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Original Article

Study of Sediment Material Utilization for Morphology Stability of Bobuatan River

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Abstract *- The phenomenon of erosion and sedimentation have been classical issues for over a decade in the Bobuatan river. The two parameters that give a significant effect to the river morphology are river course and sediment. The last one has been the cause and effect of aggradation and degradation of the river bed, which leads to the catastrophe of construction along the Bobuatan river and its surroundings. This situation becomes an important thing to perform a study about the utilization of sediment material for morphology stability of Bobuaten river in East BolaangMongondow regency, Indonesia. This study aims to produce a method or recommendation to minimize the negative effects of sediment transport and inundation on geology and ecology disasters in the Bobuatan river. The procedures to perform analysis are begun with a survey to verify which method of analysis meets the existing condition in the Bobuatan river, followed by measurement and mapping of the Bobuatan river. With the collected data from surveying, analysis was conducted manually and with the aid of HEC-HMS and HEC-RAS to generate a real-time simulation of actual conditions in the study location. From the result of the analysis, the effect of utilization of sediment transport on the morphology stability of the Bobuatan river is predicted. Furthermore, the result will be a piece of vital information and basis to define the mechanism of water resource and environment management, as well as a recommendation to disaster mitigation.*

Keywords – *inundation, sediment transport, erosion, sedimentation*

I. INTRODUCTION

River morphology emphasizes the alteration of the river's dimensions, where it refers to cross-section and long sections of the river caused by the phenomenon of erosion and sedimentation. The effort to maintain the equilibrium condition on a river is difficult to obtain due to the characteristic of the river [3]. The river basin condition has made an impact on water flow and sediment transport in a river. Hydraulic gradient and flow rate are dynamic properties, and somehow they reverse through time and place. Though it is difficult, a proposition is always hand-picked to form an equilibrium condition or more stable condition along the Bobuatan river for analysis. Current situations on the Bobuatan river are inundation, erosion, and sedimentation

II. AREA OF RESEARCH

The Bobuatan river is located on the East BolaangMongondow regency, North Sulawesi Province, Indonesia. Motongkadis, one village which is passed by the Bobuatan river and is chosen as the point of observation for the study.The coordinates are 124.5430895^{O}of East Longitude and 0.681188253^{O}of North Latitude. The length of river segment for the study is 1.975 m. This segment is also crossing the zone of quarry stone.

Fig 1: Satelite Image of Bobuat River at Motongkad Village, BolaangMongondow Regency

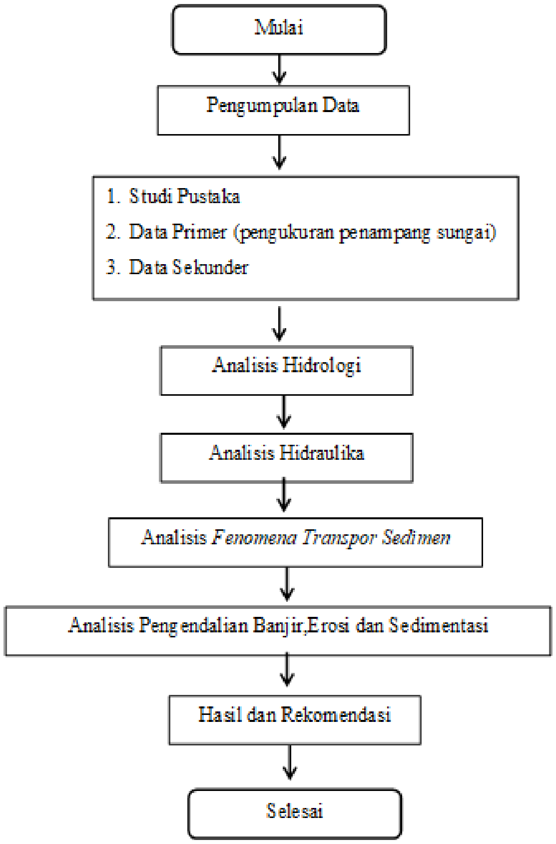

Fig 2: Procedure of Analysis

Fig 3: Schematic Geometry of Selected Segment of Bobuatan River at Motongkad Village, with Google Satelite Image

III. RESEARCH METHODOLOGY

The methodology for the study is the case study method. The phases are:

- Measurement of dimensions of the selected Bobuatan river segment;
- Analysis of designated discharge based on the measured dimensions;
- Prediction of sediment transport with the aid of HEC-HMS and HEC-RAS;
- Examination of sediment material for morphology stability of Bobuatan river;
- Determination of appropriate method for sediment control at Bobuatan river.

A. Primary Data Collection

Based on Digital Elevation Model (DEM) mapping, it is found that the Motongkad river basin has an area of about 21.641 km^2. Based on the topography mapping of the Bobuatan river, it is found that at the selected segment, the width of the river varies from 9.45 m to 33.51 m, with an average width of 22.52 m. The slope (s) upstream is 0.037, and downstream is 0.013. The length of the selected segment of the Bobuatan river is 1,975 m. About 79 cross-sections of the Bobuaten river with an interval of 25 m have been measured directly along the selected segment. The sediment samples are collected for analysis of sediment particle characteristics. The average thickness of the sediment layer is 2.3 m.

B. Data Analysis

Based on frequency analysis, the designated discharge of the Bobuatan river from several return periods is shown on Tabel I.

TABLE I
Designated Discharge of Bobuatan River

No	Return Period (Tahun)	Discharge (m3/det)
1	10	25.1
2	20	31.1
3	50	39.7
4	100	46.7

To discover the movement of sediment transport, a time series approach is used with an assumption that the designated discharge constantly flows in an interval time. In the analysis, the interval time of 48 hours is taken. Normal depth is employed as the boundary condition of upstream with the average slope of the river bed (s) of 0.02755. This number is achieved from the division of the difference of upstream and downstream elevation to the length of the selected river segment at a water temperature of 27 ^{O}C. The soil along the river bed consists of a small amount of clay, sand, gravel, and smaller to larger boulders.

IV. RESULT AND DISCUSSION

Analysis of sediment transport gives information about the pattern of sediment particle movement. The potential of the morphology of the Bobuatan river bed as the effect of sediment transport is shown in Table II.

TABLE II
Sediment Transport Analysis on Designated Discharge with Return Period of 50 Years (Q_{50})

No	River Sta.	Cross Section	Elevasi Dasar Saluran		Invert Change	Remarks
		DWG	T_0	T_{48}	(m)	
1	79	P1	97.28	97.28	0.00	-
2	78	P2	96.37	97.89	1.52	Sedimentation
3	77	P3	96.02	95.61	-0.41	Erosi
4	76	P4	94.93	95.26	0.33	Sedimentation
5	75	P5	94.33	95.41	1.08	Sedimentation
6	74	P6	93.50	94.96	1.46	Sedimentation
7	73	P7	92.46	91.26	-1.20	Erosi
8	72	P8	91.18	90.26	-0.92	Erosi
9	71	P9	89.75	90.35	0.60	Sedimentation
10	70	P10	88.30	89.99	1.69	Sedimentation
11	69	P11	87.23	86.04	-1.20	Erosi
12	68	P12	86.10	84.90	-1.20	Erosi
13	67	P13	84.98	84.28	-0.70	Erosi
14	66	P14	84.37	83.18	-1.19	Erosi
15	65	P15	83.33	82.73	-0.60	Erosi
16	64	P16	83.00	82.97	-0.03	Erosi
17	63	P17	82.01	82.31	0.30	Sedimentation
18	62	P18	81.43	82.21	0.78	Sedimentation
19	61	P19	80.88	81.75	0.87	Sedimentation
20	60	P20	79.18	81.12	1.94	Sedimentation
21	59	P21	78.54	78.64	0.10	Sedimentation
22	58	P22	76.04	78.10	2.06	Sedimentation
23	57	P23	76.54	77.05	0.51	Sedimentation
24	56	P24	76.19	76.79	0.60	Sedimentation
25	55	P25	74.40	77.77	3.37	Sedimentation
26	54	P26	74.09	72.90	-1.19	Erosi
27	53	P27	72.62	72.47	-0.15	Erosi
28	52	P28	70.59	70.02	-0.57	Erosi
29	51	P29	70.45	69.25	-1.20	Erosi
30	50	P30	68.27	67.07	-1.20	Erosi
31	49	P31	67.90	67.62	-0.28	Erosi
32	48	P32	66.41	66.58	0.17	Sedimentation
33	47	P33	65.52	65.73	0.21	Sedimentation
34	46	P34	66.43	66.42	-0.01	Erosi
35	45	P35	63.12	64.67	1.55	Sedimentation
36	44	P36	62.51	62.23	-0.28	Erosi
37	43	P37	62.56	62.64	0.08	Sedimentation
38	42	P38	61.72	61.87	0.15	Sedimentation

39	41	P39	61.10	61.61	0.51	Sedimentation
40	40	P40	60.64	60.90	0.26	Sedimentation
41	39	P41	60.29	60.13	-0.16	Erosi
42	38	P42	61.35	60.20	-1.15	Erosi
43	37	P43	60.68	59.75	-0.93	Erosi
44	36	P44	60.00	59.27	-0.73	Erosi
45	35	P45	59.33	58.37	-0.96	Erosi
46	34	P46	58.65	58.66	0.01	Sedimentation
47	33	P47	57.98	57.82	-0.16	Erosi
48	32	P48	57.31	57.72	0.41	Sedimentation
49	31	P49	56.63	57.03	0.40	Sedimentation
50	30	P50	55.96	56.82	0.86	Sedimentation
51	29	P51	55.26	56.23	0.97	Sedimentation
52	28	P52	54.91	56.19	1.28	Sedimentation
53	27	P53	54.80	55.71	0.91	Sedimentation
54	26	P54	54.60	54.84	0.24	Sedimentation
55	25	P55	54.45	53.81	-0.64	Erosi
56	24	P56	54.35	53.16	-1.19	Erosi
57	23	P57	52.43	52.63	0.20	Sedimentation
58	22	P58	51.94	52.46	0.52	Sedimentation
59	21	P59	51.33	50.69	-0.64	Erosi
60	20	P60	50.52	49.99	-0.53	Erosi
61	19	P61	50.28	49.80	-0.48	Erosi
62	18	P62	49.75	49.35	-0.40	Erosi
63	17	P63	49.27	49.73	0.46	Sedimentation
64	16	P64	48.87	49.13	0.26	Sedimentation
65	15	P65	48.44	48.24	-0.20	Erosi
66	14	P66	47.96	48.60	0.64	Sedimentation
67	13	P67	47.79	48.34	0.55	Sedimentation
68	12	P68	47.25	48.22	0.97	Sedimentation
69	11	P69	46.81	46.89	0.08	Sedimentation
70	10	P70	46.60	46.51	-0.09	Erosi
71	9	P71	46.23	45.04	-1.19	Erosi
72	8	P72	45.43	44.24	-1.20	Erosi
73	7	P73	45.08	44.78	-0.30	Erosi
74	6	P74	45.07	43.93	-1.14	Erosi
75	5	P75	44.66	44.13	-0.53	Erosi
76	4	P76	44.26	43.57	-0.69	Erosi
77	3	P77	43.85	43.54	-0.31	Erosi
78	2	P78	43.60	43.15	-0.45	Erosi
79	1	P79	43.13	42.53	-0.60	Erosi

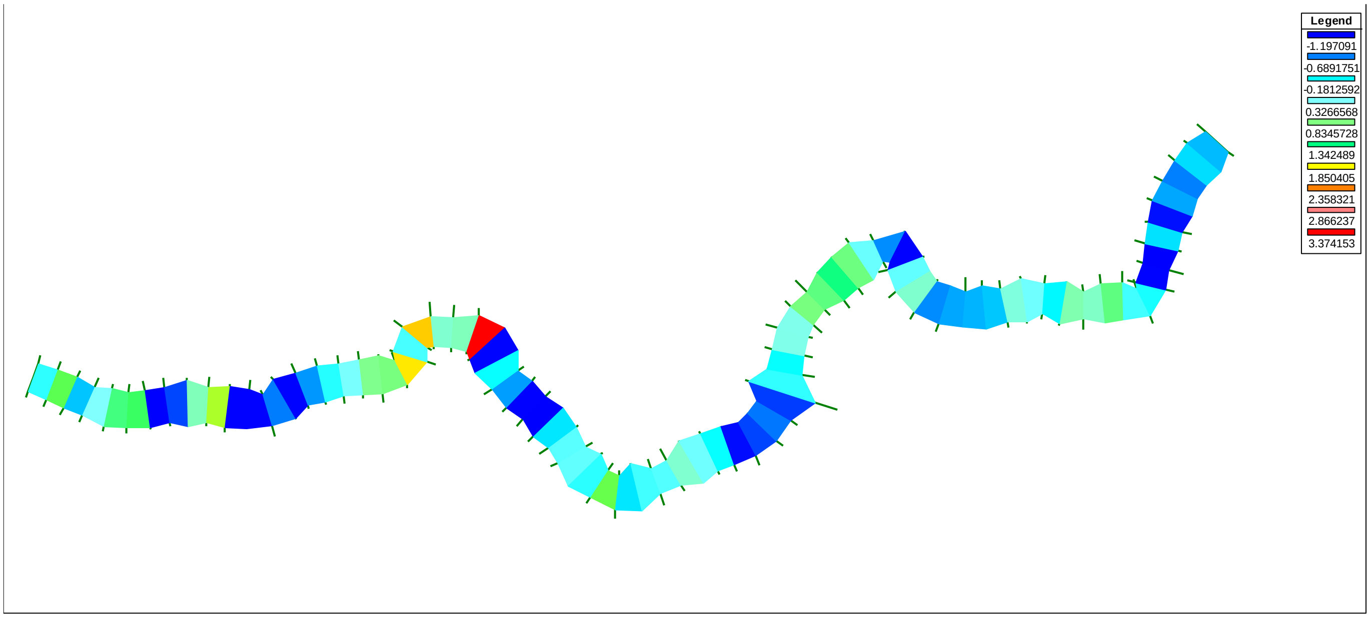

Fig 4: The Pattern of Sediment/Erosion at Bobuatan River, with Designated Discharge of Q_{50}

TABLE III
Morphology of Bobuatan River Bed at Designated Discharge of Q_{50}

River Sta.	Cross Section DWG	Q Total	Min Ch El	LOB Elev	W.S. Elev	ROB Elev	Vel.Chnl	Sed Invert El.	Invert Change
		(m3/s)	*(m)*	*(m)*	*(m)*	*(m)*	*(m/s)*	*(m)*	*(m)*
79	P1	39.70	97.28	101.30	99.22	100.73	2.14	97.28	0.00
78	P2	39.70	96.37	99.47	98.80	99.60	2.33	97.89	1.52
77	P3	39.70	96.02	97.94	97.17	98.38	2.00	95.61	-0.41
76	P4	39.70	94.93	97.71	96.80	97.70	2.21	95.26	0.33
75	P5	39.70	94.33	98.37	96.40	96.39	2.09	95.41	1.08
74	P6	39.70	93.50	96.25	95.83	95.83	2.34	94.96	1.46
73	P7	39.70	92.46	100.62	93.04	95.52	2.98	91.26	-1.20
72	P8	39.70	91.18	94.97	92.05	97.57	2.48	90.26	-0.92
71	P9	39.70	89.75	96.02	91.76	96.92	2.15	90.35	0.60
70	P10	39.70	88.30	91.24	91.31	91.30	2.36	89.99	1.69
69	P11	39.70	87.23	91.41	87.36	90.83	2.60	86.04	-1.20
68	P12	39.70	86.10	87.79	86.60	94.62	2.89	84.90	-1.20
67	P13	39.70	84.98	87.61	85.45	88.68	2.65	84.28	-0.70
66	P14	39.70	84.37	90.64	85.02	87.43	2.22	83.18	-1.19
65	P15	39.70	83.33	88.96	84.52	85.35	2.74	82.73	-0.60
64	P16	39.70	83.00	84.99	84.13	84.38	2.10	82.97	-0.03
63	P17	39.70	82.01	83.95	83.61	83.57	2.37	82.31	0.30
62	P18	39.70	81.43	87.14	83.16	83.19	2.19	82.21	0.78
61	P19	39.70	80.88	83.64	82.67	85.80	2.24	81.75	0.87
60	P20	39.70	79.18	81.63	82.10	88.64	2.35	81.12	1.94

59	P21	39.70	78.54	81.09	80.17	86.34	2.23	78.64	0.10
58	P22	39.70	76.04	79.87	79.73	81.07	2.49	78.10	2.06
57	P23	39.70	76.54	82.61	79.26	83.36	2.86	77.05	0.51
56	P24	39.70	76.19	80.93	79.18	84.39	2.03	76.79	0.60
55	P25	39.70	74.40	78.90	78.94	78.34	1.68	77.77	3.37
54	P26	39.70	74.09	79.02	73.99	76.63	2.20	72.90	-1.19
53	P27	39.70	72.62	79.39	73.32	84.50	2.81	72.47	-0.15
52	P28	39.70	70.59	73.24	71.25	76.74	2.11	70.02	-0.57
51	P29	39.70	70.45	71.91	70.73	73.97	2.69	69.25	-1.20
50	P30	39.70	68.27	71.16	68.51	72.69	2.98	67.07	-1.20
49	P31	39.70	67.90	70.01	68.32	70.44	1.88	67.62	-0.28
48	P32	39.70	66.41	70.90	67.84	69.28	2.55	66.58	0.17
47	P33	39.70	65.52	67.30	67.40	68.08	2.33	65.73	0.21
46	P34	39.70	66.43	67.10	67.01	67.63	1.68	66.42	-0.01
45	P35	39.70	63.12	67.46	66.42	66.36	2.44	64.67	1.55
44	P36	39.70	62.51	65.44	63.69	64.09	2.74	62.23	-0.28
43	P37	39.70	62.56	67.63	63.42	62.92	1.89	62.64	0.08
42	P38	39.70	61.72	64.90	62.97	62.44	2.28	61.87	0.15
41	P39	39.70	61.10	63.67	62.52	62.00	2.29	61.61	0.51
40	P40	39.70	60.64	64.67	62.17	62.46	1.81	60.90	0.26
39	P41	39.70	60.29	63.34	61.56	62.45	2.79	60.13	-0.16
38	P42	39.70	61.35	62.70	61.30	62.38	2.00	60.20	-1.15
37	P43	39.70	60.68	61.85	60.79	62.22	2.31	59.75	-0.93
36	P44	39.70	60.00	61.50	60.35	63.70	2.28	59.27	-0.73
35	P45	39.70	59.33	60.36	59.87	62.26	2.51	58.37	-0.96
34	P46	39.70	58.65	59.78	59.58	60.27	1.51	58.66	0.01
33	P47	39.70	57.98	59.75	59.21	59.93	1.86	57.82	-0.16
32	P48	39.70	57.31	58.91	58.92	59.22	1.79	57.72	0.41
31	P49	39.70	56.63	58.49	58.50	58.44	2.00	57.03	0.40
30	P50	39.70	55.96	57.99	58.05	58.41	2.04	56.82	0.86
29	P51	39.70	55.26	57.50	57.52	58.39	2.58	56.23	0.97
28	P52	39.70	54.91	57.13	57.24	57.68	1.87	56.19	1.28
27	P53	39.70	54.80	56.81	56.81	56.79	1.81	55.71	0.91
26	P54	39.70	54.60	61.20	56.13	55.39	2.90	54.84	0.24
25	P55	39.70	54.45	58.07	55.07	56.28	2.25	53.81	-0.64
24	P56	39.70	54.35	67.29	54.52	55.75	2.71	53.16	-1.19
23	P57	39.70	52.43	55.25	53.92	54.95	2.16	52.63	0.20
22	P58	39.70	51.94	54.29	53.42	53.34	2.40	52.46	0.52
21	P59	39.70	51.33	53.09	52.04	54.17	2.65	50.69	-0.64
20	P60	39.70	50.52	54.74	51.89	53.51	1.91	49.99	-0.53
19	P61	39.70	50.28	53.97	51.46	52.68	2.55	49.80	-0.48

18	P62	39.70	49.75	60.62	51.22	52.34	2.15	49.35	-0.40
17	P63	39.70	49.27	59.23	50.89	50.85	2.03	49.73	0.46
16	P64	39.70	48.87	57.73	50.50	50.69	2.01	49.13	0.26
15	P65	39.70	48.44	51.97	50.16	50.16	2.19	48.24	-0.20
14	P66	39.70	47.96	50.83	49.99	50.69	1.68	48.60	0.64
13	P67	39.70	47.79	49.61	49.62	49.51	2.02	48.34	0.55
12	P68	39.70	47.25	49.04	49.11	49.11	2.30	48.22	0.97
11	P69	39.70	46.81	48.74	48.51	48.65	2.23	46.89	0.08
10	P70	39.70	46.60	48.99	48.02	48.83	2.48	46.51	-0.09
9	P71	39.70	46.23	49.20	47.22	56.07	3.59	45.04	-1.19
8	P72	39.70	45.43	50.48	46.64	50.54	2.94	44.24	-1.20
7	P73	39.70	45.08	47.77	46.30	47.01	2.80	44.78	-0.30
6	P74	39.70	45.07	47.11	46.01	46.72	2.57	43.93	-1.14
5	P75	39.70	44.66	48.16	45.71	46.25	2.19	44.13	-0.53
4	P76	39.70	44.26	49.34	45.21	45.45	2.66	43.57	-0.69
3	P77	39.70	43.85	49.49	44.78	45.20	2.50	43.54	-0.31
2	P78	39.70	43.60	48.46	44.39	44.86	2.13	43.15	-0.45
1	P79	39.70	43.13	45.33	43.69	44.55	2.51	42.53	-0.60

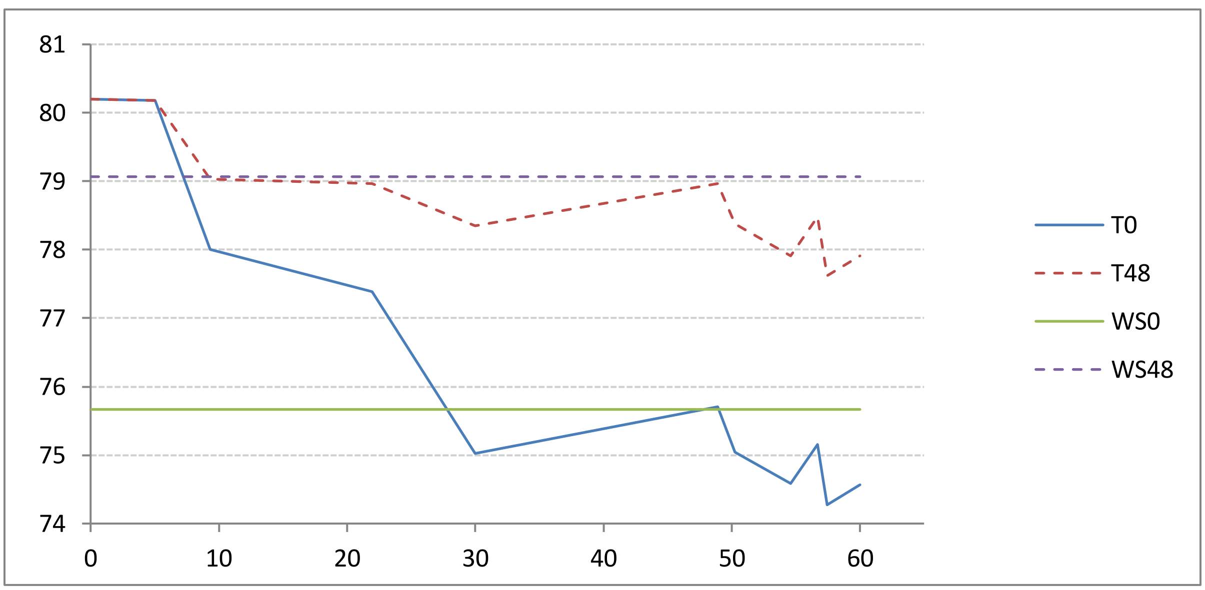

Fig 5: Comparison of Sediment Profile at Sta. 55 with Designated Discharge of Q_{50}

From Table II and Table III, the sediment transport simulation at the designated discharge of Q_{50} reveals that erosion and sedimentation along the selected segment of the Bobuatan river vary at a range of -1.20 m (erosion) and at a range of + 3.37 m (sedimentation). For the designated discharge of Q_{100}, the erosion at Bobuatan river has the maximum value of -1.2 m, while the sedimentation has the maximum value of +3.44 m. The morphology type at the Bobuatan river tends to cliff erosion, river bed degradation, and sedimentation at the inner bend of the river.

The simulation of discharge reveals that at the designated discharge of Q_{50} with 39.7 m^3/sec of flow, the overflow takes place at some points of the right bank cliff. The return period of 100 years produces discharge (Q_{100}) of 46.7 m^3/sec. Gabion construction is suggested for the protection of river banks against the overflow of Q_{100}. The analysis gives the result of ideal dimensions of Bobuatan river cross-section to drain the discharge of Q_{100} as follows:

- Width of river bed (B) = 10 m
- Slope of river bank = 1:0.56
- Width of river at designated discharge = 17 m
- Depth of designated discharge = 2.5 m
- Freeboard = 1.5 m

The total depth is 4 m for the most economic cross-section of the Bobuatan river. The potential depth of sediment based on field observation by excavation at selected locations is 2.3 m. The depth of river for utilization of sediment material is 2.1 m (< 2.3 m).

V. CONCLUSIONS

Based on the sediment transport analysis, the conclusions of the study are:

- Sand, gravel and boulder are encountered along 1,975 m of Bobuatan river at Motongkad village. At this river segment, excavation of sediment materials is allowed;
- The depth of excavation is set to 2.1 m (< 2.3 m);
- Recommendation is given to utilize the sediment material at a limited depth of 2.1 m without causing instability to the morphology of Bobuatan river.

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