

Anthropogenic Impact on River Course Shifting: A Case Study Along Hatipahar Region of The Nagavali River in Rayagada District, Odisha

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ABSTRACT

The Nagavali River within the Rayagada District of Odisha, India is flowing north to south through a narrow longitudinal valley between east and west facing ranges. Earlier the river used to flow through rocky course along the piedmont slope of the eastern ridge by forming a small waterfall locally known as Hatipahar. In the year 2006, a narrow canal had been dug through the alluvial deposit along the right bank to construct a dam for a hydrel power project. On 3rd July, 2006, torrential rainfall occurred at the upper catchment of the river causing huge discharge and thereby plenty amount of erosion of the softer alluvium across the canal. Because of this flash flood the Nagavali River started to flow through this canal leaving the earlier course abandoned. The present study was aimed to analyse all the possible causes behind the shifting of the river course. Google Earth and SRTM DEM have been used for demarcating the location and spatio-temporal changes along the river. Intensive field survey along with GPS, Dumpy Level, has been carried out in order to prepare a micro level elevation model and to understand stratigraphic - lithological scenario of the area. After that single event the river has shifted about 550 meters westward and tolled about 0.54 km² loss of land. The newly formed course has established itself over the bed rock along the Hatipahar Region and still possessing very active head-ward erosion and valley incision. This change is actively noticed upto 9.84 Km upstream of the river.

Keywords: Piedmont slope, flash flood; longitudinal valley; course shifting

1. Introduction

River morphology (Leopold et al., 1964, Nicoll and Hickin, 2010; Gregory, 2006; James and Marcus, 2006) of south-eastern India is very much dynamic in nature. While some of the rivers of the Chotonagpur Plateau are superimposed (West and Choubey, 1964; Kumar and Rai, 1981), others originating from the Eastern Ghats are structure-controlled (Swamy et al., 2008; Ramakrishna et al., 2011). All these rivers are rain fed and become seasonally vigorous with extremely high discharge. Some of the small rain fed rivers comprising of small valleys often experiences flash flood, bank erosion and other calamities. Although majority of these hazards occur naturally but few of them associated with human intervention. The Nagavali River is one small independent river system of Bay of Bengal. The River has originated from a hill (1300m) near Lakhbahal village of Kalahandi District, flows through Rayagada District, Odisha and finally enter into Andhra Pradesh through Srikakulam District where it confluence with sea. Throughout the maximum stretch of the upper catchment area within the Odisha State, the Nagavali River is flowing

in north-south direction through a narrow valley restricting by two parallel ridges located in east-west direction. After entering into Rayagada District, the Nagavali River is flowing through piedmont rocky slope of the eastern ridge by forming few break-of-slopes. One such break-of-slope is locally known as Hatipahar waterfall. The parent rock of the eastern ridge is made of Khandelite-granite of the Eastern Ghat Super Group (Geological Survey of India, 1994; Ministry of Water Resources, 2013; Odisha District Gazetteers, Rayagada, 2016). On the other hand, a thick and wide alluvium deposit with some isolated knolls is found in the western side of river. This thick deposit is extended upto the foot hill of the western ridge.

In the year 2000, the Govt of India had announced about constructions of eight hydro-powers projects along the Nagavali river basin and accordingly in the year 2006, one such project had been initiated at the Hatipahar waterfall (S1 site in Fig-1). For the construction purpose a narrow canal had been dug westward along the alluvium from the main channel. On 3rd July, 2006, torrential rainfall occurred at the upper catchment of the river, both in Kalahandi and Rayagada Districts, causing huge discharge and thereby plenty amount of erosion of the softer alluvium across the canal. Because of this flash flood the Nagavali River started to flow through this canal (Brookes et al., 1983; Islam et al., 2014, Paul and Meyer, 2001) leaving the earlier course abandoned. After that single event, continued for three days that river has shifted about 550 meters westward, and tolled about 0.54 km² loss of land. The newly formed course has established itself over the alluvium by rapid downward incision for about 36m resulting abundant exposure of bed rock in scattered places. Not only that Hatipahar Region is still possessing very active head-ward erosion and valley incision. This change is actively noticed upto 9.84 Km upstream of the river. The objectives of this paper are to analyse the nature and intensity of the floods and other probable causes that lead such avulsion in Hatipahar region. And also to identify the forces that compile the river to flow through the piedmont slope of the eastern ridge made of hard khandelite-Granite, leaving the softer alluvium untouched.

2. Location of the study area

After originating in Kalahandi District, the Nagavali River passes through Rayagada district of Odisha and enters into Srikakulam of Andhra Pradesh. Finally, it merged in Bay of Bengal near Kallepalli village of Andhra Pradesh. The total length of the river is about 256 kilometres (159 mi), of which 161 kilometres (100 mi) are in Odisha and the rest in Andhra Pradesh. The catchment area of the basin is 9,510 square kilometres. The selected study area is located along the Rayagada town and comprise of a sub watershed of the Nagavali River. Within this sub watershed a length of 14 km and an area of 27.56 sq. km of the Nagavali River is situated. The ordinates of this area is 19°7' N- 19°12'36" N and 83°26'16" E-83°29'14" E (Fig-1). This place was once famous as Hathipahar because of its waterfall and beautiful scenic beauty.

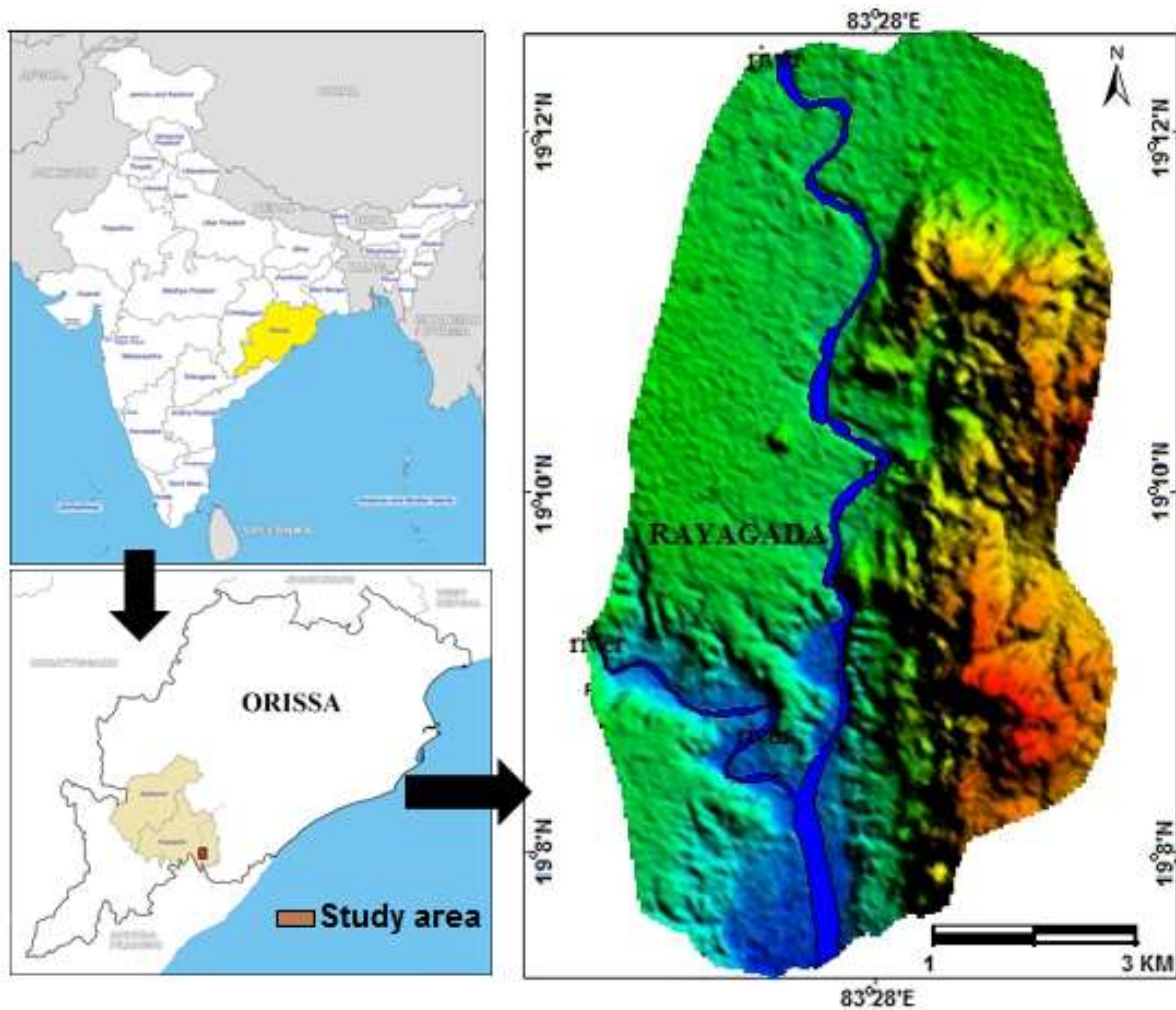


Fig-1. Location of the Hathipahar Region along Nagavali River Basin

3. Materials and methods

The sub watershed of the Nagavali River along the Hathipahar region has been extracted from the SRTM DEM (2000) and being verified from the 1972-73SOI Toposheet. Google Earth (of the year 2006, 2011 and 2018) have also been used for demarcating spatio-temporal changes along the river. 21 years rainfall data both for Kalahandi and Rayagada Districts have been collected from the Indian Meteorological Department. Intensive field survey has been carried out in order to prepare a micro level elevation model and to understand stratigraphic -lithological scenario of the area. Rock and sediment samples have been collected from the field to study the grain size variation and lithological formation of this region. Pebble imbrication of the deposited sediments are also analysed to get an account of the past surface water flow pattern of the region. Photographs are also collected from the field during high discharge and low discharge time to understand the variation of river hydrology of the region.

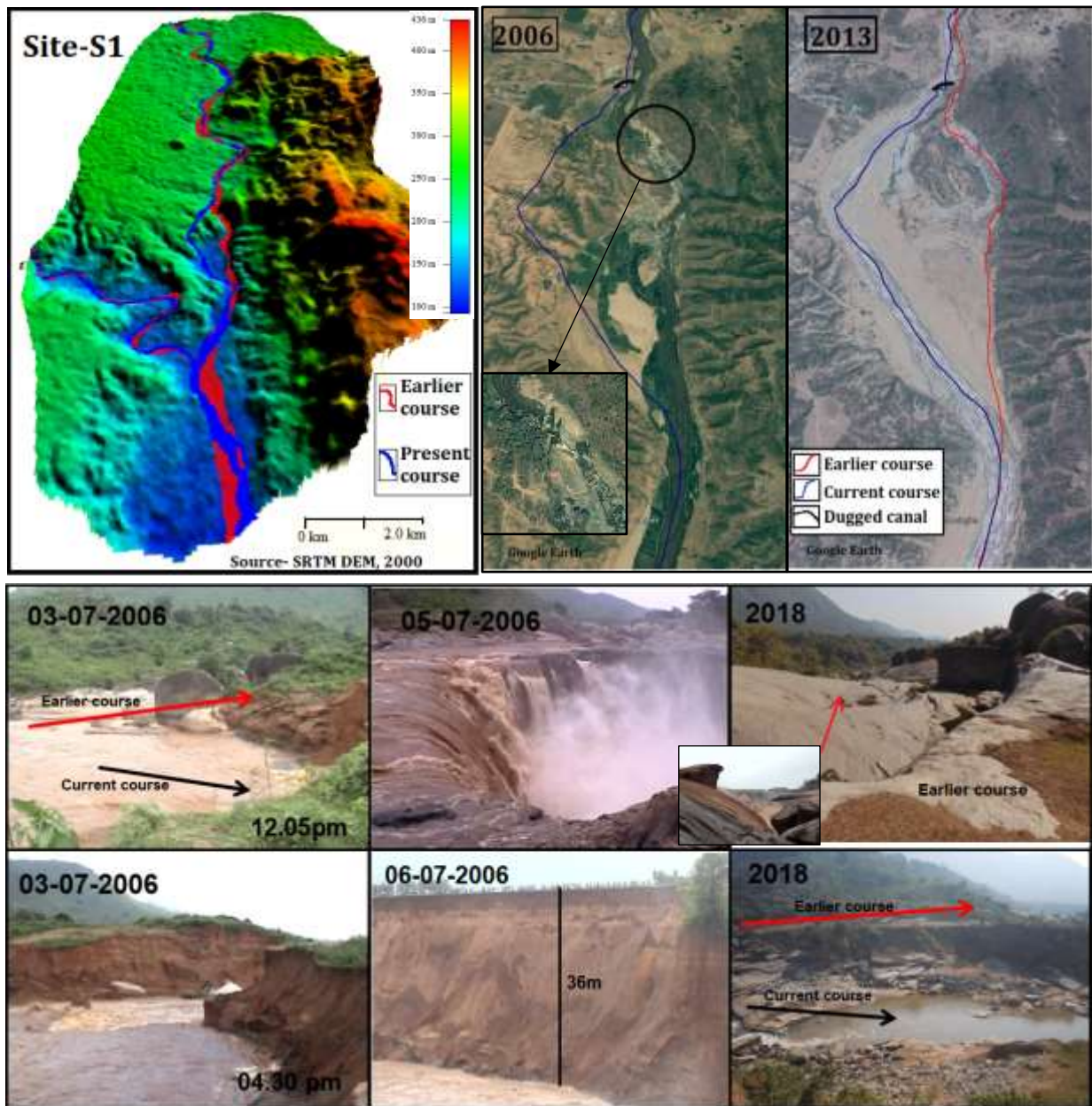


Fig-2 (A) Spatio-temporal change of the Nagavali River course detected in Google Image (2005-2011): Black circle is showing the location of the waterfall in 2005, Red colour and blue colour paths are showing the 2005 and 2011 courses consecutively in the 2011 image. (B) Field photographs showing the sequential avulsion at different time and date of that single event occurred on 3rd July, 2006. In the 2018 photograph red arrow and the black arrow are demarcation the earlier and the present courses consecutively.

4. Results

4.1. Course change along the Hathipahar region

From the Disaster Management Cell, Odisha and the local people it's been verified that before 2006, the Nagavali River was flowing through the piedmont slope of the eastern ridge by forming Hathipahar waterfall. In the 2005 Google image the course through the fall was quite clear. Again in the 2011 Google

image, it is observed that the river has shifted (Alam and Hossain; 1998) westward for distance about 500m and presently flowing through a newer course leaving the older course abandon (Fig-2A).

Although the period within which the course shifting (Bandyopadhyay et al., 2013; Dunne and Leopold, 1978; Hammer, 1972) has taken place is not clear from the image analysis but from the continuous field photograph during the event, it is very much clear that that avulsion occur within 3 days of time (Fig-2B). Avulsion started in the early morning on 3rd July 2006. Within few hours (12pm), the river had cut a wide course through the canal. At the evening of the same day, the river had incised the valley downward upto 14m. In the next two days, the river had form a wide waterfall within the newer course. But during the field visit in the year 2015 and also in 2018, that newly form break of slope was also absent. From the consecutive photographs it can be said that the avulsion and valley deepening occurred within 3 days of time (Fig-2B). The final adjustment of the slope continued actively till 2015 through head-ward erosion and valley deepening. Presently a few small break of slopes are found in the upper course instead of the earlier big one, but the process of valley deepening and erosion is still going on.

4.2. Analysis of the cross-profiles drawn along the Hathipahar region

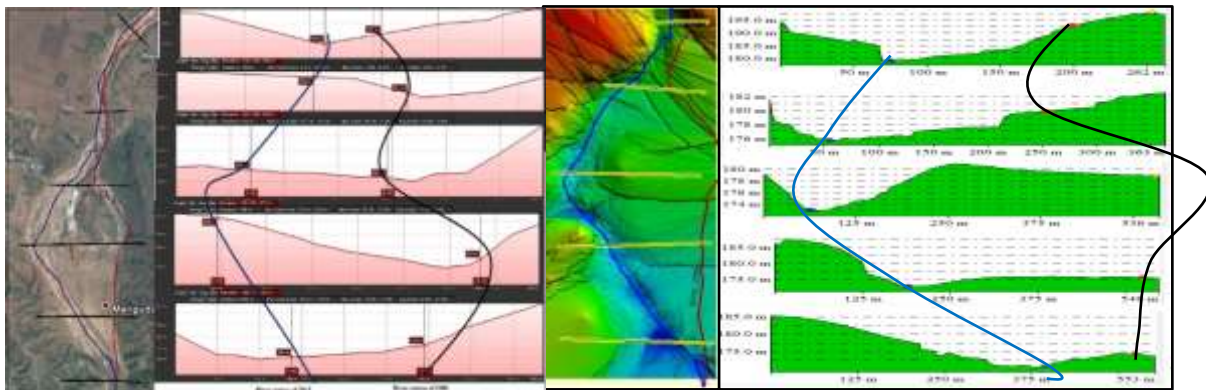


Fig-3. Cross-section showing differential lateral shifting of the river along its course in the Hathipahar region.

Six cross-sections are drawn along the Hathipahar region both in upstream and downstream part of the avulsion point (Fig-3). In the section of the upstream part it is found that both lateral and downward erosion is restricted. From few hundreds metre upstream, the river started shifting (Lewin, 1983; Gurnell, et.al, 1994; Gilvear, et. al, 2000) laterally westward and the distance between earlier and the present courses continuously increases at downstream side. The distance between the earlier and newer courses re found maximum (515m) long the 4th cross-section located at the downward side of the avulsion point. The river again meet with its earlier course at 2.23 km downstream of the avulsion point (Fig-3).

The river not only erode its course laterally but also incised downward. The maximum incision is found along the cross-section-4 and it is measured about 32m. The right bank of the river is still hanging vertically.

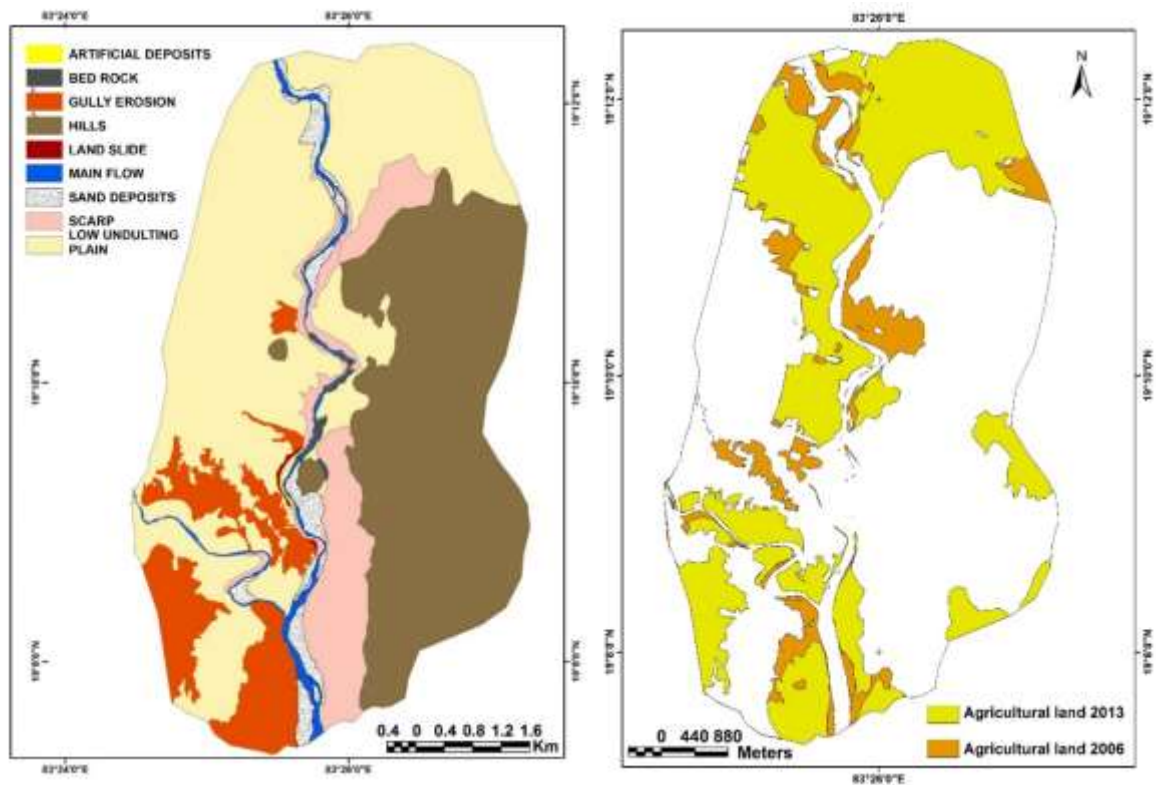


Fig-4. Extension of Gully erosion and reduction in agricultural land in between 2006-2013

4.3 Consequences of the course shift

The river has shifted 515m westward due to that single event. Not only that the river is incising the downward and the process is still active. Due to this rapid incision the right bank of the river remained vertical and are very much prone to erosion. From this vertical bank, several surface flows are occurring which leading extensive gully networks at the lower part of the area (Fig-4). Within 2006 to 2013, huge amount of agricultural land (Croke et al. 2004) was lost both in upstream and downstream part of the region either due to bank erosion (Naik, 1999; Mani et al., 2000; Davinroy et al. 2003) and soil loss or due to extension of gullies (Fig-4).

5. Discussion of probable causes behind such shifting

5.1 Rainfall analysis of the region

The very first thing which is coming in mind as the major cause of such avulsion is that huge amount of rainfall occurred in that particular year.

From the 21 year rainfall graph of both Kalahandi (upper catchment of the river) and Rayagada Districts, it is observed that although total amount of rainfall in the year 2006 is very high, it was not the sole year of high rainfall recorded in the past. Before that in the year 1993, 2001 and 2003 Kalahandi District receives higher rainfall (Fig-5). But one distinct feature is found in the graph. In all the past high rainfall years only Kalahandi District received heavy rainfall but the amount of rainfall over the Rayagada District remain comparatively low. But in the year 2006, although Kalahandi District didn't received highest among the past but both the districts received heavy rainfall. This can be one of the cause leading such avulsion.

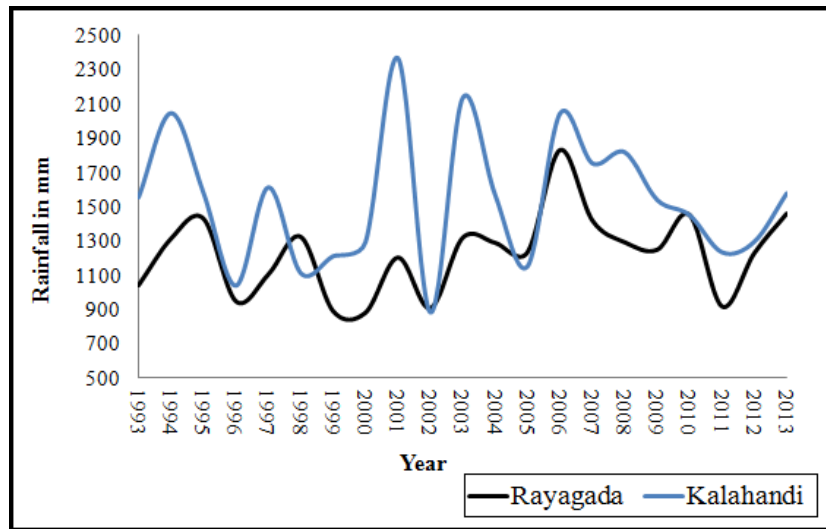


Fig-5. Rainfall analysis for the past 21 years for both Kalahandi and Rayagada District, Odisha (Source- Meteorological Department of India)

5.2 Analysis of sediment stratification over the region

As the past rainfall data of this region is limited and discharge data is not available for the Rayagada District and also for its upstream side, sediment stratigraphy (Allen and Williams, 1982; Behrensmeier and Tauxe, 1982; Bridge and Diemer, 1983; Gordon and Bridge, 1987; Kraus and Middleton, 1987; Mack and Seager, 1990; Ross, 1990; Shanley and MaCabe, 1993) at different parts of the Nagavali River basin (Torgersen et al, 2000) over the Hathipahar region has been analysed to understand evolution of such region. The analysis of sediment profiles is also help to find out earlier nature of the river and also recurrence of such hazards in the past. Three different sediment facies have been selected and analysed from different part of the Hathipahar region. The first section is taken near the nodal point from where the river has shifted and incised downward its present course. Presently this section-1 is located at the right bank of the present course and above which the earlier course is remained as hanging valley. This particular section is 17.26m high located at 182m from msl. Along this section maximum part is covered with fine sediment composed of coarse sand of <1mm diameter but there are two thin coarse sand with pebbles layers (2-20mm diameter) within it (Fig-6). In the section a wide part is composed of multiple laminated layers of pebbles which indicate irregularity in the flow. At an altitude of 189m a thick layer of sand and boulder deposits is found where the maximum diameter of the boulder is range between 0.13-0.26m. The biggest boulder is marked by black circle in the field photograph (Fig-6).

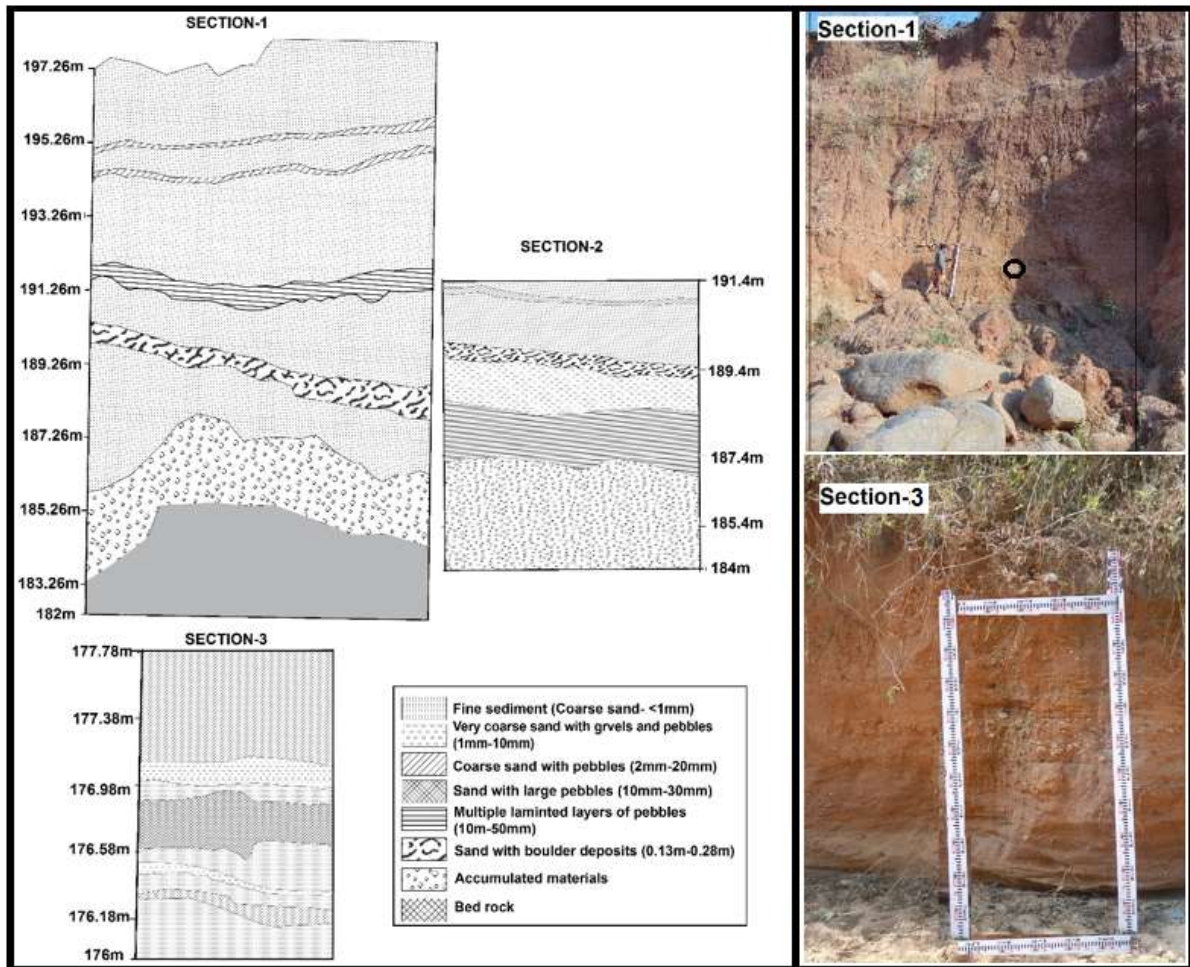


Fig-6. Grain size analysis of sedimentary sections and photographs taken along the Hathipahar region

The same layer is also found in the Section-2 almost in the same altitude. This huge boulder deposit indicating vigorous velocity of water and occurrence of mega flood in the past.

Third sediment profile is taken from a gully which is located at few km downstream. This section is revealing further lower sediment deposition. This section is about 1.78m high. Although in this section evidence of mega flood is not found but a distinct thick layer of sand with large pebbles (10-30 mm) is observed which indicate high kinetic river energy and heavy discharge (Fig-6).

6. Conclusion

From the ongoing discussion it can say that high amount rainfall in the year 2006 was not the sole reason behind such avulsion. From the analysis of pebble imbrication within the deposited sediment it is clear that the entire alluvium deposit is formed by the Nagavali River itself. But still the river was flowing through that hard piedmont slope keeping that softer alluvium untouched. One of the cause of such unnatural behaviour of the Nagavali River can be a super-flood event. As a giant boulder deposition within the sediment is noticed at certain height over the earlier course near the Hathipahar region (Fig-7), it can be considered that a super-flood was occurred in the past which forced towards the piedmont slope. Even after that flood event, the river was stuck over there and was flowing by forming waterfall. Once it's got

an opening through the softer alluvium in the form of canal and also supportive amount of discharge from the heavy rainfall, immediately it cut the canal downward and establish its newer course widely (Fig-7).

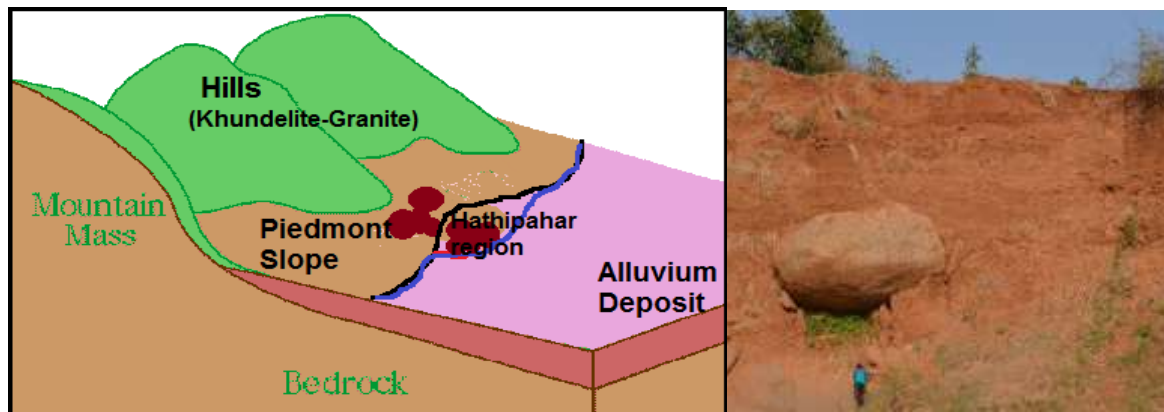


Fig-7. Proposed model showing the avulsion of the Nagavali River and the deposition of giant boulder at certain height over the earlier course along the Hathipahar region

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