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Research paper

Determine Environmental Structure Condition of River Sub System of Palembang City's Rivers using Geospatial Analysis

Fathoni Usman[1], Sumi Amariena Hamim[2]*

[1]Institute of Energy Infrastructure, Universiti Tenaga Nasional, Selangor, Malaysia
[2]Universitas Indo Global Mandiri, Palembang, Indonesia
**Corresponding author E-mail: sumi_amariena@uigm.ac.id*

Abstract

This paper present geospatial analysis to determine the environmental structure of the river sub-system of Palembang City where 70% of the city is located at lowland with elevation from 0 to 5 m above mean sea level. This lowland terrain condition induced problem of water puddle and flood during a rainfall event. A landscape ecological approach and spatial analysis approach of river sub system (RSS) morphometry characteristic were conducted to determine the environmental structure condition of the RSS. The data used to generate the DEM was the height data obtained from the map of the city line on a scale of 1:1000 with stereophotogrammetric digital technique. The line map contains spot height data made every 20 m distance in the field. From this study, new delineation of RSS boundaries was produced and gave different catchment areas. It is found that the perimeter of the RSS and the mean value of bifurcation ratio determined the value of runoff in the RSS.

Keywords: *Environmental structure; morphometric characteristics; river sub-system; geospatial analysis; multiple linear regression*

1. Introduction

Land use in the structure and pattern of urban space is a modification of the natural environment, transformed into a social environment and aquaculture environment. Land utilization is a spatial element that can be shown both location and size in a sub-system environment of the river system. River sub-system (RSS) is a part of a river area (in an urban area) functions to accommodate, store and drain water in a single drainage system. The interaction of the relationship between the composition of the natural environment will affect the condition of the RSS. The balance of arrangement of elements forming an RSS environmental structure could be measured from the condition of the infrastructure of the area. A balance between land-use change and water-carrying capacity as well as infrastructure capability in the RSS area will determine whether the environmental conditions of the RSSs are good.

Palembang is the lowland area and most of the river in the city its water level is influenced by tidal from Musi River. Palembang has a drainage system that discharges into Musi River and into the district of Banyu Asin. The results of several studies conducted by JICA, BAPPEDA of Palembang collaboration with LAPI ITB, there are 19 drainage systems within Palembang area. There are 16 drainage systems discharge into Musi River and 3 drainage systems discharge into Banyu Asin's district area.

The problem of flooding that occurs almost every year in Palembang is caused by the ecosystem imbalance of RSS environmental structure. Inundation or flooding is not only caused by high rainfall or tidal influences, but also by some physical factors, such as low water carrying capacity, changes in land function, reduced green open space, inadequate urban drainage infrastructure and the granting of Building Permit (IMB) which is not in accordance with its designation. Physical factors that contributed to flooding event is the topographic condition of Palembang. It is in the lowland structured area (depression) with the height of the area around the river is less than 5 m above sea level. Geomorphology structure of Palembang City area formed on several branches of the river that discharged through the city area. Such conditions, resulting rivers in the most area of the city will always be influenced by river tides.

Research and efforts to control the inundation in Palembang have been done with the spatial, structural and non-structural approach in urban areas in accordance with the regional characteristics. The data and methods used by some previous researchers were varied, all of which still emphasized the structural approach. While the non-structural approach to land use regulation has never been done. This paper presents the This paper present geospatial analysis to determine the environmental structure of the RSS of Palembang City where 70% of the city is located at lowland with elevation from 0 to 5 m above mean sea level.

2. Literature Study

Urban development usually follows natural ecosystem conditions. Uncontrolled development of a city due to unevenness of spatial arrangement with environment caused problems of degradation of the environmental quality of the city. One aspect of uncontrolled development or growth of the city is reflected in the use of high ecological value areas that are utilized for urban activities, regardless of the importance of quality and ecological and environmental functions [1].

One important thing of the natural environment contained in the city environment is a river or water body. River or water body will be adversely affected by municipal activities, such as occupation and reduction of floodplains, pollution of water bodies and soils, biodiversity loss, urban land intensification and expansion, water

management complexity, etc. [2]. These impacts negatively affect human health, the imbalance of urban ecology and the image of the city and potentially negative effects on the urban environment.
Changes in land cover, especially land cleared indicating during the 11 years (2002 - 2013) there has been significant land development. Visually, the development looks tend to move away from the city centre and leads to the northern part of Palembang. With the new development, the developed area has increased while the vegetation area and the water body have decreased. The area of built land increased by 3,112.92 ha (51.13%) from the area in 2002, while the vegetation area decreased by 4,820.78 ha (20.17%). The vacant land area and water bodies each also increased by 486.86 ha (18.99%) and 1,221.01 ha (32.54%). Thus, the area of land built reached about 9201.35 ha or 25.34 % of the total area of Palembang City [3].
From several studies related to the handling of puddles or floods that occurred in RSS of Bendung River, Shynta as in [4] tried to analyse and evaluate the operation and maintenance by using Duflow hydrodynamic modelling. Two approach scenarios are used to solve the inundation problem, which is by normalizing the channel and constructing several dikes. The second scenario is by operating pumps and sluice buildings. The results obtained are the water pump and maintenance operation periodically building water gate will accelerate the reduction of inundation that occurs in the RSS of Bendung River.
Gustini as in [5], using Duflow's hydrodynamic modelling model the environmental conditions of RSS in developing flood and drainage protection in the Jakabaring RSS. The approach used is structural, that is by making scenarios of installation of water gates and sliding doors by changing the width of 1 m and 3 m openings on the open channel. The results obtained, can reduce the extent of inundation from 23% to 19%. If three gates are used and the door openings up to 3 m, it can prevent flooding in the area.
Using Duflow modeling to analyze flood protection in Gandus's agropolitan development area, Sylvia as in [4] undertook several scenarios that considered the influence of the Musi River water rise and 0.5 cm of land per year. The result obtained states that the influence of the Musi River's tides greatly affects the occurrence of inundation occurring at some point on the RSS of Gandus River. Recommendations to reduce tidal influence need to be built of dikes and use of water gates in the study area.

3. Methodology

In this study, landscape ecological approach and spatial analysis approach of RSS morphometry characteristic were conducted. Furthermore, statistical analysis was performed to determine effect of the variables in the morphometry characteristic to the runoff value.

3.1. The Ecological Landscape

The ecological landscape of the sub-river area of the Palembang City river system was used to describe the characteristics of the overall RSS environment. This approach was used to assess the characteristics of RSS morphometry. The spatial approach will be obtained the function of ecosystem and interaction between the river and urban land use and can describe the condition of land by mapping the natural structure and ecosystem.
This approach was used to interpret land parameters of selected landscape components, i.e. slope gradient interpretation, soil infiltration potential, surface cover vegetation and land surface conditions supporting land drainage as well. Interpretation of potential soil infiltration to estimate the potential of soil infiltration of a region is determined through hydromorphological and hydromorfometric approaches with consideration of land surface conditions. Interpretation of surface drainage was approximated from flow density conditions. After the four selected components are interpreted and then classified.

3.2. Characteristic Analysis of Morphometry of River Sub-System

Characteristics of morphometry of river sub-system is obtained from DEM extraction and mathematical calculation which consist of 14 parameters of morphometry i.e. total length of river order, length of main river, width and perimeter of river sub-system, river branching level, flow density, frequency flow, texture comparison, relief, roughness rate, concentration time and runoff coefficient. The 14 variables were used to perform multivariate statistical analysis such as factor analysis, discriminant analysis and regression analysis

3.3. Study Area

Palembang is a low-lying land city with a height around the river less than 5 m above sea level. Geographically, the position of Palembang lies between $2^o52'$ to $3^o5'$ South Latitude and $104^o37'$ to $104^o52'$ East Longitude. Administratively Palembang City is bordered by benteng Base Village, Gasing Village and Kenten Village, Talang Kelapa Subdistrict, Banyu Asin Regency on the north side. Banyu Asin on the east side. Regency of Bakung Sub-District Indralaya, Ogan Ilir District and Gelumbang District Muara Enim Regency on the south side. Sukajadi Village, Talang Kelapa Subdistrict, Banyu Asin Regency on the west side
The city of Palembang has an area of 401 km^2 divided into 17 districts and 107 villages. Tropical climate conditions with two seasons of rain and drought. Average temperatures range from 26^oC to 29^oC. The rainy season occurs in December to March due to the blowing of the northwest monsoon. In the rainy season, the average maximum rainfall is 77 mm with 18-19 rain days per month. When this peak precipitation caused some areas in the city of Palembang flooded. In April and September, precipitation decreased gradually and became known as the transitional season and the minimum rainfall occurred in August followed by the dry season. The average evaporation ranges from 85 – 124 mm per month.
Based on Geomorphology Map of Palembang city and Peta Unit of Land, the condition of the soil layer in Palembang City is clay, sandy clay, marlstone and sandy marlstone. State stratigraphy of Palembang City is divided into 3 parts. The alluvial and Swamp units located in Seberang Ulu and swaps in the East and West parts of the City of Palembang. The central Palembang unit has a clay and impermeable clay scattered in the North of Kenten, Talang Betutu and Sungai Ringgit (Banyu Asin Regency). While in the South spread to Indralaya (Ogan Ilir Regency) and Gelumbang (Muara Enim Regency). The Palembang Bawah spread in the inside of Palembang City with the direction extends to the Southwest and Southeast is a series of anticlines.

4. Analysis and Discussion

4.1. River Sub-System Boundary

The delineation process of the RSS boundary of Palembang City in this study was based on the flow pattern and the flow direction. The flow pattern and flow direction are obtained from the Digital Elevation Model (DEM) using high point data of 25 cm intervals for 5 m DEM resolution. The altitude data was obtained from the 1:1,000 scale map in 2003 and 2004 on the interpretation of the 1:5,000 aerial photograph with stereophotogrammetry technique. The topographic parameters derived from DEM provide information that exists on the characteristics of a surface element. From the spot height data, more accurate high different was interpolated with 25 cm interval and 5 m pixel resolution especially for analysis at lowland area.

Fig. 1: The DEM generated based on high data using stereophotogrammetric digital technique

The process of delineation of the RSS of Palembang City in this study is based on the flow pattern and the flow direction. Extraction of drainage network from DEM based on gravity process, water flows from upstream to downstream and assumed no interception, evaporation and groundwater occur. With a 5 m DEM resolution, the description of drainage network in hilly areas looks better than in relatively more sloping floodplains. The DEM extraction results into nine RSS with the direction of flowing into the Musi River in the area Ilir of Palembang City. The nine RSS is located at coordinates (9,678,000 m - 9,664,700 m) Y and (459,000 m - 483,800 m) X, UTM WGS 84 Zone 48 Southern Hemisphere with total area of 116 km^2 as in Fig. 2.

Fig. 2: The 9 RSS in the Ilir district of Palembang City

The catchment area of the 9 RSS compared with previous studies is listed in Table 1. The delineation results of the RSS boundaries constructed based on DEM with 25 cm intervals and 5 m resolution are more detailed than the RSS boundaries of previous studies that have been used by the Palembang City government. As a comparison, in delineating the RSS boundary as conducted by BWSS in 2008 for the RSS boundary of Bendung River, it used the road as the RSS boundary as in Fig. 3. There was an area which its flow pattern (runoff discharge) in the RSS of Bendung River was not included in the hydrodynamic model. This will result in the difference in handling patterns in the RSS of Bendung River.

Table 1: Catchment area of the 9 RSS

River Sub System	Catchment Area (km^2)			
	JICA 2003	BAPPEDA 2004	BWSS VIII 2008	This Study
Gandus River	23.94	23.94		28.67
Lambidaro River	50.52	52.09		65.25
Boang River	8.67	8.67		9.69
Sekanak River	11.39	11.39		10.39
Bendung River	19.19	22.59	15.4	19.60
Lawang Kidul River	2.34	2.86		2.57
Buah River	10.42	10.82		9.92
Juaro River	6.86	6.86		3.45
Selincah River	4.83	4.83		11.42

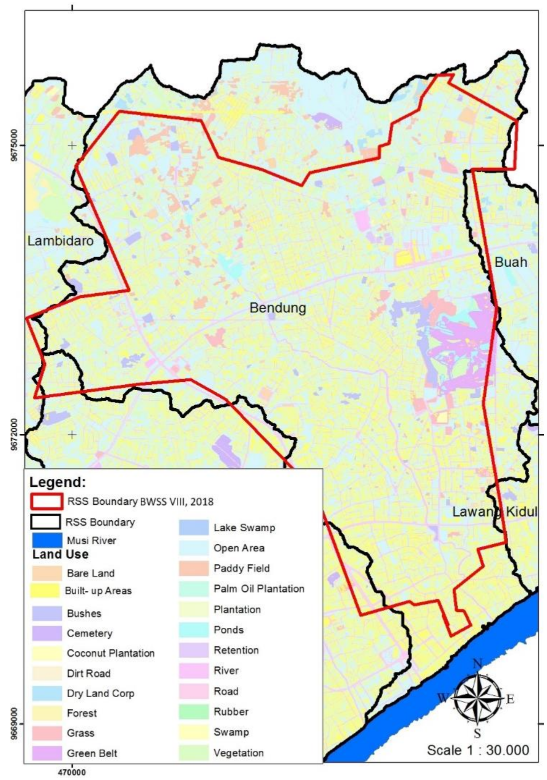

Fig. 3: The updated RSS boundary based on this study

4.2. The Result of Mapping of Land Unit at RSS of Palembang City

The land unit mapping in RSS is a slope map, land use map, land map and land unit map. The digital elevation model of the study area is presented in Fig. 3. The study area height ranged from 0 – 36 m above sea level. In the area around the Musi River or the downstream part of the sub river system in the dominance of the height less than 5 m above sea level. Hilly areas in the north with varying heights ranging from 28 – 36 m above sea level.

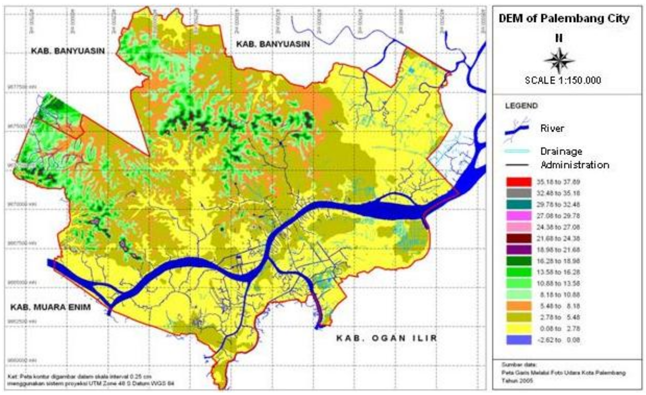

Fig. 4: The Palembang City elevation model

The slope in the study area relatively flat. It is predominantly 0% – 3% especially in the area along the Musi river and in the Seberang Ulu region, whereas the slope ranges from 5% – 8% along upstream of the RSS of Gandus, Lambidaro, Sekanak and Bendung River as shown in Fig. 5. The importance of knowing the relief and measuring the slope of an SRSS as a hydrological parameter is to know the peak flood increase. The high relief (*Bh*) of the RSS indicates the condition of flow gravity, low infiltration and runoff height. The RSS of Gandus River has the highest relief, which is 35.75 m and the lowest is in the RSS of Selincah River.

The land use pattern in the study area is taken from Palembang City Line Map on the scale of 1:1000. It is 51.7% of non-urban land use, such as swamps and plantation. As for urban areas consisting of settlements and economic activities ranged from 48.3%. In detail, the distribution of land use area of study can be seen in Fig. 6.

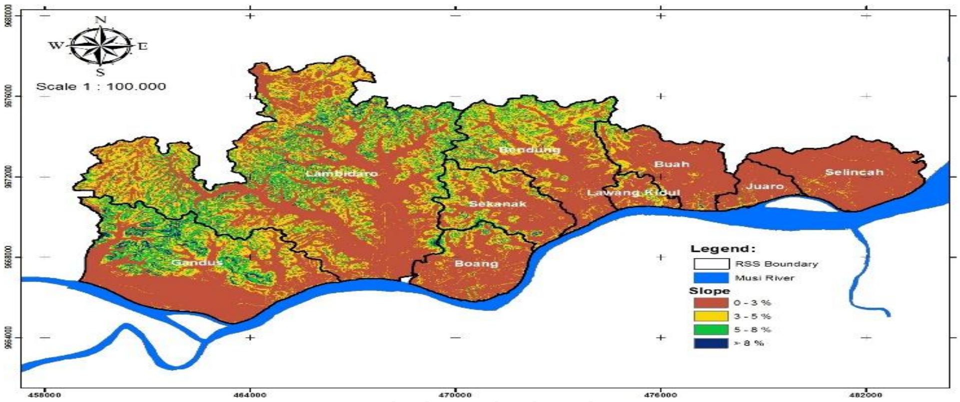

Fig. 5: The slope within the study area

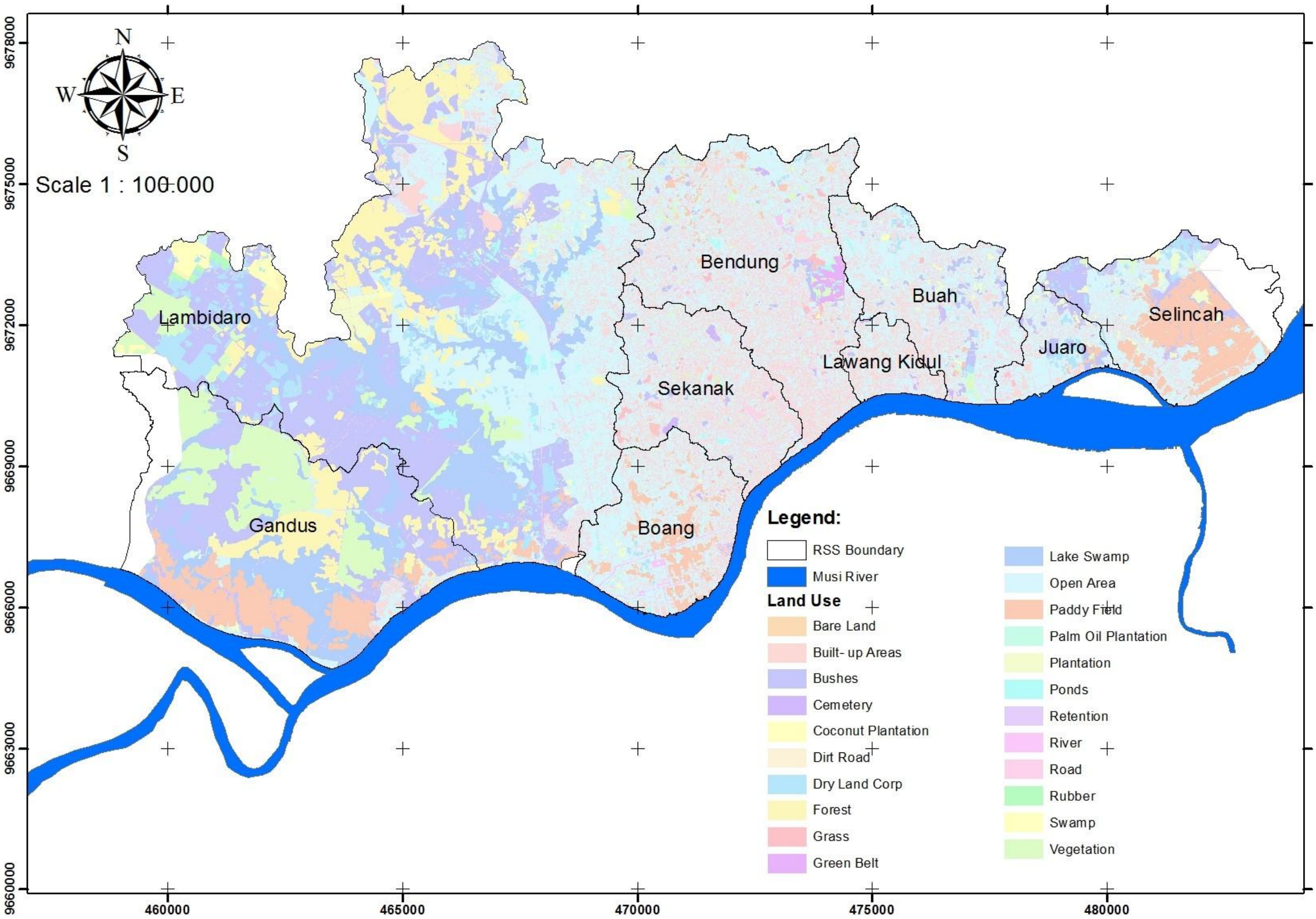

Fig. 6: The landuse map of Palembang City

Based on the Map of Land of Palembang with a scale of 1:250,000 issued by Soil Research Center and Agroclimate, IPB Bogor in 1990, the type of land in Palembang City consists of six types i.e. narrow with the slopes of less than 3% (some downstream areas of the RSS of Gandus, Lambidaro and Boang River), smooth sedimentary rocks with 3% – 8% wavy slopes (central and upstream SSS Gandus, Lambidaro and Boang River), urban residential areas and development areas along the RSS of Sekanak, Bendung, Lawang Kidul, Buah and Juaro River, fine sedimentary rocks with slopes of less than 8% (the RSS of Sekanak, Bendung, Lambidaro and Selincah River), alluvial plains above the water surface (RSS of Selincah River) and yellow alluvial plain upstream section of RSS of Selincah River.

The RSS land unit map is a map of the distribution of coefficient of runoff (C) per sub RSS. The magnitude of C obtained from the analysis varies from 0.28 to 0.70. This C value indicates that 30% – 62% of the total rainfall that falls on the RSS of the study area is still being perceived, especially in the RSS of Lawang Kidul River, which runs only 28%. While for the RSS of Bendung River and Sekanak River, 70% of the total rainfall became runoff followed by the RSS of Buah, Lambidaro and Juaro River around 60%. In the RSS of Bendung, Lambidaro, Buah and Sekanak River almost every rainfall event inundation was experienced in some locations with height varies up to 60 cm. The higher C values will result in higher runoff to the area [6]. The total coefficient of runoff per RSS was then used as input to calculate runoff discharge. the resulting value range of distribution is the C value per pixel of 5 m x 5 m from the analysis of the unit of land. In the wake area (red in color) the C value is greater than the unvegetated area with the blue color as in Fig. 7.

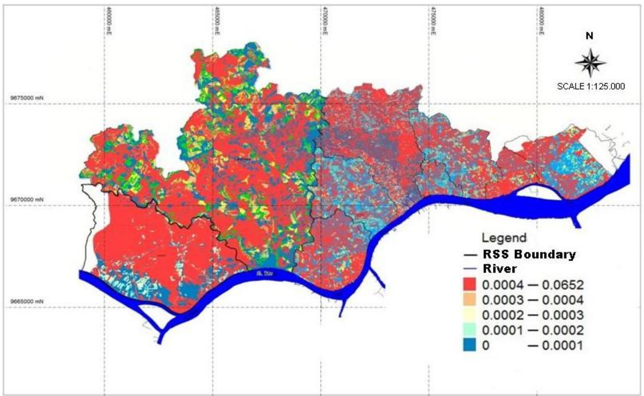

Fig. 7: The RSS land unit map of runoff coefficient, *C*

4.3. Environmental Structure Condition of Palembang City River System

This study analyzed the morphometric aspects of the RSS. It is considered as the most viable method for river basin management. Table 3 and Table 4 summarized the result of the morphometric analysis. It started with the determination of river order is an initial step in the drainage analysis of an RSS. It is defined as a measure of the position of rivers in the tributary hierarchy [7]. The results of river order analysis that is the length and number of river order depend on the size of RSS. The RSS of Lambidaro River has the highest order river of 1 – 4. The higher the river order indicates the more branches of the river and closely related to the flow of the river. A large river flow will be found in river systems that have the highest river order. The more number of river flow order 1 in an RSS then the peak discharge will be greater. The RSS of Bendung River and Sekanak River have river order 1 – 3, while for river order 1 – 2 is identified on the RSS of Boang, Buah, Gandus, and Selincah River. The number of river orders in the most studied areas is identified in the RSS of Lambidaro, Gandus, Bendung, Boang and Selincah River while the least is the RSS of Juaro River.

The classification of the obtained river order is used to determine the level of river branching in each RSS. The average branching ratio (*Rb*) is the ratio of the number of segments of a given stream to the number of first-order river segments above it. The result of the analysis of RSS drainage network using the Strahler method gave *Rb* value ranged from 1.2 – 12.3. The *Rb* value < 3 is assumed to be abnormal with high flood peaks and slow decline, present in RSS of Boang, Buah, Juaro, Lawang Kidul, Sekanak dan Selincah River. The *Rb* values between 3 – 5 are called normal with moderate flood peaks and moderate decreases found in RSS of Bendung and Gandus River. According to Ozdemir in [8], for the range of values of *Rb* between 3 – 5 for a sub-basin, the influence of geological structures can be neglected. It suggested that the geological structure of the RSS of Gandus River and Bendung River has little effect on the drainage network. While the *Rb* value > 5 is assumed to be abnormal with a high flood peak with a short decrease could be observed in the RSS of Lambidaro River. The RSS of Lambidaro River with an impressive *Rb* value of 12.3 has a rocky surface with a steep slope corresponding to a *Bh* value of 27.5 m and the slope of 0% – 70%.

The shape and extent of RSS in the study area predominantly elongated shape with *Rc* value < 0.33. The received rainfall and collecting water to reach the outlet takes a relatively long time, resulting in a substantial increase in hydrograph flow and slow decline. Only two RSS i.e. the RSS of Buah River and Selincah River tend to be elliptical with *Rc* value of 0.4.

From the analysis results obtained, the RSS of Bendung River has the highest flow frequency (*Fs*) value of 2.5 and Lambidaro River 1.6. In general, the high *Fs* corresponds to the impermeability of materials in the subsurface, vegetation, high relief conditions and low infiltration capacity [7].

Table 3: Catchment area of the 9 RSS

No	RSS	Linear Parameters											Q (m^3/s)
		n_1	n_2	n_3	n_4	*Nu*	*Lo* (km)	*Lr* (km)	*Rb*			*mean Rb*	
1	Bendung River	25	21	4		50	17.1	8.9	1.2	5.3		3.2	25.87
2	Boang River	10	4			14	6.1	3.8	2.5			2.5	11.78
3	Buah River	6	5			11	6.7	5.4	1.2			1.2	12.9
4	Gandus River	15	4			19	19.6	4.7	3.8			3.8	34.05
5	Juaro River	2				2	2.03	1.7				2.0	4.29
6	Lambidaro River	47	19	34	1	101	92.8	22.5	2.5	0.6	34	12.3	1.36
7	Lawang Kidul River	1				1	1.2	1.2				1.0	13.71
8	Sekanak River	5	2	2		9	8.2	4.6	2.5	1.0		1.8	12.27
9	Selincah River	5	2			7	5.3	1.9	2.5			2.5	81.19

n_{1-4} = River order; *Nu* = Total river order; *Lo* = Length of river order; *Rb* = Bifurcation Ratio; *Q* = Runoff value

Table 4: Catchment area of the 9 RSS

No	RSS	Area Parameters						Relief Parameters				*nD* (%)
		A (km^2)	*P* (km)	*Dd* (km/km^2)	*Fs* (km^{-1})	*T*	*Bh* (m)	*Rn*	*Tc* (min)	*C*	*Rc*	
1	Bendung River	19.6	36.4	0.9	2.5	0.7	24.5	23.6	18.7	0.70	0.19	9.29
2	Boang River	9.7	23.3	0.6	1.4	0.4	24.75	24.1	6.1	0.63	0.23	17.84
3	Buah River	9.9	17.8	0.7	1.1	0.3	19.75	19.1	15.3	0.69	0.40	10.11
4	Gandus River	28.7	35.4	0.7	0.7	0.4	35.75	25.4	19.1	0.63	0.29	75.04
5	Juaro River	3.4	10.4	0.6	0.7	0.2	5.75	5.2	16.5	0.66	0.40	26.87
6	Lambidaro River	65.3	56.9	1.4	1.6	0.8	27.75	26.3	28.5	0.66	0.25	51.87
7	LawangKidul River	2.6	12.1	0.5	0.4	0.1	14.75	14.3	3.1	0.28	0.22	0.72
8	Sekanak River	10.4	24.1	0.8	0.8	0.2	19.5	15.2	13.3	0.70	0.22	5.00
9	Selincah River	11.4	20.1	0.5	0.6	0.3	2	0.9	26	0.57	0.36	58.24

P = Perimeter; A = Area; *Lr* = Length of river; *Dd* = Drainage density; *Fs* = Frequency stream;
T = Texture ratio; *Bh* =Basin Relief; *Rn* = Ruggedness number; *Tc* = Time concentration; *nD* = Non-developed area

The flow density (*Dd*) of the RSS in the study area ranges from 0.46 to 1.42 km/km^2. The *Dd* value describes the potential for runoff, infiltration capacity, climatic conditions and land cover on an RSS [8]. The *Dd* value is also the result of the interaction of several factors that control surface runoff and affect the output of water flow and sediment from the drainage of the RSS. The highest flow density in the RSS of Lambidaro River was 1.42 km/km^2 with normal water storage conditions, with a puddle of inundation but only less than 2% of the total sub-system of the river. In the RSS of Bandung, Sekanak, Gandus, Buah, Boang, Juaro, Lawang Kidul and Selincah River, *Dd* value less was than 1 km/km^2.

Texture comparison value (*T*) is the ratio between the order to one river system with a perimeter of RSS. The highest *T* score of more than 0.4 is found in the RSS of Lambidaro, Bendung, Boang and Gandus River. This illustrates that the texture value depends on the underlying geological conditions, the infiltration capacity of the rock and the sub-system relief of the river [8]. The relief conditions in the RSS of Lambidaro, Bendung, Boang and Gandus River ranged from 24.5 to 35.75 m with a soil infiltration capacity for surface layers in a low-grade class was very low with low class dominance. Geological conditions represented by soil types that are the result of weathering of rocks contained in this RSS has a tendency as a clay and alluvial soil. Low infiltration less than 28 mm/hr tends to higher surface runoff value.

In the RSS of Juaro River, a low relief condition of 5.75 m provides the potential for high infiltration, but alluvial soil control reduces the infiltration capacity to low to very low, so rainwater tends to surface runoff. While in the RSS of Lawang Kidul River has low *T* value 0.08 with relief condition of 14.75 m but due to the dominance of alluvial soil type, the normal infiltration capacity has implications to the relatively low surface runoff.

Texture ratio (*T*) is influenced by geological conditions, relief and infiltration capacity [8]. Based on the availability of condition and geological data and the corresponding infiltration capacity is represented by the value of the runoff coefficient. While the relief is represented by the high difference (*Bh*). The result of cluster analysis between variables *T*, *Bh* and *C* on the nine RSS shows that the tendency of the RSS in the study area can be grouped into 3 groups based on the relief condition. This explains that the value of the texture ratio is strongly influenced by the relief condition, while the value of the rock or soil type and infiltration value (which is represented by the runoff coefficient value) did not show a strong influence on the texture value of the ratio.

The increase in peak discharge is the result of increased efficiency between relief conditions and flow density [8]. The highest roughness number (*Rn*) values are found in the RSS of Gandus, Lambidaro, Boang and Bendung River. The RSS with high *Rn* values indicates more susceptible to increase the peak discharge. The roughness rate obtained from the multiplication of *Bh* and *Dd* values has a very strong correlation between the variables with the correlation values of 0.836 and 0.901 respectively. The roughness number (*Rn*) did not have a strong correlation with runoff coefficient but it is strongly influenced by runoff value (*Q*) with a very strong correlation value of 0.908. Table 5 lists the correlation value of *Dd*, *Bh*, *Rn*, *C* and *Q* from the 9 RSS.

Table 5: The correlation value

Variables	*Dd*	*Bh*	*Rn*	*C*	*Q*
Dd		0.535	0.901	0.436	0.931
Bh	0.535		0.836	0.259	0.560
Rn	0.901	0.836		0.358	0.908
C	0.436	0.259	0.358		0.319
Q	0.931	0.560	0.908	0.319	

The highest time concentration *Tc* value in the RSS of Lambidaro River was 28.5 minutes followed by the RSS of Bendung River i.e. 18.7 minutes and the RSS of Buah River with *Tc* value of 15.3 minutes. This illustrates the longest time to drain water from the furthest distance to its outlet. The morphometric parameters in each RSS are correlated with each other's drainage network have determined the effect on the main channel thoroughly.

4.4. Multiple Linear Regression Analysis between Run-off and Morphometry Characteristic Variables of RSS

Regression analysis is conducted to see the relationship and how much influence between runoff variable (*Q*) as the dependent variable with the morphometric characteristics of the RSS. Characteristics of morphometry variables which become independent variable in this multiple linear regression analysis are 7 variables based on the discriminant analysis result. Those are the length of river order (*Lo*), river length (*Lr*), area (*A*), perimeter (*P*), mean *Rb*, drainage density (*Dd*) and texture ratio (*T*). Only two variables i.e. perimeter of the RSS (*P*) and mean *Rb* combination has no symptoms of multicollinearity compared with other independent variables. Table 6 shows the summary of the multilinear regression.

Table 6: Multiple linear regression summary

N = 9	Regression Summary for Dependent Variable: Q R = 0.991; R² = 0.982; Adjusted R² = 0.977 Std.Error of estimate: 3.6723				
	b*	Std.Err.	b	Std.Err.	p-value
Intercept			-11.184	3.218	0.013
P	0.446	0.118	0.746	0.197	0.009
mean Rb	0.573	0.118	4.012	0.827	0.003

The regression expression for runoff value, *Q* can be expressed as in (1):

$$Q = 0.446P + 0.57\ meanRb - 11.184 \quad (1)$$

The negative intercept value is a cumulative condition that corrects the two variables i.e. *P* and mean *Rb* indicating the ability of surface infiltration. Fig.8 shows the scatter plot of predicted and observed values based on (1). The regression analysis shows that the perimeter of RSS (*P*) is very influential to the amount of runoff in the RSS. The RSS which has equal size of area to other RSS but different in shape, would not always provide an equal runoff (flood discharges) [9], [10]. The shape of RSS can be represented by the perimeter of the RSS, the amount of runoff is more affected by the perimeter of the RSS.

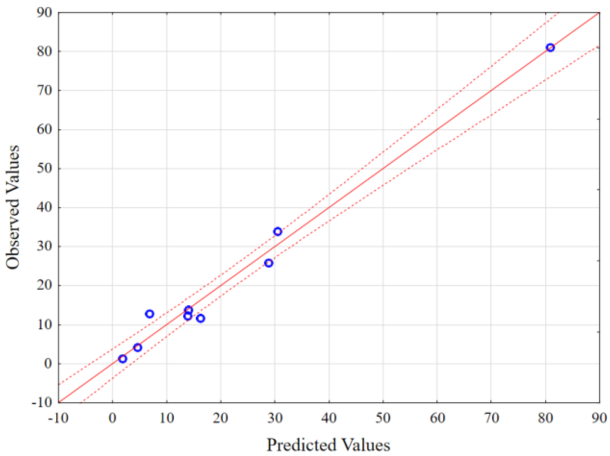

Fig. 8: The predicted and observed scatter plot

From this analysis, it is revealed that the changes in land use due to landfill, will alter drainage patterns and changing its boundary. So, it will increase the amount of runoff that must be served by the existing drainage system. On this basis, the RSS boundary is important because it will determine the drainage system services that should be provided in the RSS. The higher the level of a river branching in the RSS, the density value of the flow would be higher, so the greater the velocity of runoff for the same amount of received rainfall. Therefore, with the high level of river branching the peak runoff will be achieved in a faster time.

5. Conclusion

Morphometric analysis of The RSS of Palembang City rivers at its Ilir region revealed that there are 9 RSS boundaries grooved with 1st to 4th order. The morphometric characteristic was calculated and analysed using geospatial analysis in GIS. The perimeter (*P*) and mean bifurcation rate (*Rb*) were used to determine the effect of the morphometric characteristic of RSS to runoff value (*Q*). The environmental structure condition was determined. It could be useful for further analysis to determine the effect of land use changing on predicting the inundated area within the RSS and for developing the RSS management system.

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