Assessment of Meandering Characteristics from Image Analysis of the Gorai River at Kamarkhali Bend

Md. Alim-Uz-Zaman

Abstract— Meandering process is the most significant morphological property of an alluvial river and it is caused by the topographic, hydrologic and hydraulic factors of the streams and their drainage areas. In a meandering river the length of the river increases by eroding the outer bank at a bend until a loopcut occurs. When the meandering ratio increases then possibility of loopcut also increases. But it is interestingly observed that in the Gorai River at Kamarkhali, around 100km downstream from offtake of the river, the bend is migrating inner side and outer side repeatedly instead of occurring a chute cutoff though the sinuosity value is very high. The bend is a striking feature of the Gorai which is the tortuous 20 km loop in the river at Kamarkhali. The radius of curvature of the bend is too small to be sustainable. That is why the bend has been found changing over time. The present study has been undertaken with the help of ArcGIS tool to examine the meandering parameters of the Gorai River at the Kamarkhali Bend using satellite images from 1972 to 2019 collected from USGS website. Analyzing the bend it is found that meander length varies from 9061m (2003) to 18825m (1972), meander width varies from 4672m (2003) to 7355m (1972), meander ratio varies from 0.39 (1972) to 0.53 (1975), sinuosity varies from 3.10 (1975) to 5.91 (1997), wave length varies from 2600m (2009) to 3550 (1972), radius of curvature varies from 495m to 887m (2011), min width varies from 163m (2000) to 430m (1975) and maximum width varies from 293m (2000) to 805m (1972).

Index Terms— Gorai River, Kamarkhali Bend, Loopcut, Meander Ratio, Morphological Property, Sinuosity, Radius of Curvature.

1 Introduction

NATURE of an alluvial river or stream is its dynamic change over time, and it is one of the most common features of a river. Meandering process is the most significant morphological property of an alluvial river and it is caused by the topographic, hydrologic and hydraulic factors of the streams and their drainage areas. Channel migration is fully influenced by the mechanism of meandering processes of development of the channels [1]. A meander, in general, is a bend, developed is a sinuous course of the channel. The zone is known as a meander belt, where a meandering stream shifts its channel from time to time within its floodplain or valley floor. An oxbow lake is formed, when a meander gets cut off from the mainstream. Analysis of meandering parameters are important for planners and designers for restoration of rivers and balancing the river systems [2]. Sometimes the civil engineers, designers and planners face problems to maintain stable infrastructures like road, bridges, as the meanders migrate downstream in a very short time [3]. Furthermore, Lane (1955), Leopold and Maddock (1953), Santos-Cayudo and Simons (1973), Schumm (1971), and Rechard and Hasfurther (1980) found several general relationships between meander processes and the hydrologic and hydraulic parameters in rivers. Meandering processes have been identified as the main reasons of dissipating excess stream energy by some fluvial morphologists. Therefore, to stabilize the channels, meandering process is considered as a potential design technique [2]. Meandering parameters, to be analysed, are mainly meander length, meander width, meander ratio, sinuosity, meander wavelength, radius of curvature, width of the river and types of bend migration, such as expansion, extension, rotation, translation and combination processes.

Gorai, a strongly meandering river, is the major distributary of the mighty river Ganges, in its right bank side which is the major source of freshwater in the south west region of Bangladesh. Its catchment area is of 15160 km² and located between 21° 30′ N to 24° 0′ N latitude and 89° 0′ E to 90° 0′ E longitude [4]. Taking off from the Ganges at Talbaria, the river flows towards the Bay of Bengal through the Madhumati and Baleswar Rivers [5]. It is known that the length of a meandering river increases by eroding the outer bank at a bend until a loopcut occurs. When the meandering ratio increases then possibility of loopcut also increases. But it is interestingly observed that in the Gorai River at Kamarkhali, around 100km downstream from offtake of the river, the bend is migrating inner side and outer side repeatedly instead of occurring a chute cutoff though the sinuosity value is very high. The bend is a striking feature of the Gorai which is the tortuous 20 km loop in the river at Kamarkhali [6].

Therefore, to assess the meandering parameters, mentioned earlier, and type of bend migration of the Kamarkhali Bend of the Gorai River analysing the satellite images of different years with the help of ArcGIS tool, this study has been taken off. Location of the Kamarkhali Bend of Gorai River, considered here, is shown in Fig. 1.

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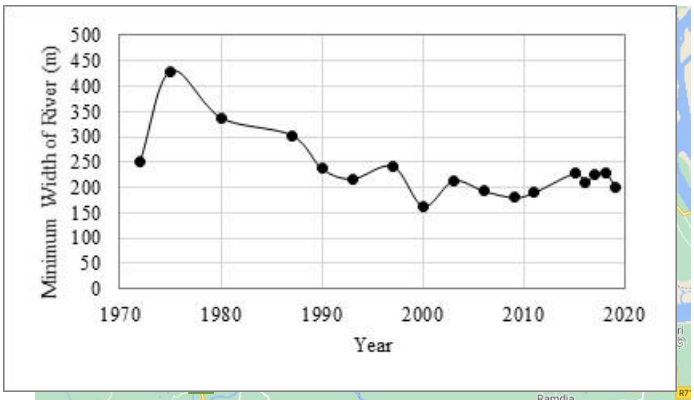


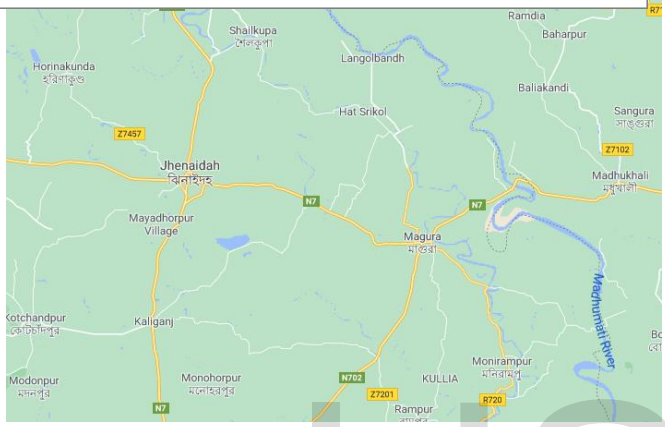


Fig. 1. Study area of Gorai River at Kamarkhali Bend

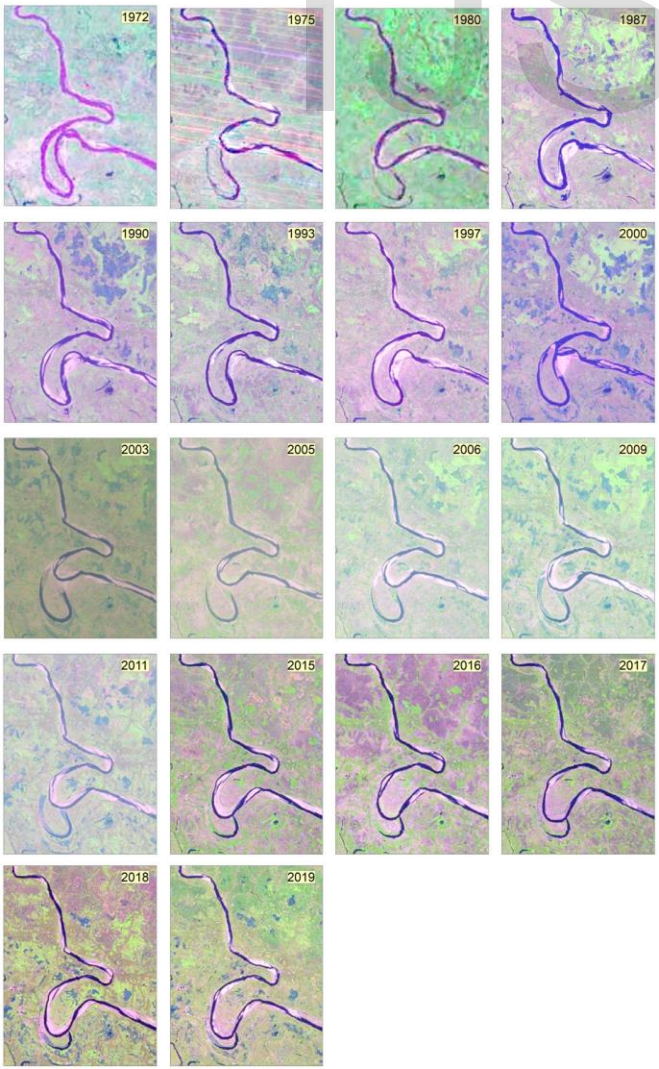


Fig. 2. Series of satellite images of Gorai River at Kamarkhali Bend from 1972 to 2019

2 Materials and Methods

Satellite images of different years for the Gorai River has been collected from USGS website to analyze the meandering parameters. For this study, satellite images of 1972, 1975, 1980, 1987, 1990, 1993, 1997, 2000, 2003, 2005, 2006, 2009, 2011, 2015, 2016, 2017, 2018 and 2019 have been collected as shown in Fig. 2. The software ArcGIS 10.3 has been used to analyze the images of Gorai River at Kamarkhali Bend for the above mentioned meander parameters. Critical changes of this bend are revealed in Fig. 10. Firstly, the banklines were delineated for the selected years from the images using ArcGIS 10.3. Then, using ArcGIS tool, movement of the bend, its length along the river, axial length, width, sinuosity, radius of curvature, meander ratio, etc. were measured.

3 Results and Discussions

3.1 Width of the River

Width of the Gorai River at Kamarkhali Bend has been measured from the images considering distance from bank to bank. From Fig. 3, the minimum width has been found, from the time series, as 163 m in 2000 and maximum width has been found as 805 m in 1972. The trend shows a decreasing pattern of minimum width per yar from 1972 to 2009. The overall trend also shows a decreasing pattern in case of maximum width per year.

3.2 Radius of Curvature

The radius of curvature of the curve at a particular point is defined as the radius of the approximating circle. Fig. 4 presents the variation of radius of curvature over time. It has been found that the maximum radius of curvature is 887 m in 2011 and minimum is 495 m in 1993. It is interesting to observe that radius of curvature shows a Sin curve pattern which indicates that the bend is moving of shifting repeatedly within its meander belt.

3.3 Meander Wavelength

The meander length or wavelength is the distance of one meander along the down-valley axis. Fig. 5 shows the variation of wavelength of the bend in different years. The wavelength varies from 2600 m to 3550 m. Minimum wavelength has been found in 2009 and maximum wavelength has been found in 1972. This parameter also indicates to a decreasing pattern of the bend per year.

Fig. 3. Variation of minimum (A) and maximum (B) river width over time

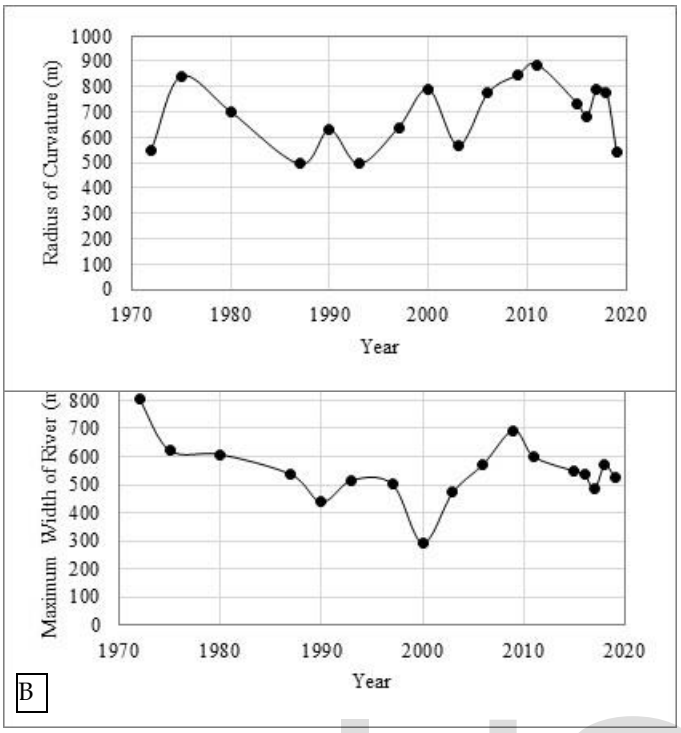


Fig. 4. Variation of radius of curvature over time

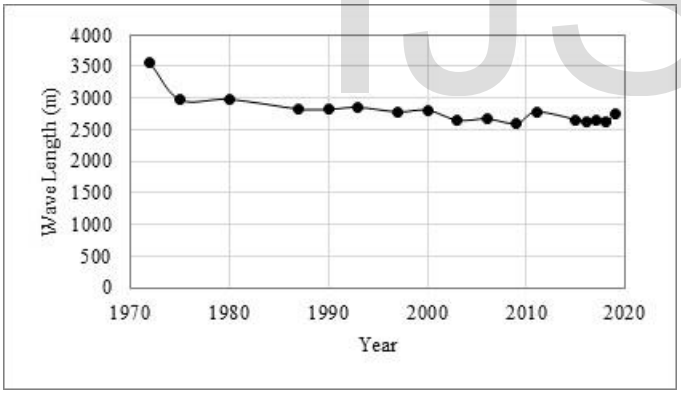


Fig. 5. Variation of meander wavelength over time

3.4 Sinuosity

It is the ratio of the length along the channel (i.e. actual length) to the direct axial length of the river. Fig. 6 shows the variation of sinuosity of the band in different years. The sinuosity varies from 3.10 to 5.91. Minimum sinuosity was found in 1975 and maximum sinuosity was found in 1997. It is also interesting to mention that the sinuosity values follow a Sin curve and it has been found that the bend is swinging over its active zone or meander belt. The wavelength of the curve is equivalent to 28 years which indicates that during every 28 years pattern of movement of the bend is repeating.

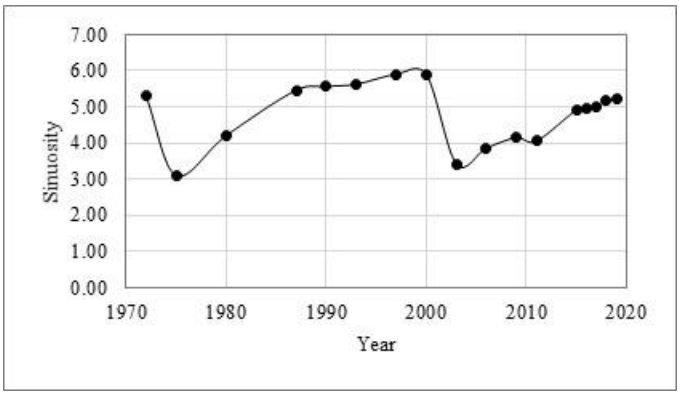


Fig. 6. Variation of sinuosity over time

3.5 Meander Width

It is the distance between the outer edges of clockwise and anti-clockwise loops of meander. Fig. 7 shows the variation of meander width of the band in different years. The meander width varies from 4672 m to 7355 m. Minimum meander width was found in 2003 and maximum meander width was found in 1972. Like the sinuosity values meander width follows a Sin curve and it is observed that the wavelength of the curve is equivalent to 28 years and the pattern of movement of the bend is repeating in every 28 years.

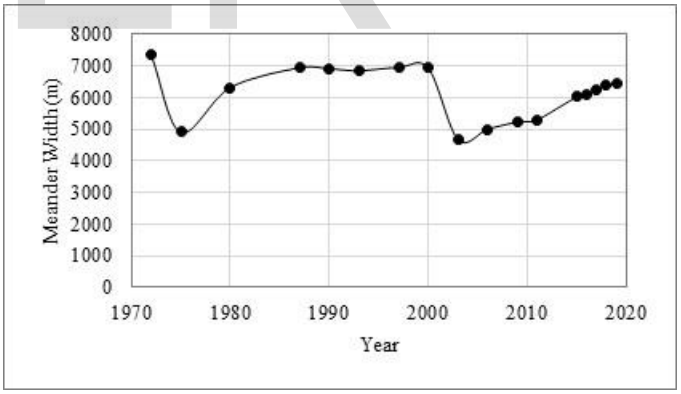


Fig. 7. Variation of meander width over time

3.6 Meander Length

It is the axial length of two sequential meanders measured between the apex of the meanders. Fig. 8 shows the variation of meander length of the band in different years and it follows a Sin curve pattern like meander width mentioned earlier. The meander length varies from 9061 m to 18825 m. Minimum meander length was found in 2003 and maximum meander length was found in 1972.

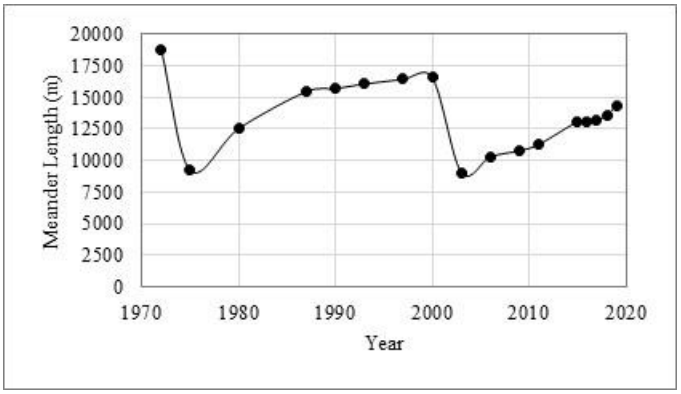


Fig. 8. Variation of meander length over time

3.7 Meander Ratio

It is the ratio of meander width to meander length. Fig. 9 shows the variation of meander ratio of the band in different years. The meander ratio varies from 0.39 to 0.53. Minimum meander ratio was found in 1972 and maximum meander ratio was found in 1975.

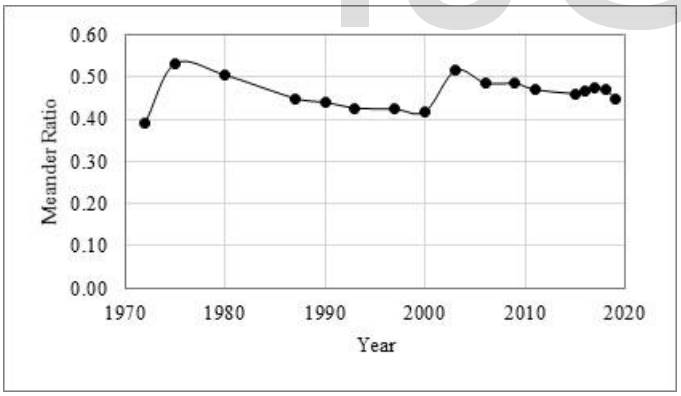


Fig. 9. Variation of meander ratio over time

3.8 Bend Migration

Satellite images of different years were inspected to know how the Kamarkhali Bend of Gorai River migrated through time, as stated earlier. From Fig. 10, it is seen that the bend migrated by following a complex combination processes. Comparing the images of different years, bend migration was determined. From the analysis it has been found that the Kamarkhali Bend has been swinging from year to year. From this it can be predicted that by 2028 to 2030 another cutoff might occur at this bend which is the most interesting thing of this bend.

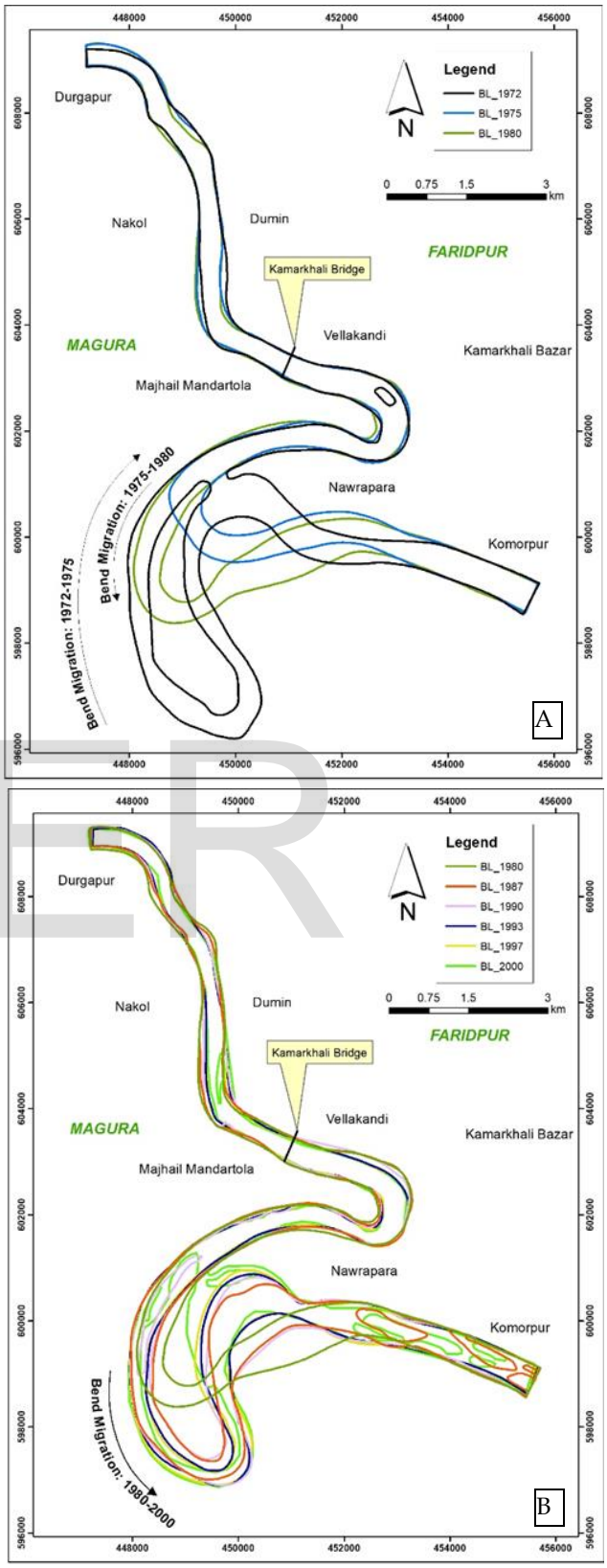
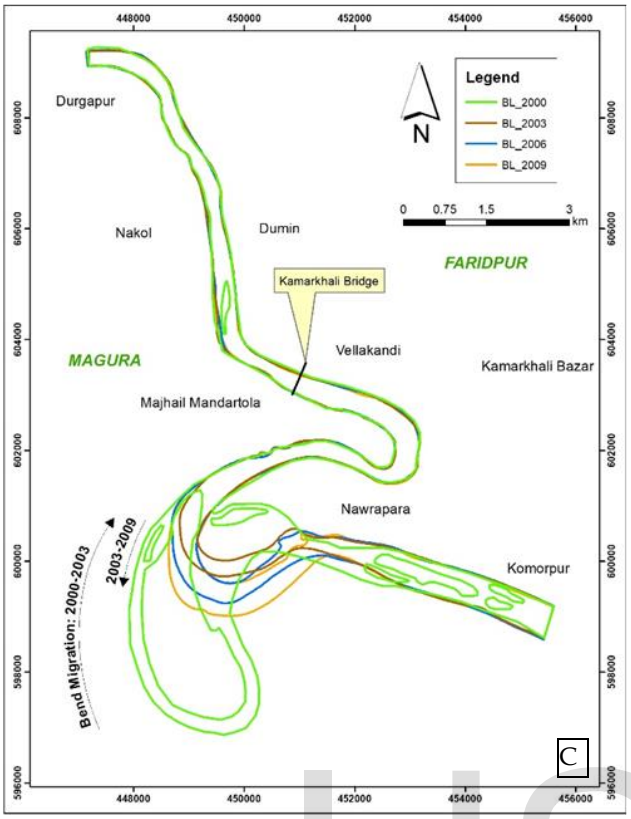


Fig. 10. Bend migration of Kamarkhali Bend over time (Continued)



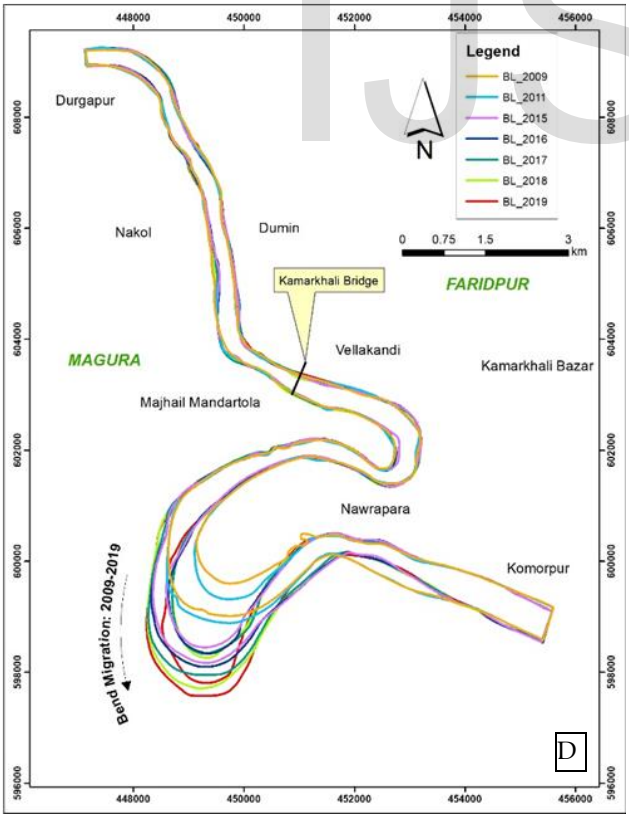


Fig. 10. Bend migration of Kamarkhali Bend over time

4 Conclusion

In this work, the meandering parameters have been analyzed for Gorai River at Kamarkhali Bend specially for its tortuous feature using satellite images from 1972 to 2019 with the help of ArcGIS 10.3 tool. It is interesting to observe that the bend is swinging from year to year and at every 28 years it repeats its course of migration zone. From this it can be predicted that by 2028 to 2030 another cutoff might occur at this bend. Analyzing the bend it is found that meander length varies from 9061m (2003) to 18825m (1972), meander width varies from 4672m (2003) to 7355m (1972), meander ratio varies from 0.39 (1972) to 0.53 (1975), sinuosity varies from 3.10 (1975) to 5.91 (1997), wave length varies from 2600m (2009) to 3550 (1972), radius of curvature varies from 495m to 887m (2011), min width varies from 163m (2000) to 430m (1975) and maximum width varies from 293m (2000) to 805m (1972). The bend shows a combination of all types of bend migration.

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