THE MORPHOTECTONIC CHARACTERISTIC OF BUOL WATERSHED AND IMPLICATION TO SPATIAL PLANNING IN BUOL REGION, CENTRAL SULAWESI, INDONESIA

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ABSTRACT

The Buol watershed is located on the northern arm of Sulawesi Island. Geomorphology in this region is controlled by developing faults. Geomorphological analysis is done to obtain objective results. Geomorphological variables can explain significantly the geomorphic process itself. The studio, field and laboratory methods is used in this research. Studio analysis consists of topographical map, satellite imagery, Ratio of valley Floor Width to Valley Height (Vf), Mountain Front Sinuosity (Smf), Drainage density (Dd), and Bifurcation Ratio (Rb) analysis. Also, statistical test is used to determine the relationship between these variables. Research area in watershed Buol has landform, namely lowland, low hills, hills, and high hill. Drainage pattern that developed namely anastomotic, sub-dentritic, sub-parallel, trellis, and sub-trellis drainage pattern. The results of the watershed morphometry analysis show calculation of the average value of Rb is 1.48 to 6.24, value of Dd average from 1.17 to 2.45., Smf value ranged from 1.6 to 1.76 and Vf ratio range from 0.5 to 1. That phenomenon shows that the Buol watershed is controlled by tectonic.

Keywords: Buol watershed, geomorphology, morphotectonic, quantitative, tectonic

1. INTRODUCTION

The Sulawesi Island consists of 4 arms, namely northern arm, eastern arm, southeastern arm, and southern arm. Tectonic conditions of North Sulawesi's arms greatly affect earthquake activity and ground movement in the central Sulawesi region. Buol depression is a watershed area, a product of tectonic activity in the northern arms of Sulawesi. This tectonic activity is able to reactivate the old faults. The faults contained in this area are expressed by geomorphological conditions in this Buol basin. The geological order can be reflected by geomorphological conditions, which can be examined from the aspects of morphography, morphometry, and morphogenetic. Morphography is the morphological units, which can be valleys, ridge, mountain, and so on. Morphometry is a quantitative aspect of morphology, which includes the angle of the slope, the dimension of the watershed, the dimensions of the valley, the ratio of the river branch and so on. Morphogenetic is a morphological characteristic of endogenous and exogenous processes. Morphotectonic watershed is a tectonic-related landscape character (Doornkamp, 1986). Tectonic activity in Buol region is high due to the Palu-Koro minor fault control, resulting in the threat of geological hazards such as earthquakes, landslides, floods. This research is important for the Buol area which is still at the development stage, the area is still underdeveloped since it was only in 1999 that Buol Regency stands which is the division of Toli-Toli Regency. In this case the morphotectonic watershed can be an approach in determining the zoning of disaster and spatial direction.

In the northern part of Buol District which is morphologically adjacent to the sea and the pedagogic morphography may be potentially flooded areas. Flood is an event of inundation in the flood plain due to river water flows caused by flow discharge exceeds its capacity. In addition, due to the overflow of river water, floods can occur due to the condition of the river body that is no longer accommodating to flow. The river flows can affect infrastructure, facilities and economic activities. In some areas that develop into a city that is usually associated with pedagogic areas then this area has the potential to experience flooding. The morphological approach is a research of the physical condition of the urban environment which, among others, is reflected in the existing road system, the building blocks of both

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residential and non-commercial areas as well as individual buildings which have the physical/morphological basis of Buol. Based on the above explanation, this research was conducted to determine disaster zoning and spatial planning in buol district based on morphotectonic research of watershed.

The purpose of this research is to determine the extent to which morphotectonic affect disaster, so it can be used as a basis in spatial arrangement in Buol area. The objectives of this research is:

1. Knowing morphotectonic characteristics of Buol watershed area
2. Knowing the effect of morphotectonic to the geological disaster zone of Buol watershed area

Slip Fault
Subduction

The research area is partly located in Biau District, Momunu Sub-district, Bukal District and Tiloan Sub-district, Buol Regency, Central Sulawesi Province. The area of Buol River Basin is 1,680 Km². Geographically located at 120º 56' 47.36 " - 121º 27' 8,61" E and between 0º 40 ' 38.41 "- 1º 12' 25.26" N. Buol Regency in the north is administratively adjacent to the territory of Philippines. Regency of Parigi Moutong in the south. Regency of Tolitoli in the west and Regency of North Gorontalo in the west.

Figure 1. Research area map

Based on the division of physiography of the mandala of Sulawesi, the research area is included in the West Mandala, namely the western and northern parts of Sulawesi, and is dominated by volcanic and plutonic rocks, which is the magmatic route resulting from subduction of northern Sulawesi.

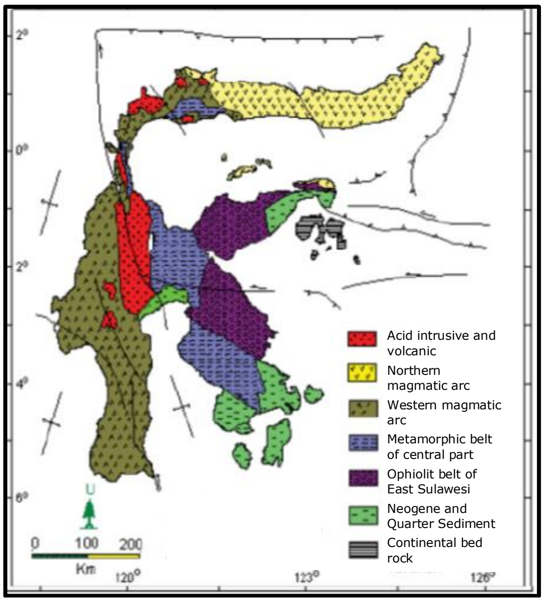

Figure 2. Sulawesi mandala (Van Leeuwen, 1994)

Regional stratigraphy Table 1 describes the regional stratigraphic conditions of the research area based on regional geological maps made by the previous researcher (Ratman, 1976).

Table 1. Stratigraphy of research areas (Ratman, 1976)

Code	Formation	Age	Explanation
Qal	Aluvium	Recent	Spread across the east to the southwest of the research area
Qs	Lakes and rivers deposit	Recent	In the middle of the research area
Ql	Coral Limestone	Plistocene	Spread from the north, southwest and northeast of the research area
Qts	Molasa Celebes	Pliocene	Scattered in the southern research area
Tms	Marine Sediment	Miocene	Scattered in the northwest of the research area
Tts	Tinombo Formation	Oligocene	Scattered in the northwest of the research area
Ttv	Volcanic Rocks	Oligocene	In the west of research area
Gr	Intrusive	Miocene	In the

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	rocks		southwest of the research area

The geologic structure developed in the research area is a fault in the Middle Miocene of the East Sulawesi and the central part of the Geological Mandala of West Sulawesi. At the same time a local transgression takes place in the Southeast Sulawesi arm and a volcanic activity occurs at The North and South Arms (Sukamto, 1973). Intra Miocene orogenetic phase is seen prominently in some places, especially in Central West Sulawesi Mandala, whereas orogenesis before Intra Miocene may occur twice, ie before and after Eocene. Larami's Orogenesa occurs in the Late Cretaceous to the Early Miocene, lifting and folding the Mesozoic sediments and other old sediments, then stalled by the influence of horizontal movement and causing various north-south-trending hood faults or precisely north-western north of the organ. Horizontal style stops and is followed by the formation of a congestion that causes the bulge or puffiness (Sukamto, 1973).

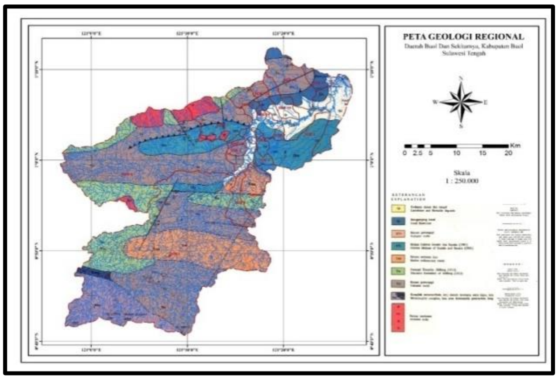

Figure 3. Regional Geology of research area (modified from Sukamto, 1973 and Ratman, 1976)

2. METHODOLOGY

To obtain a comprehensive research result, this research method includes research design, data required, test variables and data acquisition methods and data analysis methods. This research method essentially focuses on field observation data assisted by laboratory research in the form of spatial analysis. In the preparation phase includes literature review, determining the location of research, preparing research materials, equipment and research design in the field. Field research was conducted based on geospatial analysis. The analysis is used to find out the general description of the research area which includes the estimation of rock spread, alignment, slope, mapping of river flow pattern and so forth. Field research stage is a research activity that directly observes the object on the surface of the earth research area. Relation with this morphotectonic characterization, field measurement is measurement of geological data structure, Smf, Vf, and rock which will be the main data about the morphotectonic carotization. Spatial analysis is conducted on data related to supporting mapping in the morphotectonic characterization research of disaster zoning and spatial planning in the research area. Deterministic and probabilistic approach is used in the calculation of risk index or to search for morphotectonic correlation with disaster and spatial planning in the research area. The final step of the research is the preparation of dissertation report. The data of the research and its analysis are presented in the form of text description, tables, graphs, and maps in the research area.

3. RESULT AND DISCUSSION

3.1 Morphology of Research Areas

The landform is the appearance of the earth's surface. Referring to Van Zuidam (1985) based on the absolute likelihood value, in the research area there are 3 land formation namely plain, hills, and mountains.

1. Plain landform

The shape of the plains is divided into 2 types (Van Zuidam, 1985) including low plains and plain. The low plains form is located in the Northeast Buol Watershed area, extending from the Middle East to the East, occupying about 211 km2 in the Buol Watershed area with elevations of 20.6 to 50 mdpl. Percentage of area of low plains landform is 12,6% from total area of research area. The shape of the plain of land in the Northeast extends from the middle to the Northeast, occupying about 84 km2 with elevation of 50-100 mdpl. Has a percentage of about 5.04% of the total area of research.

2. Hills landform

The form of hilly land can be divided into 3 types (Van Zuidam, 1985), including low hills, medium hills, and high hills. The low hills have elevations of 100 to 200 meters above sea level, the hills are having an elevation of 200 to 500 meters above sea

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level, and the high hills have elevations of 500 to 1500 meters above sea level. The low hills are in the Middle East extending from the middle to the Northeast and to the East, occupying about 125.1 km2. Has a percentage of about 7.5% of the total area of research. Forms of hilly land in the Central and Northeast extends from the Southwest to the Northeast and in the East Buol Watershed, occupies about 442.9 km2. Has a percentage of about 26.6% of the total area of research. This form of high hill land is located in North and South, occupies about 770,74 km2 Buol watershed. With a percentage of about 46.2% of the total area of research area.

3. Mountains landform

This form of mountainous land is in the West and South, has elevations ranging from 1500 to 1975 mdpl, occupies about 31.26 km2 of Buol River Basin. With a percentage of about 1.87% of the total area of research.

Valley Form

The shape of the valley that develops in the Buol basin is divided into 2 kinds, namely the shape of the U valley and the shape of valley V. U valley shape is located in the Central to East Sea which is a form of pedataran land and found surface deposits (Aluvium) scattered in the river basin Buol. This indicates that the downstream of the river enters the stage of the old river (Van Zuidam, 1985). The valley form V develops in the upper reaches of the Buol Watershed in the Central, South and West areas of research that develops on hilly and mountainous terrain. This V-shaped valley shows the development of a young river, characterized by erosion that plays vertically through the sharp valleys (Van Zuidam, 1985).

Drainage Pattern

The distribution of drainage pattern in Buol basin refers to the grouping according to Howard (1967) is divided into five types as :

1. Anastomatic pattern
2. Sub-Dendritic pattern
3. Sub-Trellis pattern
4. Parallel pattern
5. Sub-Parallel pattern

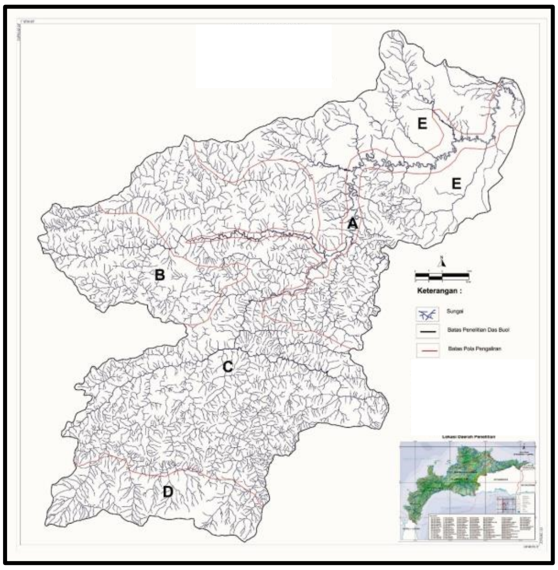

Figure 4. Drainage pattern of the research area: (A) Anastomatic; (B) Sub-dendritic; (C) Sub-trellis; (D) Paralel; (E) Sub-paralel

Slope

The results of slope calculation according to Van Zuidam (1985), there are 4 slope slope size found in research area. The results of these calculations are then displayed into the slope of the slope of the research area (Figure 5). The result of morphometric calculation shows that the steep slope (30% -70% or 13.5^0 - 31.5^0) occupies 37.75% of the research area, the slope of the steep slope (15% - 30% or 6.75^0 -13.5^0) occupies 32.25% Of the research area, slopes of slopes slope (7% - 15% or 3.15^0 - 6.75^0) occupy 3.25% of research area, slopes are very gently sloping (2% - 7% or 0.90 - 3.150) 6.25% and slope of flat slope (0 % - 2% or 0^0 - 0.9^0) occupy 20.50% of the research area.

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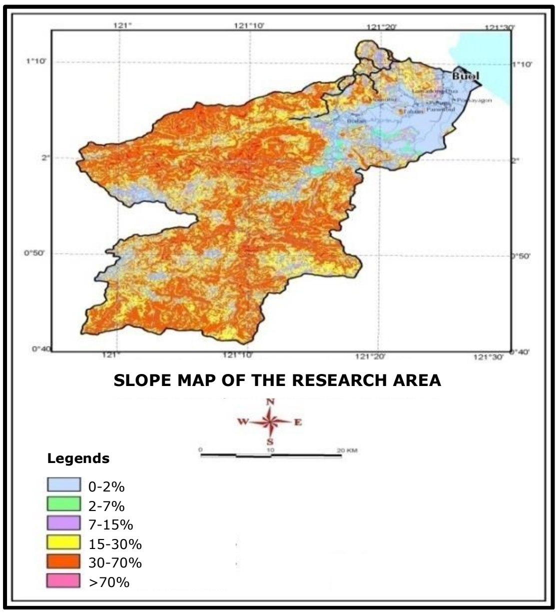

Figure 5. Slope map of the research area

Watershed Morphometry

Watershed (DAS) is a catchment area that is limited by the ridge. The research area is the Buol basin, which is subdivided into sub-watersheds. The watersheds in the research area are divided into 17 sub watersheds. The following is the distribution of sub watersheds located in the research area (Figure 6). The morphometric analysis of the watershed is used as a parameter in the determination of tectonic activity based on a quantitative assessment of a watershed geometry by analyzing the watershed area, watershed shape, river branch ratio (Rb) and flow density (Dd).

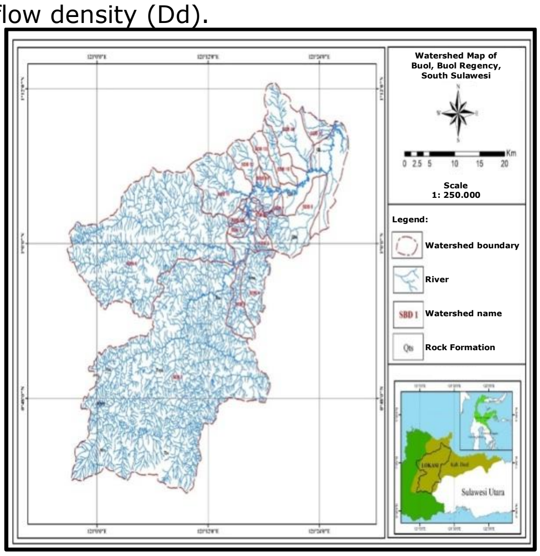

Figure 6. Map of the sub-watershed of Buol distribution

Watershed Area

The area of the watershed (watershed) is the catchment area, the wider the watersheds are much more capable of catching water. Watershed area is the flow between the width of the watershed and the length of the watershed. Watershed plays a role in the analysis of drainage densities in determining the level of permeability of rocks in the sub-catchments. From the extensive analysis of the Buol sub-basin can be obtained the width of Buol sub basin ranges from 2.82 - 335.04 km2. Of the broad value may be helpful in the analysis of the flow pattern density (Dd).

Watershed Shape

In determining the form of Buol watershed will always be related to the broadness and width of the watershed. The formation of Buol watershed refers to Sosrodarsono and Takeda (2003) and Ramdan (2006). Based on the analysis carried out on Buol watershed by dividing into 17 sub watersheds, the results obtained are 6 sub-watershed DAS, 2 parallel sub-watersheds, and 7 radial-shaped sub-basins and 2 DAS sub-basins in the form of Complex. Seen from these results that Buol Watershed has a varied watershed shape.

River Branch Ratio

The result of calculating the value of river branch ratio (Rb) of each sub watershed can be seen from the value of Rb1-2 has a range of 1 to 11. From these results provide information that seen from the average value of Rb indicated that in the sub-watershed there are 2 indications . In SBD2, SBD14, SBD16 may be indicated not deformed due to tectonic influence, possibly when deformation may be caused by other aspects. While SBD 1, SBD3, SBD4, SBD5, SBD6, SBD7, SBD8, SBD9, SBD10, SBD11, SBD12, SBD13, SBD15, SBD 17 indicate deformation due to tectonic effect, because it has an average Rb value below 3 and Above 5 (Verstappen, 1983).

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Table 2. River Branch Ratio of Buol Sub-Watershed

Sub watershed	Number of river order segments					Number or river segments	Rb Value			
	1	2	3	4	5		Rb1-2	Rb2-3	Rb3-4	Rb4-5
SDB 1	312	62	9	3		386	5,03	6,89	3	
SDB 2	636	135	33	9	3	816	4,71	4,09	3,67	3
SDB 3	60	11	3	1		75	5,45	3,67	3,00	
SDB 4	117	10	4	1		132	11,70	2,50	4,00	
SDB 5	20	8	10			38	2,50	0,80		
SDB 6	10	5	4			19	2,00	1,25		
SDB 7	14	8	4			26	1,75	2,00		
SDB 8	83	14	4	1		102	5,93	3,50	4,00	
SDB 9	11	9	1			21	1,22	9,00		
SDB 10	10	4	4			18	2,50	1,00		
SDB 11	101	44	43	2	13	203	2,30	1,02	21,50	0,15
SDB 12	21	12	10			43	1,75	1,20		
SDB 13	16	6	8			30	2,67	0,75		
SDB 14	5	1				6	5,00			
SDB 15	20	2	1			23	10,00	2,00		
SDB 16	27	8	1			36	3,38	8,00		
SDB 17	11	4	2	1		18	2,75	2,00	2,00	

Drainage Density

Based on the results of calculation in the table above, it can be seen that the sub watershed in Buol watershed has a value (Dd) ranging from 1.17 to 2.45, then based on the value can be concluded that the value of streaming density in the watershed Buol included in the medium category (Hidayah, 2008). According to Hidayah (2008) the characteristic of the density level of drainage is flowing through the rock with hard resistance so that the transported sediment transport is smaller and the distance of the flow of the stream is relatively slightly tenuous. The following classification of river density index according to Hidayah (2008) is in Table 4.

Tabel 3. Drainage Density of Buol Sub-Watershed

Sub watershed	River Length (L)	Watershed Area (A)	Drainage Density (Dd)
SDB 1	319,80	135,37	2,36
SDB 2	646,30	335,04	1,93
SDB 3	70,93	28,94	2,45
SDB 4	109,30	44,64	2,45
SDB 5	17,77	7,50	2,37
SDB 6	18,40	9,28	1,98
SDB 7	12,37	5,07	2,44
SDB 8	85,13	65,32	1,30
SDB 9	15,85	6,83	2,32
SDB 10	12,69	5,66	2,24
SDB 11	137,62	74,47	1,85
SDB 12	35,78	25,03	1,43
SDB 13	23,83	19,20	1,24
SDB 14	6,74	2,82	2,39
SDB 15	27,16	16,63	1,63
SDB 16	78,13	66,75	1,17
SDB 17	24,83	17,52	1,42

Table 4. Classification of drainage density level index (Hidayah, 2008)

No.	Index (Dd) km/km²	Value	Information

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1.	< 0,25	Low	if the Dd value is low then the river channel passes the rock with hard resistance so that the transport of sediment transported by the stream is smaller.
2.	0,25 – 10	Medium	
3.	10 – 25	High	If the value of Dd is very high then the flow of the river through waterproof rocks. This situation will show that the rain water into the flow will be greater.
4.	>25	Very High	

Morphotectonic Watershed

The morphotectonic conditions of Buol watershed can be supported by morphometric parameters, namely the ratio of river branch (Rb) and the flow density (Dd). In addition to the morphometric parameters to determine the tectonic activity required also the parameter of mountain facial sinusitas (Smf) and supported by the parameters of the valleys valve width ratio and valve height (Vf).

Sinuosity of Mount Front (Smf)

Sinuosity of Mountain Front (Smf) can be defined as the ratio between the mountain face length (Lmf) and the length of the projection of the mountain face to the plane (Ls) (Doornkamp, 1986). Based on the classification (Table 5) the research area included into the active tectonics supported by the form of drainage pattern residing in relatively elongated research areas with narrow valley base shapes and steep inclination. The results of calculation shows that there are some Smf values in the research area is outside of the classification Smf Doornkamp (1986). Therefore, the authors refer to another theory, i.e. if the value of Smf approaches value 1 then it indicates that there has been an active uplift. The value of the Mount Sinusity Index (smf) can be calculated using the equation (Doornkamp, 1986):

$$Smf = Lmf / Ls$$

Lmf : long face of the mountains along the bottom / valley.
Ls : long straight up the mountain face.

Table 5. Classification of Sinusity of mountain front (Doornkamp, 1986)

Class	Smf	Tectonic Activity
1	1,2-1,6	High Active Tectonic
2	1,8-3,4	Medium Active Tectonic
3	2,0-7,0	Non Active Tectonic

From the results of smf value analysis can be seen that the value of smf in the research area ranged from 1.15 to 1.76. Based on the classification (Table 5) the research area included into the active tectonics supported by the form of drainage pattern residing in relatively elongated research areas with narrow valley base shapes and steep inclination.

Comparison of Valley Width and Valley Height (Vt)

The ratio of width to valley floor width to valley height (Vf) is an analysis of the lifting rate in a research area based on the width of the baseline ratio of the valley with the height of the valley. From the result of value analysis (Vf), referring to the classification of VF ratio according to Keller and Pinter (1996), where Vf ratio having value <0,5 has high uplift, for Vf ratio value 0,5 - 1 has value (Uplift) medium and for the value of Vf ratio worth> 1 have low V level. Based on the classification, the research area includes (uplift) low up to high (uplift) level. The high (uplift) level is 5 points in SDB 1, SDB 2, SDB 9, SDB 10, SDB 11,

3.2 Discussion

Morphotectonic Characteristics in Buol Watershed

The morphotectonic state of Buol watershed is based on several aspects of the river flow pattern, which develops, the constituent lithology, the morphometric characteristics of the watershed, and the morphotectonic characteristics. Morphotectonic characteristics of Buol watershed, then the research area is divided into several morphotectonic units, as follows:

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1. High Morphotectonic Unit

High Morphotectonic units are located in the Central and West research areas, including SDB1, SDB2, SDB9, SBDB10, SDB11. The drainage pattern that develops in this unit is a sub-trunk, sub-dendritic and sub-parallel drainage pattern. The lithology contained in this high morphotectonic unit is sandstone lithology, claystone, breccias, tuff, and sandstone metas.

2. Medium Morphotectonic Unit

The morphotectonic units are being distributed in the West, Southwest and East parts of the Buol Basin, including SDB 1, SDB2, SBD3, SDB4, SDB5, SDB6, SDB8, SDB7, SDB12, SDB13, SDB14, SDB15, SDB16, and SDB17. The field obtained litologi growing ie claystone and metasediment sandstone, and sandstone.

3. Low Morphotectonic Unit

Low morphotectonic units are located in the Northeast and Central Buol Watershed where there is anastomatic river which has an old stage based on the shape of the U basin where the river has a lateral erosion force and the place of precipitated alluvium aged Recent.

Effects of Morphotectonic Characteristics on Geologically Hazardous Zones

1. Flood

Rb value can also be used to know the potential flood of a region (Purwanto, 2013). SDB15 the number of Rb-1 has a value of 10 and Rb-2 has a value of 2, SDB6 Rb-1 value is 2.00, Rb-2 value is 1.25, SDB7 Rb-1 has a value of 1.75 and Rb-2 has a value 2, Rb shows the value of Rb <3 indicating the flow of the river has a rapid rise in flood waters, while SDB14 Rb1 value 5,00, and SDB8 for Rb-1 value 5,93, Rb-2 value 3,50 and Rb- 3 values of 4.00, if the Rb value ranges from 3 to 5 indicates the flow of the river has a rise and decrease in flood water is not too fast or not too slow, whereas if the value of Rb> 5 signifies the flow of the river has a rapid rise in flood waters as well.

2. Earthquake

Based on the Map of the Earthquake Shock Hazard Indonesia Year 2001 that in the Sulawesi Sea region some Toli-Toli regency, Buol Regency and some areas of Gorontalo Province are at the dangers of earthquake shocks with the acceleration value of soil in bedrock of 0.25 g for lapse 500 Years with, 0.05 g (gravity) (Kertapati, 2001).

Morphogenetic Implication of Buol Watershed on Spatial Planning of Buol Regency

Buol District, originally a Buoli District Toli-Toli and later expanded into a stand-alone Regency established by Law of the Republic of Indonesia Number 51 Year 1999 on the establishment of Buol District, Morowali District and Banggai Kepulauan Regency, has a considerable comparative advantage, Its strategic location in the political, economic, social, cultural and defense and security aspects. Comparative advantages Buol District has not been managed optimally because of the limited ability of local governments and communities in planning, financing and implementing development. The enactment of Law Number 25 Year 2004 regarding National Development Planning System and Presidential Regulation of the Republic of Indonesia Number 5 Year 2010-2014 concerning that every Local Government is obliged to prepare development plan shall prepare a systematic, directional, integrated and sustainable development plan taking into consideration regional comparative advantage And the ability of local financial resources.

CONCLUSION

The Buol River Basin (DAS) is formed due to active tectonic control and proven by Ratio River Bifurcation Ratio analysis of some Sub DAS (SDB) in Buol Watershed. The research area is divided into several morphotectonic units, which are as follows: The High Morphotectonic Unit is located in the Central and West research areas, including SDB1, SDB2, SDB9, SBDB10, SDB11. Moderate Morphoteconic Unit. Spread over the West, Southwest and East parts of the Buol Basin, covering SDB 1, SDB2, SBD3, SDB4, SDB5, SDB6, SDB8, SDB7, SDB12, SDB13, SDB14, SDB15, SDB16, and SDB17. The Low Morphotectonic Unit is located in the Northeast and Central Watershed Buol.
Research areas are Prone to geological disasters in the research area include flood and earthquake hazards With the Law of the Republic of Indonesia Number 51 Year 1999 regarding the establishment of Buol District, Morowali District and Banggai Kepulauan

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Regency, has a considerable comparative advantage, especially its strategic location in the political, economic, social, cultural and defense and security aspects. Comparative advantages Buol District has not been managed optimally because of the limited ability of local governments and communities in planning, financing and implementing development.

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