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Morphological Study of The Pulai Watershed on Bintan Island, Riau Island

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Abstract. The Riau Islands are a group of small islands whose entire land is divided into watersheds. One of the watersheds in the Riau Islands that is currently the main source of raw water for the community is Sei Pulai. The condition of the watershed on Bintan Island is greatly influenced by its morphometrics. The purpose of this study is to determine the morphological characteristics of the Pulai watershed on Bintan Island. This research was conducted in 2024 with observation by survey. Data processing is carried out by physical mapping of watersheds (soil, slope and geology). The results of the analysis showed that the Island watershed was included in the category of high rainfall (average rainfall of 2,500 -< 3,000 mm/year) but the intensity of rainfall was relatively low with an average ± 19.11 mm/day; the widest geological characteristics were composed of Pre-Tertiary and Quaternary sedimentary formations and igneous rocks consisting of granite and diorite; geomorphological characteristics consist of hills and undulating, rivers have low relief, laminar river flows and no rapids are found, with clear river water color; The slope of the Pulai watershed varies with class I slopes covering an area of ±412 Ha (7%); class II covering an area of ±4,071 Ha (74%); class III covering an area of ±897 Ha (16%); class IV covering an area of ±36 Ha (1%) and class V covering an area of ±83 Ha (2%); the shape of the slope of the Pulai watershed which has a hilly area with a sunken slope will produce a sharper hydrograph uplift. In general, the morphological characteristics of the Pulai watershed are geologically dominated by slopes of 8-15%, while geomorphology is dominated by the shape of old volcanic plains. Efforts are needed to rehabilitate and plant protected areas to overcome erosion caused by the slope of hilly land and fragile soil characteristics, especially protected areas outside forest areas during the rainy season.

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1 Introduction

A watershed is generally defined as an expanse of area or area bounded by a topographic boundary (ridge or ridge) that receives, collects rainwater, sediment, and nutrients and drains them through tributaries and exits in the main river into the sea or lake [1,2]. This definition includes hydrogeology, groundwater flow dynamics, soil types, properties, and their relationship to other environmental parameters within the watershed [3]. A watershed is an ecosystem, where elements of organisms and the biophysical environment as well as chemical elements interact dynamically [4]. In a watershed ecosystem, watershed zoning can be divided into upstream, middle and downstream areas, each with distinct characteristics and management needs [5,6]. The upstream watershed is characterized as a conservation area so that it has an important meaning, especially in terms of protecting water system functions and environmental services [7,8]. Any form of biophysical and land use change that occurs in the upstream area will have an impact on the downstream area [9], including in the form of changes in fluctuations in discharge and sediment as well as dissolved materials in the water flow system (affecting water quality and quantity) [10].

Watersheds are a natural ecosystem where hydrological biophysical processes occur in it. These processes are part of the hydrological cycle or water cycle. The processes that occur in a watershed can be divided into 3 (three) main components of the process in a watershed, namely input, processor and output. Precipitation is the main input [11], with hydrological processes like evaporation, transpiration, soil water movement, and groundwater flow acting as processors in the watershed [12]. The output is typically streamflow at the basin outlet [13]. The application of morphometric indicators helps assess the physical characteristics of watersheds, which can inform land use and management strategies to reduce erosion and improve sustainability [14].

Some inputs in watersheds are natural, for example, rainfall and human intervention in the form of land management [4,11]. The input into the watershed which is natural and human intervention is then processed in the watershed, therefore the watershed is also analogous to a processor. The processes that occur in a watershed are influenced by the characteristics of the watershed, where the characteristics of the watershed are composed over natural factors that are not easy to manage and natural factors that are easy to manage. Natural factors that are not easy to manage are geology, morphometry, macro relief, and some soil properties. Meanwhile, natural factors that are easy to manage are vegetation, macro reliefs and some soil properties [4,15]. By applying these techniques, the study highlights the spatial variability of hydrological processes across the watershed and provides a framework for improving water resource management in the region [16].

An inventory of watershed characteristics is needed to realize the preservation and harmony of the ecosystem as well as increase the utilization of natural resources for humans in a sustainable manner. A thorough inventory of watershed features is crucial for proper management, involving the assessment of natural resources such as drainage, soil, topography, groundwater, and land use [17]. As a first step in watershed management, it is necessary to first know the characteristics of the watershed. Etymologically, the term watershed characteristics is a distinctive trait, which is attached to the watershed which includes watershed morphological variables. The Pulai Watershed is one of the watersheds in the Riau Islands that is included in the classification of restored watersheds where in the Pulai Watershed there is a reservoir that needs to be preserved so that the quality and quantity of water are maintained. The growth of tourism on Bintan Island has led to increased real estate development, which may affect the morphology of the river basin [18].

2 Method

This research was carried out from July to September 2024 in the Pulai River Basin, Bintan Island. The materials used in this study are stationery and maps including topographic maps, land maps, geological maps and slope maps. The survey equipment required includes GPS, cameras, computer kits and ArcGIS 10.8 software.

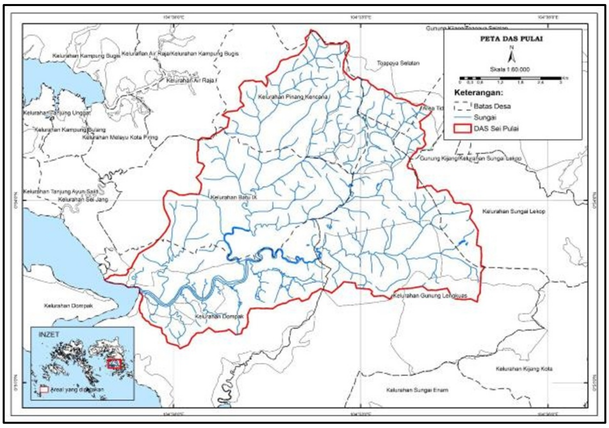

Fig.1. Map of the Pulai Watershed on Bintan Island, Riau Islands

The stages of this research are carried out by:

1) Delineation of watershed boundaries and drawing of watershed basemaps
2) Secondary data collection includes: topographic maps, trench maps and geological maps
3) The use of primary data/field surveys includes observation and measurement of watershed conditions and watershed slopes, while secondary data is obtained through agency survey activities at related agencies/agencies to obtain variable data on watershed characteristics
4) Data analysis includes:

a) Rainfall and Perception of Rainfall

Rainfall data and rainfall perceptions obtained in the 2012-2023 range from BMKG Raja Haji Fisabilillah were then grouped based on the Watershed Characteristics Identification Guidelines, 2013 [19]. Rainfall categories are: rainfall < 1500 mm/year (very low category); 1500 < 2000 mm/year (low); 2000-< 2500 mm/year (moderate); 2500-<3000 mm/year (high) and >=3000 mm/year (very high). Meanwhile, rain intensity data consists of: rain intensity 13.60 mm/day (very low); 13.61-20.70 mm/day (low); 20.71-27.70 mm/day (moderate); 27.71-34.80 mm/day (height) and > 34.81 mm/day (very high).

b) Morphological characteristics of watersheds

a. The geology and geomorphology of the watershed obtained by observation or experiments in the field. Field data is then processed through the interpenetration and reconstruction of a geological and geomorphological model.
b. The topography of the watershed area consists of 4 variables, namely:
   1. The elevation of the watershed known from the topographic map is measured in the field. The relationship between elevation and watershed area is expressed in the form of a hypometric curve

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2. The orientation of the watershed is expressed in azimuth degrees of compass direction. The flow direction of the Pulai River is used as a general guide to the orientation of the watershed.
3. The slope of the watershed slope uses an Abney level or clinometer tool. In aerial portraits, slope measurements are carried out using a slope meter with the formula Slope (%) = (C x I) / A, where C = contour interval (m); I = total Length of the contour (m); A = watershed area (m2), if the slope is uniform, then the formula Slope (%) = (c/d) x 100 is used, where c = the difference in the elevation of the highest and lowest points in the watershed (m); d = horizontal distance between the elevation of the highest and lowest points (m). The slope classification consists of 5 classes, namely class 1 with a slope of 0-<8 % (flat/slope); class 2 with a slope of 8-<15 % (slightly sloping); class 3 with a slope of 15-<25 % (slope); class 4 with a slope of 25-<45% (steep); and class 5 with a slope of 45% and above (steep).
4. The shape of the watershed slope uses a hydromorphometric approach. The classification of watershed slope shapes consists of 2 classes, namely Convex if more than 50% of the hipsymmetric curve is convex and Concave if more than 50% of the hipsometric curve is concave.
5. The soil structure is obtained from secondary data where soil grouping is based on several soil types including Gleiso, Kambisol, Alluvial and Podsolik.

3 Results and Discussion

3.1 Rainfall and Intensity

Rainfall is the height of rainwater that collects in a flat place, does not evaporate, does not permeate, and does not flow. Rainfall of 1 (one) millimeter means that in an area of one square meter in a flat place is accommodated with water as high as one millimeter or as much as one liter of water. Rainfall units are always expressed in millimeters or inches, but in Indonesia the rainfall units used are in millimeters (mm). Rain is a water input that enters a watershed, therefore knowing the amount of rainfall is very important. The following is presented rainfall data based on BMKG Raja Haji Fisabilillah.

Table 1. Tanjungpinang City Rainfall Index from 2012 to 2023

No.	Year of observation	Rainfall Measurement Results (mm/year)
1.	2012	2938.0
2.	2013	3389.5
3.	2014	3094.4
4.	2015	1413.0
5.	2016	3217.8
6.	2017	2981.2
7.	2018	3006.7
8.	2019	2367.8
9.	2020	3002.9
10.	2021	3878.6
11.	2022	2912.0
12.	2023	3155.0

Source : BMKG Tanjungpinang City [20]

Based on the Rainfall index table in Tanjungpinang, the Pulai River watershed is included in the category of high rainfall because it has an average rainfall value between 2,500 -< 3,000 mm/year, which is 2946.4 mm/year.

Rainfall intensity is the amount of uncombined rainfall over a certain period of time. If it is said that the intensity is large, it means heavy rain and this condition is very dangerous because it can cause floods, landslides and negative effects on plants. The daily rainfall intensity for 1 year is the average intensity of rain every day for 1 year, while the annual rainfall intensity is the total of all rainfall intensities throughout the year. The results of the Characteristics of Rainfall Intensity on Bintan Island in general or the Pulai watershed in particular in 2023 have a rainfall intensity of ±19.11 mm/day or is included in the low category, as can be seen from the following table:

Table 2. Rainfall Intensity in 2023

No	Moon	Rainfall (mm)	Number of Rainy Days (Days)	Average (mm/day)
1.	January	932.1	14	66.58
2.	February	3.9	2	1.95
3.	March	188.5	14	13.46
4.	April	382.8	18	21.27
5.	May	272.4	18	15.13
6.	June	229.8	19	12.09
7.	July	165	15	11.00
8.	August	481.6	25	19.26
9.	September	395	16	24.69
10.	October	227.7	17	13.39
11.	November	408.1	27	15.11
12.	December	191.7	18	10.65
	Sum	3878.6	203	224.60
	Average			19.11

Source : BMKG Tanjungpinang City (2023) and BPDAS Riau Islands (2022) [21,22]

3.2 Geology

The geology of the Bintan Island area, Riau Islands is composed of Pre-Tertiary and Quaternary sedimentary formations as well as igneous rocks consisting of granite and diorite. Rock formations of Triassic age, occupying almost the entire land in the central part of Bintan Island, these formations are the widest spread. Cretaceous rock formations only occupy a small part of the P. Bintan area, namely the southern southeast coast area and several places in the central part. Igneous rocks are quite widespread, consisting of granite and diorite, occupying the northern and eastern coasts of the P. Bintan area and several other places that are scattered irregularly in the central part, forming the hilly area of P. Bintan such as Mt. Lengkuas and Bukit Bintan Besar. Most of the body of Bukit Bintan Besar (eastern part) is formed by diorite rocks and some (western part) is formed by granite rocks. In addition, in the P. Bintan area, volcanic rocks suspected to be Permo-Carbon age were also found consisting of liparite (porphyry kwarsa). The rocks were found in the Tanjung Agap area (the western tip of P. Bintan), Bukit Bintan Kecil and Mount Kijang. An example of liparite from

Mount Kijang is the same as the liparite in the Jambi area which is Permo-Carbon age, on that basis the rock is considered to be Permo-Carbon age [22].

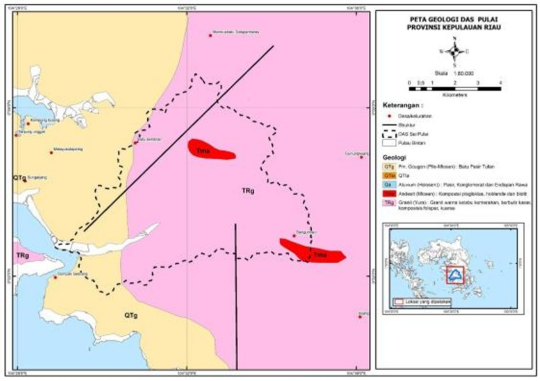

Fig. 2. Geological Map of the Pulai Watershed

3.3 Geomorphology

The topographic variables in the characteristics of this watershed are divided into 4 variables, namely watershed height, watershed orientation, watershed slope slope and watershed slope shape. The four topographic variables have a close role in the process of infiltration, surface runoff and erosion that occurs due to rainwater. The following is presented with the cleanliness of the Pulai watershed.

Table 3. Pulai Watershed Slope

No.	Code/Class	Slope (%)	Area (Ha)	Category
1.	I	0-8	412.71	Flat
2.	II	8-15	4071.43	Ramps
3.	III	15-25	897.35	Less Steep
4.	IV	25-45	36.81	Steep
5.	V	>45	83.17	Very steep

Based on Table 3. The Pulai watershed area has slopes varying as follows: the area with slope class I is 412.71 Ha (7%), slope class II is 4,071.43 Ha (74%), slope class III is 897.35 Ha (16%), slope class IV is 36.81 (1%) and slope class V is 83.17 Ha (2%). Broadly speaking, the total land slope class in the Pulai watershed area is as follows:
- The land area of 4,484.14 Ha or 81% of the area has a land slope of < 15%.
- The land area of 1,017.33 Ha or 19% of the area has a land slope between > 15%.

3.4 The Shape of the Slope

Based on the hydromorphometry approach for watersheds that have hilly areas with concave slopes, it will produce a rise in the hydrograph (rising limb) sharper than the convex slope shape. The shape of the average watershed slope can be seen on the hypsometric curve which is also used in the calculation of watershed height.

3.5 Soil

The type and distribution of soil in a watershed is very influential in controlling subsurface flow through infiltration. Variations in soil types with certain depths and areas will affect the characteristics of soil moisture storage infiltration and storage. The selection of soil variables is also a function of the purpose of the study, for example to study the overland flow in a single watershed, then the watershed is divided into zones according to soil type, but if to study in more detail, it is necessary to classify the soil type in detail as well, which is based on the geological surface boundary of the watershed concerned, namely: percentage of permeable rocks, The percentage of rocks is less permeable. Another variable that needs to be considered is the depth of the impermeable layer and the average permeability of the horizon A. Soil types with sand texture will have a higher infiltration rate than soil types with clay texture. Thus, soil types with sand (coarse) texture will have smaller surface runoff than soil types with clay texture (fine). For this condition, the dominant watershed with a fine-textured soil type is more prone to erosion than the dominant watershed with a coarse-textured soil type.

4 Conclusion

Based on the rainfall of the Pulai watershed, it is classified as high but the intensity of rain is relatively low. The morphology of the Pulai watershed on Bintan Island is characterized by a granite and diorite sedimentary arrangement that occupies almost the entire central part of Bintan Island, with the geomorphology of undulating hills, the rivers are classified as old stages with low reliefs, and the flow of the river is laminar with clear water color which indicates inactive erosion activities. The dominance of the slope of the Pulai watershed slope < 15% covering an area of 4,484.14 Ha (81%) and > 15% covering an area of 1,017.33 Ha (19%). The shape of the dominant slope is concave with hilly areas.

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