 1.4     | 0.7     | 0.6     | 1.0     | 1.3     |
| WS 3 | 1.3    | 0.6     | 1.6     | 0.8     | 0.6     | 0.9     | 1.3     |
| WS 4 | 1.4    | 0.5     | 2.1     | 0.7     | 0.5     | 0.8     | 1.4     |
| WS 5 | 1.4    | 1.1     | 0.9     | 0.7     | 0.5     | 1.2     | 1.4     |
| WS 6 | 1.6    | 0.3     | 3.9     | 0.6     | 0.4     | 0.6     | 1.6     |
| WS 7 | 1.8    | 0.2     | 6.1     | 0.6     | 0.3     | 0.5     | 1.8     |
| WS 8 | 1.5    | 0.5     | 2.0     | 0.7     | 0.5     | 0.8     | 1.5     |
| WS 9 | 1.7    | 0.4     | 2.8     | 0.6     | 0.4     | 0.7     | 1.7     |
| WS 10 | 1.5   | 0.3    | 3.0     | 0.7     | 0.4     | 0.6     | 1.5     |
| WS 11 | 1.5   | 0.3    | 2.9     | 0.7     | 0.5     | 0.7     | 1.5     |
| WS 12 | 1.6   | 0.4    | 2.3     | 0.6     | 0.4     | 0.8     | 1.6     |
| WS 13 | 1.5   | 0.6    | 1.6     | 0.7     | 0.4     | 0.9     | 1.5     |
| WS 14 | 1.4   | 1.2    | 0.9     | 0.6     | 0.3     | 1.2     | 1.8     |
| WS 15 | 1.4   | 1.0    | 1.0     | 0.7     | 0.5     | 1.1     | 1.5     |
| WS 16 | 1.6    | 0.6    | 1.7     | 0.6     | 0.4     | 0.9     | 1.6     |
| WS 17 | 1.8    | 0.2    | 5.9     | 0.5     | 0.3     | 0.5     | 1.9     |

Table 6 Classification of watershed shape based on $L_{br}$

| Par | Watershed shape categories |
|-----|---------------------------|
|     | Circ. | Oval | Semi oval | Elongated |
| $KG$ | None | WS 2, 3, 14, 15 | WS 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17 |
| $R_{f}$ | WS 5, 14, 15 | WS 2, 3, 4, 8, 13, 16 | WS 1, 6, 9, 10, 11, 12 |
| $S_{w}$ | WS 2, 3, 5, 13, 14, 15, 16 | WS 4, 8, 12 | WS 9, 10, 11 |

4. CONCLUSION

The watersheds at the Serayu-Bogowonto river basin were classified into four categories, i.e.,

1. Circular
2. Oval
3. Semi-oval

Fig. 4 Watershed shapes with $L_{bm}$ and $L_{br}$ (b)

Fig. 5 Watershed shape classification (a)
4. Elongated

Fig.5 Watershed shape classification (b)

circular, oval, semi-oval, and elongated. From the result and discussions, it can be concluded that the length of a watershed is a very important parameter in watersheds shapes classification. The watershed shape is classified depending on the angle of view. Based on the maximum length of the watershed, from the 17 watersheds, none were classified as circular, 4 as oval, 5 as semi-oval, and 8 as elongated shapes. Based on the length of the river, the watersheds were classified as 5 as circular, 3 as oval, 5 as semi-oval, and 4 as elongated shapes. Finally, GIS is a powerful tool for the manipulation and analysis of spatial information relating to watershed morphometric parameters.

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