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Sediment Dynamic in Barito Delta, Southern Kalimantan, Indonesia

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Abstract

The objective of the research was to analyze the sediment dynamic during wet and dry seasons both in subaqueous and subaerial of Barito Delta. Barito Delta is located in southern part of Kalimantan Island. The delta boundaries are Barito River in the East, Kapuas Murung River in the West, Java Sea in the South and PulauPetak River in the North. The decline of forest land in the delta and in the catchment might increase the sediment supply for delta development.
The data of the research were collected through field survey both in the subaqueous and in the subaerial. The equipment used in the research was sediment sampler for the subaqueous and hand auger for the subaerial. The sediments taken in both areas of subaqueous and subaerial were treated for grain size, sorting and skewness. The sediment deposition pattern was analyzed through Landsat imageries interpretation.
The results proof that sediment grain size in subaqueous delta in wet season consisted of clay, silt, fine sand and medium sand. Sorting of sediment in wet season and dry season was poor-very poor. The skewness in wet season had the positive value in all samples while the skewness in dry season had partly negative value and partly positive value. Tidal and wave came from seaside had important role for sediment redistribution during dry season, especially along the Kapuas Murung River. The texture of sediment in subaerial was dominated by fine sediment with mottles due to the influence of quartz materials and tide fluctuation. Peat ripe status in Barito delta is sapric-peaty soil.

Keyword: Barito delta, Sediment dynamic, Subaqueous, Subaerial, Wet season, Dry season.

1. Introduction

Delta was built by river and marine. Sediment was transported by river from the mountain then deposited in mouth of river. Current and waves eroded and dispersed the sediment in mouth of river [1]. Delta was land for fish production, wetland, wildlife habitat, water treatment, agricultural, tourism, and population centre [2, 3]. Delta contained the fertile soil, ground water, and petroleum [4, 5].

Delta consists of subaqueous and subaerial. Subaqueous is the part of delta plain below tide limit dominated by marine process. Subaerial is the part of delta above tide limit or sea level [1, 4, 6].

River is the most important agents fordelta evolution controlling [7]. River delivers water and sediment from watershed to delta and estuary [7-9].The changes of sediment supplyare caused by two main types, i.e. natural and human [7]. Natural influences for delta consist of temperature changes and desertification. Human influences for delta dynamic consist of dam construction and demand of water for agriculture, human and industrial [7].

Barito Delta is located in southern part of Kalimantan Island. Barito Delta is wetland area in southern Kalimantan. Land use in Barito Delta is dominated by agriculture. The coastal area in Barito Delta is used as the mangrove area. The mangrove forest in Barito Delta is dominated by *Rhizophora* forest. *Rhizophora* species consists of *Rhizophora apiculata* and *Rhizophora mucronat.* Along of river is dominated by ***Sonneratia caseolaris*** [10]**.**

Barito Delta has been developed during the period of 1862-2008. Barito Delta has been developed to south direction during the period of 1862-1997 and period of 2004-2008. The highest of delta development occurred during the period of 1985-1997 due to the land use change to agriculture. Reduction of area occurred during the period of

1997-2004 due to the stop of a millionacresof land" project for agriculture in year 1997/1998, hence the supply of sediment to delta is decreased [11]. The swampy forest in Barito Delta has been decreased during period 1862-2008 [12]. Land use changes have been influenced for sediment supply. Sediment supply in wet season and dry season have influenced for delta development. The objective of the research was to analyze the sediment dynamic during wet and dry seasons both in subaqueous and subaerial of Barito Delta. The location of Barito Delta is presented in Fig-1.

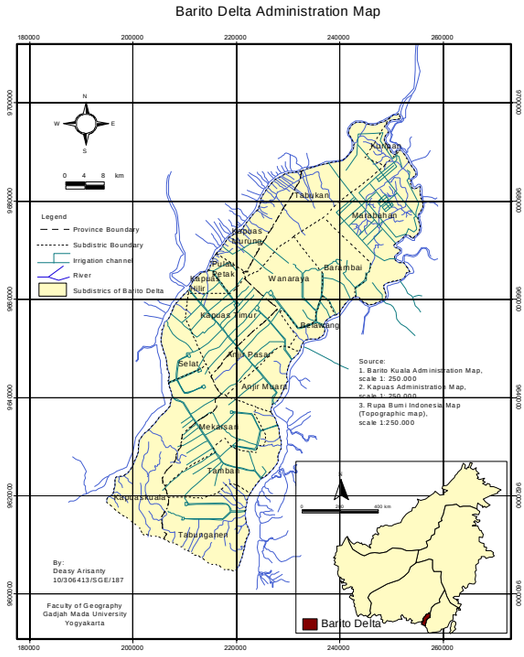

Fig-1.The Location of Barito Delta [12, 13]

2. Methodology

Data is obtained in subaqueous and subaerial. Sediment sampler is used for collecting the bed load samples in subaqueous. Bed load is measured in dry season and wet season. The number of sampling is 22 samples. The analysis of bed load grain size uses Casagrande classification. The analysis of bed load consists of grain size (% gravel, % sand and % mud), sorting, and skewness. MH-Detec [14] has been estimated the pattern of sediment using the LANDSAT TM False color composite (RGB=432). The multiyear of LANDSAT satellite images are analyzed with the ENVI Software using the false color composite 432 to determine the pattern of suspended sediment in dry season and wet season. The analysis of sediment deposition class uses ROI (region of interest). The multiyear of sediment deposition maps are compared to determine the sediment deposition changes in dry season and wet season. Sediment core in subaerial delta is obtained from hand bore. The number of hand bore sampling is 51 samples. The analysis of texture uses the pipette method. Bulk Density analysis is used to determine the peat ripe status. Landform is used as the sampling area of subaerial. Locations of samples are presented in **Fig-2** and **Fig-3.**

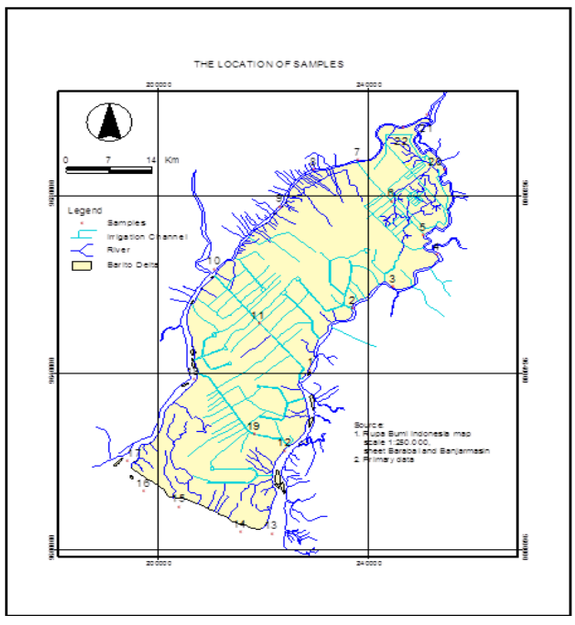

Fig-2. Location of sample in subaqueous

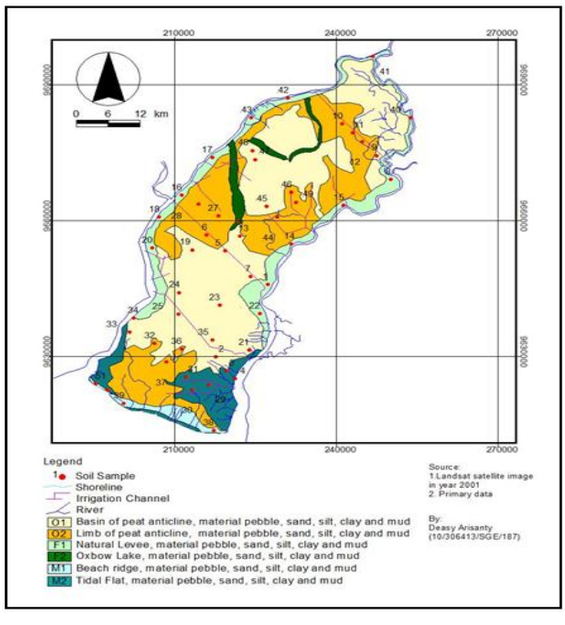

Fig-3. Location of samples in subaerial

3. Result and Discussion

a. Bed Load Characteristic in Wet Season and Dry Season

Bed load grain sizes of Barito Delta in wet season are fine size, i.e. clay, silt, fine sand and medium sand. Fine sand, silt and clay are located in river. Medium sand is located in shore. Material of Barito River consists of fine sand in middle of delta, clay in upper of delta, and silt in mouth of river. Bed load of Kapuas Murung River consists of silt and clay. Bed load in Barito Delta has the positive value due to the domination of river deposition. Bed load has poorly-very poorly value of sorting in wet season. River has more important role for sediment deposition than marine in wet season. Characteristic of bed load data in wet season is presented in **Table-1.**

Table-1.Characteristic of bed load in wet season

Sample	Location	Coordinate	Mean	Median	Sorting	Skewness	Grain size class
1	Barito River 1	3^0 12" 28.8" S 114° 33'19.4" E	2	2.1	1.5 (Poorly Sorted)	0.25	Fine sand
2	Barito River 2	03° 6'54.4"S 114 °37'05.0"E	2.7	2.1	2.7 (Very Poorly Sorted)	0.8	Fine sand
3	Barito River 3	03°03'47.7"S 114 °39'51.8"E	1.83	2	1.35 (Poorly Sorted)	0.10	Fine sand
4	Barito River 4	02°58'42.0"S 114°46'05.6"E	4.9	5.5	3.6 (Very Poorly Sorted)	0.060	Clay
5	Barito River 5	02°56'42.5"S 114°45'32.8"E	5.93	6.4	4.03(Very Poorly Sorted)	0.10	Clay
20	Barito River 6	02°56'42.5" S 114°45'32.8" E	5.9	6.2	4.37 (Very Poorly Sorted)	0.188	Clay
21	Barito River 7	02°43'51.7" S 114°44'32.8" E	5.56	5.9	4.18(Very Poorly Sorted)	0.35	Silt-Clay
22	Pulau Petak River 1	02°43'51.7" S 114°45'50.7" E	4.73	4.6	3.8(Very Poorly Sorted)	0.55	Silt
6	Talaran channel (irrigation channel)	02°52'19,22" S 114 °48'50.9"E	5.7	5.7	4.54(Very Poorly Sorted)	0.65	Silt
7	Pulau Petak River 2	02°48'25.7"S 114 °38'12,5"E	4.23	3.9	3.6 (Very Poorly Sorted)	0.60	Silt
8	Pulau Petak River 3	02°53'23.6"S 114°30'11.1"E	5.2	5.2	4.19(Very Poorly Sorted)	0.54	Silt
9	Pulau Petak River 4	02°56'26.3" S 114°27'18.1"E	5.4	5.4	4.25(Very Poorly Sorted)	0.48	Silt
10	Kapuas Murung River 1	03°01'13.7"S 114°23'39.0"E	5.87	6.3	4.47(Very Poorly Sorted)	0.28	Clay
11	Serapat Channel (irrigation channel)	03°07'45.3"S 114°28'57.8"E	5.7	5.7	4.40(Very Poorly Sorted)	0.59	Silt
12	Barito River 8	03°21'12.7"S 114°31'14.8"E	5.57	5.5	4.48(Very Poorly Sorted)	0.73	Silt
13	Barito River Mouth	03°26'37.8"S 114°30'08.3"E	5.6	5.7	4.153(Very Poorly Sorted)	0.218	Silt-clay
17	Kapuas Murung Rivermouth	03°23'09.2" S 114°15'01.8"E	5.3	5.3	4.19(Very Poorly Sorted)	0.51	Silt
18	Kapuas Murung River 2	03°18'18.3"S 114°17'43.3"E	5.67	5.7	4.47(Very Poorly Sorted)	0.58	Silt
19	Tamban Channel (irrigation channel)	03°19'54.4"S 114°28'12.3"E	5.16	5.3	3.81 (Very Poorly Sorted)	0.15	Silt
14	Nearshore 1	03° 30'07.9"S 114 °28'49.4"E	4.567	5	3.17(Very Poorly Sorted)	0.028	Silt
15	Nearshore 2	03°28'22.4"S 114°22'15.7"E	4.085	5.1	4.08(Very Poorly Sorted)	0.64	Silt
16	Nearshore 3	03°26'53.6"S 114°18'39.1"E	1.7	1	1.73(Poorly sorted)	0.42	Medium sand

Bed load grain sizes of Barito Delta in dry season consist of silt-fine sand. Grain sizes in river are silt-clay. Barito River is dominated by clay and silt. Pulau Petak River is dominated by clay and fine sand. Sediment in Kapuas Murung River is dominated by silt and clay. Bed load in Barito Delta consists of poorly-very poorly value of sorting in dry season. Sediments have positive value and negative value of skewness during dry season. Positive value of skewness is located in eastern part of delta. Negative value of delta is located in western part of delta. Negative value of skewness describes that marine has impact for sediment deposition in dry season. Characteristic of bed load in dry season is presented in Table-2.

Forest in Barito Catchment Area had been decreased during the period 2000-2009. The forest in catchment had been decreased about 1,047,163.82 hectare or 16.38% during the period 2000-2009. Percentage of land forest in South Kalimantan and Central Kalimantan Province in year 2009 was about 4.15% and 38.77%, respectively. The decreased of land forest in catchment area was influenced by forest degradation, illegal logging, forest fire, and mining [15].

Swampy forest in Barito Delta was decreased during the period 1862-2008 due to land use changes in Barito Delta. Land use in Barito Delta in year 1862 was dominated by swampy forest with the area was about 2,198.36 km^2. Development of irrigation channel for agriculture had impact for agriculture development in Barito Delta. Irrigation channel had been built in Barito Delta in year 1946 for agriculture and transportation network. Settlement and

agricultural land had been increased rapidly during period 1985-2008, whereas the swampy forest had been decreased due to land conversion. The swampy forest in year 2008 was about 752.52 km^2 [13].

Table-2. Characteristic of bed load in Dry Season

Sample	Location	Coordinate	Mean	Median	Sorting	Skewness	Gain size class
1	Barito River 1	3^0 12" 28.8" S 114^o 33'19.4" E	6.033	6	4.828(very poorly sorted)	0.760	Silt-Clay
2	Barito River 2	03^o 6'54.4"S 114 ^{o}37'05.0"E	5.9	5.9	4.677 (very poorly sorted)	0.625	Silt-Clay
3	Barito River 3	03^{o}03'47.7"S 114 ^{o}39'51.8"E	5.133	5.3	4.367(very poorly sorted)	0.716	Silt
4	Barito River 4	02^{o}58'42.0"S 114^{o}46'05.6"E	5.567	5.5	4.512(very poorly sorted)	0.710	Silt
5	Barito River 5	02^{o}56'42.5"S 114^{o}45'32.8"E	3.367	3	2.881 (very poorly sorted)	0.42	Silt
20	Barito River 6	02^{o}56'42.5" S 114^{o}45'32.8" E	3.833	4	3.178(very poorly sorted)	0.287	Silt
21	Barito River 7	02^{o}43'51.7" S 114^{o}44'32.8" E	6.833	7	5.162(very poorly sorted)	0.465	Clay
22	Pulau Petak River 1	02^{o}43'51.7" S 114^{o}45'50.7" E	5.433	6.8	3.814(very poorly sorted)	-0.151	Clay
6	Talaran channel (irrigation channel)	02^{o}52'19,22" S 114 ^{o}48'50.9"E	3.7	5	2.388(very poorly sorted)	-0.204	Clay
7	Pulau Petak River2	02^{o}48'25.7"S 114 ^{o}38'12,5"E	4.667	5	3.537(very poorly sorted)	0.122	Clay
8	Pulau Petak River3	02^{o}53'23.6"S 114^{o}30'11.1"E	3.167	2.3	3.072(very poorly sorted)	0.928	Fine sand
9	Pulau Petak River	02^{o}56'26.3" S 114^{o}27'18.1"E	4.167	4	3.458(very poorly sorted)	0.407	Silt
10	Kapuas Murung River 1	03^{o}01'13.7"S 114^{o}23'39.0"E	6	6.5	4.359(very poorly sorted)	0.07	Clay
11	Serapat Channel (irrigation channel)	03^{o}07'45.3"S 114^{o}28'57.8"E	6.1	7	3.931(very poorly sorted)	-0.309	Clay
12	Barito River8	03^{o}21'12.7"S 114^{o}31'14.8"E	3.7	6.2	1.952(poorly sorted)	-0.374	Clay
13	Barito River mouth	03^{o}26'37.8"S 114^{o}30'08.3"E	1.633	1.7	1.284(poorly sorted)	0.333	Fine sand
17	Kapuas Murung River mouth	03^{o}23'09.2" S 114^{o}15'01.8"E	5.1	6.1	3.603(very poorly sorted)	-0.08	Clay
18	Kapuas Murung River2	03^{o}18'18.3"S 114^{o}17'43.3"E	5.433	5.8	4.064(very poorly sorted)	0.173	Clay
19	Tamban Channel (irrigation channel)	03^{o}19'54.4"S 114^{o}28'12.3"E	6.567	7	4.432(very poorly sorted)	-0.151	Silt
14	Nearshore 1	03^o 30'07.9"S 114 ^{o}28'49.4"E	2.767	2.6	3.789(very poorly sorted)	0.731	Fine sand
15	Nearshore 2	03^{o}28'22.4"S 114^{o}22'15.7"E	2.8	2.3	2.615(very poorly sorted)	0.549	Fine sand
16	Nearshore 3	03^{o}26'53.6"S 114^{o}18'39.1"E	5.633	6.8	3.572(very poorlysorted)	-0.243	Clay

Sediment of Barito Delta is dominated by fine sediment, such as fine sand, silt and clay. Barito River discharge of Barito Delta in wet season is about 1,731 m^3/s. Barito River discharge of Barito Delta in dry season is 1,008.75 m^3/s. Development of Barito Delta as a lobate delta shape is influenced by river [13].The influenced of river has been resulted the fine sediment in wet season and dry season. River also results poor-very poor sorting both in dry season and wet season. Skewness of bed load has the positive value in wet season. Skewness of bed load in dry season has the positive value in eastern part of delta and the negative value in western part of delta. River discharge decreases during dry season, hence tidal and wave have the important role for sediment transport.

The land use changes in Barito Delta during the period 1862-2008 had impact for sediment dynamic in Barito Delta. Land use changes had increased the sediment, hence delta developed during the period 1862-2008. Irrigation channel also has impact for sediment characteristic. Straightening of small streams meandering into irrigation channels has increased the amount of sediment and accelerates the rate of sediment transport to mouth of river. Sediment is deposited quickly in the mouth of the river, so that the sediment has poor-very poor sorting, domination of fine sediment, and positive value of skewness.

b. Sediment Deposition Pattern

MH-MH-Detec [14] estimated the sediment deposition pattern using LANDSAT TM false color composite. This research also estimated the pattern of sediment accumulation using LANDSAT TM false color composite (RGB=432). The images for delta deposition pattern analysis consist of LANDSAT TM in year August, 17 1997; February, 22 1999; June, 17 2004; and July, 6 2005.

Image on August, 17 1997; June, 17 2004; and July, 6 2005 explained the deposition of sediment in dry season. High concentration of sediment (red) in dry season is located in mouth of river, shore and river. Low concentration of sediment (blue) is located in the sea. High accumulation of sediment in shore was redistributed by wave and current. River discharge was low capacity for sediment transport due to the water river volume decreased in dry season.

Image on February, 22 1999 explained the pattern of suspended sediment deposition in wet season. River discharge was high in wet season due to the water river volume increased in wet season. The influenced of river discharge for sediment transportation was higher than the influenced of marine in wet season. The sediment deposition pattern of Barito Delta is presented in **Fig-4.**

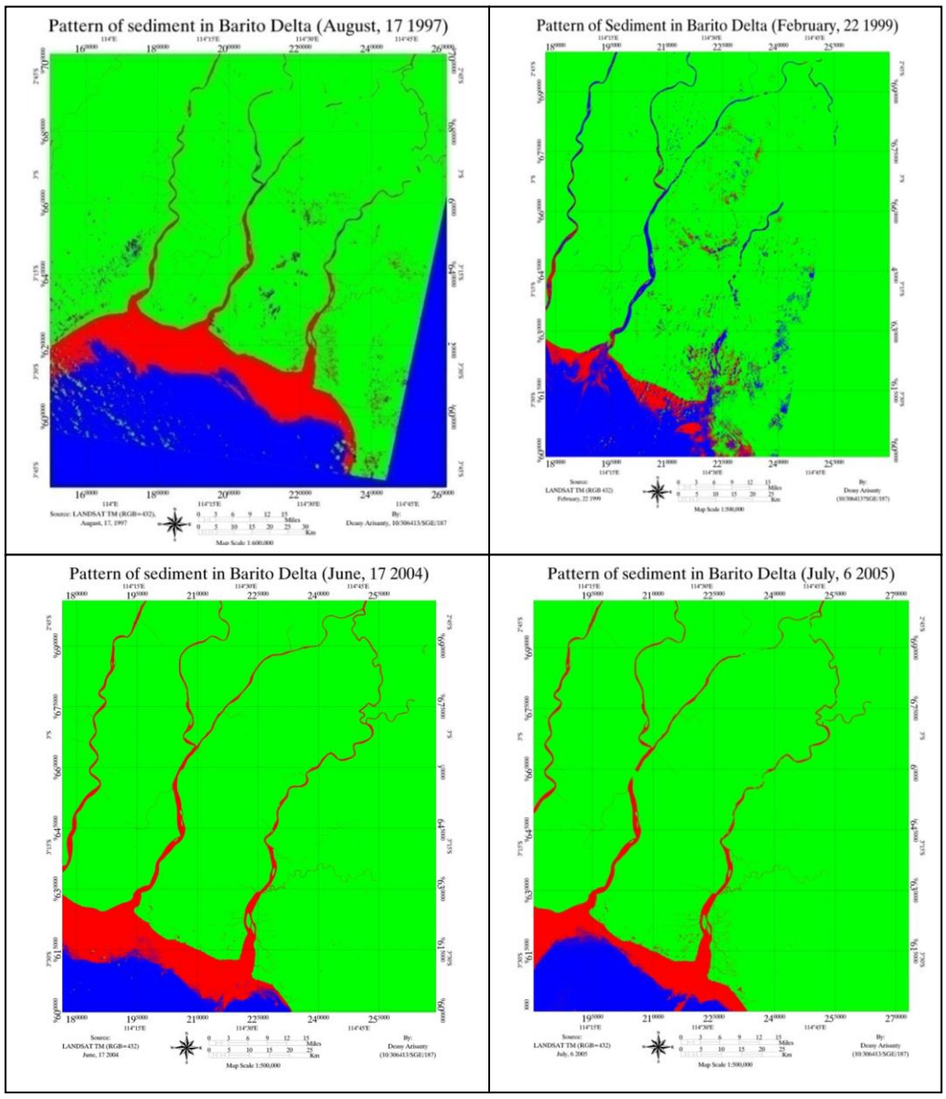

Fig-4. The sediment deposition pattern of Barito Delta

c. Sediment Characteristic in Subaerial

Materials in subaerial of Barito Delta are fine sediment, such as clay, silt, silty clay, silt loam, clay loam. Clay can be found in natural levee, tidal flat, basin of peat anticline, and limb of peat anticline. Clay in natural levee, basin of peat anticline and tidal flat are found in 1-4 m. Silty clay, silt, silt loam, clay loam can be found in all of landform. Fine sand is found in 1.5-2 m in basin of peat anticline. The location of fine sand in natural levee landform is deeper than basin of peat anticline.Quartz minerals can be found in all of landform.

The influence of water is clearly in soil morphology. Oxidation condition can be found in the surrounding of river because of the tide fluctuation. High tide in Barito River is about 2-2.5 m and low tide in Barito River is about 0.5 m. Tidal fluctuation influences aeration condition in the soil, hence mottling can be found in 0-2 m of soil depth. Reduction condition is found in the central of delta (basin of peat anticline landform) because of the water inundation in central of delta.

Peat can be found in central of delta (basin of peat anticline landform). Peat ripe status of Barito Delta is sapric-peaty soil, because the value of bulk density is more than 0.27 gram/cc. Peat in Barito Delta is classified as Topogenic peat [16], hence the peat soil has high organic matter for agriculture. Peat in central of delta with the thickness about 1 m was estimatedapproximately 2,350 years [17]. Agriculture area in central of delta has impact for the thickness of peat. The thickness of peat in central of delta, as the agriculture area, is about 1-2 m. Activity ofpeat landsburning for agriculturereducespeat thickness. Agriculture activity has impact for peat developing in delta.

4. Conclusions

Bed loads of Barito Delta in wet season and dry season are dominated by fine sediment. Bed load in wet season and dry season has poorly-very poorly value of sorting. Sediment skewness has positive value in wet season. Skewness sediment in dry season has positive value in eastern part of delta and negative value in western part of delta. Wave and tidal has the important role for sediment distributing in dry season. Land use changes in Barito Delta have impact for sediment dynamic in subaquous of Barito Delta.

Sediment in subaerial is dominated by fine sediment. Quartz minerals can be found in all of landform. Mottling can be found in Barito Delta due to tide fluctuation. Peat ripe status in Barito Delta is sapric-peaty soil. Peat of

thickness decreased due to the agriculture activities. Human activities have impact for sediment characteristic in subaerial of Barito Delta.

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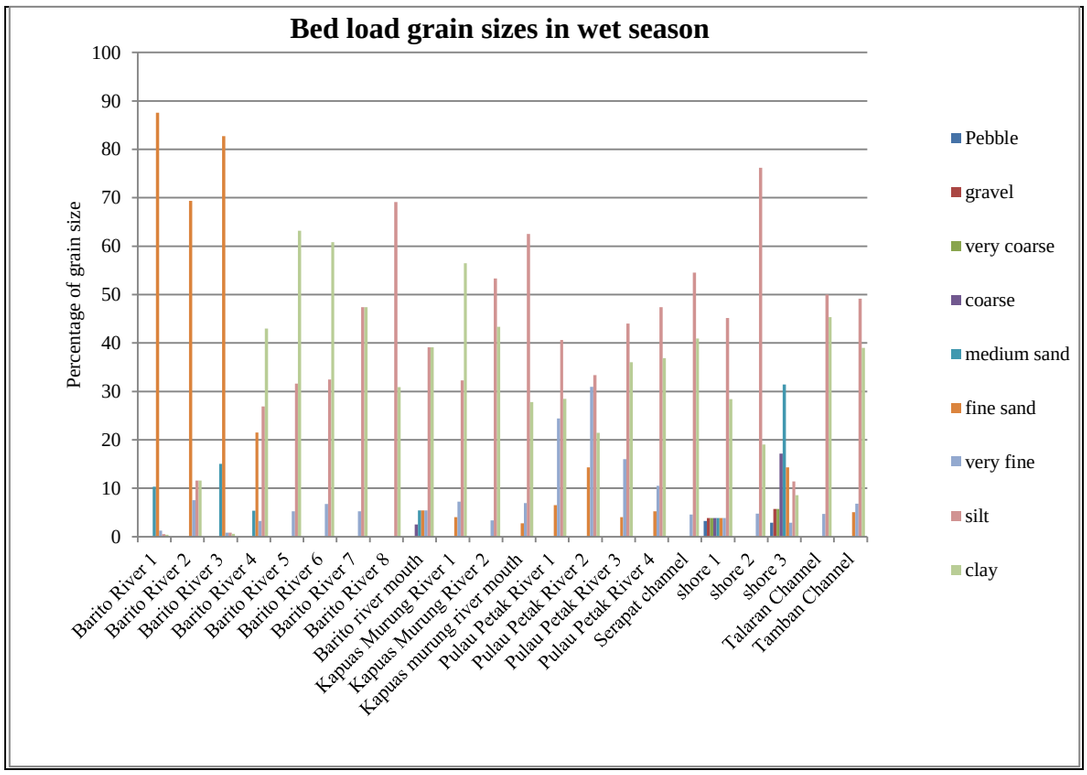
APPENDIX
Bed Load Grain Sizes Data
1. Wet Season

Sample Location	Percentage of grain size								
	Pebble	gravel	very coarse	coarse	medium sand	fine sand	very fine	silt	clay
Barito River 1	0	0	0	0	10	88	1	1	0
Barito River 2	0	0	0	0	0	69	8	12	12
Barito River 3	0	0	0	0	15	83	1	1	1
Barito River 4	0	0	0	0	5	22	3	27	43
Barito River 5	0	0	0	0	0	0	5	32	63
Barito River 6	0	0	0	0	0	0	7	32	61
Barito River 7	0	0	0	0	0	0	5	47	47
Barito River 8	0	0	0	0	0	0	0	69	31
Barito river mouth	0	0	0	3	5	5	5	39	39
Kapuas Murung River 1	0	0	0	0	0	4	7	32	56
Kapuas Murung River 2	0	0	0	0	0	0	3	53	43
Kapuas murung river mouth	0	0	0	0	0	3	7	63	28
Pulau Petak River 1	0	0	0	0	0	7	24	41	28
Pulau Petak River 2	0	0	0	0	0	14	31	33	21
Pulau Petak River 3	0	0	0	0	0	4	16	44	36
Pulau Petak River 4	0	0	0	0	0	5	11	47	37
Serapat channel	0	0	0	0	0	0	5	55	41
shore 1	3	4	4	4	4	4	4	45	28
shore 2	0	0	0	0	0	0	5	76	19
shore 3	3	6	6	17	31	14	3	11	9
Talaran Channel	0	0	0	0	0	0	5	50	45
Tamban Channel	0	0	0	0	0	5	7	49	39



2. DRY SEASON

Sample Location	Percentage of grain size								
	Pebble	**gravel**	**very coarse**	**coarse**	**medium sand**	**fine sand**	**very fine**	**silt**	**clay**
Barito River 1	0	0	0	0	0	0	0	46	54
Barito River 2	0	0	0	0	0	0	3	51	46
Barito River 3	0	0	0	0	0	0	6	70	23
Barito River 4	0	0	0	0	0	0	7	57	36
Barito River 5	0	0	7	6	6	27	12	35	8
Barito River 6	0	0	0	0	7	28	0	53	12
Barito River 7	0	0	0	0	0	0	0	12	88
Barito River 8	27	7	0	0	0	0	0	12	54
Barito River mouth	0	0	0	0	31	69	0	0	0
Kapuas Murung River 1	0	0	0	0	0	0	5	27	68
Kapuas Murung River 2	0	0	0	0	0	11	0	44	44
Kapuas Murung River mouth	0	0	0	0	9	18	0	9	64
Pulau Petak River 1	0	0	0	0	0	23	0	8	69
Pulau Petak River 2	0	0	0	0	0	6	12	59	24
Pulau Petak River 3	0	0	0	0	0	60	10	20	10
Pulau Petak River 4	0	0	0	5	5	23	9	36	23
Serapat Channel	0	0	0	0	0	0	0	5	95
shore 1	0	0	0	0	0	50	33	17	0
shore 2	0	0	0	0	0	73	12	15	0
shore 3	0	4	4	4	4	4	0	18	64
Talaran Channel	0	9	11	8	8	8	4	13	41
Tamban Channel	0	0	0	13	8	8	13	3	56