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MORPHOMETRY ANALYSIS OF SILAT SUB-WATERSHED BASED ON GEOSPATIAL TECHNOLOGY IN THE SILAT HULU SUB DISTRICT

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ABSTRACT

This study aims to obtain morphometric data from the Silat sub-watershed. The method used is a survey and interpretation of secondary data. Secondary data is taken from Remote Sensing Images, Topographic Maps, and Administration maps. The morphometric data taken were the area, shape, circumstance, river length, river order, height, and drainage density. Data analysis using the Spatial Analyst Tool, namely Hydrology, Map Algebra, and Density tools from ArcGis 10.8. Based on the research results, it is known that the Silat watershed has an area of 466 km², a circumference of 147 km, and a river length of 51 km. The shape of the Silat watershed is elongated because the Circularity Ratio value is 0.27 (<0.5), and the Elongation Ratio value is 5.14 (round). The order of the river network is up to order 6, with a branching index (Rb) of order 1 = 2.03; 2nd order = 2.09; 3rd order = 1.75; 4th order = 1.84; and 5th order = 0.96. The Weighted Average Branching Index (WRb) was 2.73 (<3). The Silat sub-watershed has a height of 32 - 255 meters above sea level. Low river density, dendritic river flow pattern.

Keywords: *GIS; Morphometric Characteristics; Remote Sensing; Silat Sub-watershed*

INTRODUCTION

Watersheds can be identified from various points of view, including from the point of view of the watershed ecosystem from a single ecosystem, hydrology. The morphometric analysis of watersheds is useful to investigate the erosion status of watersheds, flood proneness, and critical areas suffering from soil erosion within the drainage basin (Bajirao et al., 2019). River flows will carry various sediment loads and materials (Pamuji et al., 2020; Primanggara & Suprapto, 2014).

A Watershed is a land area that has a unitary river and tributaries that occur in an ideal unit for natural resource management such as land and water-related to natural resource conservation and disaster mitigation in the context of sustainable development, which functions to accommodate, store, and drains water from rainfall into lakes or into the sea naturally, which is divided into boundaries on land which are topographical separators and borders at sea to water areas that are still affected by land activities (Cahyadi, 2017; Dharmananta et al., 2019). The watershed has a boundary from the land area, the topographic separator, and the sea area border to the water area still affected by land activities (Pamuji et al., 2020; Subekti et al., 2009), which has specific morphometric characteristics.

Morphometric analysis is fundamental in the study of watersheds. This morphometric analysis serves to identify and assess the characteristics of the watershed and its changes. In addition, it is also in understanding the potential of groundwater and in terms of overcoming problems related to watershed management, especially soil erosion due to flash floods during peak discharge (Mangan et al., 2019). Watershed morphometry analysis is fundamental for hydrologists and geomorphologists to address serious environmental problems such as soil erosion, slope instability, flooding, landslides, and extreme surface runoff (Conforti et al., 2011; Mangan et al., 2019).

Watershed morphometry is a quantitative measure of watershed characteristics related to the geomorphological aspects of an area. Morphometry is a shape and size, a landform expressed in a mathematical calculation of the configuration of the earth's surface, which is appropriate for understanding the relationship between various aspects that exist in a watershed (Cahyadi, 2017; Rekha et al., 2011; Sukristiyanti, 2018; Wagener et al., 2001). Morphometric analysis can be used in watershed management, the interactions between geomorphological conditions, and hydrological characteristics.

Inventory of watershed morphology and morphometry can be used to prepare watershed management plans and prepare watershed management information systems. The existence of a reciprocal relationship between natural resources (vegetation, land, and water) as a natural system (natural system) and humans as a social system (social system) forms a relationship of interaction (interrelationships) and interdependence (interdependency) which will determine the characteristics of the watershed in question (Pamuji et al., 2020; Subekti et al., 2009). Parameters in watershed morphometry are essential elements about the response of rainwater falling in the watershed to runoff; information on soil conditions, slope characteristics, runoff characteristics, topography, surface water potential is crucial.

Several morphometric parameters used to analyse the characteristics of a watershed are the order of the river, the number of rivers, the length of the river, the area of the watershed, and the length of the watershed, river flow density, and main river profile (Obeidat et al., 2021; Sadad & Ridlo, 2021). Morphometric analysis has been widely used to assess the vulnerability of watersheds to natural hazards such as flash floods and erosion (Ahmed & Srinivasa Rao, 2015).

The physical characteristics of the watershed are shape, size, drainage density, length, and size of the river, which are highly correlated with hydrological parameters characterized by the appearance of a drainage basin that can cause flood disasters (Mesa, 2006; Prouty, 1952) which have an impact on the community.

The Regional Disaster Management Agency of Kapuas Hulu Regency noted that from several sub-districts above, the Silat Hulu sub-district had the highest number of families affected by the flood, namely 3,879 families/6,537 people. Villages affected by flash floods in Silat Hulu District are Nanga Dangkan Village, Dankan Kota Village, Lebak Najah Village, Nanga Ngeri Village, Landau Badai Village, Nanga Lunggu Village, Entebi Village, Landau Rantau Village, and Nanga Luan Village, with high water levels, the flood there are approximately 2-3 meters. Research related to the character of the watershed and river flow patterns to minimise the risk due to flooding is very necessary.

In recent years, there has been a marked increase in the level of watershed management through the characteristics of a watershed (Hasan et al., 2017; Purwanto et al., 2022). Many studies related to spatial-based morphometric analysis, namely Remote Sensing and Geographic Information Systems. Remote sensing has the ability to obtain synoptic views of large areas and is very useful in analyzing drainage morphometric parameters (Hasan et al., 2017; Prabu & Baskaran, 2013). Flood risk analysis can be done through watershed morphometric measurements with the help of Geographic Information Systems (GIS).

Geographic Information Systems are currently used to assess drainage basins' various terrain and morphometric parameters. Quantitative morphometric characterization of a watershed is considered the most satisfactory and objective method for proper watershed management planning. It allows users to understand the relationship between various watershed characteristics and flood phenomena and make comparative evaluations of different watersheds (Zende et al., 2013).

In several kinds of literature, we found that researchers used remote sensing and GIS technologies for morphometric analysis and prioritization by considering different linear, areal, and watershed relief aspects. In this paper we focus on the input data used, the methodology adopted, and conclusions for better watershed management. This study aims at the watershed's morphology and morphometry analysis, and the characteristics of the Silat sub-watershed.

MATERIALS AND METHODS

Study Area

This research was conducted in the Silat Sub-Watershed, part of the Kapuas Watershed, West Kalimantan Province. The Kapuas River Watershed from Kapuas Hulu Regency to Kubu Raya is approximately 14,000,400,000 hectares. This river is the longest river on the island of Kalimantan and the longest river in Indonesia, with 1,143 km. Sub-watershed Silat has an area of 466 Km² or 46,625 Ha. The Silat sub-watershed is astronomically located between 111°52’0" - 112°24'30" E and between 0°40'30" - 0°16' 0" N **(Figure 1)**. This research is located in one of the sub-districts in Kapuas Hulu Regency, namely the Silat Hulu District.

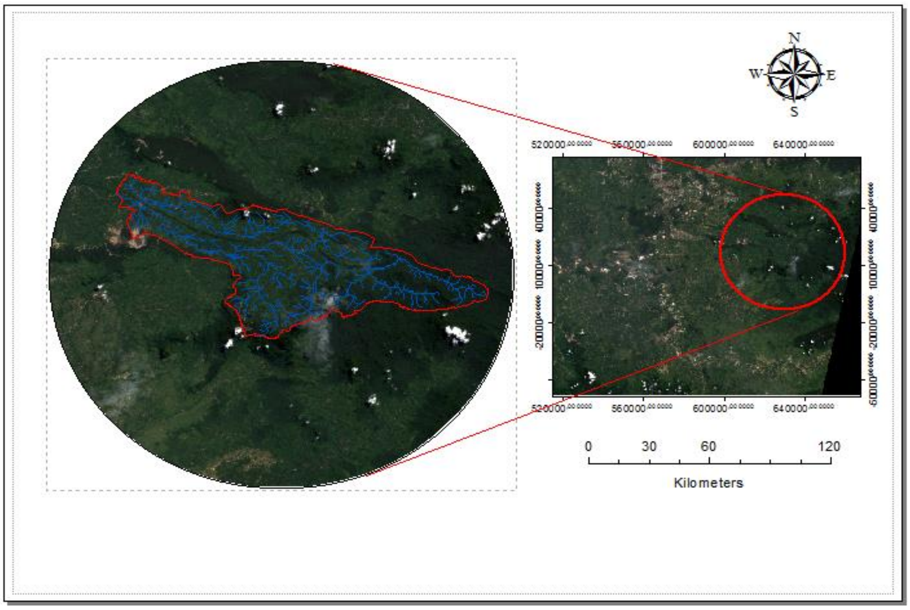

Figure 1. Study Area.

Data collection

The method used in this research is a survey and interpretation of secondary data. Secondary data is taken from Remote Sensing Imagery, Topographic maps, and Administration maps. The data was taken from Remote Sensing data, namely from DEM images with a resolution of 10 x 10 m acquired on August 17, 2020, and November 21, 2020, obtained from the ALOS PALSAR image. The morphometric data taken in this study were area, shape, circumference, river length, river order, sub-watershed height, and drainage density. The technique of collecting and analysing data from Remote Sensing uses the Spatial Analyst Tool, namely the Hydrology tool, Map Algebra and Density from ArcGis 10.8, while data collection in the field uses the Area of Interest (AOI) method using the Global Positioning System (GPS).

Metodhology

The overall research methodology can be seen in **Figure 2.**

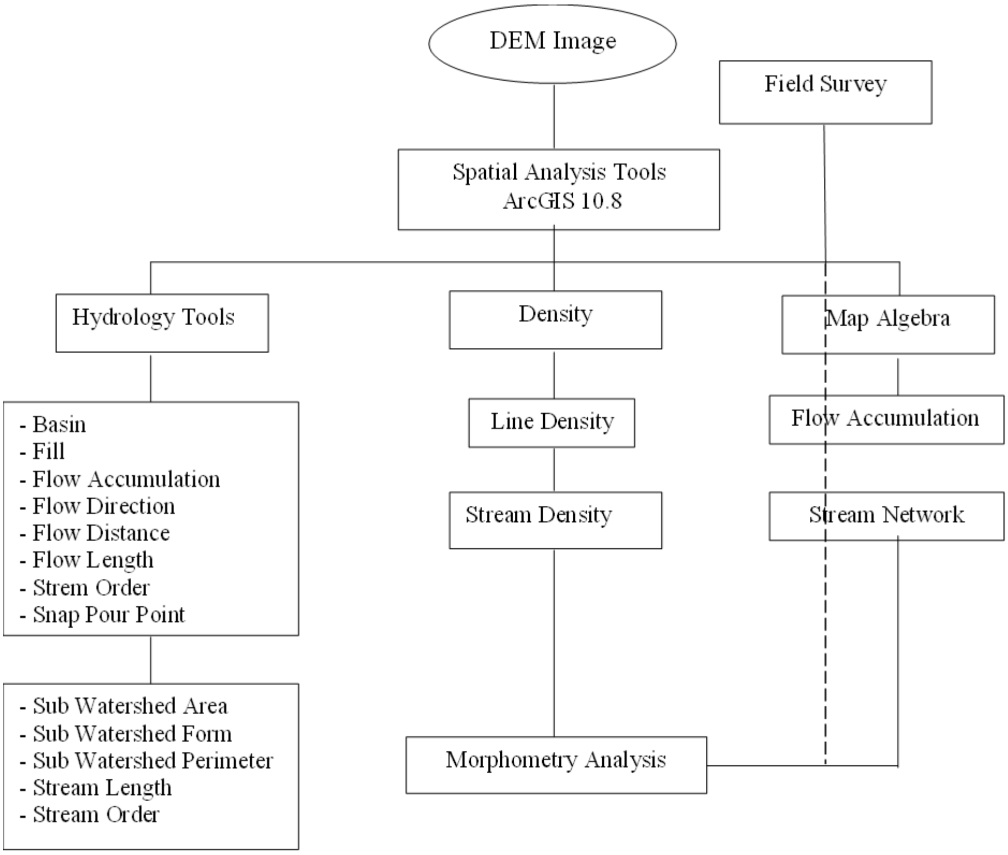

Figure 2. Research Method

RESULTS AND DISCUSSION

Several quantitative parameters will be measured in the morphometric analysis of the Silat sub-watershed, including:

Watershed Characteristics

The results of measuring the morphometric characteristics of the Silat Sub-watershed using the Geographic Information System in ArcGIS 10.8. They were divided into four main factors: the sub-watershed area, the sub-watershed length, the width of the sub-watershed, and the perimeter of the sub-watershed. The attribute data for the morphometric characteristics of the Silat Sub-watershed can be seen in **Table 2**.

Table 2. Characteristics of Silat Sub-watershed.

No	Morphometric Characteristics	Kilometres	Hectar (Ha)
1	Area	466 Km²	46.625
2	Lenght	51	
3	Wide	9,13	
4	Perimeter	147	

Source: Result Analysis 2022.

Shape of Sub Watershed

The form of the watershed influences the pattern of river flow and peak sharpness. The shape of the Sub Watershed is a comparison between the area of the Sub Watershed and the length of the river. By comparing the configuration of the sub watershed, a flood discharge index can be made based on the Circularity Ratio of the sub watershed, determining the shape of the Sub watershed based on Miller (Primanggara & Suprapto, 2014) using the circularity ratio formula. The form of the Sub watershed is challenging to express in quantitative terms, but it can be approximated by the Circularity Ratio. The following is a description of the Roundness Ratio (Rc) and Longitudinal Ratio (Re) sub-watershed, namely **(Table 3**):

Table 3. Circularity Ratio (Rc).

No	Rc	Description
1	>0.5	The shape of the watershed is rounded, peak discharge lasts a long time, and its decline.
2	<0.5	The shape of the Longitudinal Watershed, the peak discharge comes quickly, and the decrease.

Source: (Pattiselanno, 2017).

Elongated figures dominate the shape of the Silat Sub Watershed, and this is due to the circularity ratio of <0.5, namely 0, 27, and the Elongation Ratio of 5.14 (Round). Based on the data, the Silat Sub Watershed is elongated and slightly rounded, resembling a bird's feather (Rc < 0.5) and (Re = 5.14).

This condition indicates that the Silat Sub Watershed has the characteristics of a peak discharge that comes quickly and decreases, but the surface flow rate to the outlet is slower. This shows that the longer the flow path in the Kapuas watershed and the Silat Sub Watershed results in the broader catchment area that the river can eceive from each branch of the upstream Silat. The shape of the Silat Sub Watershed will influence the pattern of river flow and the sharpness of the peak of the flood discharge if the main watershed, namely the Kapuas watershed, overflows.

It can be concluded that the shape of the Silat sub-watershed basin is narrow. Therefore, the flood confluence time is short for a narrow basin (Liu, 2011). Therefore, the small basin circularity ratio of the Silat River supports the formation of a high flood peak, which easily drains large amounts of runoff from the basin during rainy days to the Silat Sub Watershed.

Main River Length

The length of the Sub Watershed is equal to the flat distance from the river mouth to the upstream along the main river. Based on the measurement results through the ArcGIS 10.8 program, it is found that the length of the main river in the Silat sub watershed is 51 Km. This can prove that the Silat Sub Watershed is a large sub watershed, which can affect the length of the water flow flowing by the sub watershed and watershed, affecting the amount of discharge and suspended load divided into each branching of the river. The below is a Map of the Length of the Main River in the Silat Sub Watershed, as for **Figure 3**.

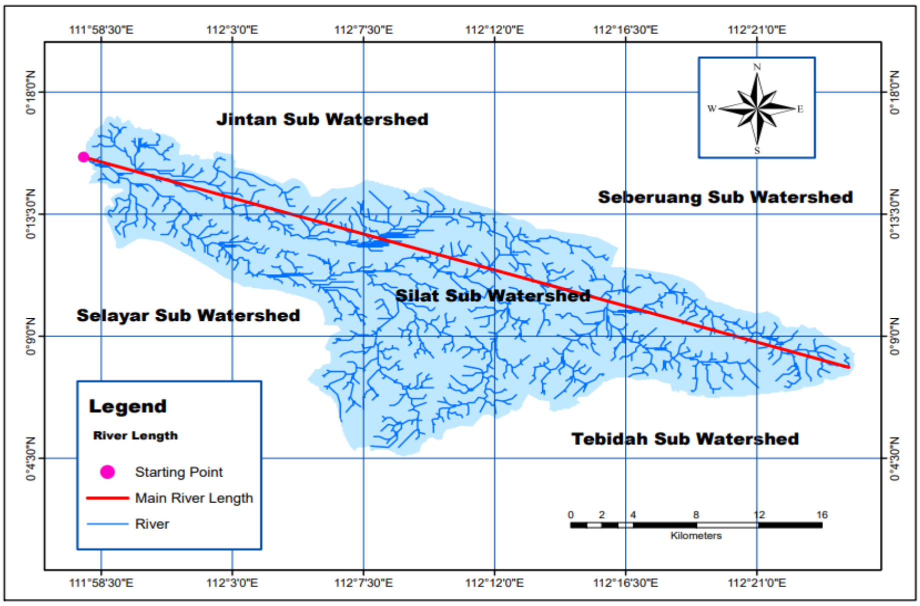

Figure 3. The Length of The Main River in The Silat Sub Watershed.

The typology of the river from upstream to downstream has a tortuous pattern. The consequence of this is that the length of the river will increase. This means that the slope of the river is decreasing and the implications for the average flow rate in the river are also decreasing. If the flow velocity in the river decreases, the peak time of the flow hydrograph will be longer (Tunas et al., 2017). The impact is the potential for the peak of the flood to occur longer.

River Orde

The flow pattern or arrangement of rivers in a Sub Watershed is an essential physical characteristic of each drainage basin because river flow patterns affect the efficiency of the drainage system, and hydrographic elements and flow patterns are decisive for Sub Watershed managers to determine the soil and surface conditions of the watershed, especially erosion power. The flow pattern depends on the Sub Watersheds' topography, geology, climate, and vegetation conditions.

The quantitative method for classifying rivers in a watershed is systematically ordering rivers and river branches, such as using ArcGIS 10.8. The order and level of river branching is the branching position of the river channel in the order in which there is the main river in a watershed. Based on the Strahler method, the most upstream river channel with no branches is called the first order (Order I), the meeting between the first order is called the second order (Orde II), and so on until the main river is marked with the most significant order number. The analysis of Silat Sub Watershed orders is six and has a river length in each order, as shown in **Table 4**.

Table 4. River Orde Length.

River Orde	Length (Km)	Rb	WRb
1	357	2.03	3.02
2	176	2.09	3.09
3	84	1.75	2.75
4	48	1.84	2.84
5	26	0.96	1.96
6	27	-	-
	Total Length = 718		Mean= 2,73

Source: Data Analysis (2022).

The value of Weighted Mean Bifurcation Ratio (WRb) < 3, then the river channel has a rapid increase in flood water level, while the decline is slow. The higher the bifurcation ratio, the greater the probability of flooding. (Ahmed & Srinivasa Rao, 2015; Subekti et al., 2009). The order of the Silat Sub Watershed river can be seen in **Figure 4**.

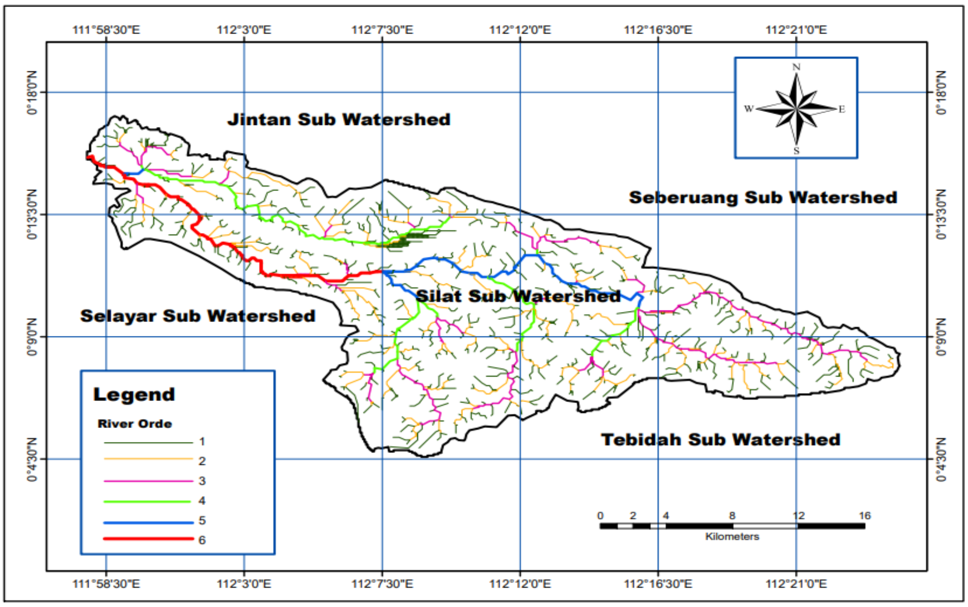

Figure 4. The Orde of the Silat Sub Watershed River.

Watershed Elevation

The watershed height is the most important factor affecting temperature and rainfall patterns, especially in areas with mountainous topography. The height of a place can be known through a topographic map or from a Digital Elevation Model (DEM) image, and field measurements. The height of the Silat Sub Watershed can be seen in **Figure 5**.

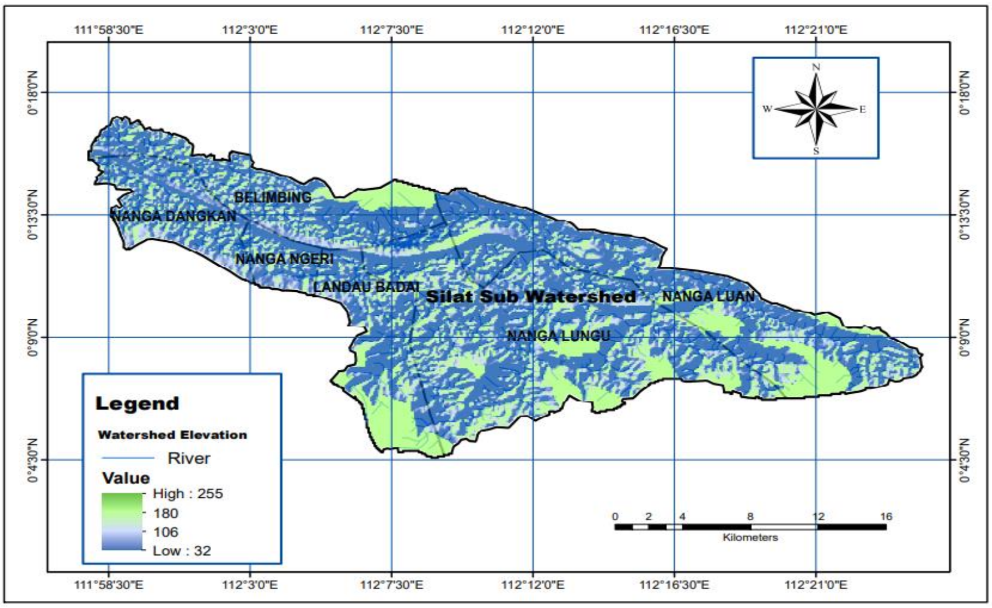

Figure 5. The Elevation Of The Silat Sub Watershed.

Based on the map above, the elevation of the Silat Sub Watershed is dominated by areas with an altitude of 32-223 m, namely Nanga Dankan, Nanga Ngeri, Landau Badai, and Belimbing Villages. Meanwhile, areas with a height of up to 255 meters above sea level are Nanga Lungu Village, Nanga Luan, the southern part of Landau Badai, and the northern part of Belimbing Village.

Flood disasters often occur in areas that have low topographic elevations or downstream areas. This is evidenced by 53.2% of the data on flood events recorded at low altitudes ranging from -1 m to 199 masl. This data shows that areas that have low altitudes have a greater likelihood of flooding, so there is a need for special handling of floods in these areas (Jati & Santoso, 2019).

Drainage Density

Drainage density is an index number (comparison between the total length of the river divided by the sub watershed area) which shows the number of tributaries in a Sub Watershed. Drainage density reflects the average river length in a certain unit area. River Density Index can be seen in **Table 5**.

Table 5. Drainage Density Index.

No	D*d* (Km/Km²)	Density Class	Description
1	< 0,25	Low	The river channel passes through rock with hard resistance, then the sediment transport caught in the river flow is smaller than the channel that passes through the rock with softer resistance if other conditions that affect it are the same.
2	0,25 – 10	Currently	The river channel passes through rocks with softer resistance so that the transported sediment transport will be greater.
3	10 – 25	High	The river flows through rocks with soft resistance so that the sediment transport carried by the flow will be greater.
4	>25	Very high	The river flows through impermeable rocks. This situation indicates that the rainwater that becomes the flow will be greater when compared to an area with low Dd passing through rocks with large permeability.

Source: (Subekti et al., 2009).

The drainage density of the research area can be seen in **Figure 6**. The greater the value of Dd, the better the drainage system in the area. The greater the total surface flow and the less groundwater is stored in the area. From the analysis results using ArcGIS 10.8, the researchers found that Dd = 0.10 Km/Km². Then the density of the Silat Sub Watershed is 0.10 Km/Km². Based on the criteria for the River Density Index, the density of the Silat Sub

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Watershed river is classified as a low-density class. It which indicates that the river channel passes through rocks with hard resistance and will cause sediment transport stuck in the river flow to be smaller when compared to the flow-through rocks with low resistance, softer (Ahmed & Srinivasa Rao, 2015; Rajasekhar et al., 2020). The consequences of other conditions that affect it will be the same.

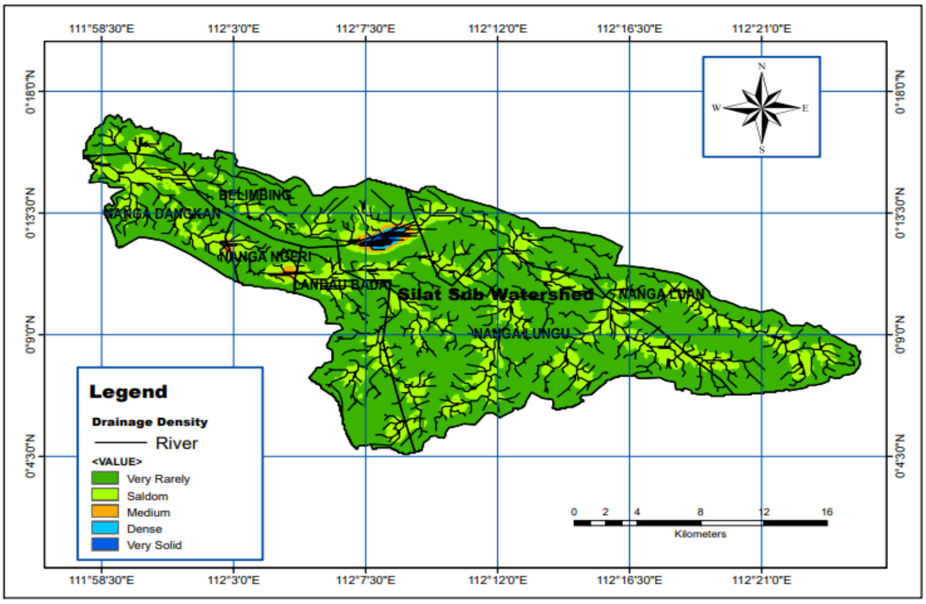

Figure 6. Silat Sub Watershed Drainage Density.

CONCLUSIONS

The Silat Sub Watershed has an area of 466 Km² or 46,625 Ha, with a circumference of 147 Km for the Silat Sub Watershed and a length of 51 Km for the Watershed. The shape of the Silat Sub Watershed is dominated by elongated shapes resembling bird feathers, a Circularity Ratio value of 0.27 (<0.5), and the Elongation Ratio value of 5.14 (round class). The Weighted Average Branching Index (WRb) of 2.73 (<3) means that the river channel has a rapid increase in flood water level, while the decline is slow. The Silat Sub Watershed has varying elevations of 32 to 255 meters above sea level. The density of the existing river is dominated by the low-density class, which indicates that the river channel passes through rock with hard resistance and causes sediment transport caught in the river flow to be smaller than that of the track that passes through rock with softer. The Silat Sub Watershed area, which is in Silat Hulu District, Kapuas Hulu Regency, has a relatively high potential for flood disasters. This is caused by natural factors, namely the characteristics of the Sub Watershed and human factors (the presence of illegal mining). The following are the natural conditions that occur at the research site (**Figure 7, Figure 8, Figure 9, and Figure 10**):

Figure 7. Silat Sub Watershed.

Figure 8. Gathering of Silat Sub Watershed Flows.

Figure 9. Water Conditions Due to Mining Activities.

Figure 10. Road infrastructure to the location post-flood research.

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