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POTENTIAL CAUSES OF NAVIGATION PROBLEM IN PUSSUR RIVER AND INTERVENTIONS FOR NAVIGATION ENHANCEMENT

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ABSTRACT

In this study, historical and recent hydrographic survey charts of the navigation routes in Pussur river were collected from Mongla Port Authority (MPA) and analyzed to assess the trends of morphological changes at the potential sites over the years. It is found that the navigation route in MPA jetty area and its approaches is slightly scouring where the upstream i.e Chalna to Digraj is being silted up (rate approx. 0.22 to 0.95 m/yr). Downstream of mooring buoy is also slightly silted in last few years. The channel is quite stable in Joymonirgol to Hiron point. The current navigational channel at outer bar has siltation pattern (rate approx. 0.35 m/yr) where the west channel is scouring. High backfilling rate is found after dredging (upto 1.3 m/year) in the Sabur Beacon to Joymonirgol area. Channel bed siltation, nmerous wrecks at different positions and humen disturbences are found to be the main cause behind the navigational problems in the river route. The main humen interventions that causing siltation are reducing the upland flow after construction of Farakka barrage and construction of polders around the Pussur River. Approximately 52 wrecks including the sunken ships and sunken barges loaded with cement, billets, jute and jute goods at the bottom of the Pussur River also caused siltation and deterioration of draft. These sunken barges are acting as dangerous silt traps. In this research, some site specific potential measures (purpose based) are suggested including capital dredging and structural interventions to enhance the navigability.

1. INTRODUCTION

Southwestern region of Bangladesh is bounded by the Ganges and the Lower Meghna in the east and by the Indian Border in the west and by the Bay of Bengal in the south. The coastal region of Bangladesh and the rivers in this region shows a continuing process of siltation progressing generally from northwest to southeast. The significant source of upstream freshwater at South-west Bangladesh is the flow of Ganges through Gorai to Pussur. Pussur River is situated in South Western part of Bangladesh and Mongla Port is established on left bank of this river. The Port is the second gateway of Bangladesh situated at the confluence of Pussur River and Mongla Nulla, approximately 71 nautical miles (about 131 km) upstream from the Fairway buoy (approaches to the Pussur River) of the Bay of Bengal. The Port provides facilities and services to the international Shipping lines and other concerned agencies providing shore based facilities like 5 (five) Jetty berths (total length 914m), have a capacity of about 6.5 million tones general cargo/break bulk and 50,000 TEUS. The midstream berth (7 buoys & 14 anchorages) have a capacity of about 6.00 million tones. Total 33 ships can take berth in the Port (in the Jetties, buoys and anchorage) at a time. However, alike other modern port of the world Mongla Port is keen to provide highest port facilities, so that bigger draft ships can enter in to the port channel safely.

Many estuarine and coastal areas around the globe are found to be significantly influenced by human activities. Such activities includes harbor construction, reclamation, dredging and disposal, coastal protection schemes, poldering, dam or barrage construction, commercial fishing, etc. Sediment transport and river morphology of rivers can also be changed significantly due to human activities (Walling, 2006). The vulnerability of many large deltas in the world are increasing due to such disturbances (Syvitski and Saito, 2007; Syvitski et al., 2009). The empolderment schemes in the Pussur basin, harbor and jetty operation of Mongla port, dredging and disposal, fish farming, etc. affected the morphology and ecology of Pussur river significantly. Mongla Port was designed for an average 8.5m draft ship. But after the construction of Jetties at Mongla Port, the depths in several areas of Pussur Channel reduced significantly and regular maintenance dredging is required to provide adequate depth alongside the berths, in the approaches to the berths and in the Southern Anchorage areas (IWM, 2004). The main cause of this siltation is empolderment schemes between the Sibsa and Pussur rivers carried out between 1966 and 1974, resulting in reduction in tidal storage and redistribution of flow, mostly between the Sibsa and the Pussur river, starting in 1959 (DHI, 1993; Farleigh, 1981; Farleigh,1984). Since 1979, several dredging efforts had been made to restore the navigability of the Pussur River. However, because of continued high siltation rates, none of the dredging efforts could sustain a navigable channel and requirement of maintenance dredging has been significant (Malek and Ashraf, 2004). Entrance to the Pussur River is about 6 miles wide at the mouth and has a bar over about 5 miles known as Outer bar where depth is about 6.2m CD (Chart Datum). Ships having draft up to 7.5m can cross the bar in all seasons. The bar is relatively stable with sea bed elevation of -6.4 m CD. With the existing depth in the outer bar, maximum 8.5 m draft vessel can cross the outer bar and enter the port at normal high tide (IWM, 2013). But the depths over the anchorage area of the channel permit anchoring of 11m draft vessels. Outer bar area is only obstacle for the ships of 11m draft to enter into the anchorage area of Mongla Port.

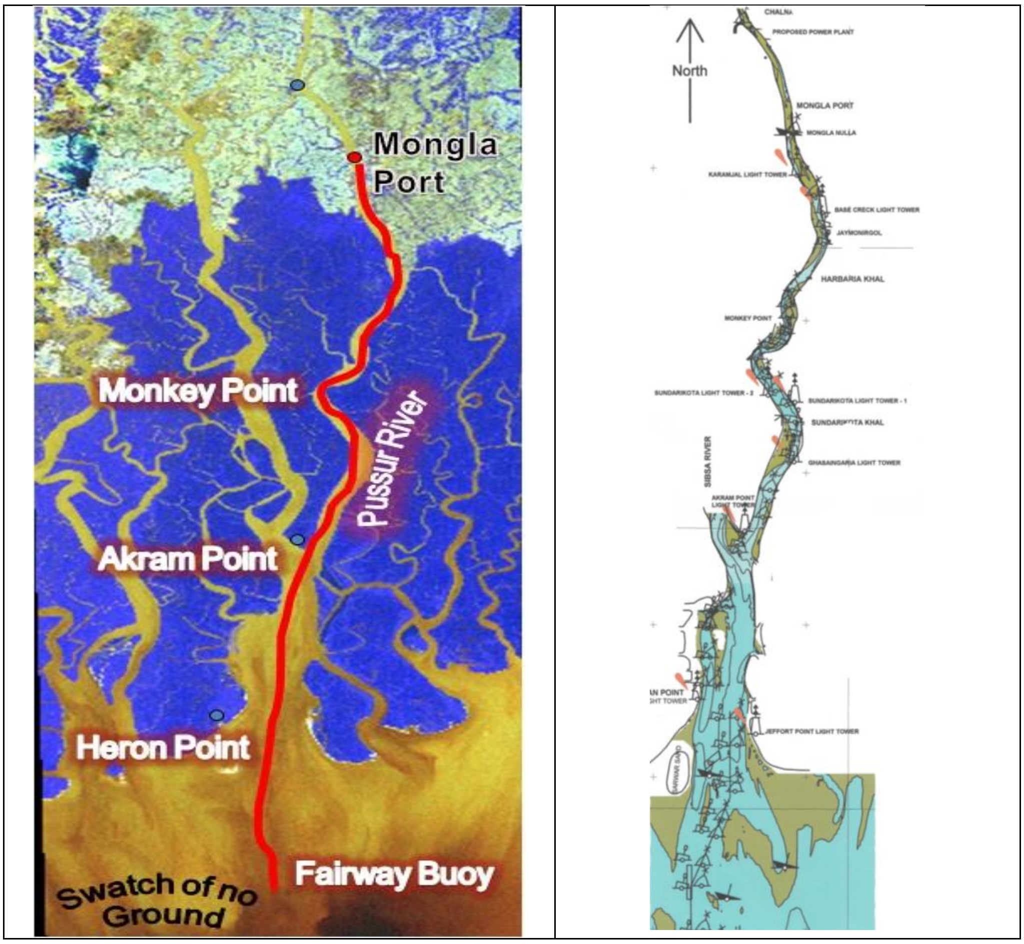


Figure 1: Study reach of Pussur river (IWM, 2013)

Being an important water course for Bangladesh, Gorai River has drawn attention of different national and international researchers (Islam and Karim, 2001; Clijncke, 2001; Sarker, 2002;

Islam and Gnauck, 2012; Shamsad et al. 2014). However, the studies regarding the morphology of Pussur river are very few and those are mainly concentrated on the navigability required for the activities of Mongla port. The overall objective of the study is to investigate the previous bathometric survey data and available hydrographic charts to characterize the change in morphological behavior of Pussur River. The causes of navigation problem, previous intervention and future plan of MPA to improve navigability, dredging history of the river and effectiveness of dredging are discussed. Some potential measures to enhance navigability are also suggested.

2. METHODOLOGY

The study area covers about 145 km navigation route of Pussur River from Fairway Buoy (Bay of Bengal) to Chalna. The Rampal power station is a proposed 1320 megawatt coal-firedpower station located at Rampal Upazila of Bagerhat District and 13 km upstream of Mongla Port. Mongla Port is situated on the east bank of Pussur River about 131 km upstream from the fairway buoy. Figure 1 shows the study reach of Pussur river. Bathymetric data surveyed by Mongla Port Authority (MPA) is the main secondary source of the bathymetric data. MPA bathymetric charts surveyed for different years from Chalna to Fairway buoy have been collected to analyse the past changes in the morphology of the Pussur River. MPA historical and recent hydrographic surveys of the navigation routes in Pussur river was analyzed to assess the trends of morphological changes at the potential sites over the years. Based on the availability of the hydrographic charts, erosion/ deposition scenarios will be assessed for different years. The port limit of MPA started from fairway buoy (in the open sea) and ends at chalna. Total length of port limit is 149 km. Between Mongla Port and the sea, the Pussur River channel is generally straight, with weak meanders. One strong meander of importance for navigation at the confluence with Monkey point, 35 km downstream of Mongla. The width of the channel increase from 1000 m at Mongla, 1500 m at downstream of Monkey point; 3000 m at downstream of Akram Point (Sibsa River confluence); and some 6000 m wide at Hiron Point.

3. POTENTIAL CAUSES OF NAVIGATION PROBLEM IN PUSSUR RIVER

During the establishment of MP at present location, there was sufficient depth for berthing of 8.5 m draft vessel. Siltation started at Jetty area and its approaches after 1980 (MacDonald, M., 1998). One of the main reasons of siltation is reducing the upland flow after construction of Farakka barrage (Mirza and Hossain, 2000; Ali et al, 2012; Kowser and Samad, 2016) and construction of polders around the Pussur River (Dusgupta et al. 2014; Islam and Gnauck, 2008). Another threat for navigability is the wrecks at different position of Pussur River.

3.1 Channel Bed Siltation

Siltation in Pussur River mainly happens in three segments which are: (a) Chalna to Digraj-upstream of MP (b) Mongla Port to Base Creek Khal- Harbour area and (c) Downstream of Hiron Point- Outer Bar. The rate and amount of siltation/ scouring in those three areas has identified in various study and which are summarized below:

3.1.1 Chalna to Digraj- upstream of MP

In the feasibility study for capital dredging of Pussur River from Mongla port to Rampal power plant, IWM (2015) pointed the sedimentation and scouring in 05 dredging areas as Table 1. It is observed that the channel is aggrading type with yearly rising of bed level varies from 0.21 to 0.97 m.

Table 1: Sedimentation in different segments between Mongla jetty to Chalna (considering changes between years 2013-2015)

Location of navigation channel segment	Average Siltation depth (m/year)
Power Plant Turning Ground (600 m × 300 m segment)	0.97
Power Plant Jetty Front (500 m × 200 m segment)	0.43
Maidara - Jetty Front (2400 m × 200 m segment)	0.45
Digraj – Maidara (3140 m × 200 m segment)	0.21
Sabur Beacon – Digraj (3000 m × 200 m segment)	0.21

3.1.2 Harbour Area

Table 2 shows the natural siltation/scouring rate at harbor area calculated from hydrographic chart comparing the data of 2013 with 2008. Note that within this period no dredging was performed in the channel. It is observed that the channel is slightly degrading type with yearly lowering of bed level varies from 0.12 to 0.32 m. However, in this area, the high backfilling rate after capital/maintenance dredging is the main problem to get sufficient draft. Figure 2 shows the longitudinal bed profile from Digraj to Mongla showing backfilling within one year after dredging the channel in the year of 2014. After completion of Harbour Area Dredging project, the monitoring consultant IWM carried out monitoring survey and develop mathematical model to access the backfilling rate of dredging. According to their opinion backfilling rate was 50-80% of capital dredging per year.

Table 2: Natural siltation/scouring rate at harbor area calculated from hydrographic chart.

Sl.	Sections	Bed Level (m below CD)		Siltation (+)/ Scouring (-) rate (m/yr.)
		2008	2013	
01	Kleenheat LPG Jetty	4.9	6.1	-0.24
02	Middle of MPA jetty-09	4.2	5.8	-0.32
03	North Side of MPA Jetty-05	4.2	4.9	-0.14
04	MPA Vessel Berth	4.4	5.4	-0.20
05	Wreck Pavlina	3.8	4.4	-0.12

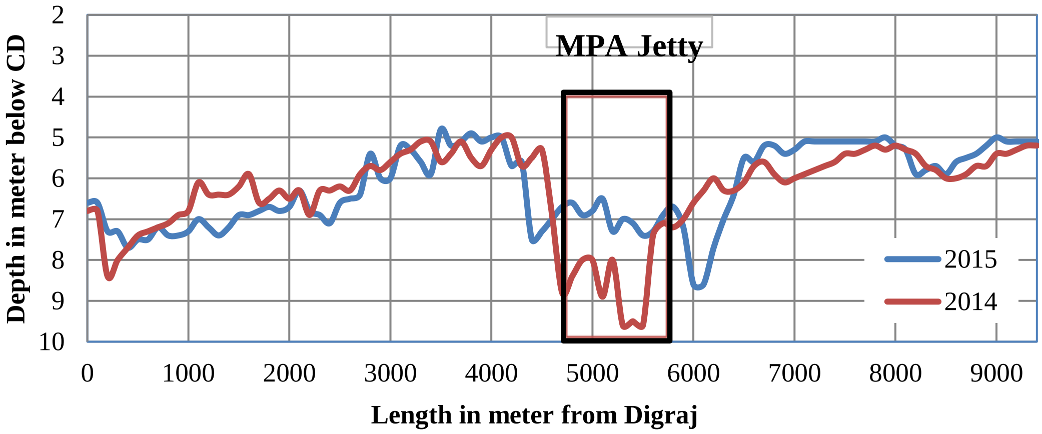


Figure 2: Longitudinal bed profile From Digraj to Mongla showing backfilling within one year (2014 is the dredging year).

3.1.3 Outer Bar Area

Table 3 shows the natural siltation/scouring rate at Outer bar area calculated from hydrographic chart comparing the data of 2009 to 2016. At outer bar area presently shipping channel is on the eastern side of wreck ocean wave. But this channel is being silted up and the shallow portion is extending towards east side day by day. Note that within this period no dredging was performed in the channel. In the downstream of buoy 14, the bar is found to be gradually raised up, where the sedimentation rate at two points are found to be about 0.35 m/year.

Table 3: Sedimentation and scouring in Outer Bar

Longitudinal position	Transverse distance from west bank (m)	Siltation (m/year)
Wreck Ocean Wave	750	1.1
	2250	0.13
Buoy 14	5250	0.38
	6375	0.33

3.2 Obstacle due to Wrecks

During the liberation war and thereafter, some local and foreign ships, (13 local and 5 foreign) sank at different reaches in the Pussur channel. MPA has taken steps several times to remove the wrecks. Top portion of some wrecks have been removed but the bottom and sides of these wrecks still remain in the channel. MPA has difficulty in removing all the portion of wrecks fully. Detail information of foreign wrecks are available in MPA. But information's of local wrecks are not available. MPA only have the location of those local wrecks.

For instance, one of the wrecks in the outer bar area (wreck ocean wave) causes siltation at its downstream. Thus the existing navigation route at the downstream east side of the wreck is narrowing and swallowing and causes threat to the existence of the route. MPA is planning to shift/relocate the route to the west side channel after performing the required dredging.

Table 4: List of foreign and local ship (Wreck) sunk in Pussur Channel (Source: MPA)

Sl.	Name of Ship	Length (m)	Width (m)	GRT (MT)	NRT (MT)	Location	Year
Foreign Wrecks							
01	MV Ocean Wave	174.09	22.90	15,684	6,539	About 2 km west of buoy B-16 at the entrance of Pussur	1999
02	MV Cheri Lazu	135.43	16.00	3,776	2,119	About 6.7 km west of Fairway Buoy	1984
03	Unknown	-	-	-	-	About 3.4 km east of buoy B-7 at the entrance of Pussur	-
04	Unknown	-	-	-	-	About 13 km south of Dublar Char	-
05	MV Pavlina-1	143.66	20.65	9,627.56	4,900	At the confluence of Mongla Nulla and Pussur river (West Side)	1994
Local Wrecks							
01	Barge President-1	-	-	-	-	Mongla Anchorage Area	1993

02	Barge NSC -8/E	-	-	-	-		1995
03	MV Shah ali	42.79	8.81	344.00	-		1997
04	Barge KSY-508	28.15	7.31	-	-		2000
05	Unknown	-	-	-	-		-
06	Unknown	-	-	-	-		-
07	Unknown	-	-	-	-	Mongla Nullah	-
08	Unknown	-	-	-	-		-
09	Unknown	-	-	-	-		-
10	Unknown	-	-	-	-		-
11	Barge Akash Prodip-5	-	-	-	-	Joymonirgol	2005
12	Unknown	-	-	-	-		2010
13	Unknown	-	-	-	-		2012

3.3 Human Disturbances

The navigability of Pussur River also suffered a lot due to human activities along with the natural reasons. After construction of MPA jetty at present location depth around jetty area started to reduce. The main reason of siltation is reducing the tidal prism in surrounding Pussur River. To maintain the Pussur with sufficient draft required for navigation, it is most significant to keep the volume of the tidal prism unchanged, or at least not decrease it.

According to the observations of MPA officials, the human interventions mainly responsible for changing the morphology of Pussur River are:

- Construction of polders and coastal embankments, which prevents tidal water to spread over the land which has decreased the tidal prism considerably in the river.
- Excavation of Mongla-Ghasiakhali link channel, which diverted a great volume of tidal water from its original course
- Restriction of upland flow due to less discharge of water from Padma to Modhumati and Nabaganga, Kobadak Bhairab and ultimately to Pussur due to Farakka withdrawal of Ganges water.
- Less availability of fresh water in the system increased the salinity of water. This increased salinity, which in turn, is causing more siltation in the estuary by flocculation processes.

The sunken ships and sunken barges loaded with cement, billets, jute and jute goods at the bottom of the Pussur River also caused siltation and deterioration of draught. Approximately 52 wrecks are lying at Joymanirgol to Bajua. These sunken barges are acting as dangerous silt traps.

4. MPA INTERVENTIONS TO ENHANCE NAVIGABILITY

4.1 Maintenance Dredging

Mongla Port was designed for berthing ships having 8.50 m draft. Upto 1980 there was not any siltation problem either in Jetty front or Channel area. But after 1980 siltation started in Jetty front Area. From that time regular maintenance dredging was performed in jetty front area. In the meantime it was seen that siltation has started in Harbour Area (About 13 km downstream from Port Jetty). For regular maintenance dredging, Mongla Port Authority has 02 nos 18" dia Cutter Suction Dredger. From the establishment of the Port, the quantity of maintenance dredging are listed in Table 5.

4.2 Capital Dredging

In spite of above maintenance dredging, to remove the siltation, 03 capital dredging projects have been implemented in the year of 1991 - 1992, 2000 - 2004 & 2013-2014. The most recent capital Dredging project titled “Harbour Area Dredging” has completed in the year 2014. After completion of this project, ships having draft of 7.50 m can easily take berth at Mongla Port. The details of 03 Capital Dredging Project are described in Table 6.

Table 5: Details of Maintenance Dredging performed by MPA in Pussur Channel to increase the navigation depth.

Dredging period	Dredger Authority	Dredging Area	Dredging Quantity (Mil. cu.m)	Dredger Type
1979-1981	BWDB	Jetty front (J5-J9)	0.325	CSD
1983-1987	BIWTA	Jetty front (J5-J9)	0.695	CSD
1988-1990	BWDB	Jetty front (J5-J9) & Confluence	0.523	CSD
1993-1996	Khanak dredger of CPA (TSHD)	Southern Anchorage confluence & Sabur Beacon	0.226	TSHD
1994-2001	BWDB	Jetty front (J5-J9)	0.813	CSD
2003-2004	BWDB	Jetty no- 8 & 9	0.069	CSD
2004-2005	Basic dredging Co.	Jetty no- 8 & 9	0.054	CSD
2005-2006	BWDB	Jetty no- 8 & 9	0.069	CSD
2007-2008	BWDB	Jetty no- 8 & 9	0.108	CSD
2009-2010	BWDB	Jetty no- 8 & 9	0.071	CSD
2012-2013	MPA’s own Dredger	Jetty no- 8 & 9	0.017	CSD
2015-2016	AZ dredging Company Ltd	Approach and Pontoon front of Nil Komol	0.155	CSD
Total			3.125	

Table 6: Details of Capital Dredging performed in Pussur Channel to increase the navigation depth.

Dredging period	Dredging Company	Dredging Area	Dredging Quantity (Million cu.m)	Dredger Type
1991-1992	China Harbour Engineering Company, China	Harbour Area	3.551	CSD
2000-2004	PT. Rukindo- Basic Dredging Partnership (a joint venture of Indonesia and Bangladesh).	Harbour Area	2.79	CSD & TSHD
2013-2014	China Harbour Engineering Company, China	Harbour Area	3.406	CSD
Total			9.747	

The total volume dredged over the period 1979 to 2016 is about 12.872 Mm^3, which is equivalent to an average of 3,47,000 m^3 per year. Out of 37 years record, around 3.0 Mm^3 dredging was done in the Jetty Front to maintain the berthing pocket alongside the jetty. This is a localized dredging requirement is a continuous problem and the practice has been for maintenance dredging using Cutter suction dredger. The dredging operations at the jetty front area were required mainly to clean up very shallow patches just along the berths. This sediment deposition is formed by the sliding down of sediment that accumulates due to the cluster of piles under the apron. This is considered the main reason of quickly filled up of the dredged areas alongside the jetties to natural river bed level.

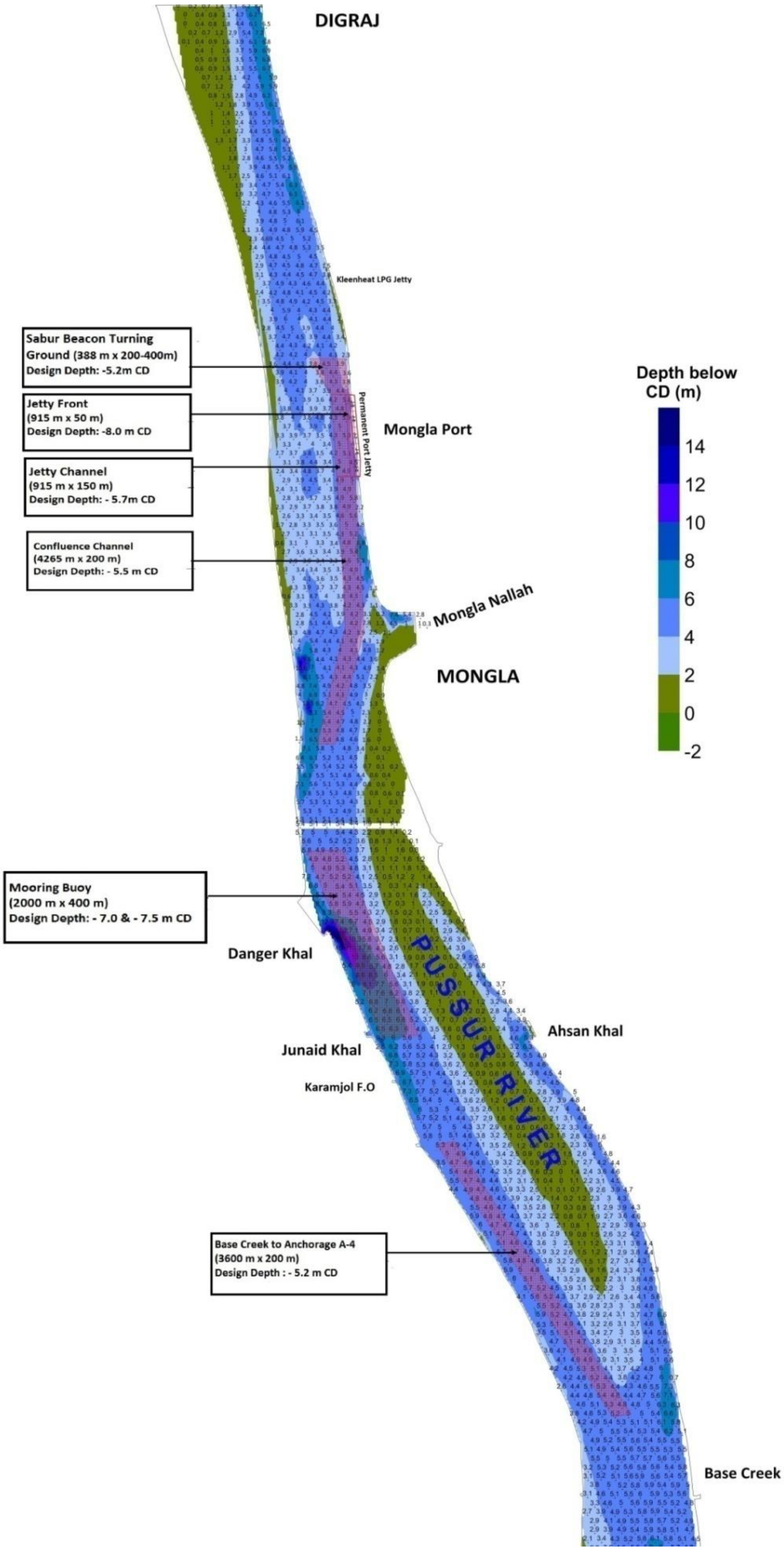


Figure 3: Location and alignment of dredging Segments at Harbour Area (Source: MPA)

5. BACK-FILLING RATE AND EFFECTIVENESS OF DREDGING

Upto now MPA has considered the dredging as the only option to improve the navigability. The dredging already completed by MPA and their future plan was presented above. However, the positive impact of dredging on navigability of Pussur channel is not found so significant due to the high backfilling rate. In this section, the backfilling rate is analyzed comparing the bed profile before and after dredging in several sections of Pussur channel. For this, the capital dredging in the year of 2014 in different segments of Pussur navigation route is considered. That time, Harbour Area (Base creek to MPA Jetty) was dredged upto 8.0 m at Jetty front, 7.0 to 7.5 m at Mooring Buoy and 5.5 m at other areas. Total 3.506 million cubic meter deposited silt was dredged at a cost of 112.0 crore taka. Figure 3 shows the location and alignment of the dredging in Harbour area of Pussur channel. The backfilling rate of those capital dredgings are presented below.

5.1 MPA Jetty Area

MPA has 5 nos Jetty having total length of 915 m. The jetty area is situated at concave end of a small mender. Ships berth here in both high and low tide and for that minimum 8.0 m draft required at 50 m wide are in front of Jetties. For movement of other vessels another 150 m required more than 5.0 m draft which called Jetty channel. In the year 2013, depth at MPA jetty front & Jetty Channel was reduced to -5.50 m & -4.0 m CD which was increased to more than -8.0 m & -5.5 m CD accordingly in the year 2014. After one year the depth at jetty front & Jetty channel has reduced to -7.50 m and -5.2 m CD respectively. But in the same time the west side of channel has deepened about 0.8 m. This implies that the concave end (East side) has silted up more than 1.0 m and convex end (West Side) scoured 0.8 m within one year. Jetty area has silted due to sliding of loose material underneath the jetty. Moreover this area was dredged like a pocket which is also a reason of quick siltation. A comparative bed profile of the year 2013, 2014 & 2015 has presented in Figure 4.

5.2 Confluence Channel

Approach at the confluence of Mongla Nullah and Pussur is known as confluence Channel. Merchant ships entered into port only in high tide and for that minimum 5.0 m draft required in this area. In the year 2013, at front of MPA vessel berth and along wreck pavlina was reduced to -4.2 m CD which was increased to more than -5.5 m CD in the year 2014.

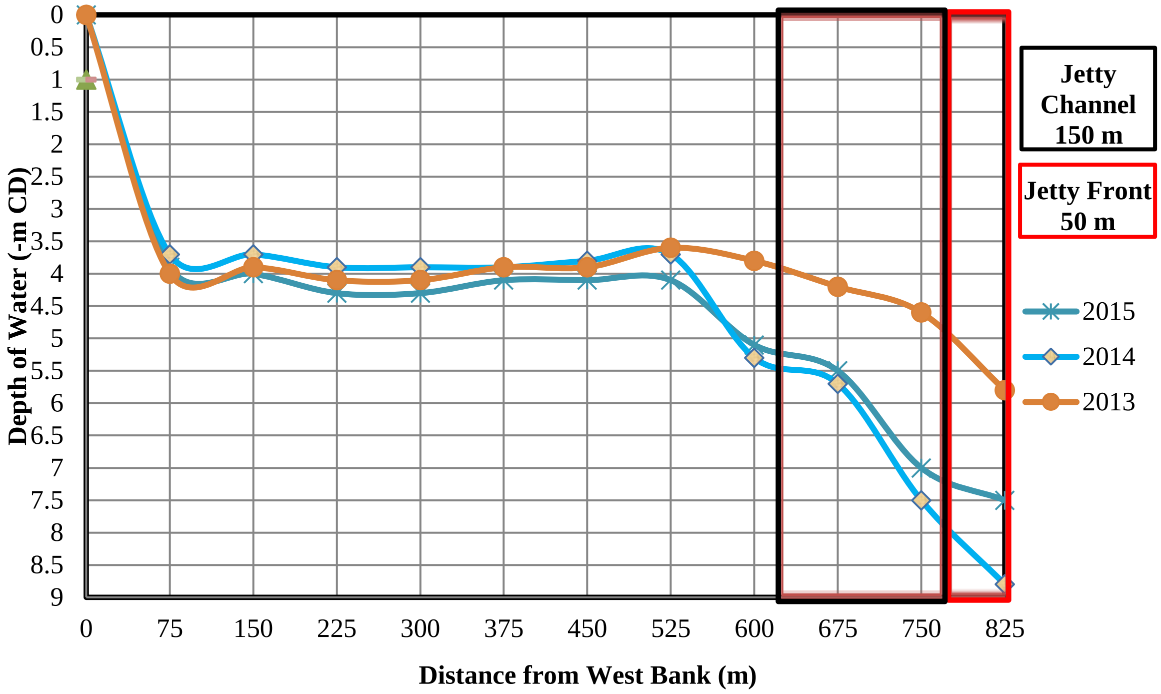


Figure 4: Cross section at Jetty Front before and after dredging (Dredging: 2014)

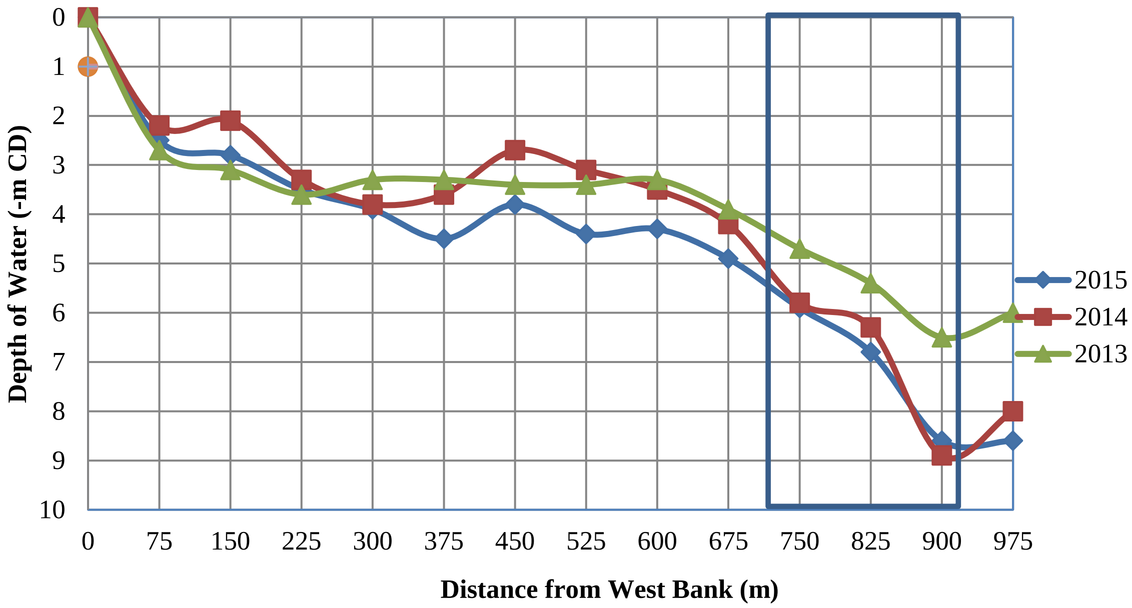


Figure 5: Cross section at Confluence Channel before and after dredging (Dredging: 2014).

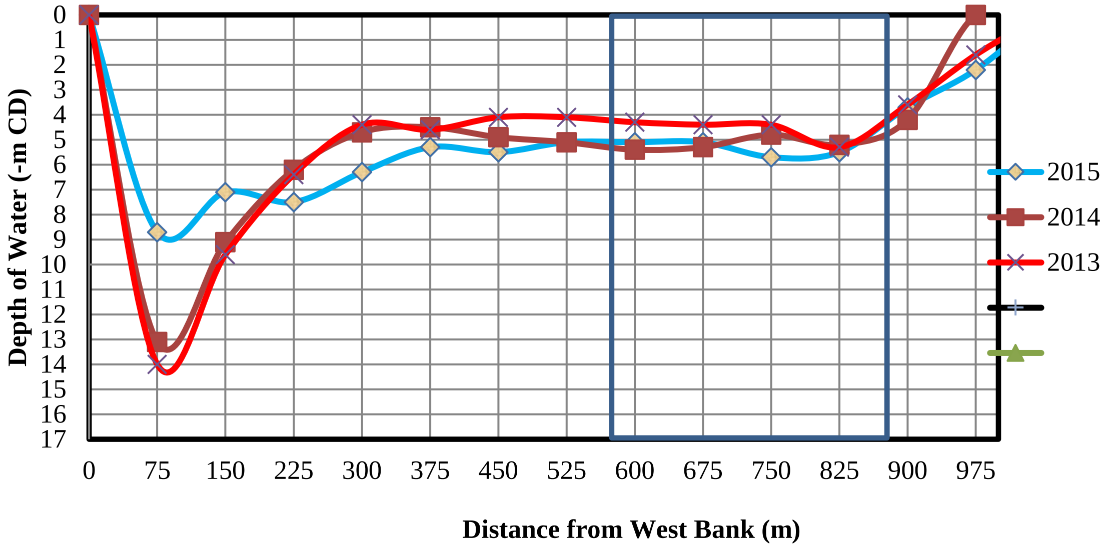


Figure 6: Cross section at Confluence Channel before and after dredging (Dredging: 2014).

After one year the depth at MPA vessel berth and along wreck pavlina has increased to near 6.0. But in the same time the west side of channel has silted up. This implies that the concave end (East side) has scoured and convex end (West Side) has silted. A comparative bed profile of the year 2013, 2014 & 2015 has presented in Figure 6. After the confluence channel, the navigation route is shifted from east bank to west bank side.

5.3 Mooring Buoy Area

At this section, the river is braided with two channels having the main navigation route near the west bank of the river and a small channel near the east bank with a shoal in between. In 2013, the depth at mooring buoy area was reduced to - 4.0m CD. Ships anchor in this area for unloading and for that minimum -7.5 m CD depth required. This area was dredged to more than -7.5 m CD in the year 2014 which has decreased to -6.0 m CD within one year. This area has silted mostly because of creating a deep pocket like jetty front (west side). Siltation happens along the full segment here. A comparative bed profile of the year 2013, 2014 & 2015 has presented in Figure 7.

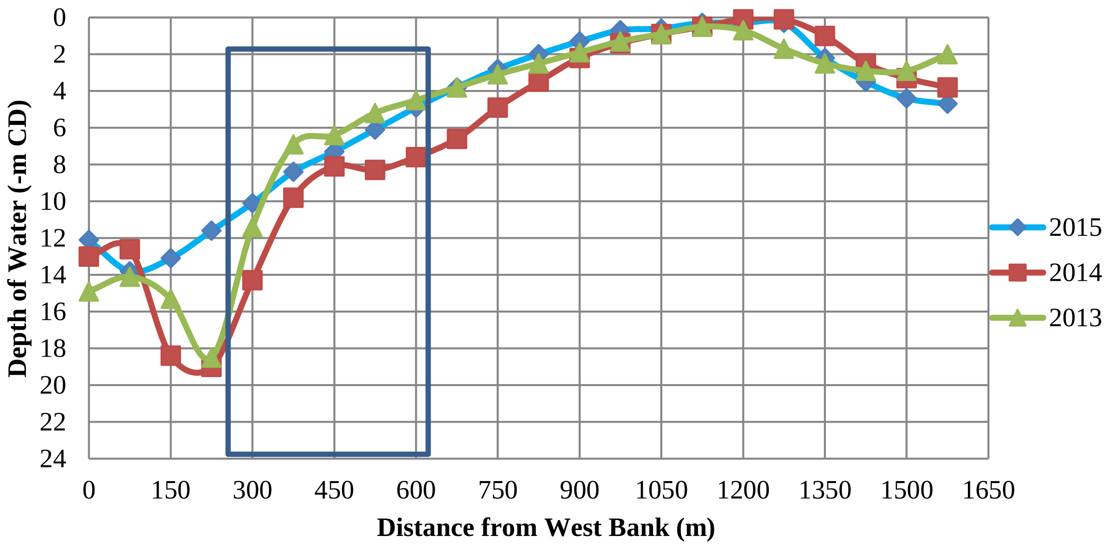


Figure 7: Cross section at Mooring Buoy Area before and after dredging (Dredging: 2014).

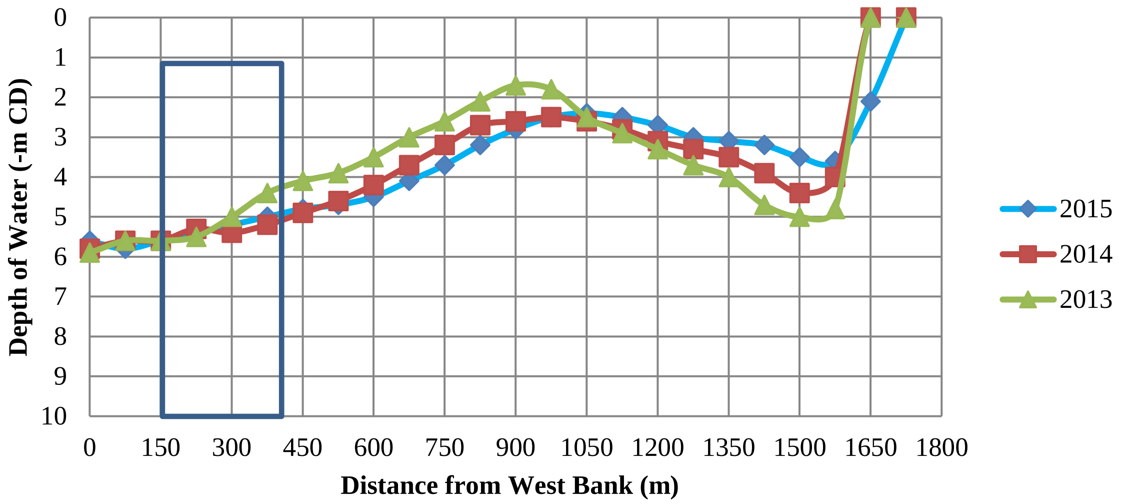
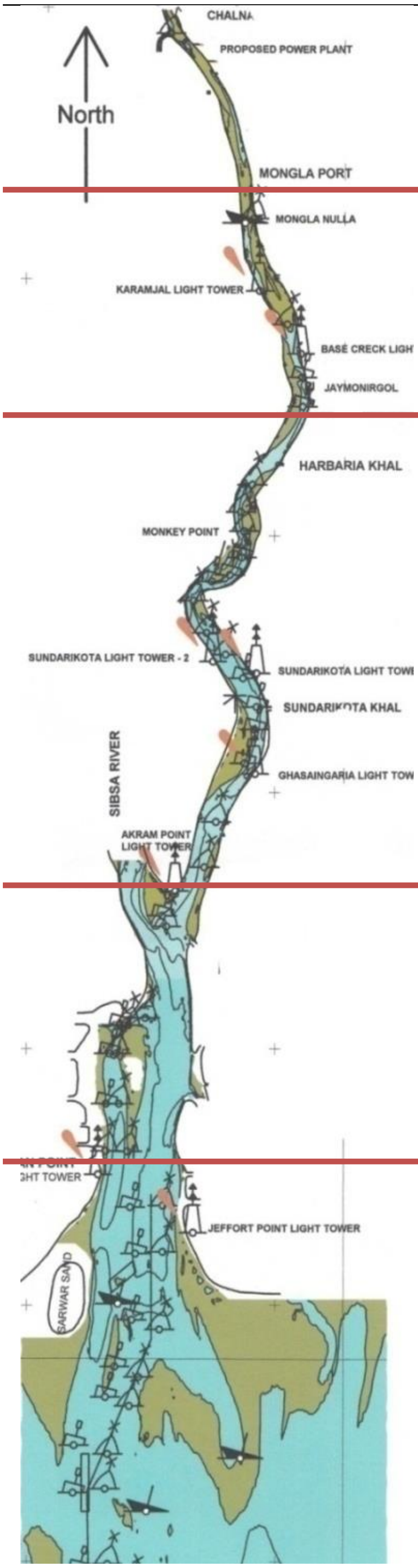


Figure 8: Cross section at Base Creek Area before and after dredging (Dredging: 2014).

5.4 Base Creek Area

Braided condition with two channels is continued up to this section having the main navigation route near the west bank of the river and a small channel near the east bank with a shoal in between. Before the capital dredging in the west side navigation channel, the depth in this area was reduced to -4.5 m CD. Ships only pass this area during the high tide and considering that base creek area was dredged upto -5.2 m CD. After one year of dredging the main navigation channel hasn't changed significantly. But the East side of this channel (Convex side) has deepened about 0.8 m naturally. A comparative bed profile of the year 2013, 2014 & 2015 has presented in Figure 8. The channel near the east bank of the river is found to be silted up by about 0.5 m in 2014 and about 1.0 m in 2015 compared to previous years.

The rate of backfilling after dredging measured in the field by MPA is given in Table 7. The backfilling rate is found to be very high for jetty front (1.0 m) and Mooring Buoy area (1.5 m).



<u>Chalna to Sabur Beacon</u>

- Very shallow depth (-1 to -5 m CD)
- High siltation rate (0.22 to 0.95 m/yr)
- Capital dredging is required to get required draft for navigation

<u>Sabur Beacon to Joymonirgol</u>

- Shallow depth (>-6 m CD)
- Mildly scour prone (scour rate 0.20 m/yr)
- High backfilling rate after dredging (upto 1.3 m/year)
- Maintenance dredging and structural intervention are required

<u>Joymonirgol to Akram Point</u>

- Depth is more than -9m CD
- Quite stable
- Slightly scour prone (scour rate 0.06 m/yr)
- No dredging is required
- Structural intervention can be done to channelize the flow and increase the draft.

<u>Akram Point to Hiron Point</u>

- Depth > -9m CD
- Quite stable
- No dredging is required

<u>Hiron Point to Fairway Buoy</u>

- Outer bar area relatively shallow (Depth < -7.5m CD)
- Obstacled by Wreck
- High siltation rate (0.35 m/yr.) at downstream of wreck
- Capital dredging and shifting of navigation route is required

Figure 9: Segment-wise characterization for navigability and geomorphic features of Pussur River

Table 7: Backfilling rate in the dredged navigation route of harbor area (Source: MPA)

Area/ Section	**Field Measurement of backfilling rate (m/year)**
Jetty Front	1.00
Jetty Channel	0.30
Confluence Channel	-0.50
Mooring Buoy	1.50
Base Creek to Anchorage A-4	No Change after dredging

6. PROPOSALS FOR ENHANCEMENT OF NAVIGABILITY

From the analysis of result, the summary on the geomorphic characteristics, navigability and required interventions are presented in Figure 9 classifying the segments of Pussur channel having similar nature. It is found that the MPA jetty area and its approaches is mildly scouring where the upstream i.e Chalna to Digraj is being silted up. Downstream of mooring buoy is also slightly silted in last few years. The channel is quite stable in Joymonirgol to Hiron point. The current navigational channel at outer bar has siltation pattern where the west channel is scouring. To enhance the navigability of Pussur channel following interventions are proposed.

- Capital dredging is required to get required draft for navigation from Sabour Beacon to Rampal Power Plant and for outer bar area to remove the sediment in the existing route or fix up a new route in the nearby area.
- To improve the berthing pocket depth in front of the jetty, in addition to maintenance dredging, sheet piling could be proposed as a solution. The rapid siltation rate in front of the jetty is due to the sliding of the sediment from the jetty underneath.
- The main reason of siltation is low velocity of flood and ebb flow. If the velocity of flow could be increased in vulnerable sections such as MPA Jetty area and danger khal area, then the bed could be scoured naturally.
- Velocity could be increased by contracting the channel using structural interventions. For the canalization effect near the jetty area, spur dykes/groins/ guide bund opposite to jetty may also require as a structural intervention. The deflected flow due to the structural intervention in east bank may cause bank erosion at the upstream of the jetty area, a bank revetment may propose to prevent this.
- For the canalization of the Mooring Buoy area, structural measures can be proposed to close the eastern channel along the inner bar. For more effective result, a bank revetment at the western bank, opposite to inner bar may be required.

However, these structural measures require in depth study to establish the effectiveness.

7. CONCLUSION

Channel bed siltation (upto 0.95 m/year), High backfilling rate after dredging (upto 1.5 m/year), numerous wrecks at different locations of navigation route (approximately 52 wrecks including the sunken ships and sunken barges) and humen disturbences (including the Farakka barrage at upstream and construction of polders around the Pussur River) are found to be the main causes behind the navigational problems in the river route. In this regard, some site specific potential measures (purpose based) are suggested including capital dredging and structural interventions to enhance the navigability.

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