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An Investigation on Shifting and Subsidence of Right Embankment of Devee River at Bauriakana, Puri District of Odisha

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Abstract

The agriculture and other socio-economic developments of a locality are dependent on the water resource available in a particular area. When the source of water is a river the area is exposed to hydrological extreme events like flood. The deltaic parts of the river are highly fertile thus having high population intensity and raised socio-economic conditions.The shifting character of the river to either side raises a concern along the villages of the side as a measure part of geographical area is engulfed by the river with flood occurrences. The precious fertile land is exchanged as river bed while the other side is loaded by sand where nothing can be grown. As our rural economy is more or less agriculture based, losing a land to river, breaks the backbone of the rural poor. In this study a river named Devee which is a distributary branch of Mahanadi show a similar kind of behavior as it occupied a huge land to the right at a place called Bauriakana but the other side is with a huge sand cast. The gradual shifting of right embankment, the subsidence at particular spur, the historical developments for protective measures and geo morphological behavior like sinuosity is investigated in this study.

Keywords: Shifting of River, Mahanadi, Devee River, Bauriakana, Socio-Economic.

Introduction

Flood related devastations are the general features in delta region of the Mahanadi Basin, which destroyed the social and economical condition of the people frequently. In particularly every two to three years high flood come to the Mahanadi basin and inundate the deltaic land for a longer duration due to a breach or overtopping and the release of water to the sea takes a longer time. Sometimes the control of these floods becomes inevitable and in other parts few structural measures are made to avoid a disaster. In this study a very peculiar phenomenon has been taken up at the right embankment of the Devi river at Bauriakana near Kakatpur of Puri district.

Due to shifting of the right embankment a huge land has been occupied by the river at a particular stretch and simultaneously the opposite side is heavily sand casted. Further during the post flood period when the first tide comes and recedes the embankment and spurs gradually slides vertical. So the construction and consolidation of spurs and embankments becomes a recurring subject throughout the year. As this spot is highly sensitive to flood it needs to be studied the characteristics of the stream flow as well as geomorphology of the river and embankment. At the first instance, the sinuosity, existence of paleo channel, grain size and compaction of the embankment soil, positioning of spurs are found to be few important aspects responsible for this kind of failures.

In these areas agriculture and cattle remains the prime occupation. If the shifting will occur in regular interval then both economy and social relations will be under strain. Loosing livelihood and paternal properties will definitely endanger the professional skills of the dwellers. It is verified from the studies of Ghosh and Sahu, 2018; Laha et al., 2013; Briggs et al. 2008; Rudra, 1996, that there is a huge socio-economic impact on the river shifting victims. Out of the many impacts the most important is displacing the people and its consequent impact on generation to generation due to loss of socio-economic ties and avenues (Ghosh and Sahu, 2018).

Huge losses to real estate are found due to Ganga river bank erosion in the Maldah district of West Bengal (Laha et al., 2013). Guite and Bora (2016) have described the river bank erosion status of Subanasiri river of Assam state where around 461.49 sq.km of agricultural land and 134.05 sq.km of forest land has been lost due to lateral migration of river bank between 1956 to 2010.

Siddik et al. (2017) have investigated the deterioration of economic and social conditions of the local people along the bank of river Pandob in Barishal distict of Bangladesh due to the river bank erosion process since 2002.

Mishra and Subhalaxmi (2018) have identified the danger zone of the river near village Bauriakana where the shifting of the river from left to right side is well marked. A huge land at the tune of 15000 hectare was found to be within the river affecting around 105000 people.

Baki (2014) in his work has given a clear picture of river bank erosion along river Gorai in Bangladesh. The socio-economic impact due to loosing the precious lands has affected the people of the area in its worst possible way.

Ghosh and Sahu (2019) in their study related the river bank erosion along Ganga-Bhagirathi embankment in Jangipur Sub division of Murshidabad district of West Bengal with the loss in education among the school going children. The loss in income, infrastructure, socio-economic deterioration also affected in many ways the dwellers of the locality.

Study Area

The river Mahanadi enters in to delta at Mundali near Cuttack and covers around 9500 sq. km. of only delta area. Then it spreads into branches and sub-branches and releases around millions acre feet of flood water through the river network. Although most of the deltaic channels are embanked, but the apprehension of its failure and overtopping still persists. The delta has a very poor land slope and overlain by thick fine grained clayey soil. The site at Bauriakana (Fig.1), it is a sensitive place during flood as the right embankment always remains under verge of breaching. The dense settlements are well marked in the figure.

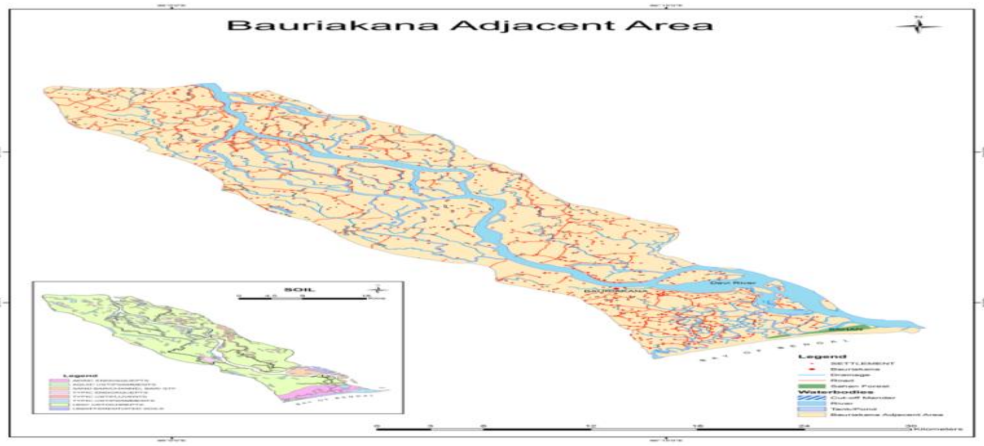

Fig.No.1. Location of study Area

It has been observed that the erosion of right embankment is primarily due to the meandering action of the river as it starts bending near Bhandisahi and adding to this effect a small sand island is formed at left side of the river ultimately the path of the water flow is diverted to the right side and thus the right embankment is under pressure. In order to mitigate the effect of flow current along the right embankment 14 spurs have been constructed.

The present sand cast at left side was earlier not there and has come up only within the last 20 years (as revealed from local inquiry). The effect of sea is also felt at this location as the coast is only 5 km away. A huge fertile agricultural land and settlements are found near and around this embankment close to Kakatpur city. So precautionary measures regards to this embankment is highly essential to check the damage done by the flood disaster.

The river mahanadi is flood prone and so also its major distributary river Devee. In its first objective the details of the shifting and subsidence of the right embankment is investigated in field with historical developments that occurred for the issue. Further the the sinuous tendency of the river is investigated for taking necessary protection measures.

The study is based on the hypothesis that a sinuous river has a tendency to shift its course. So its both sides will be in danger for sand casting and breaching. A new river may come up, possibility of ox bow lake formation is there. This study deals with investigation of sinuosity values for its geomorphological property for shifing characteristics.

Result and Discussions

The delta of large Mahanadi river system starts from Mundali (near Cuttack city). The distributary branches of the system can deliver a maximum peak discharge of 9.5 lakh cusecs (26885 cumecs). So considering this the maximum discharges at different flood years are shown in Table No.1, where it shows that in the year 1980, 1982, 2008 catastrophic floods are seen in the delta. Mostly the floods are occurring in the month of August or September.

Table No.1 Flood occurrences at river Mahanadi with maximum discharges at delta head

Sl. No.	Year	Date	Peak flood at Mundali (Cumecs)
1	1958	19th July	33960
2	1959	14th Sept.	35516.5
3	1961	11th July	36365.5
4		18th July	32601.6
5		8th Sept.	33054.4
6		16th Sept.	36931.5
7	1969	1st Aug.	29941.4
8	1980	22nd Sept.	35601.4
9	1982	31st Aug.	44827.2
10	1991	14th Aug.	35969.3
11	1992	30th July	32092.2
12		21st Aug.	31413
13	1994	13th July	28979.2
14		6th Sept.	30592.3
15	2001	17th July	39620
16		20th July	39846.4
17	2003	30th Aug.	38205
18	2006	23rd Aug.	37016.4
19	2008	20th Sept.	44742.3
20	2011	11th Sept	38686.1
21	2014	8th Aug.	31497.9
22	2019	15th Aug	26432.2

As evident from local information and satellite imageries that the river Devee is gradually shifting to right side. Since 1955 the right embankment shifted so many times spoiling acres of land and the present position of the embankment is settled only after 2008 flood.

In the process it has engulfed nearly 1 km of precious land over a longer patch. Thus a huge population is affected at right side and on the reverse the left side is getting a large sand deposit. The river gradually drifts from left embankment. The figure (Fig.2) below shows the process of river shifting from 1965 to 2006. Due to huge loss of agricultural land the livelihood of local people is getting massively affected.

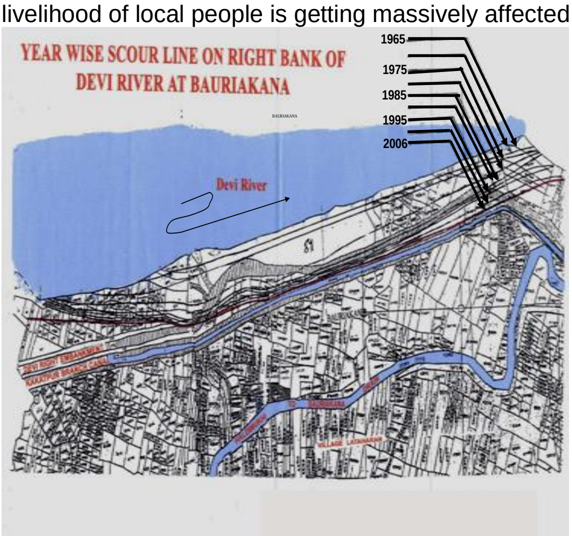

Fig. No..2. Scour line of right embankment and huge agricultural land at right bank of study area

The left side also has huge agricultural land (Fig.3) justifying the locality as an agricultur based economy area. Generally the agriculture profession is labour oriented and manpower based, which develops dependency and that creats a social bonding.

Fig. No.3. Left embankment and huge agricultural land at right bank of study area

The shifting of river bank is the output from the gradual process of bank erosion. The deposition and erosion go side by side and it depends on the morphology, river current and flow, the embankment material and other factors. When the sediment deposition is less in comparison to that has been eroded, the bank erosion starts. This is a situation of active and continuous river bank erosion (Charlton, 2008) which is resulted through the encroachment of more river bed area. Thus the bank shifts gradually. If the river is more flood prone and the morphology allows a higher impact over the particular part or the stretch of location, then the chance of river shifting is more prominent. This phenomenon is common along deltaic rivers all over world, it is more felt in South East Asia due to high population intensity and losing of fertile land.

During this time the deltaic areas also remain exposed to heavy monsoon rainfall at the tune of around 1200-1400 mm (only during monsoon). The chance of breaching or overtopping of the embankment is also there to add to the plight of the local people. During recent time the flood of year 2008, 2011 was very catastrophic.

Adding to this another difficulty lies in the right embankment is that a constant subsidence at a particular location during post flood period which also accelerates the shifting of bank. Regarding this we have collected much previous information and found the claim correct (Fig.4).

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Fig.No. 4. Embankment Subsidence during 2008

During our visit to the spot also realized the problem is genuine. In order to resist this government has constructed as many as 14 numbers of spurs to deviate the flow current. Few salient points have been identified during our visit to the spot are noted as:

The mark of subsidence is seen in right embankment. The subsidence shown in Fig.5 is the result after release of flood water of 2014. The tidal effect is well marked as understood from local inquiry and the site is around 10 km upstream from Bay of Bengal. It is also evident from local inquiry that the sand cast which is seen at left side of the river is getting created only 20 years back. Few also told a branch of river/ nullah was releasing from the main river near spur 9-11 and the present embankment is made over that, which promotes subsidence. Another feature was evident that no subsidence occurs during flood but it happens only when the flood water recedes.

Fig.No.5. Subsidence of Right Embankment

The information is mostly collected during our visit to the study area and contact with local people and officials (Fig.6).

Fig.No.6. Field visit by the team to study area (Year-2015)

As this incident may lead to a huge catastrophe as few floods and cyclone driven floods occur during post flood periods, different technical studies are made on this. Earlier report and studies are also recorded as in Table 2.

Table 2: Reports and visits to the spot

S.No.	Organization	Date of Visit	Places of Visit	Visit Note
1.	CWPRS, Pune	27 - 29 Sept 2007	Puri	15.10.2007
2.	Dr. Kanetkar	27 - 29 Aug 2008	Paradip, Puri, Puri-Konark road, Chilika,	Awaited
3.	IIT, Madras, Chennai Dr. Sundarvadivelu	27 - 28 Oct 2007	Puri, Pentha, Satabhaya	7.11.2007
4.		27 - 29 Aug 2008	Chilika	Awaited
5.	ICMAM (Integrated Coastal & Marine Area Management), Chennai Dr. B.R.Subramanium, Director	2007		Given
6.	4 member team led by Dr. M.V.Ramanmurthy	22 - 23 Aug 2008	Chilika mouth, Gopalpur	Awaited
7.	IOM, Anna University, Chennai Dr. R.Ramesh	2007		Not known
8.	National Institute of Oceanography, Goa Dr. B. Pravakar Rao, DAS Balsubramanium, NSN Raju B.P.Raju	1-Aug-07	Puri, Gopalpur	Not known
9.	INDOMER, Chennai Dr. P. Chandramohan, MD Dr. Vani Tesway, Scientist	9 - 10 Aug 2008	Chilika mouth, Gopalpur	Awaited

Possible Solutions

Earlier IIT, Chennai has given his recommendation for construction of adequate Spurs 14 nos. of spurs from RD 77.570 m and 79.044 m at right embankment. It has also been realized that the much of the damages have been averted by application of these spurs.

Our team also investigated the same spot and identified few salient points which may be adding some inputs to prevent the effect of flow current on the embankment.

The spurs generally deflect the flow from one side to other in order to put less pressure on the most affected side. Here it is placed at right to protect embankment and to gradually cut the sand cast at left so that river water will be coming to the middle of the course instead of concentrating at right.

As the team found there are 14 spurs to deflect the current still the damage existing although minimized. So after investigating the site and local inquiry the adequacy of spurs as well as the location was under question. The main strike of current is at spur 9-11. The role of other spurs is to gradually moderate the flow and deflecting is also needs verification from the water resources department. Another, the dimension of the spurs for the hydrodynamic design also plays very important role, which is to be referred for verification (Fig.7).

Fig.No.8. The spur locations and probable effect of currents at right embankment (source: google earth)

The meandering characteristics start from spur 1. So at least one physical modeling can be tested for dimension and location of spur1. The investigation for existence of a branch channel must be continued through tests like Undisturbed Soil Sample (UDS), electrical resistivity tomography (ERT) This study is in support of the IIT Chennai Report regarding the inadequacy of the number of Spurs and also recommends for quick repair of the damaged Spurs.

A morpho-metric analysis is suggested to be taken up after taking the river width and cross section at places like Bhandisahi (Where river starts bending), near Spur 1, near Spur 10 and downstream of Spur 14. The sinuosity property of the river is to be tested in broad in order to analyse meandering behavior of the river. The sinuosity property is a very significant one with regard to river and embankment behavior as realized from following literature studies.

It has been realized that, sinuosity as an important aspect for this kind of failures. Generally the stream sinuosity indexes are usually derived by dividing the length of a reach as measured along a channel by the length of a reach as measured along a valley (Muller, 1968). Incorporating Geographic Information System (GIS) and satellite images the sinuosity index is introduced here as a tool of 'river morphology' which is branch of geomorphology and it would deal with form of stream and adjoining area as brought about by erosion , transportation and deposition of sediments by running water (Garde, 2006). Earlier Ghosh and Mistri (2012) have used the toposheets, satellite images and GIS for measuring the temporal pattern of river Damodar with the help of Mueller's Sinuosity Index to unfold the magnitude of river instability, contributing factor of Sinuosity and chances of flood with a probability of changing course. Das (2012) has made a geospatial analysis to understand the meandering behaviour of Barak River in southern Assam between 1988 and 2010.

In lieu of satellite imageries the freely available google earth image at different period is considered and the beginning of the bend just before the target spot at Bauriakana. On physical verification of site it was decided to divide the upstream of target length into 3 parts as shown in Fig.8 and the morphological values are calculated from the river stretch imagery for the year 2004, 2010 and 2016.

Fig. No.9. Showing bends at upstream of study area

River Bank within the study area is digitized as polygons for these three years and sinuosity index (SI) are calculated. The parameters are calculated as per Mueller's Sinuosity Index (Fig.9) and its standards and limiting values of SSI are mentioned in Table 3. The SSI (Standard Sinuosity Index) is calculated as a ratio as CI / VI.

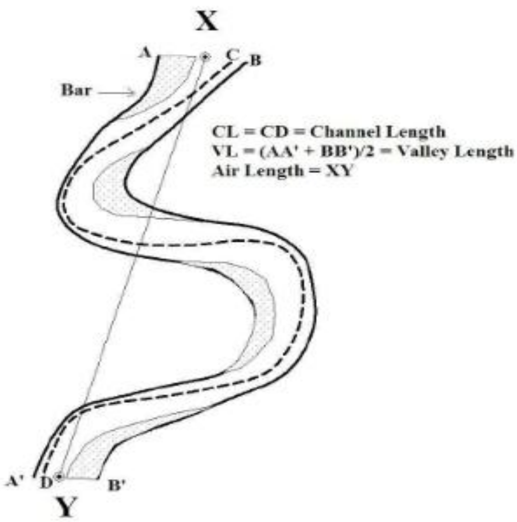

Fig.No.10. Parameters as per Mueller's Sinuosity Index

Table No.3 Standard Sinuosity Values

Type	Sinuosity
Straight	< 1.05
Sinuous	> 1.05
Meandering	> 1.5
braided	> 1.3
Anastomosing	> 2.0

The analyses for designated 3 bends are calculated and noted in the Table No.4. From the base values of channel length, Valley length and Air length are calculated and noted as mentioned in Table 4. The channel index and valley index are calculated from the equation given in Fig.10 and finally SSI is calculated as a ratio between CI/VI. By judging the values over a time period between 2004 to 2016 conclusions drawn as mentioned below.

Table No. 4 Geo-morphological indices at the study area

	Year- 2004						
SL NO	Name of reaches	CL	VL	AL	CI	VI	SSI
1	Kalakha to Arakhakuda	9.894	10.006	6.168	1.604086	1.622244	0.988807
2	Arakhakuda to Rokida	8.84	8.781	8.341	1.059825	1.052751	1.006719
3	Rokida to Khandasahi	6.584	6.4795	5.93	1.110287	1.092664	1.016128
	All lengths are in km						
	Year-2010						
SL NO	Name of reaches	CL	VL	AL	CI	VI	SSI
1	Kalakha to Arakhakuda	9.783	9.667	5.998	1.631044	1.611704	1.012
2	Arakhakuda to Rokida	8.66	8.777	8.355	1.036505	1.050509	0.98667
3	Rokida to Khandasahi	6.385	6.563	6.036	1.05782	1.087309	0.972878
	All lengths are in km						
	Year- 2016						
SL NO	Name of reaches	CL	VL	AL	CI	VI	SSI
1	Kalakha to Arakhakuda	10.429	10.3655	6.479	1.609662	1.599861	1.006126
2	Arakhakuda to Rokida	8.312	8.47	7.933	1.047775	1.067692	0.981346
3	Rokida to Khandasahi	7.041	7.253	6.705	1.050112	1.08173	0.970771
	All lengths are in km						

It is revealed from the analysis that in all 3 bends the sinuosity is under the safe limit during the period 2004 to 2016 although it is increasing. The Bend 1 is at comparatively at high risk. In tis regard we can conclude that few more spurs can readjust the river morphology without giving much load and impact on the right embankment. In order to check scouring at the toe of spurs stone dumping, stone pitching or vertiver grass plantation may be done.

Conclusion

The study site is an appropriate example of river shifting and its related plights. Although the dangers are averted by construction of spurs but the fury of the flood may not be averted. Shifting of the river to the right side was found to be a regular process by which a huge cultivable land has come under the river bed while the left side is sand casted making the land unusable. As a huge land is lost or wasted on both side a huge impact on the socio economic front is visible. Earlier the area was mostly agriculture dependent and now the shifting is well marked to other professions. Further few are shifted from the river bank villages disrupting their social bondages. The government made infrastructures are also hampered many a time.

The subsidence of right embankment will also be a constant threat, thus demanding a permanent a concrete solution. In the process of restoration the government has made number of spurs on the right bank in order to deviate the flood current. However the efficiency of the system will largely depend upon the adequacy, efficiency and suitability of those spurs.

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