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PREDICTION OF RIVER BANK SHIFTING PROCESS AT THE CONFLUENCE

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ABSTRACT

Flow pattern near the estuary of a river junction is very complex in nature. According to the direction of flow, separation and stagnation zones are formed, where flow velocity generally drops. This type of anomaly in velocity distribution causes siltation, thus the direction of the free way for water flowing changes very frequently. For this reason explanation of the erosion and deposition process as well as the geometric pattern change due to the channel flow in a junction is very complex. In this study two junctions of the confluences of Rupsha River are considered for predicting the pattern during 2030 by the linear regression method. During analysis all the confluences are considered as in natural condition. From the result, it is observed that one confluence is predicted well, while other one is incorrectly predicted. This happens because of recent human activities turn the confluence far from the natural state.

Keywords: *Confluence, Erosion, Linear Regression, Landsat, River Bank, Prediction*

1. INTRODUCTION

Erosion and deposition near the branch estuary in the junction and river bank is very common in nature. Erosion causes great harm to the habitat pattern as well as the land property, whereas deposition or siltation decreases navigability and reservoir capacity of the river. Whole river system acts as a stream, which is always prone to change its pattern by erosion and deposition. Stream being a dynamic system changes its course to attain stability. In this continuous process of attainment of stability planform, morphology and other features of streams change to cope with it (Khan and Ali, 2016). Trimble (1997) says that sediment from stream bank can account for as much as 85% of watershed sediment yields bank retreat rates as high as 1.5 to 110m/year have been documented. According to ASCE (1998), beside water quality impairment, stream bank retreat impacts flood plain residents, riparian ecosystems, bridges other stream-side structures. Also Lawler (1995) states that, stream bank retreat typically occur by a combination of three processes, sub aerial processes erosion, bank failure and fluvial erosion. The excessive river bank can also contribute into the total sediment load in rivers (Ercan and Younis, 2009). For this reasons prediction of the future condition of the land property near the river bank and confluence zone is an important task. It is also helpful for urban and regional planning. In this study an attempt is taken to predict the future pattern of the two junctions of Rupsha River with adjacent rivers during 2030 by linear regression method. Position of the two confluences are shown in Figure 1 and summarized in Table 1. In this study, these two confluences are considered in natural condition. This type of study is helpful for planning land use pattern near the river bank.

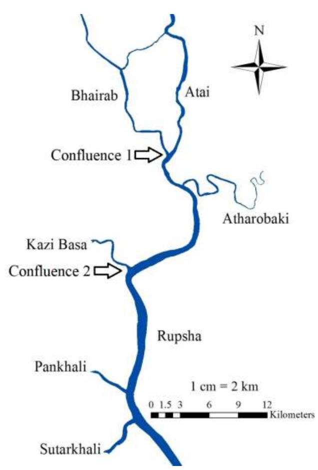

Figure 1: Position of the two confluences in study area.

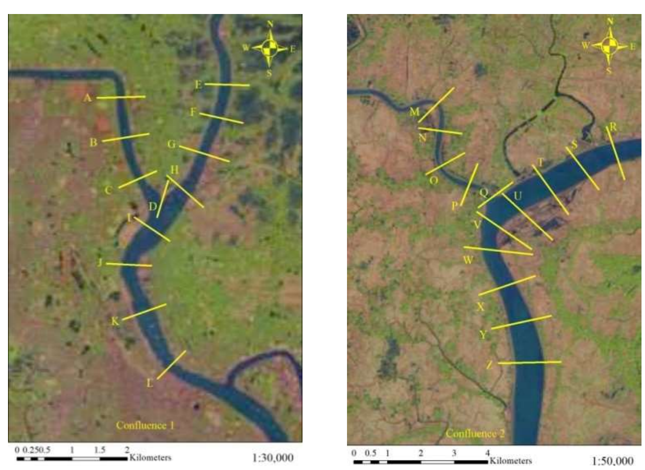

Figure 2: Position of the cross-sections in Confluence 1 and Confluence 2 (RGB image 2018).

Table 1: Position and accumulated rivers at the confluences

Confluence	Name of the Rivers meet at Confluence	Position
Confluence 1	Bhairab-Atai-Rupsha	22°50'52.05"N, 89°33'33.09"E
Confluence 2	Rupsha-Kazibasa	22°44'23.23"N, 89°31'26.84"E

2. METHODOLOGY

Confluence 1 and Confluence 2 are divided in several sections, whereas Confluence 1 belongs to 12 sections and Confluence 2 belongs to 14 sections. The sections of these confluences are represented in Figure 2. Each section is named after English alphabet A-Z. Geo-referenced images from 1988 to 2018 are collected to extract the latitude and longitude data from the image pixel along the cross sections. Then using ArcGIS 10.4.1 software package, the latitude and longitude data of the left and right bank along the cross-section of each year is measured. In this way total 30 numbers of data set are collected from 1988 to 2017 for each 26 numbers of sections, also data set for 2018 is also prepared for accuracy analysis. Then linear regression statistical method is applied, using 30 numbers of data set from 1988 to 2017 to predict the latitude and longitude of the left bank and right bank of each 26 sections for year 2018.

This approach help to predict the data set for year 2018. After calculating the latitude and longitude of 2018, actual data set is compared with the calculated one to determine the percent error of the each calculated latitude and longitude data, for both left and right bank. Then this statistical method is applied to predict the bank and confluence positions for the year 2030. In this study relative position is compared in between year 1988 and 2018, of the each confluence. Then predicted position of left and right bank of each section during 2030 is represented comparing with 2018.

2.1 Source of data

These geo-referenced images are used in this study are Landsat Look Images with Geographic Reference produced from Landsat 5, 7 and 8 missions and downloaded from the website https://earthexplorer.usgs.gov/.

2.2 Governing equation

Linear regression method is developed based on following equation,

$$y = X\beta + \varepsilon \tag{1}$$

where,

$$y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix}, X = \begin{pmatrix} X_1^T \\ X_2^T \\ \vdots \\ X_N^T \end{pmatrix} = \begin{pmatrix} 1 & x_{11} & \cdots & x_{1p} \\ 1 & x_{21} & \cdots & x_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & \cdots & x_{np} \end{pmatrix}, \beta = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \vdots \\ \beta_p \end{pmatrix}, \varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{pmatrix} \tag{2}$$

- y is a vector of observed values y_i ($i = 1,2,3....n$)is called the regress and, endogenous variable, response variable, measured variable, criterion variable, or dependent variable.
- X may be seen as a matrix of row-vectors $x_{i1}, x_{i2,}........, x_{ip}$ are called regressors, exogenous variables, explanatory variables, covariates, input variables, predictor variables, or independent variables. The matrix X is sometimes called the design matrix.
- β is a $(p+1)$-dimensional parameter vector, where β_0 is the intercept term (if one is included in the model—otherwise β is *p*-dimensional).
- ε is a vector of values ε_i is called the error term, disturbance term, or noise. This variable captures all other factors which influence the dependent variable y_i other than the regressors x_i.

The percent error formula is useful tool for determining the precision of the calculations. The formula is given by:

$$\%\, error = \left(\frac{Value_{measured} - Value_{actual}}{Value_{actual}} \right) \times 100 \tag{3}$$

3. RESULTS

Confluence 1 and 2, as well as the both left and right bank of the adjacent rivers are less susceptible to shift, which is shown in Figure 3 and 4, where pattern of the two confluences during 1988 and 2018 are almost same.

During 1988, main and branch river is narrow in shape near the estuary of the Confluence 1 (Figure 3), whereas in 2018 main and branch rivers are widened near the estuary. Especially the delta is eroded in a certain amount, which widens the estuary and the bank of the main river just opposite to the branch estuary also eroded. If the eroded mass of the particle is not migrated from estuary zone, then the volume must be deposited bottom of the confluence and makes it shallower. On the other hand main channel and branch remain same in position, all through the year from 1988 to 2018.

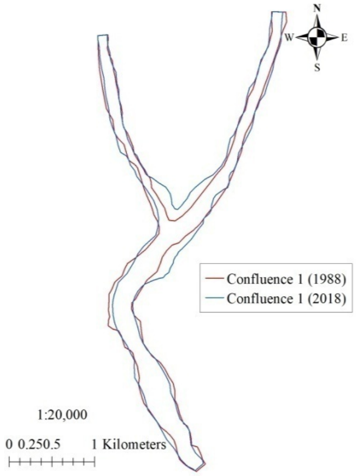

Figure 3: Relative comparison of Confluence 1 in between 1988 and 2018.

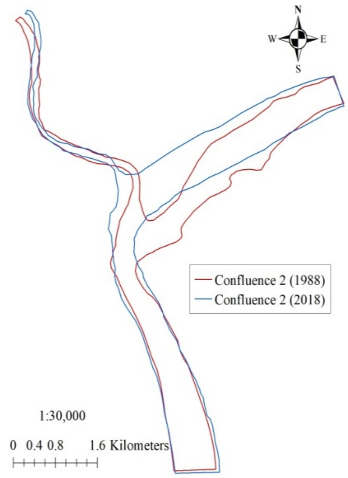

Figure 4: Relative comparison of Confluence 2 in between 1988 and 2018.

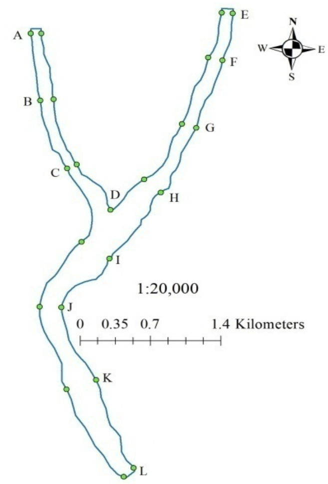

Figure 5: Calculated coordinates of the left and right bank of each section on actual pattern of Confluence 1 during 2018.

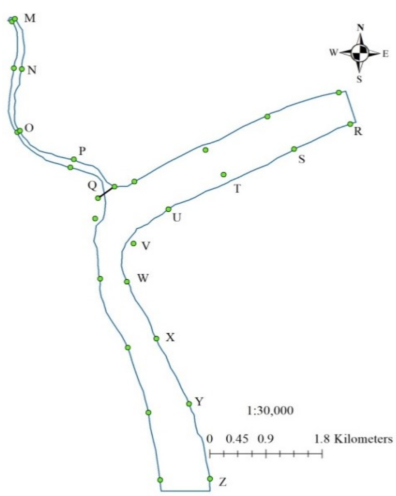

Figure 6: Calculated coordinates of the left and right bank of each section on actual pattern of Confluence 2 during 2018.

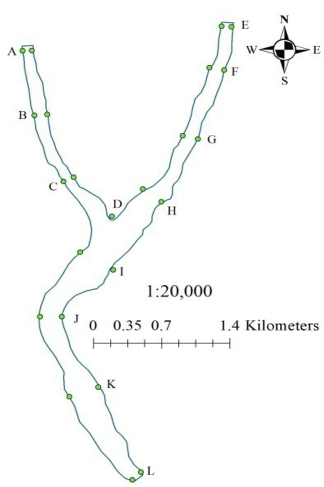

Figure 7: Predicted coordinates during 2030 on actual pattern of Confluence 1 in 2018.

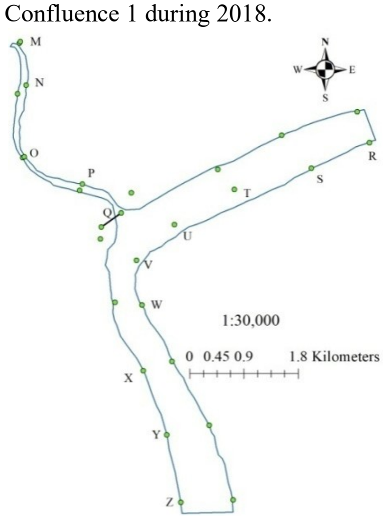

Figure 8: Predicted coordinates during 2030 on actual pattern of Confluence 2 in 2018.

On the other hand Confluence 2 is changed enormously as compared with Confluence 1, especially near the branch estuary (Figure 4). Far end of the branch of the selected section is displaced from its original position during 1988. But the northern and southern corner of the main channel remains more or less same. The main channel is widened in most of its length. But the apex of the main channel curved is prolonged to the direction of branch estuary. Here in 2018, the branch mouth is reduced in section than 1988 and the reason is obviously erosion, which is very common at the outer curve of the meander. The delta between branch and the main channel is completely disappeared at 2018. On the other hand, right bank at the inner curve of the meander, just opposite to the branch estuary is moved towards West, which is caused due to the deposition of the eroded particle just from opposite bank.

In this study, an attempt is taken to predict this bank and whole confluence pattern shifting process, as well as the erosion deposition process of the banks. For this prediction linear regression statistical method is used, to calculate the latitude and longitude of left and right bank of each section for year 2018. In Figure 5 and 6, this calculated coordinates are inserted on actual confluence pattern of 2018. The green color points are the calculated coordinates of left and right bank of the sections and the blue color lines are the actual confluence pattern. Figure 5 shows that, the calculated coordinates of the left and right bank fit perfectly with Confluence 1 pattern. Confluence 1 is less susceptible to change pattern. Only left and right bank of Section I and Point D at the apex of the delta is shifted significantly, which is shown in Figure 3. This method applied for the prediction of the coordinates during 2018, performs well to calculate near exact values of the of the coordinates of left and right bank of Section I and Point D, as well as other coordinates.

But Confluence 2 is more susceptible to change pattern than Confluence 1, which is shown in Figure 4. Following Figure 6 shows the position of calculated coordinates on actual Confluence 2 pattern in 2018. In this figure points shown as the calculated left and right bank coordinates of Section Q, are joined together with a line. This is simply to reduce the confusion of relative positions of the other coordinate denoting points.

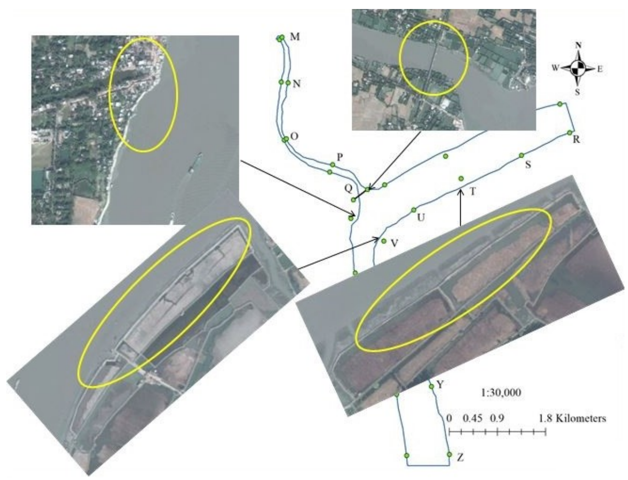

Figure 9: Human activities around Confluence 2.

Figure 6 shows that calculated coordinates of the both banks of section T, V and left bank of Q, are failed to predict the actual position during 2018. As it is compared with other sections, then decisions can be made as it is not an error at all. Here left and right bank of Section M is shifted significantly, which is already shown in Figure 4. By this current method this shifted position is predicted perfectly. The reason of this miscalculation is human activities, which affects this natural shifting process. This calculation method considers the two confluences are under natural condition. Confluence 1 is situated at the center Khulna city, whose adjacent river's banks are occupied by human activities for many years. So banks of the adjacent rivers are quite stable for different human usages like urbanization and industrialization. On the other hand Confluence 2 is situated in a rural area, which is urbanized now a day. The wrong prediction of Section T, V and Q is due to the recent urbanization process, took place surround the estuary, which makes the banks more stable to change their pattern (Figure 9). But calculation method over predicts the results, considering natural erosion and deposition rate of the adjacent river banks. In Table1 the level of percent error of the calculated result to the actual data is represented.

Based on this calculation method, a prediction is made to realize the future position of Confluence 1 and Confluence 2 in 2030. In this situation the confluences are considered in natural condition and change their pattern in a natural rate, similar to previous years. Figure 7 and 8 show the result. From Figure 7, it is observed that, during 2030 Confluence 1 remains same in position. Point D at the apex of the delta slightly moves to the north. Left bank and right bank of every section is displaced slightly, especially section H and I. in case I left bank is eroded and right bank is deposited to a certain amount. Meanwhile right bank of I is eroded significantly.

In Figure 8, the futuristic condition of Confluence 2 is represented. Also, here coordinate points of left and right bank of Section Q are joined together to separate them from Section U and V related coordinate points. In Figure 8 section M, Q, T, U and V show significant shifting characteristics. Shifting of T and V do not have any significance, as it is already observed in Figure 6. Again left bank shifting of Section Q is also predicted wrong. So it is important to observe the shifting process of Section M, U and right bank of Q. If the natural process is considered constant like 2018 till 2030, then shifting process of M and U, make the meander curve more acute than today. In case of Section Q, If the left bank will remain same in position, then shifting process of right bank will convert the branch estuary to a narrow passage, even the branch may be died. The other sections are very less susceptible to change their pattern.

Table 1: Actual, Calculated vales and percent errors of coordinates of the sections

Cross section		Latitude (Left bank)	Longitude (Left bank)	Latitude (Right bank)	Longitude (Right bank)
	Actual	22.86611	89.55078	22.86617	89.551807
A	Calculated	22.86608	89.55078	22.86611	89.55178452
	% error	0.000132	7.42E-06	0.000262	2.50982E-05
	Actual	22.859445	89.551862	22.859659	89.553099
B	Calculated	22.859398	89.5518691	22.85954554	89.55314955
	% error	0.0002036	7.963E-06	0.000496312	5.64489E-05
	Actual	22.852708	89.554587	22.853103	89.555477
C	Calculated	22.852647	89.5546317	22.85305984	89.55554471
	% error	0.0002691	4.9933E-05	0.000188852	7.56072E-05
	Actual	22.848686	89.558915		
D	Calculated	22.848562	89.558948		
	% error	0.0005412	3.6901E-05		
	Actual	22.868621	89.569204	22.868619	89.570281
E	Calculated	22.868574	89.5692008	22.8685339	89.57026371
	% error	0.0002065	3.5804E-06	0.000372141	1.93029E-05
	Actual	22.863325	89.567867	22.863082	89.569267
F	Calculated	22.864041	89.5680217	22.8637982	89.56941432
	% error	0.0031314	0.00017271	0.003132561	0.000164481
	Actual	22.857358	89.565643	22.856994	89.567027
G	Calculated	22.857326	89.5656339	22.85697034	89.56704608
	% error	0.0001412	1.0172E-05	0.000103522	2.13056E-05
	Actual	22.85174	89.562139	22.850479	89.563781
H	Calculated	22.851703	89.5621061	22.85043769	89.56377599
	% error	0.0001606	3.6692E-05	0.000180785	5.59031E-06
	Actual	22.845363	89.556253	22.843733	89.558989
I	Calculated	22.845315	89.5562225	22.84368226	89.55895479
	% error	0.0002112	3.4014E-05	0.000222109	3.82025E-05
	Actual	22.838737	89.552334	22.838708	89.554456
J	Calculated	22.838707	89.5523187	22.83869221	89.55444806
	% error	0.0001322	1.7058E-05	6.91204E-05	8.8638E-06
	Actual	22.830587	89.555101	22.831575	89.557897
K	Calculated	22.830499	89.5551517	22.83150542	89.55799052
	% error	0.0003872	5.6656E-05	0.00030475	0.000104421
	Actual	22.821852	89.560846	22.822802	89.56181
L	Calculated	22.821843	89.5608914	22.82274902	89.56181782
	% error	3.998E-05	5.0661E-05	0.000232133	8.73217E-06
	Actual	22.767856	89.505476	22.76827	89.505933
M	Calculated	22.767798	89.5055306	22.76824625	89.50594802
	% error	0.0002539	6.0979E-05	0.000104319	1.67818E-05
	Actual	22.760742	89.505964	22.760635	89.507228
N	Calculated	22.76072	89.5059745	22.76203219	89.50722579
	% error	9.705E-05	1.1758E-05	0.006138608	2.46561E-06
	Actual	22.751003	89.506697	22.751231	89.507125
O	Calculated	22.750973	89.5067563	22.75121039	89.50715493
	% error	0.000132	6.6264E-05	9.05749E-05	3.34398E-05
P	Actual	22.745773	89.515135	22.74701	89.515639
	Calculated	22.745794	89.5151444	22.74702236	89.5156771

	% error	9.048E-05	1.0516E-05	5.43307E-05	4.25662E-05
	Actual	22.741931	89.520527	22.743026	89.522059
Q	Calculated	22.741217	89.5195797	22.74300308	89.52208063
	% error	0.0031376	0.00105821	0.000100766	2.41589E-05
	Actual	22.758108	89.556806	22.753463	89.55862
R	Calculated	22.758099	89.5566795	22.75335588	89.55855532
	% error	3.994E-05	0.00014122	0.000470804	7.22162E-05
	Actual	22.754376	89.545676	22.749411	89.550033
S	Calculated	22.75421	89.5456376	22.74933759	89.54992933
	% error	0.0007311	4.2891E-05	0.000322676	0.000115767
	Actual	22.749633	89.535659	22.744284	89.540076
T	Calculated	22.748898	89.5361211	22.74523348	89.53906588
	% error	0.0032299	0.00051612	0.004174569	0.001128125
	Actual	22.743908	89.525321	22.73972	89.530471
U	Calculated	22.74385	89.5252014	22.73973583	89.53058448
	% error	0.0002538	0.00013355	6.96033E-05	0.000126753
	Actual	22.737664	89.520102	22.735001	89.524532
V	Calculated	22.738081	89.5191922	22.73440325	89.52530953
	% error	0.0018333	0.00101635	0.002629214	0.000868512
	Actual	22.729059	89.520165	22.728716	89.524338
W	Calculated	22.728966	89.5202475	22.72855974	89.5243904
	% error	0.0004109	9.22E-05	0.000687479	5.85316E-05
	Actual	22.718606	89.524726	22.720089	89.52909
X	Calculated	22.718533	89.5247982	22.72003193	89.52918477
	% error	0.0003199	8.0664E-05	0.000251183	0.000105849
	Actual	22.708837	89.528264	22.710236	89.534517
Y	Calculated	22.708742	89.5282737	22.71018646	89.53453413
	% error	0.000417	1.08E-05	0.000218161	1.91334E-05
	Actual	22.698584	89.530304	22.698902	89.538063
Z	Calculated	22.69849	89.5303342	22.69884601	89.53808328
	% error	0.0004161	3.3724E-05	0.000246647	2.26527E-05

4. CONCLUSIONS

Linear regression method can be applicable for the prediction of river bank shifting, if the bank of the river is in natural state. Thus a slope is developed from the simple Time vs. Latitude or Longitude graph and from the developed slope, coordinates of past and future can easily be calculated. In this process of prediction river bank is considered in natural state. If bank formation and shifting process is affected by human activities then the prediction method brings erroneous result. If the movement of the coordinates of bank is complex and non-linear in nature then this method is not applicable. In this situation more precise and complex solution method such as Machine Learning can bring more accurate result. In this study percent error is very small. That means calculated coordinate is very similar to the actual coordinate. But such a small difference can bring major error. Each degree of latitude is approximately 69 miles (111 kilometers) apart. The range varies (due to the earth's slightly ellipsoid shape) from 68.703 miles (110.567 km) at the equator to 69.407 (111.699 km) at the poles. Again a degree of longitude along the equator is exactly 60 geographical miles (96.54 kilometers), as there are 60 minutes in a degree. So small variation can be erroneous. Small time interval between the data collection can be more effective for prediction.

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