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River Bed Erosion and Sedimentation Behavior in Discharge Fluctuation Condition

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Abstract: Erosion and sedimentation in the rivers are a function of the water flow velocity and sediment concentration that carried away transported in the flow, this flow velocity is very depend on the discharge quantity. The second most important factor is dimensions and geometry of the river, among others, is the shape and size of cross section of the river also pattern of river plan form. This research was carried out using daily fluctuations discharge data in 1992 up to 2011 on the meandering river. By applying KUN-QARSHOV method can be obtained descriptions of the erosion and sedimentation behavior as follows: • Horizontal Erosion and sedimentation: At inflection point from low tide to high tide on bottom of the river ocurrs sedimentation, otherwise at the inflection point from high tide to low tide on the bottom of the river ocurrs erosion. • Verticall Erosion and sedimentation: At inflection point from low tide to high tide on river bottoms occurring erosion, otherwise at the inflection point from high tide to low tide on the bottom of the river occurring sedimentation.

Key words: Discharge fluctuation · Erosion · Meandering river propagation · Sedimentation

INTRODUCTION

River flow conditions are naturally always depend on the season conditions [1], so it could be said that there is no river with constant discharge conditions [2-4]. Generally condition of the season in Indonesia [5-7] are classified into two seasons, those are dry season which characterized as a rare rain and wet season with frequent rain. With different condition of rain intensities between two seasons cause discharge conditions of the river be fluctuate. River discharge fluctuations that occur every time leads to the occurrence of hydraulic condition changes in the river such as: high water flow, stream velocity, radius of hydraulic, wet circumference and wet area.

KUN-QARSHOV is a method developed for predict river propagation and movement based on condition of discharge fluctuations as main consideration Odgaard, A. J. [8]. Besides the main considerations, this model also accommodates other influence parameters on erosion and sedimentation Brice, J.C. [9]; Hooke, J. M. [10]; Hudson, P.F. *et al*. R.H. [11], such gradations and sediment content Julien, P. Y. [12], stream velocity Leopold *et al*. [13], dimensions and geometry of the river Keady, D. M. *et al*. [14]; Morisawa, M. [15]. This research applies KUN-QARSHOV method in Brantas River in Indonesia to get a description of erosion and sedimentation behavior under discharge fluctuation influence. The primary consideration are the discharge fluctuations data as recorded the daily discharge data in 1992 up to 2011. With the daily discharge data can be obtained output as magnitudes of erosion and sedimentation caused by every change of discharge, thus can be described as the relationship between the discharge change with erosion and sedimentation behavior in the river.

MATERIALS AND METHODS

Discharge Caracteristics:

- In naturally condition no river has constant discharge condition in any time. Type of river

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discharge characteristic [5] in series data can be classified into: High tide defined as a increasing of discharge quantity and a increasing of the water level surface.

- Low tide defined as a decreasing of discharge quantity and a decreasing of the water level surface.
- The maximum high tidal discharge is the maximum discharge at high tide.
- The minimum low tide discharge is the minimum discharge at low tide times.

Meandering River Geometry Movement: Sinuosity of river is measured and stated in geometry parameters of meandering river, the definition of the parameter geometry according to meandering river Park Namgyu [16]; Ikeda, S. *et al*. [17] as stated in Figure 1. with the following information: a = meander amplitude, r_c = radius of curvature meander, W= river wide, ϕ = meander arch angle and θ = relative angle ($0 < \theta < \phi\_$).

KUN-QARSHOV Method: There are two causes of changes in river geometry, namely, erosion and sedimentation. The method of computation by using the equation of sedimentation and erosion equation [7] introduced is called the method of KUN-QARSHOV. This method begins by analysis of the relationships between parameters to get value of sedimentation and erosion.

Sedimentation Equation: Sedimentation (E) is a function of $E = f(Q, V, A, h_b, O, S, r_c, \phi,\_\theta,\_\lambda,\_a, t)$, each parameters in this function is related to sedimentation process.

Derive relationships between above dimensionless parameter numbers obtained sedimentation is following function:

$$E \approx \frac{Q}{r_c V}.\frac{A}{r_c^2}.\frac{h_b}{r_c}.\frac{r_c}{O}.S.\frac{\theta}{\phi}.\frac{a}{r_c}.\frac{r_c}{\lambda}.\frac{1}{t} \qquad (1)$$

Therefore, S is the content of suspended sediments and Q is discharge rate per unit time, then S and Q being the numerator and t becomes to denominator. The relationship between θ and ϕ is a comparison that reflects the character of the sedimentation or erosion on the position in which θ and ϕ are located. If $\theta\_/\phi = 0$ and $\theta\_/\phi = 1$, erosion and sedimentation in the cross-section of the river on balanced condition. If $0 < \theta\_/\phi < 1$ river cross section on unbalanced condition it means that occurs erosion or sedimentation.

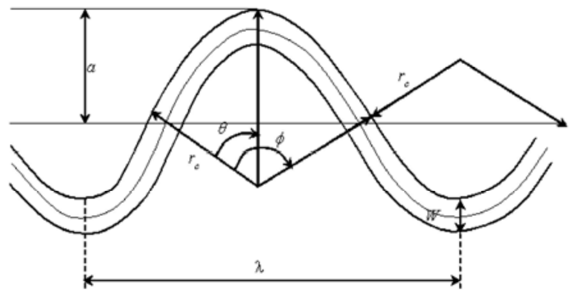

Fig. 1: Meandering river parameter

Erosion Equation: Erosion (G) is a function $G = f(Q, V, A, h_b, O, D_{50}, r_c, \phi,\_\theta,\_\lambda,\_a, t)$, analogous to the analysis of the relationships between the parameters to get the magnitude of sedimentation, to get the quantity erosion is from a function:

$$G \approx \frac{Q}{r_c V}.\frac{A}{r_c^2}.\frac{h_b}{O}.\frac{D_{50}}{r_c}.\frac{\phi}{\theta}.\frac{\lambda}{\alpha}.\frac{1}{t} \qquad (2)$$

River geometry changes caused by sedimentation and erosion occur at any time, any discharge change and at every point on the bottom of the river. The both incident is change in the river geometry towards horizontal Δh and vertical Δv. Whenever there is a change of discharge fluctuations the every oints change ofΔh and Δv. Both is the difference between E with G can be written by the equation $\Delta h = h_0 + (E - G)$ and $\Delta v = v_0 + (E - G)$. If Δh and Δv are positive then sedimentation to occur and negative then happened to erosion.

By this KUN-QARSHOV method river geometry changes the result from erosion and sedimentation as a result of discharge fluctuations can be determined in detail at each change discharge.

Study Area and Data Collection

Description of Study Area: The Brantas River Basin is located in east Java, Indonesia. This river flowing a long 320 Km, some segments are included in meandering river segment classification. Among of them are the Mojokerto segment the study area in this research, a long 6,378 metres. Visualization and description of study area as shown in Figure 2.

Discharge Fluctuation Measurement: Discharge rate data was collected from 1992 up to 2011 from the measurement of Automatic Water Level Recorder (AWLR) Brantas River. AWLR station is located on the geographical position of the 07^{0}28'00" south latitude and 112^0 26'00" east longitude.

Fig. 2: Brantas meandering river from Google Map

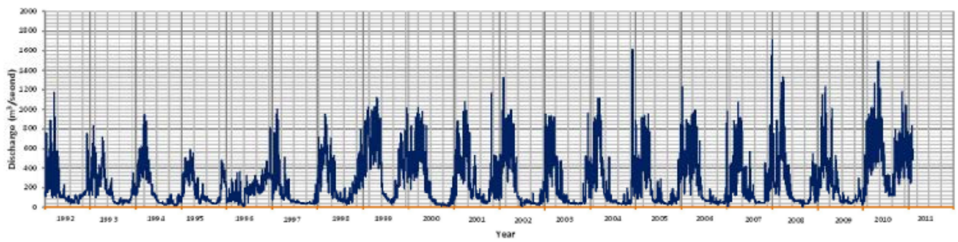

Fig. 3: Brantas River Hydrograph 1992 - 2011

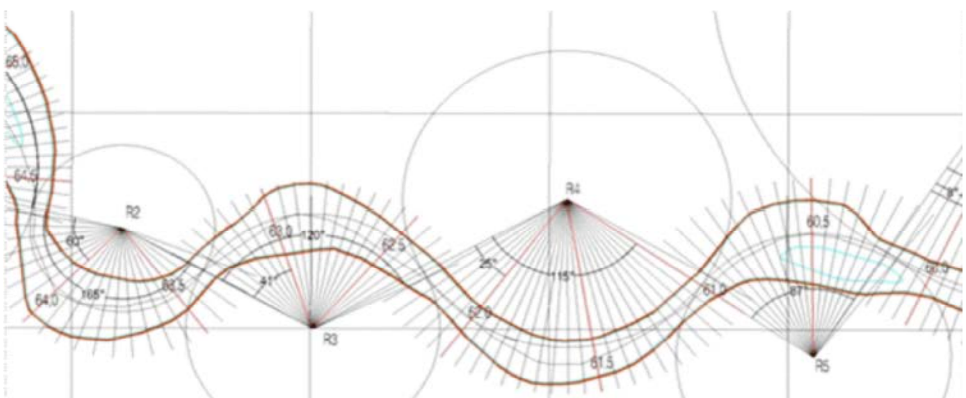

Fig. 4: Meandering river parameters measurement

Discharge fluctuation in this study is shown as graphically of Brantas River hydrograph in Mojokerto collected 1992 up to 2011 expressed in Figure 3.

Meandering River Geometry Measurement: Measurement of meandering river parameters carried in the Brantas River as seen in Figure 4. Then compared with image taken from Google Map as show in Figure 2. On meander arch on each of bends of the river are marked by notation R1 to R6. thus can be obtained meander parameters. Meander parameter from analysis results for this location in detail shown in Table 1.

Length of the reviewed river is river segment measured is 6,380 metres with meanders axis is 3,290 metres. In terms of the classification of the river according to the Morisawa theory [15] that river segment is included in the classification of meander if sinuosity is larger than 1.5. Thus the river segment researched is in scope of the meandering river with number sinuosity 1.94.

Application: Applicability of the KUN-QARSHOV method was verified [5] and was applied in Brantas River for 6,380 metres, by nineteen years series data. The application is intended to get the velocity of meander

Table 1: Meandering Brantas River parameters measurement

Point of Measurement		Meander Parametre							
		r_c *(metre)*	η ′ metre η	*a (metre)*	η ′ ^η η	η ′ ^η η	η ′ ^η η	η ′ ^η η	*W (metre)*
R1	KB 65	722	1828	409	60	-	-	109	173
R2	KB 64	357	1382	505	60	-	-	165	295
R3	KB 63	490	1900	395	41	-	-	120	292
R4	KB 62 & 61	634	1919	434	25	115	-	115	197
R5	-	531	1832	316	-	-	-	87	355
R6	KB60 & 59	1462	1809	261	8	47	-	61	179

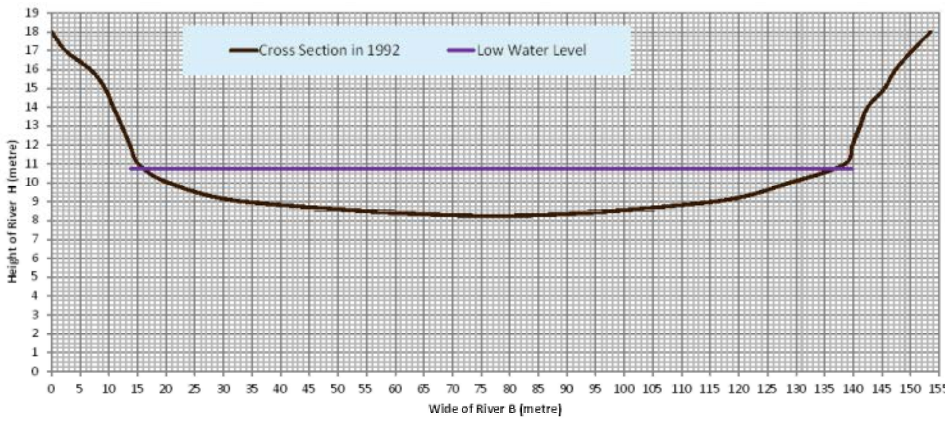

Fig. 5: Initial condition Brantas river geometry 1992 in Brantas River Km 59

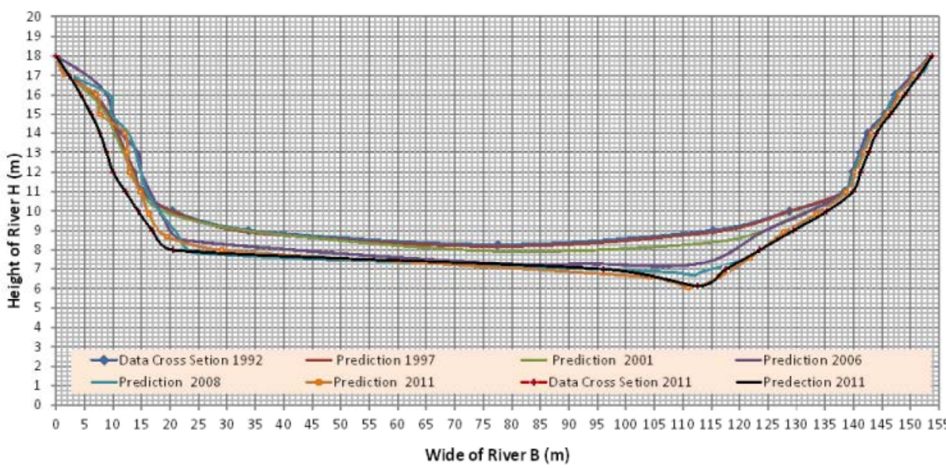

Fig. 6: Historical movement and change of river geometry on Brantas River Km 59

migration. The other output is analyzed to obtain the behavior of erosion and sedimentation in this paper.

Discharge Fluctuation (*dQ*) with Horizontaly Geometry Change (*dH*) Relationship: Discharge fluctuations expressed in discharge change perunit time (*dQ*/sec), while horizontal geometry change expressed in a horizontal direction changes perunit time (*dh*/sec). Thus the relationship between fluctuations discharge with horizontal geometry changes is: relationship (*dQ*/sec./day) against (*dh*/sec./day). To get a clear, reviewed one point in Brantas River Km 59 as shown in the Figure 5.

Historical changes and movement geometry simulation results obtained from rivers with discharge data 1992 up to 2011 expressed in Figure 6.

The relationship of simulated results with daily discharge data 1992 up to 1997 is expressed in a graph as shown in Figure 7. Details of the relationship of discharge

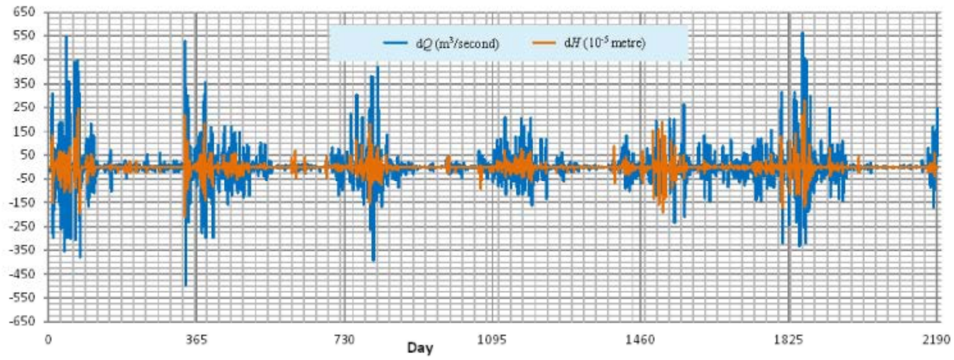

Fig. 7: The Relationship Of Discharge Fluctuations With Horizontal Geometry Changes In Brantas River Km 59. (1992 up to 1997)

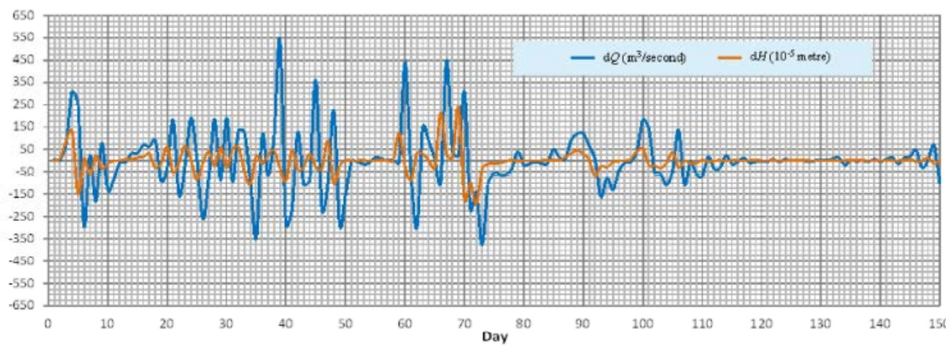

Fig. 8: The details of the relationship of discharge Fluctuations With Horizontal Geometry Changes in Brantas River Km 59 During the first 150 days on January 1992.

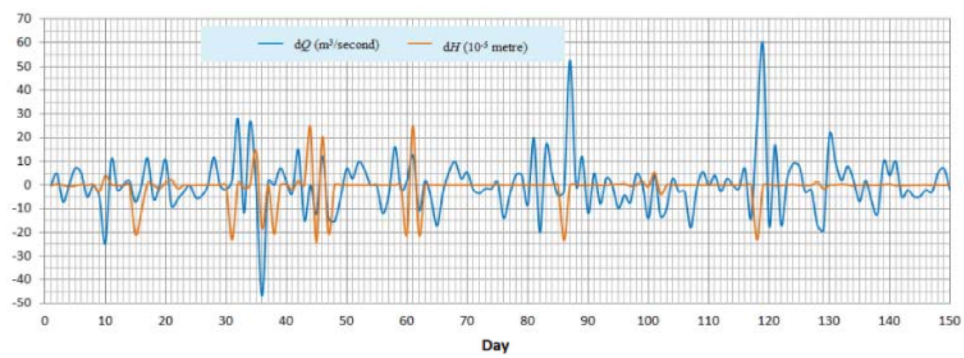

Fig. 9: The details of the relationship of discharge Fluctuations With Horizontal Geometry Changes in Brantas River Km 59 During the first 150 days on June 1992.

fluctuations with horizontal geometry changes in Brantas River Km 59, in the first nine days on January 1992 and June 1992 is shown in Table 2.

Considering the graph in Figure 7. Figure 8. Figure 9 and Table 2. could be found the important conditions as follows: on high tide (*dQ* positive) on the bottom of the river occurring sedimentation (*dH* positive), on the high tide condition but value of to day *dQ* is smaller than *dQ* previous day then in the river bed occurs erosion (dH negative). At the time of low tide (*dQ* negative) at the bottom of the river ocurrs of sedimentation.

At infletion point from low tide to high tide on botom of the river ocurrs sedimentation, otherwise at the inflection point from high tide to low tide on the botom ifthe river ocurrs erosion. 4.2. Discharge Fluctuation (*dQ*) with Verticaly Geometry Change (*dV*) Relationship.

Table 2: Details of the relationship of discharge Fluctuations With Horizontal Geometry Changes in Brantas River Km 59, The First Nine Days on Januari 1992 and June 1992.

Date	06/01/1992	07/01/1992	08/01/1992	09/01/1992	10/01/1992	11/01/1992	12/01/1992	13/01/1992	14/01/1992
ΔQ (m^3/dt)	5,00	5,00	80,00	309,00	252,00	-295,00	21,00	-182,00	78,00
ΔH (10^{-5} m)	0,05	10,81	89,12	132,01	-149,69	8,41	-60,58	23,27	-34,81

date	05/06/1992	06/06/1992	07/06/1992	08/06/1992	09/06/1992	10/06/1992	11/06/1992	12/06/1992	13/06/1992
dQ (m^3/dt)	0,00	4,80	-7,20	0,00	7,20	5,20	-5,20	0,00	-4,80
dH (10^{-5} m)	-0,35	0,56	0,00	-0,56	-0,26	0,26	0,00	0,35	-2,92

Table 3: Relationship of Discharge Fluctuations With Vertical Geometry Changes in Brantas River Km 59, The First Nine Days on January and June 1992

date	06/01/1992	07/01/1992	08/01/1992	09/01/1992	10/01/1992	11/01/1992	12/01/1992	13/01/1992	14/01/1992
dQ (m^3/dt)	5,00	5,00	80,00	309,00	252,00	-295,00	21,00	-182,00	78,00
dV (10^{-5} m)	-0,05	-10,81	-89,12	-132,01	149,69	-8,41	60,58	-23,27	34,81

date	05/06/1992	06/06/1992	07/06/1992	08/06/1992	09/06/1992	10/06/1992	11/06/1992	12/06/1992	13/06/1992
dQ (m^3/dt)	0,00	4,80	-7,20	0,00	7,20	5,20	-5,20	0,00	-4,80
dV (10^{-5} m)	0,35	-0,56	0,00	0,56	0,26	-0,26	0,00	-0,35	2,95

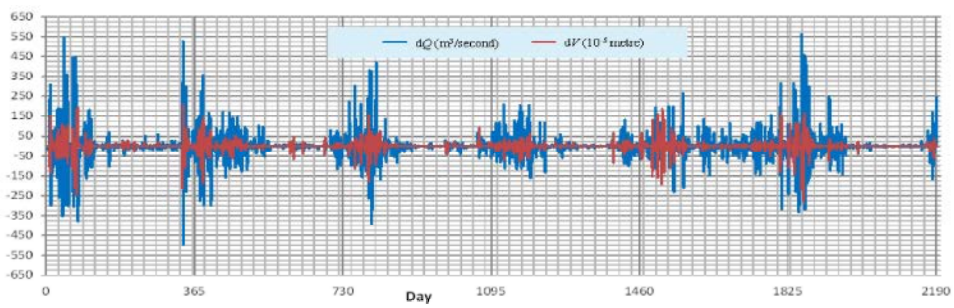

Fig. 10: Discharge Fluctuations With Vertical Geometry Changes Relationship In Brantas River Km 59. (1992 up to 1997)

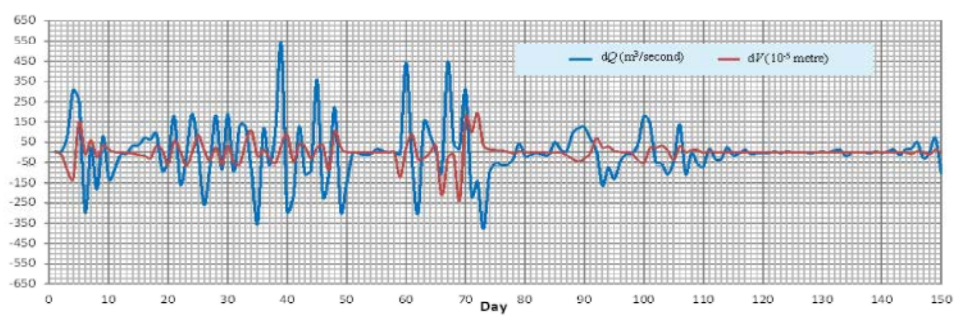

Fig. 11: Relationship of Discharge Fluctuations With Vertical Geometry Changes in Brantas River Km 59 During the first 150 days on January 1992

As well as the relationship between discharge fluctuations with horizontal geometry changes, the discharge fluctuations with the vertical geometry changes relationship is shown in Figure 10. stated in the description dV (10^{-5} metres) equal as in Table 3. is the vertical geometry changes in daily time scale. The Figure 10. is then detailed in Figure 11. Figure 12. and Table 3.

Having regard to the graphs in Figure 10. Figure 11. Figure 12. and Table 3. could have taken essential conditions are: on high tide (dQ positive) on the bottom of the river occurring erosion (dV negative), on the condition high tide but the value of to day dQ is smaller than previous day dQ then in the botom of river occurs sedimentation (dV positive). At the low tide condition (dQ negative) at the bottom of the river is ocurrs erosion.

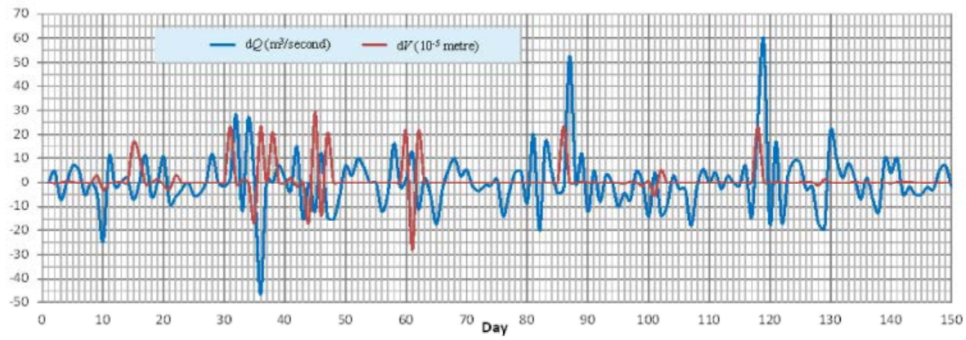

Fig. 12: Relationship of Discharge Fluctuations With Vertical Geometry Changes in Brantas River Km 59 During the first 150 days on June 1992

At inflection point from low tide to high tide on river bottoms occurring erosion, otherwise at the inflection point from high tide to low tide onthe botom of the river occurring sedimentation.

CONCLUSIONS

The Main Conclusions Are as Follows:
Discharge Fluctuation Behavior:

- Fluctuations go down on ranges 1992 up to 1995, fluctuations are increase at range 1995 up to 2002 and about over a range 2002 until 2011 in generally fluctuations are increase up.
- The smallest maximum discharge occurred in 1995 is 584 m3/second, the largest maximum discharge occurred in 2007 is 1707 m3 / second.
- The smallest minimum discharge occurs in 2008 is 6 m3/second, the largest minimum discharge occurs in 2010 reached 60 m3/second.

Horizontal Erosion and Sedimentation Behavior:

- At high tide in the river occurs sedimentation, at high tide but discharge fluctuations change smaller than discharge fluctuations in previous day in the river occurs erosion.
- At the time of low tide, sedimentation occurs in the river. In the event of changes turning point from low tide to high tide sedimentation occurred in the river, otherwise at the time of the turning point from high tide to low tide in the river erosion occurs.

Vertical Erosion and Sedimentation Behavior:

- During the high tide is happening on the bottom of the river is occurring erosion, when high tide conditions but discharge fluctuations change is smaller than discharge fluctuations change in day before then in river bottoms is occurring erosion.
- At the time of low tide at the bottom of the river is occurring sedimetation. In the event of changes turning point from low tide to high tide erosion is occurring, otherwise at the time of the turning point from high tide to low tide in the river is occuring sedimentation.

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