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HYDROLOGICAL CHARACTERISTICS OF PUSSUR RIVER AND ITS NAVIGABILITY

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ABSTRACT

Mongla Port is the second gateway of Bangladesh and an eco-friendly seaport of the country situated at the bank of Pussur River about 131 km upstream from the Bay of Bengal. 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. The objective of the study is to investigate the hydrological characteristics of Pussur river based on available bathometric survey data and hydrographic charts and to study the availability of required draft for navigability of Pussur River. From the longitudinal section of navigation route of Pussur River, it has found that about 16 km river reach called outer bar at the entrance of Pussur river don't have enough draft for 7.5 m draft vessel. From Hiron Point to Harbaria Anchorage, the river has sufficient draft to navigate upto 10.0 m draft vessel. But about 13 km in the base creek area and Port Jetty area called inner bar is suffering for scarcity of sufficient water depth even for 7.0 m draft vessel. The upstream of Harbaria anchorage is shallower and maximum 7.5 m draft vessel can arrive to Mongla Port. At Present, the water depth in upstream area of Mongla Port is about -4.5 m CD. As the channel proceeds from Port Jetty to the proposed power plant jetty at Rampal, the depth further decreases and minimum water depth of this stretch is about 2-3 m, only ordinary inland vessels can negotiate with this depth. Therefore, these areas require proper interventions (dredging and/or structural) to enhence the navigability of the pussur river.

Keywords*: Navigability, Pussur river, Vessel Draft, Hydrographic Chart, Bathometry*.

1. INTRODUCTION

Mongla Port, the second gateway of Bangladesh is the most eco-friendly seaport of the country, 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 is well protected by the largest mangrove forest known as the Sundarbans, part of which has been declared as "World Heritage" in 1997 by UNESCO. 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 & 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.

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 (ADB, 1996). 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).

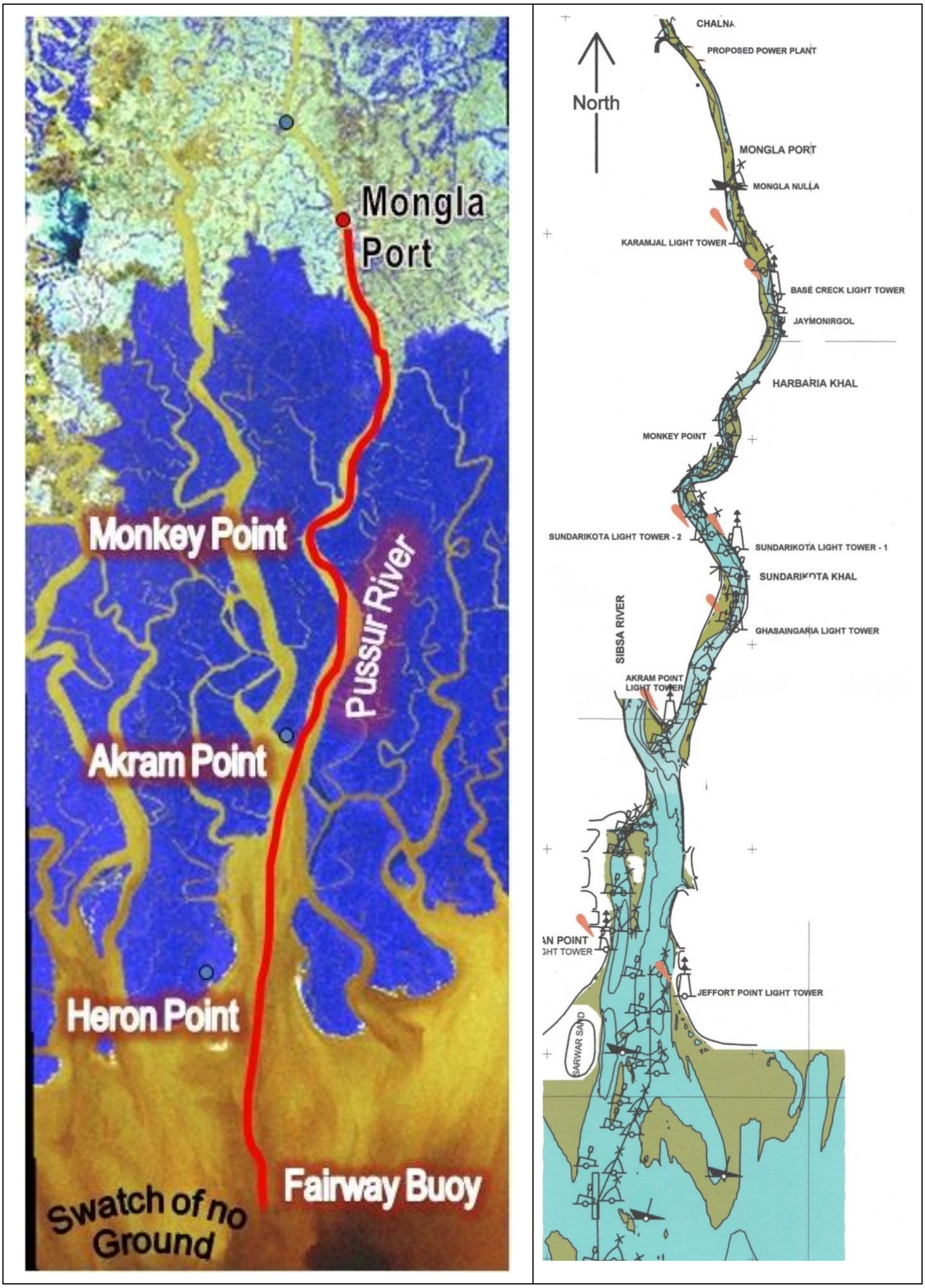


Figure 1: Study reach of Pussur river (IWM, 2013)

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 (IWM, 2013). 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. 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.

Moreover Government of the Republics of Bangladesh has undertaken a project to set up a 1320 MW (2 x 660 MW) Coal based Thermal Power Project at Rampal in Bagerhat district of Khulna division, Bangladesh. The power plant is located at approximately at 13 km upstream of Mongla port on the left bank of Pussur River. The power plant is envisaged to be based on super critical technology and fuel envisaged for power generation is imported coal. Around 5.00 Million Tons Per annum (MTPA) of imported coal shall be required for the project which amounts to approximately 15,000 tons of coal movement per day through Pussur river channel. The Power plant authority plans to procure coal from Indonesia or Australia or South Africa or elsewhere. The coal will brought to Bangladesh in partly loaded mother vessels of approximately upto 55,000 DWT, which will berth at Harbaria Anchorage/ Hiron Point Anchorage. But due to non availability of sufficient depth, coal from Harbaria Anchorage/Hiron point will be transshipped to feeder ship having draft approximately 7.50 m. Presently the water depth in upstream area of Mongla Port is about -4.5 m CD. After establishment of power plant, the navigation channel of Mongla Port will be extended another 13 Km.

Mongla Port Authority (MPA) has implemented three capital dredging project between 1990 to 2014. But after every capital dredging the back filling rate is very high and it's becoming a very big challenge for the existence of Port. Therefore it is a very important task to understand the hydrological and morphological characteristics of Pussur River. The overall objective of the study is to investigate the previous studies, available bathometric survey data and hydrographic charts to characterize the Pussur River and availability of required draft for navigability.

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 bed topography of the Pussur River.

2.1 Topographical Features of Pussur River

The navigation channel as well as the Port limit of MP has started from Fairway Buoy, a deep point in the Bay of Bengal. After fairway to Akram point the wider approach is known as approach to Pussur. At the Akram point it is divided into streams, the eastern one is Pussur and the western one is Sibsha. The main stream of Pussur Channel started from Hiron Point and ended at Chalna. The downstream portion of Hiron Point is actually a part of the sea. Between Mongla Port and the sea, the Pussur River channel is generally straight, with weak meanders. Only one strong meander is observed at the confluence with Monkey point, 35 km downstream of Mongla. Sinuosity for the whole Pussur Channel from Chalna to Hiron Point has calculated. According to MPA Hydrographic chart no. MPA/HP-CB/12(a)/2008 & MPA/CB-D/12(b)/2008, the areal distance (straight) of Hiron Point to Chalna is 55 km out of the channel length of 91 km. The ratio of straight length to channel length is found as 1:1.65, which implies that the channel is mildly meandering. According to Leopold and Wolman (1957), a river can be considered straight till the sinuosity 1.5. For Pussur river, the sinuosity just crossed the limit.

Based on the MPA Hydrographic charts and available information from hydrographic section of Mongla port, it is observed that the width of the Pussur River varies at different sections between 700 m to 3000 m and approach to the Pussur is about 6000 m. The width and available minimum and maximum depth of those sections are described in Table 1. The minimum depth is found to be varied from 1.4 m to 11.7 m below CD. It can be noted that the lowest depth is found at upstream (Chalna) that gradually increases towards downstream with the highest minimum depth at Mazhar Point to D'Suza Point and again decreases at further downstream near Fairway Buoy. The maximum depth is found to be varied from 7.5m to 29.6 m below CD from upstream to downstream, respectively.

Table 1: Width and Depth of Pussur River at different segments (Source: MPA).

Sl.	River Reach	Length of River Reach (km)	Width of Channel (m)	Min. Width of Navigation Channel (m)	Min. Depth (m Below CD)	Max. Depth (Below CD)
01	Fairway Buoy to Hiron Point	46.30	10,500-6,000	1500	6.2	23
02	Hiron Point to Tinkona Dwip	18.52	7,500 3,750	3500	10.9	22.6
03	Tinkona Dwip to Kagaboga Khal	16.67	4,000-2,500	1800	9.7	19.4
04	Kagaboga Khal to Sundorikota Khal	9.26	2,625-2,125	1000	9.1	22.5
05	Sundorikota Khal to Cheilabogi Khal	9.26	2,150-1,250	900	8.5	29.6
06	Mazhar Point to D'Suza Point	9.26	2250-950	700	11.7	28.0
07	Harbaria to Joymonirgol	9.26	1,800-1,125	550	6.3	23.2
08	Base Creek to Mongla Nulla	9.26	1,750-760	300	5.2	9.8
09	Mongla Nulla to Digraj	9.26	1,500-700	200	5.0	7.5
10	Digraj to Chalna	9.26	1,000-7,00	200	1.4	7.5

2.2 Hydrological Characteristics of Pussur River

The variation of water depth and tidal characteristics in the study area over the years is studied by water level. The water level data analysis shows that the maximum tidal ranges at Mongla during the dry and monsoon period at spring tide in 2015 are about 3.75 m and 3.4 m, respectively. In neap tide the maximum tidal ranges for the dry and monsoon period are 2.0 m and 1.9 m. The seasonal variation at Mongla port between March and September is obtained about 0.9 m. In this study, water level was measured at Chalna for 7 days. The observed tide data has plotted in Figure 3. The observed data shows that the tidal range is higher at Chalna than Mongla.

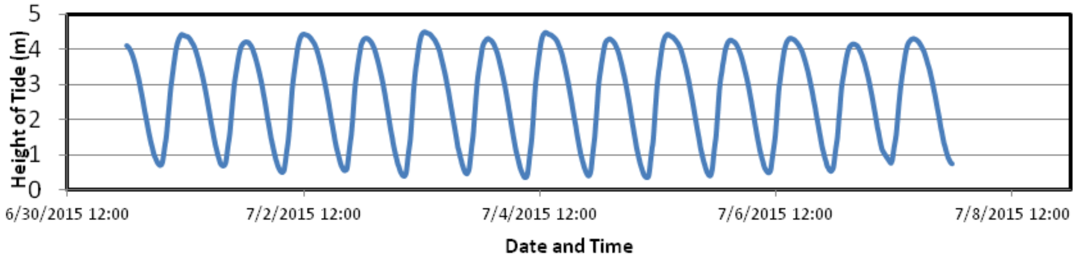


Figure 3: Water level at Chalna (IWM, 2015)

Table 2: Maximum, Minimum and Mean water level and Maximum Tidal range (IWM, 2015).

Location	Duration	Max WL (mPWD)	Min WL (mPWD)	Mean WL (mPWD)	Max Tidal Range (m)
Chalna	07/01/2015 to 07/07/2015	4.518	0.314	2.41	4.204

During weeklong study, the measured water level was found to be varied from 0.314 to 4.518 mPWD (Table 2). Here, the mean water level shows the calculated arithmetic average value of all the measured water level during the measuring period. The tidal range was calculated by the algebraic difference of two consecutive high tide and low tide. Near the Rampal Power Plant at Dacop the tidal range is about 4.204 m.

Semi-diurnal tides with a tidal period of about 12 hours 25 minutes are predominant in the Bay of Bengal. According to the Bangladesh Tide Tables 2015, the mean Tide Levels at Mongla, and Hiron Point along Pussur River are 2.31m and 1.7m in CD respectively (Table 3). The tidal regime is larger at Mongla than at Hiron Point.

Table 3: Tidal levels at Mongla and Hiron Point

Stations	Lowest	Mean	Highest
Mongla (Bangladesh Tide Tables, 2015)	-0.261	2.310	4.882
Hiron Point (Bangladesh Tide Tables, 2015)	-0.256	1.700	3.656

Discharge is an important key factor for the navigability of Pussur Channel. Siltation or scouring of river bed is directly related with the discharge. To understand the hydrology of study area, discharge has measured during spring and neap covering both flood tide and ebb tide. The observed data has plotted in Figure 4 and 5. The summarized observed data has given in Table 4 which shows that the flow in ebb tide is always higher than flood tide at Mongla.

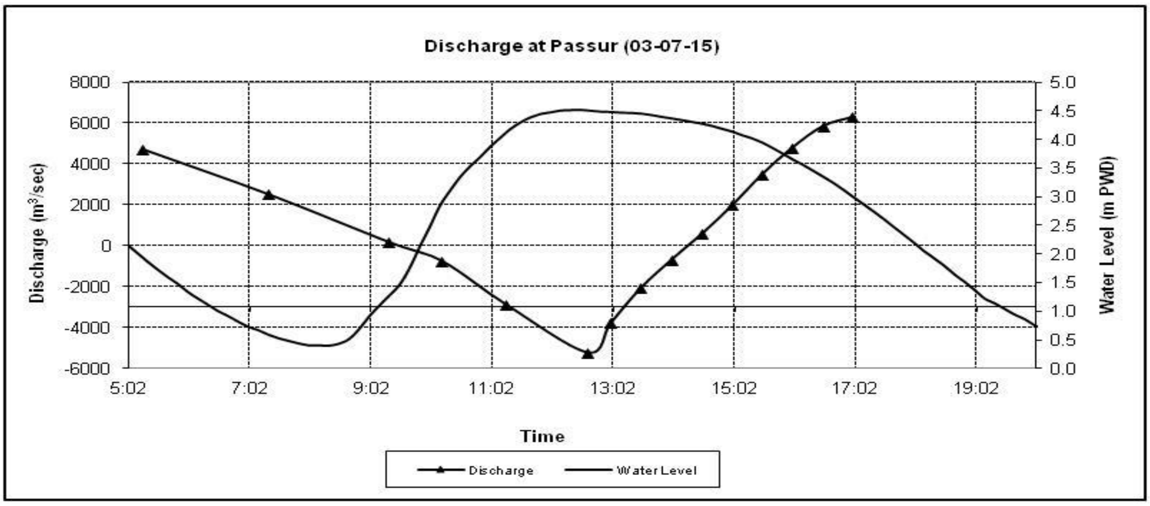


Figure.4: Discharge and water level during spring tide at Mongla (IWM, 2015)

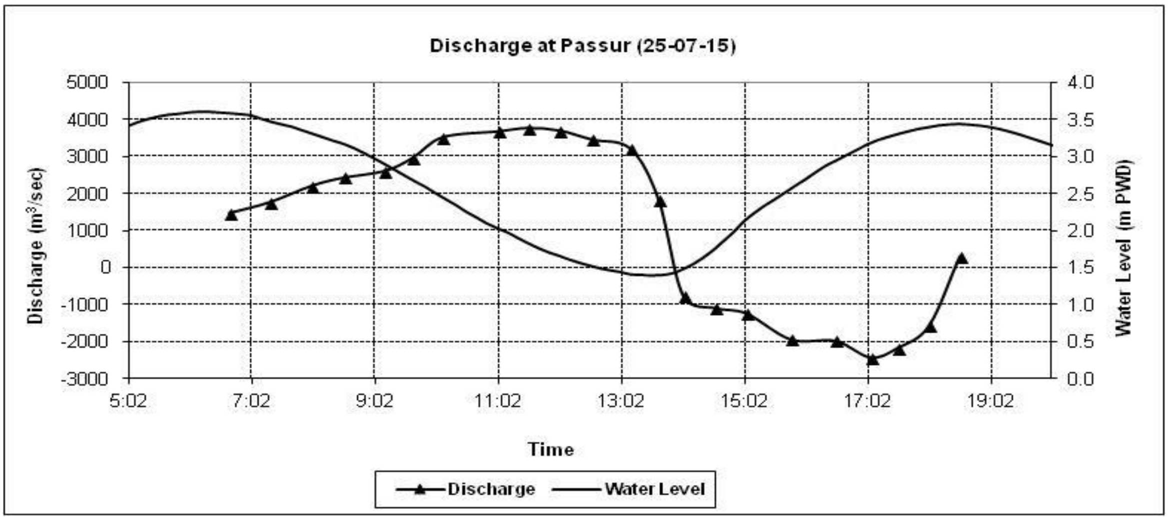


Figure 5: Discharge and water level during neap tide at Mongla (IWM, 2015)

Table 4: Maximum discharge during flood tide and ebb tide (IWM, 2015)

Location	Measurement Period	Type of tide	Max flow during flood tide	Max flow during ebb tide
Mongla	03-07-2015 (half hourly)	Spring	5227	6272
Mongla	25-07-2015 (half hourly)	Neap	2434	3771

3. SEDIMENT TRANSPORT IN THE PUSSUR RIVER

The navigability of Pussur channel is mainly suffering for high sedimentation in the main stream. Sedimentation mainly occurs in dry season when the flow velocity reduces significantly. According to the discussion with the concerned officials of MPA, it was found that the area of tidal prism has reduced significantly after constructions of polders and sluice gates at the mouth of khals of Pussur River. Before those interventions, tidal flow with high sediment volume was allowed to enter into khals and open areas where most of the sediments were deposited and fresh water returned in the river at ebb tide. But now most of the sediments deposit in the river due to those interventions.

DHI (1993) has collected a large quantity of data on this river, based on which the governing physical processes and the nature of the sediment transport processes in the Pussur River can be understood. From the suspended samples analysis, DHI concluded that the main part of the suspended sediment material consists of silt which is only represented in the bed material by approximately 5 percent. Consequently, the suspended sediment picked up in the measurements for the main part consists of wash load. Silt is generally not found in the bed along the main flow of Pussur River indicates that suspended silt contribute in any significant way to the erosion/deposition processes along the river. The bed material along the main flow areas of the bigger rivers is fine sand. Closer to the banks it is often mainly silt. The suspended fine material does not contribute significantly to erosion/sedimentation processes in the main flow regions of the bigger rivers including the navigation channel of Mongla Port. The transport of bed material is significantly smaller, of the total sediment approximately of one third (DHI, 1993).

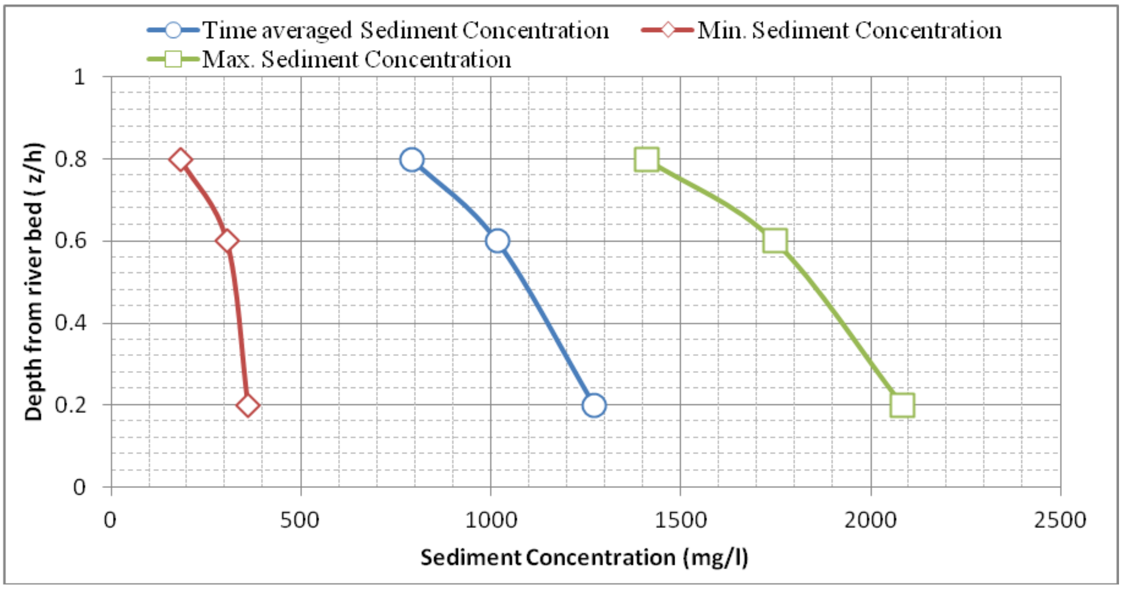


Figure 6: Depth-wise variation of Suspended sediment concentration in the Pussur River at Mongla Port area during spring tide

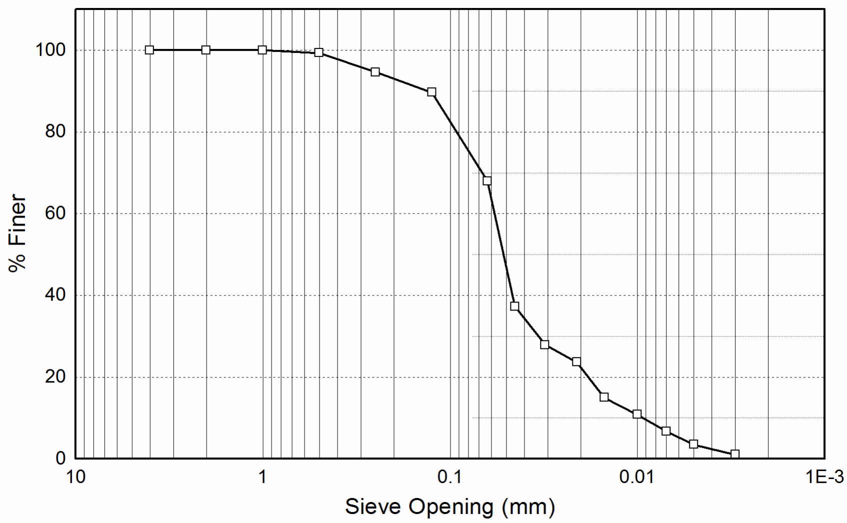
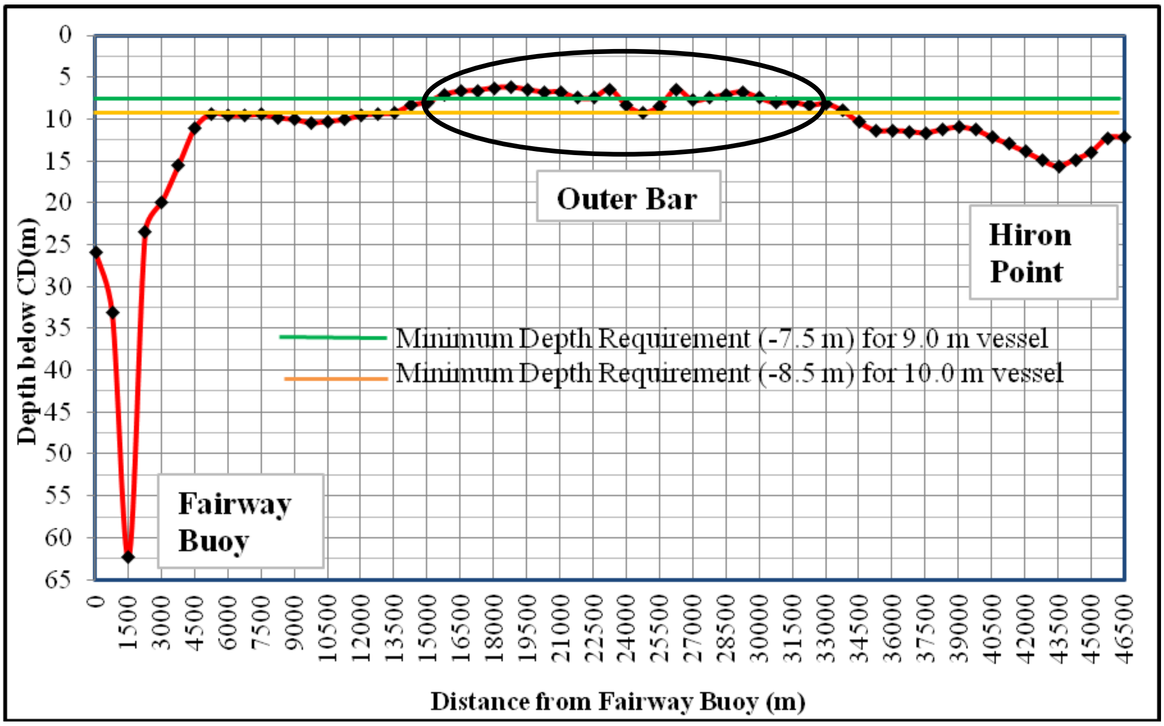


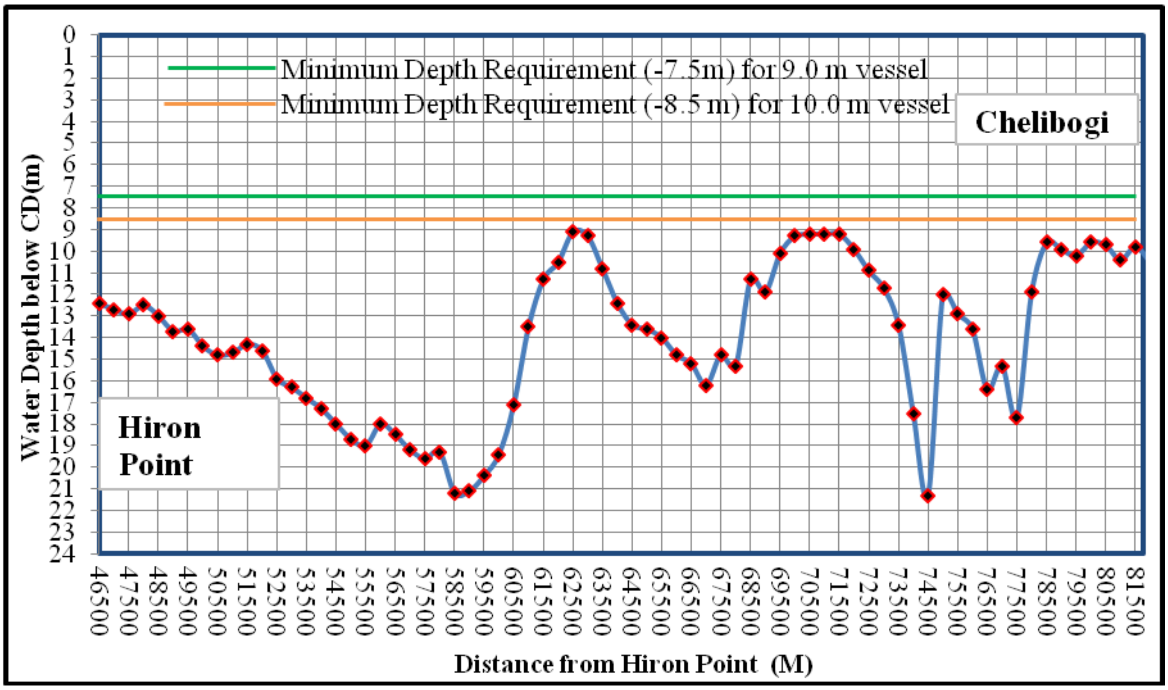
Figure 7: Average grain size distribution of bed material

In this study, suspended sediment concentration at 0.2d, 0.6d and 0.8d (d is the water depth) has been measured during the spring tide for 13 hours. The result shows that, sediment concentration near the river bed (i.e. at 0.8d depth from surface) is always higher than the upper layers at 0.6d and 0.2d from surface. At 0.8d, the concentration varies from 359.65 mg/l to 2096.06 mg/l in flood tide which changes inversely with water level and velocity. At 0.2d, the concentration varies from 153.6 mg/l to 1478.0 mg/l. Figure 6 shows the depth-wise variation of suspended sediment concentration for three scenarios: minimum, maximum and time averaged (12 hrs) sediment concentration profile. It is observed that at low concentration the sediment concentration profile is quite stiff and nearly vertical, means sediment gradient is low. On the other hand, the profile is flatter for higher concentration, and in this case the sediment concentration gradient along the depth is high. In the time averaged profile, the concentration is found as 790 mg/l at 0.2d depth and 1270 mg/l at 0.8d depth. From the time averaged profile, the mean concentration is estimated about 1000 mg/l.

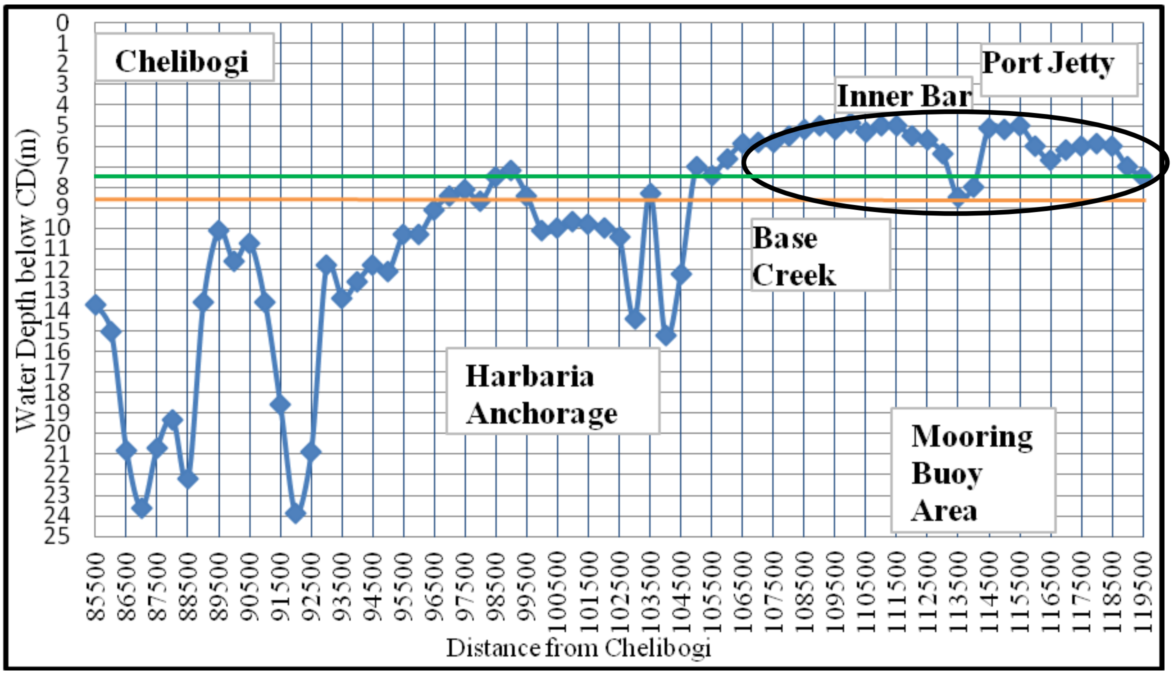
Sediment deposits in the estuaries consist of various proportions of gravel, sand, silt, clay and organic matter. Mc Dowell & O'Corner (1977) reported that gravel and sand are often found at the seaward ends where wave action and residual currents remove the finer fractions, while fine sand, silt, clay and organic matter (often collectively referred to as mud), is found in the upper reaches of an estuary. To investigate the characteristics of river bed material near the Mongla Port area, 4 (four) bed samples were collected and analyzed. Sieve analysis of the bed material shows that the Fineness Modulus (FM) of the collected samples are 0.30, 0.60, 0.48 and 0.49, i.e. the bed material is mostly sandy. Figure 7 shows the average grain size distribution of bed material, where d_{50} is found as 0.052 mm.



(a) Fairway Buoy to Hiron Point



(b) Hiron Point to Chelibogi



(c) Chelibogi to Mongla Port

Figure 8: Long profile of Pussur River along the navigation line

4. NAVIGATION ROUTE AND ITS NAVIGABILITY

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. The distance of different important location of Pussur River are given in Table 5.

Table 5: The distance of different important location of Pussur River (Source: MPA)

Important location of Pussur River	Channel Distance
Port Limit (North-South)	149.0 km

PP Jetty - Fairway	131.0 km
PP Jetty - Hiron Point	87.0 km
PP Jetty - Akram Point	68.5 km
Hiron Point - Fairway	44.0 km
Hiron Point - Akram Point	18.5 km
Akram Point - Fairway	62.5 km
PP Jetty - Jhapjhapia River	18.0 km
PP Jetty - Base Creek	13.0 km
PP Jetty - Harbouria Khal	22.0 km
Naval Jetty - Hiron Point	91.0 km

The Bathymetry of the Pussur River has been analysed reach wise from Chalna to Akram Point and also at the Pussur entrance at outer bar area based on the bathymetry charts from 2005 to 2016. The major findings on the navigability of the Pussur river is that, the river has navigation problem for the last two decades mainly from Chalna to Chilla Bazar. After Chilla Bazar, starting from Joymonirgoal, the river shows a more stable navigable reach up to Akram Point and the river is more meandering. Figure 4.9 presents the water depth below CD along the navigation channel from Chalna to Fairway Buoy for the year 2008. From the long section of Pussur River, it has seen that about 16 km river reach called outer bar at the entrance of Pussur river don't have enough draft for 7.5 m draft vessel (Figure 4.9a). From Hiron Point to Harbaria Anchorage, the river has sufficient draft upto 10.0 m draft vessel (Figure 4.9a & 4.9b). Harbaria Anchorage has sufficient draft to handle 10.0 m draft vessel. But about 13 km in the base creek area and Port Jetty area called inner bar is suffering for scarcity of sufficient water depth even for 7.0 m draft vessel (Figure 4.9c). The Pussur River is surveyed by MPA by dividing into 10 segments. However, for navigational purpose, the channel can be divided into following three sections:

Section 1: Fairway Buoy to Akram Point (Downstream to upstream)

The available water depth at Fairway Buoy is above 20-25 m. This depth gradually decreases as ships approach to the river channel due to draft restriction at the outer bar. The shoals along the outer bar in the southern section of 20 km restrict entrance of larger vessel of above 20,000 DWT.

Section 2: Akram Point to Harbaria

The available water depth at Akram Point anchorage ranges from 10 to 15 m. The depth of the channel between Akram Point and Harbaria varies in different stretches. From Akram Point to Kagaboga Khal, it varies from 11 to15 m. After a short patch having 8.00 m to 9.50 m water depth, 10 m up to 21 m depth is available up to D'Souza point. After D'Souza the depth again decreases and up to Harbaria Canal, where the depth is 8 m.

Section 3: Harbaria Anchorage to Chalna

Available water depth at Harbaria Anchorage is 8.5 m~10 m. As the channel proceeds, the depth further decreases from Harbaria to Port Jetty ranging between 5.00 m to 7.50 m. This trend continues up to the proposed power plant jetty at Rampal. Minimum water depth of this stretch is about 2-3 m, only ordinary inland vessels can negotiate with this depth.

5. CONCLUSION

Fresh water flow of Padma Piver and Gorai River is very important for the morphology of Pussur River. Due to low velocity of Pussur River, most of the sediments deposit on river bed which is reducing navigation depth. The most critical sections of this river are: (a) Mongla Port to Rampal power plant, (b) Harbour Area and (c) Outer bar area. Due to depth restriction at outer bar, maximum 8.5 m draft vessel can arrive upto Harbaria anchorage.

The upstream of Harbaria anchorage is shallower and maximum 7.5 m draft vessel can arrive to MP.

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