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Original Article

Effect of Channel Width Contraction at Bogibeel Bridge Site on the Morphology of the River Brahmaputra

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ABSTRACT

The purpose of construction of bridge over the river or stream is to ensure and facilitate the smooth communication over the waterways. However, in certain engineering designs of bridge, a significant portion of waterway is occupied by the piers placed on the river bed and approach road build on the river bed. This results the constriction of the natural waterway. When the waterway is constricted because of the construction of bridges, it results detrimental effects on the morphology of the streams. The major consideration of the paper is to study the effect of constriction of the natural waterway on the river bank morphology and river island due to bridge construction. In this study, 4.94 km long Bogibeel Bridge constructed over the river Brahmaputra is taken into consideration to study the morphological changes in its upstream and downstream portion of the river reach due to the constriction of the waterway. With the completion of the construction of the piers and approach road of Bogibeel Bridge, some significant morphological changes have already been observed. The satellite imageries of the area over two decade clearly indicates the changes that took place in the river bank morphology due to the construction of the bridge structure on the river bed. Some significant gradual modification in the river bank as well as on the permanent river island is identifiable with the progress of the bridge construction. The portions of the river bank which recede alarmingly due to changes in the configuration of the river channel have been identified to take up effective and sustainable measures to reduce or stop the current erosion.

KEYWORDS: *Brahmaputra, Morphology, River bank, River island, Bogibeel, LANDSAT*

1. INTRODUCTION

In land transport system construction of bridges / culverts are necessary to cross waterways. Construction of these crossing structure on the river bed may cause for alternation of stream morphology (Resh, 2005; Wheeler *et al.,* 2005; Merril and Gregory, 2007; Bousk *et al.,* 2010). These crossings can have negative effect on the hydrology and ecology at regional level (Gregory and Brookes, 1983; Wellman *et al.,* 2000; Hancock, 2002; Blanton and Marcus, 2009). The constriction of waterways due to the construction of culverts and bridges can increase stream flow velocity, shear stress, turbulence of flow, development of deep scours, channel braiding and downstream bank erosion (Sing, 1983; Grade and Kothyari, 1998; Richardson and Richardson, 1999; Kothyari and Ranga_Raju, 2000). There are many negative impact of bridge construction with unwanted number of piers of the bridge. It may result heavy sedimentation on river bed, frequent flooding, and losses of water carrying capacity effecting the river navigation. In alluvial channels, local erosion occurs in places where the flow pattern is disrupted due to the influence of a submerged structure like a bridge pier (Kuspilić *et al.,* 2010).

The river Brahmaputra is one of the largest rivers in the world with the average width of 8 km flowing through a valley with an average width of 80 km. This is a braided river characterized by multiple active migrating river channels with average discharge of about 19,800 m^3/sec. During flood the discharge increases to 1,00,000 m^3/sec. It carries water and huge amount of sediments from the Himalayan mountain range in the north, Missimi Hills in the east, Naga Patkai Hills in the south east and the Meghalaya plateau in the south. The north bank and south bank of the river Brahmaputra within the state of Assam is connected by three bridges constructed at Goalpara, Guwahati and Tezpur. A new bridge constructed in the downstream of Dibrugarh (at Bogibeel) is completed in the year 2018. Out of these four bridges the newly constructed Bogibeel bridge results the maximum constrain of the natural water way of the river Brahmaputra.

2. STUDY AREA

Bogibeel Bridge is a combined road and rail bridge over the Brahmaputra River in the north east Indian state of Assam connecting Dhemaji district in the north bank and Dibrugarh district in the south bank of the river. The geographical location of the center point of the bridge is 91°45´´ Longitude and 27°24´´ Latitude. The construction work of this 4.94 km bridge was started in the year 2002 and is completed at the end of 2018. The Bogibeel bridge has 39 spans of 125m each and a superstructure of composite welded steel truss and reinforced concrete. The bridge is supported by 42 piers of which 38 piers are in the river bed. The size of each pier is 12m along the river course and 18m meter across the river course. There is a 2 km approach road into the bridge over the river bed in the north bank and a 1 km approach road over the river bed in the south bank. The natural width of the river in the bridge construction site is around 8.5 Km. (Figure 1)

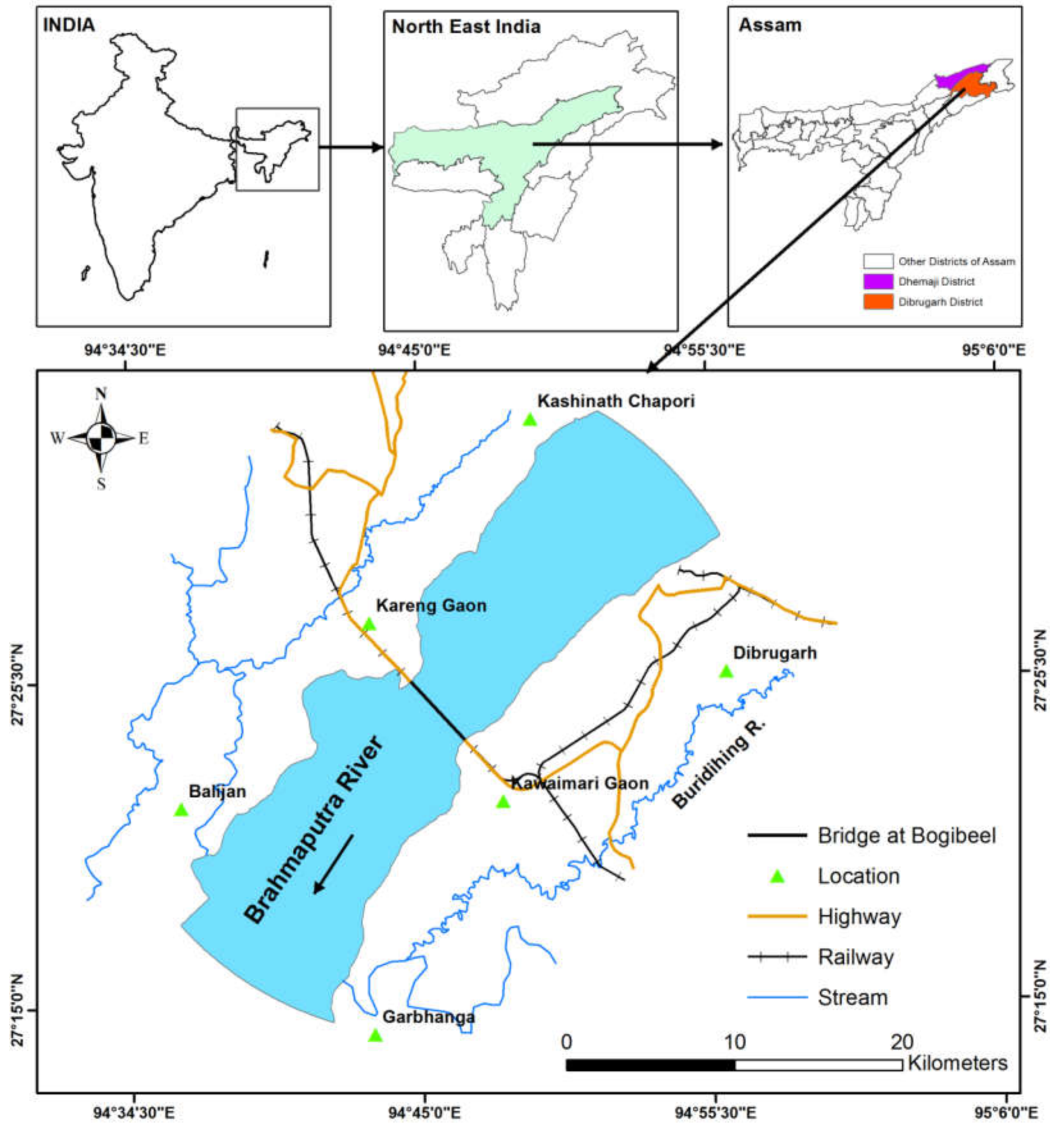


Figure 1: Location map of the Bridge over the River Brahmaputra at Bogibeel, Dibrugarh

3. STATEMENT OF THE PROBLEM

The construction of 4.94 km Bogibeel bridge at a point over the river Brahmaputra where its natural width is 8.5 km creates obstruction in the natural flow of water. The width of the river is reduced by extending the approach road of the bridge into the river bed. Moreover, the construction of 39 concrete piers of the bridge results the disruption of flow in the natural waterway of the river, particularly during the flood season. Though the bridge is operational in 2018 but obstruction of the water way was completed in the year 2010. The river bank and bed erosion attain a new dimension due to the obstruction of the water way. The objective of the study is to monitor whether any significant changes in the river morphology can be observed as the post bridge construction effect. Morphological changes on the river islands, river bank and river channel are considered during the study and these changes in the river reach were monitored in a 40 km river reach in the upstream and downstream of the site of bridge construction.

4. OBJECTIVE OF THE STUDY

The objective of the study is to monitor the nature of overall changes in the river channel in the pre, during and post river channel contraction years due to construction of bridge over the river Brahmaputra at Bogibeel. For the purpose, the study intended to look into the following aspects on the Brahmaputra river channel from the temporal remote sensing data of last 25 years (from 1994 to 2018).

- Effect on stable sand bars (river islands) in the upstream and downstream river reach of Bogibeel.
- Behaviour of channel migration within the river reaches under consideration.
- Identification of fresh bank erosion / deposition sites.

5. DATABASE AND METHODOLOGY

The river morphology before, during and after the Bogibeel bridge construction was studied by visual interpretation of the satellite imageries. Satellite imageries of the TM / ETM+ / OLI sensor with 30 meter resolution in LANDSAT satellite and sensor with 10 meter resolution in Sentinel-2A Satellite were selected for the study. The satellite imageries acquired during the month of December every year are used for the study. In this dry season, cloud-free imagery is available and water level, vegetation cover and other ground conditions are relatively consistent. The imageries of dry season from the year 1994 to 2018 were taken for the studying the river channel migration and sand bar (River Island) study.

Based on the stages of bridge construction and contraction of the natural width of the river channel, the study period is divided into Pre Contraction (1994 to 2002), During Contraction (2004 to 2008) and Post Contraction (2010 to 2018) stages.

For channel migration study, the channels of the river Brahmaputra is demarcated from the dry season imageries. The channels are digitized from the imageries at two years interval and finally the overall changes for the year 1994 to 2002, 2004 to 2008 and 2010 to 2018 were evaluated with GIS overlay analysis.

The land mass on the river bed with vegetation cover throughout the year are considered as stable sand bar (river island). The trend of morphological changes on these stable sand bars (river islands) before, during and after bridge construction are studied in two years interval from the year 1994 to 2018 using the dry season (December) imageries. Moreover, the permanent sand bar (River Island) on the Brahmaputra river bed during 1994 to 2002, 2004 to 2008 and 2010 to 2018 are identified using the GIS overlay analysis technique.

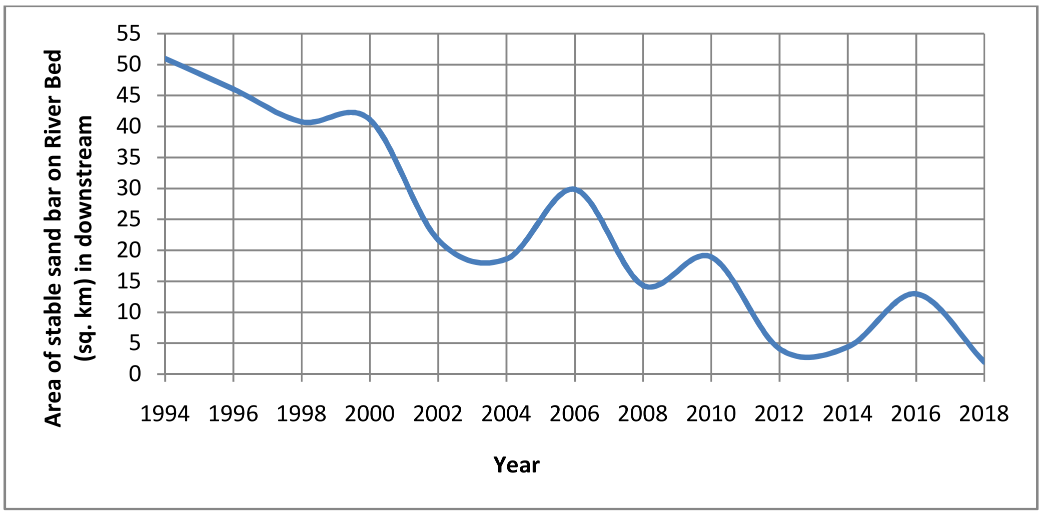
Available wet season imageries of the years 1997, 2002, 2005, 2007, 2010, 2013, 2015, 2017 of the study area are used to monitor the bank line migration of the river. The changes in bank line over the year are observed by demarcating the bank lines from the available wet season imageries.

6. RESULTS AND DISCUSSION

From the satellite imageries it has been observed that the natural width of the river at Bogibeel, which was 8.5 km, starts contracting from 2003 and in 2010 the river attain the width of 4.9 km. The findings of the possible affect on various geomorphological aspects of the river because of the creation of 'bottle neck' by altering the natural width of the river channel are discussed below.

Sand bar (River Island) study

The sand bars (River Island) covered with vegetation in the dry season is considered as stable island for that particular year. Stable sand bars, exist in the month of December, were digitized from the satellite imageries in every two-year interval from 1994 to 2018. The spatial distribution as well as total area covered by these river islands varies over the year. The objective was to see whether their existence on the river bed in the upstream and downstream reach of the bridge at Bogibeel was affected due to the contraction of the river width at bridge construction site. For the purpose, the area covered by the stable island was plotted against the year for the upstream and downstream reach (Figure 2). From the plotted graph, it has been observed that in the downstream reach of 20km, the area of stable river island was linearly decreasing till 2003. Since 2003, when the river width starts contracting, the area of the stable island still maintains the decreasing trend but decrease was nonlinear in nature. Nonlinear decreasing trend can be attributed to the adjustment of the river to the new flow regime. Decreasing trend of the area of stable Sand Bars (river islands) over the year indicates the increasing river bed erosion in the downstream reach. Whereas, in the upstream reach of 20 km, it has been observed that the area of the stable landmass was in the decreasing trend in the pre-construction period but from 2003 the area was nonlinearly increasing. This indicates the tendency of increasing deposition on the river bed in the upstream of the bridge site as an effect of width contraction. The year wise spatial deposition of the stable sand bars in the pre, during and post contraction are shown in Figure 3, 4 & 5.



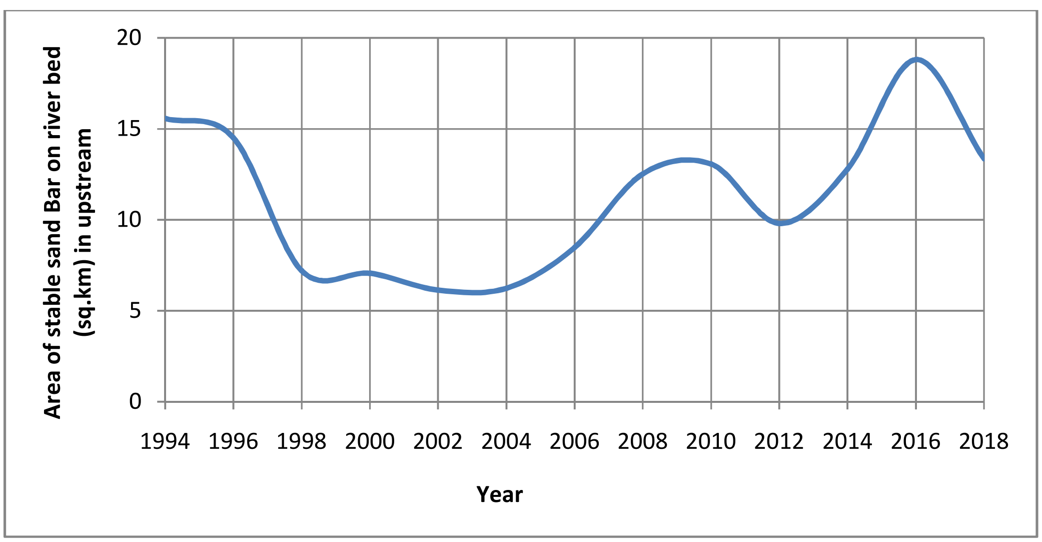


Figure 2: Changes in the area of stable sand bar over the years in the downstream and upstream reaches

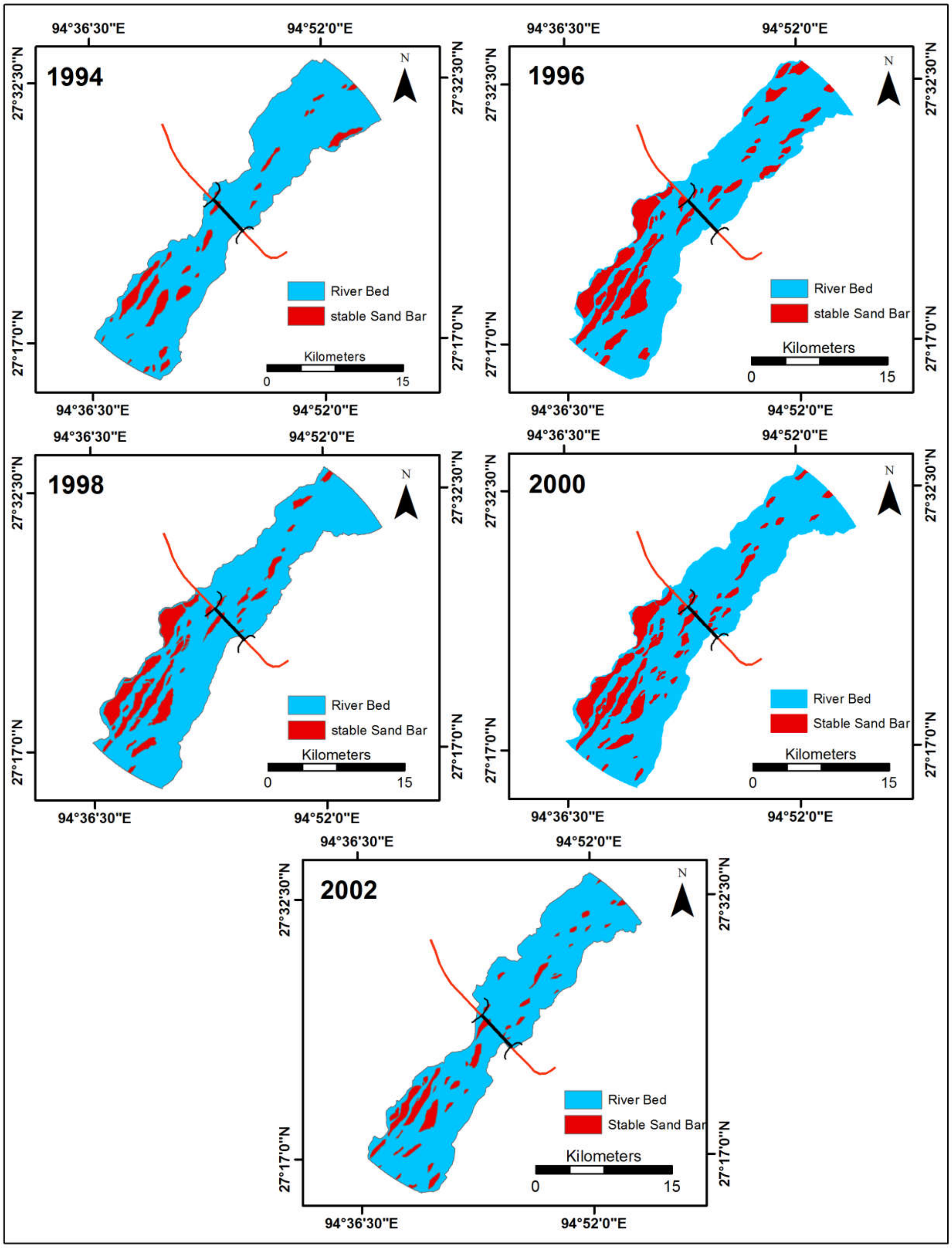


Figure 3: Year wise distribution of Stable Sand Bar in the Pre- Contraction Period

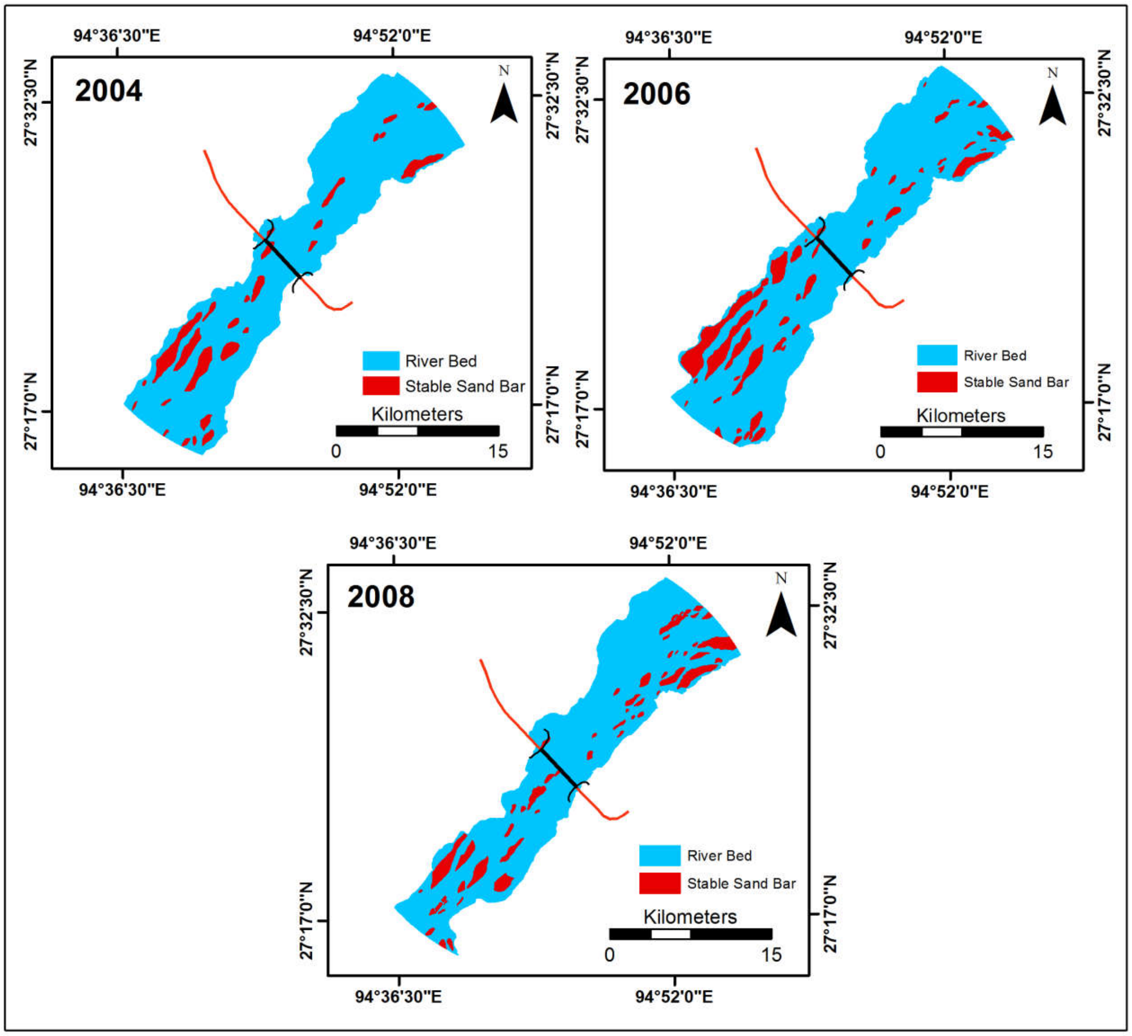


Figure 4: Year wise distribution of Stable Sand Bar in the During- Contraction Period

Out of the stable sand bars appeared in the river bed every year, there are only a few sand bars which can be considered as permanent in nature. Only the sand bars which exist continuously over a period of years can only be considered as permanent. In this study, the permanent sand bar in the pre-Contraction, during- Contraction and post- Contraction period within the studied reach were determined. This was done by applying the union overlay operation on the stable sand bar layers in GIS. A permanent sand bar in the pre-contraction period (1994 – 2002) was found out by considering the stable sand bar layers from 1994 to 2002 for union (Figure 6). Similarly, Permanent sand bars in the during-contraction period (2004 – 2008) and post-contraction period (2010 – 2018) was found out by considering the stable sand bar layers from 2004 to 2008 and from 2010 to 2018 respectively. To see the effect of width contraction on these permanent sand bars, the area of the permanent sand bar was plotted against the three stages of bridge construction (Figure 7). In the plot it has been observed that the area of the permanent sand bar was decreasing within the studied 40 km reach of the river. The decrease in area of these sand bars was very steep after the complete width contraction of the river (in post contraction stage). From the distribution of the permanent sand bars as shown in the Figure 6, it has been observed that in the post-contraction period, no permanent sand bar exist in the downstream reach. This observation is validated by the decreasing trend of the area of stable islands over the year in the downstream reach.

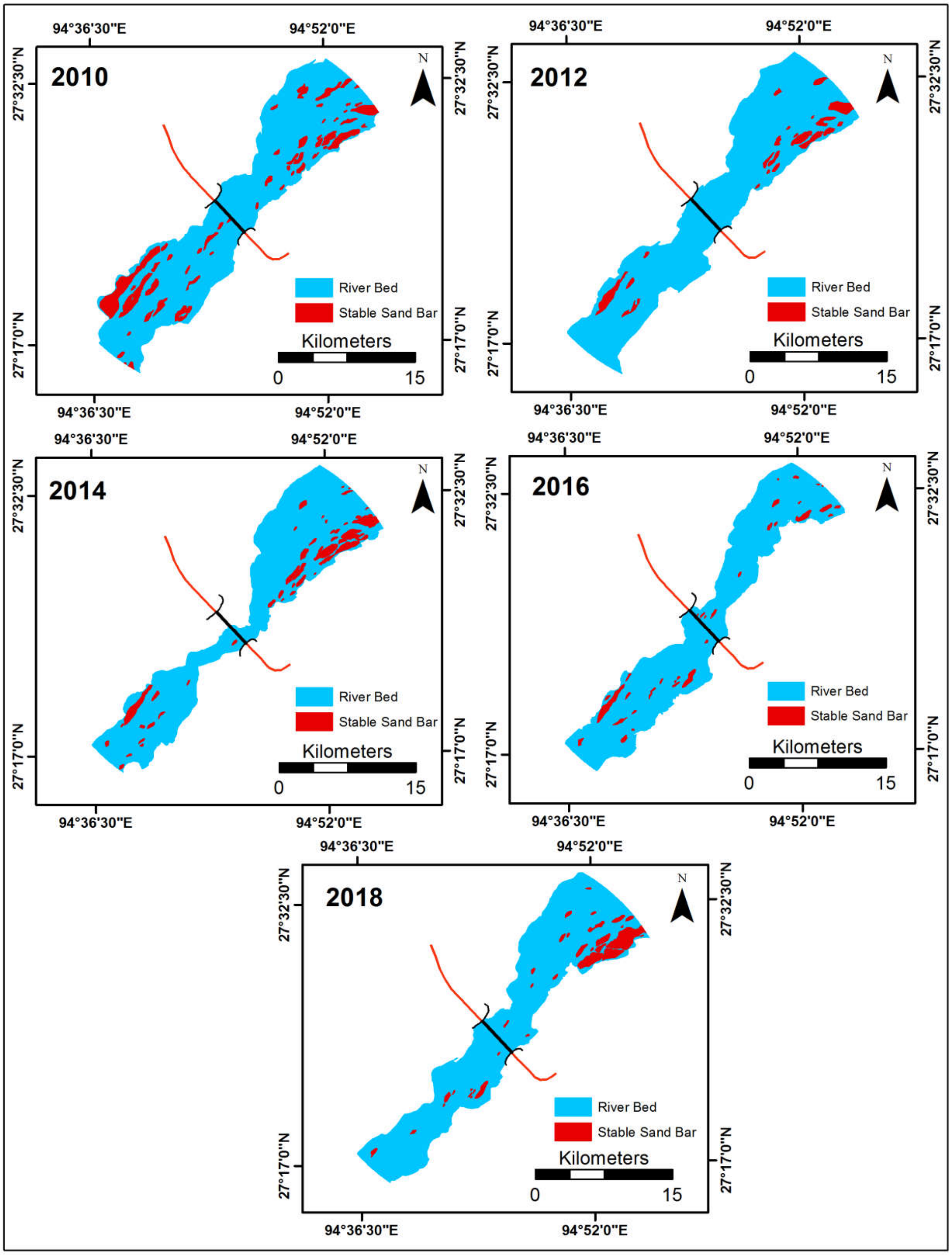


Figure 5: Year wise distribution of Stable Sand Bar in the Post- Contraction Period

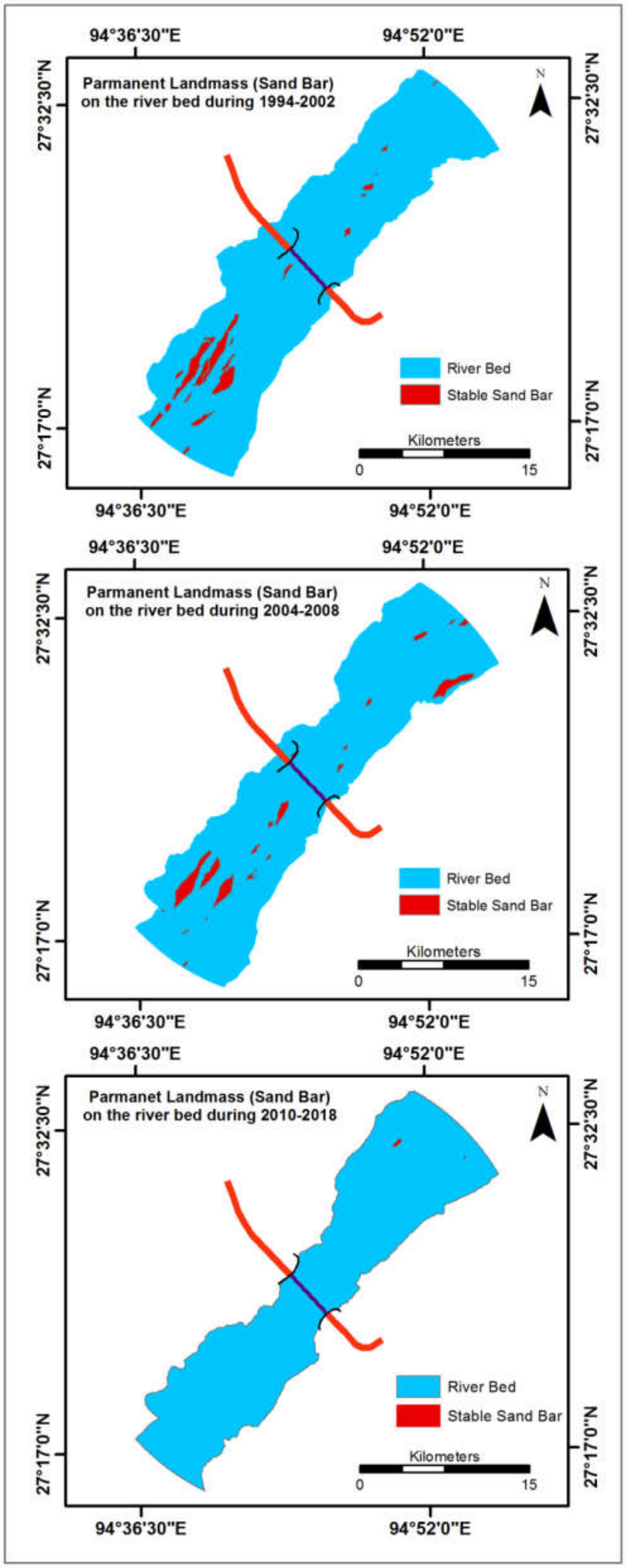


Figure 6: Permanent sand bars in the Pre, During and Post contraction stage of the bridge

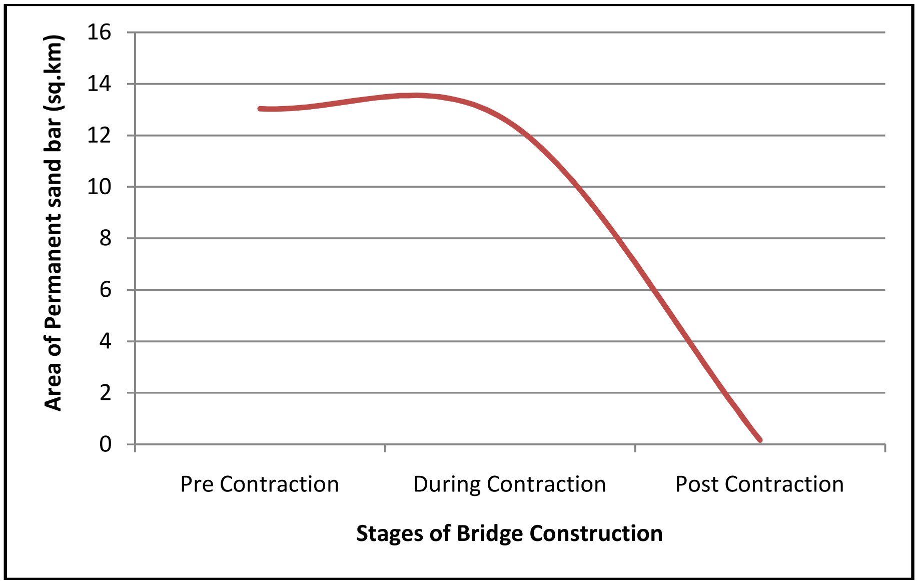


Figure 7: Changes in the area of permanent sand bar over the years.

Channel Migration

To observe the channel migration all the active river channel in the month of December were digitized from the imageries of available years. Using GIS overlay analysis the active river channels were determined for the periods of 1994 – 2002 (pre-contraction), 2004 – 2008 (during-contraction) and 2010 – 2018 (post-contraction) (Figure 8). This provides the river channels which were active in the respective periods. From the maps of the active river channels of three periods it has been observed that major channel adjustment took place in the downstream of the bridge site. Because of the construction of approach road of the bridge in the north bank, the river channels in the north bank of the downstream reach was completely dried out (Area A in the map of Figure 8). The active river channels in the downstream were shifted to the south. The guide bank constructed in the north bank deflected the flow direction and directing of river flow towards the south bank in the downstream. Its affect on the south bank was prominent during the flood season when the river bed was completely filled with water. Moreover, the active river channel that strike the south bank of the downstream reach was shifting in the upstream direction towards the bridge (shown with arrow in the map of Figure 8).

Bank Migration

Triggering of river bank migration because of the contraction in the river width can be verified from the river bank lines digitized from the wet season satellite imageries. The river bank lines were digitized for the years 2002, 2005 and 2007 and fall under the pre and during contraction period. During these periods, the natural width of the river was not completely contracted. Further the river bank lines for the years 2010, 2013, 2015 and 2017 were digitized which fall in the period when the natural width of the river was constrained due to bridge construction. The superimposition of the bank lines (Figure 9) showed the bank line recession in the north bank of the upstream reach (Kashinath Chapori) in the post construction period (2010 and beyond). This area is located in about 18 km upstream of the bridge location. This may be the effect of the contraction of river width in the year 2010. Other than this location no significant bank line migration was observed in the studied 40 km river reach.

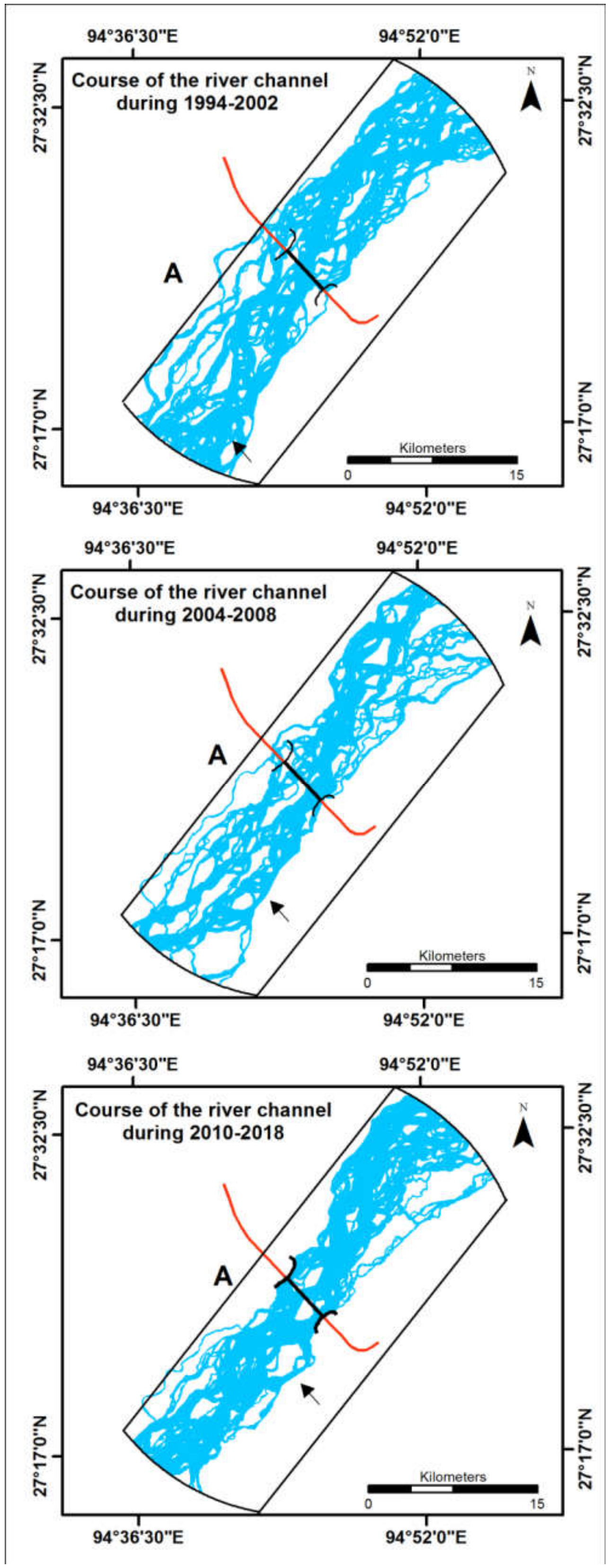


Figure 8: Active river channels in various contraction stages of the bridge

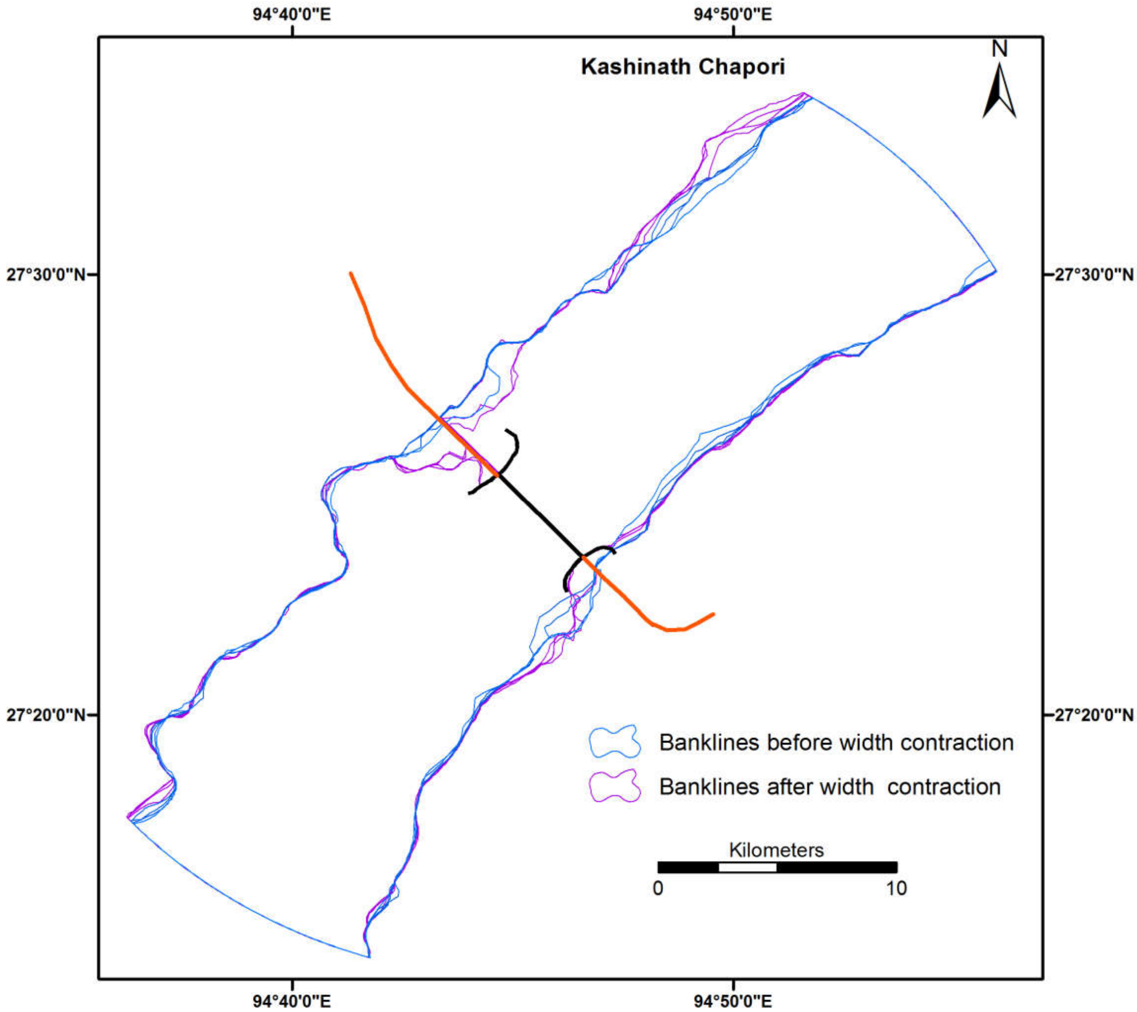


Figure 9: Superimposition of river bank line

7. CONCLUSION

The contraction of natural width of the river Brahmaputra at the site of the bridge constructed at Bogibeel is the cause of morphological changes in the river reach. The changes are studied within the 20 km downstream and upstream reachs of the bridge site. The study of the river reach from the satellite imageries of last 25 years shows these changes in the pre and post width contraction period. The contraction of width results increasing rate of river bed erosion in the downstream reach and deposition in the upstream reach. This is evident from the changing trend in the existence of River Island on the riverbed. In the post contraction period there is a significant migration in the river channel in the downstream reach and number of active river channels in the north bank is dried out. Till 2018 no major river bank migration is recorded within the studied reach, except identifying one erosion site in the north bank of the upstream reach. Further morphological modification along the river channel is expected over the period of time to adjust itself with the forced channel width contraction.

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