Northwest Hydraulic Consultants
Euroconsult Mott McDonald

Memo

To:	Guy Jones, Team Leader
From:	Angela Thompson, Knut Oberhagemann
cc:	Peter de Vries, EKN; Erik Mosselman, Deltares
Date:	March 2017
Re:	Site visit on 13 March 2017

1 Introduction

Both Blue Gold and the Flood and Riverbank Erosion Risk Management Investment Program (FRERMIP), Project-1 are implemented by the Bangladesh Water Development Board (BWDB) with financing from the Dutch Government – in the case of FRERMIP, it is routed through the ADB. Both projects incorporate pilot works into their design with the purpose of testing innovative, low-cost structures and river training approaches relevant to the project concepts. In both cases the Royal Netherlands Embassy (RNE) strongly guided the consultant's and BWDB's design team to apply the concept of "semi-permeable" spurs, which consist of vertical pile structures with screens closing the top half of the cross section. The concept replicates the well-known and widely used bandalling, and in terms of dimensions for Blue Gold the application of "improved bandals" tested during the times of FAP22 in the Jamuna upstream of Phulchari from 1996 until 1999. The concept is suitable for non-tidal sand-bed rivers with defined flow direction, where it is able to achieve some accumulation of sediment downstream of the bandals.

A joint team of consultants from Blue Gold and FRERMIP visited Polder 22 and 29, located opposite of the Lower Bhadra River on 13 March. The team consisted of:

Guy Jones	Team Leader Blue Gold,
Mofazzal Ahmed	Program Leader IWRM Blue Gold
Alamgir Chowdhury	Deputy Team Leader Blue Gold …
Knut Oberhagemann	Team Leader FRERMIP
Angela Thompson	Numerical Modeller FRERMIP

The team assessed the breached embankments in Polder 29 (Figure 1-1) where the application of "semi-permeable spurs" has been proposed as pilot works to secure the site against erosion, as well as the geotechnical failure of the embankment at Polder 22. Apart from information pertaining to the pilot works, general design and construction experience about BWDB design and construction works were exchanged and are reflected in this memo. In addition, emergency measures, a part of both projects, were discussed.

This memo is structured in three main sections: Section I Data Collection looks at the data needs for meaningful designs and monitoring. Section II Emergency Works discusses the risk during the upcoming flood season and suggests potential emergency measures. Section III Long-term

Solutions, discusses alternatives for protecting the polder embankments in the long-run against erosion.

Figure 1-1: Areal view of the Chandghar area of Polder 29, where the embankments breached (Image from Google Earth, November 15th, 2016)

2 Data Collection

2.1 Basic Design and Monitoring Data

The purpose of river monitoring is to provide specific information about the general bed and flow patterns in channel reaches over time, which are typically used for designs. Monitoring data can also be used (in parts) for numerical modelling, for example to test design alternatives against a number of design flow conditions. In line with accepted international standards, all designs for riverbank protection must consider three elements.

(i) The water – the impact of the flowing water on the structure and the stability of the underlying soil

(ii) The soil – the bank material and slope stability, the more so when depending on falling aprons securing the work against toe scour and consequently the obligatory needs for adaptation works over time, when depending on aprons or when the soils are weak parts of the slopes need to be flattened to attain acceptable safety factors.

(iii) The structure - separating the soil and the water, typically consisting of elements large enough not transported by the river with gaps small enough to secure the underlying subsoil in place.

Consequently, three types of monitoring data are collected:

(i) Bathymetric data provide a true representation of the river bed and –banks during the survey. Typically, single beam echo-sounders are used along adequately spaced cross sections as perpendicular to the flow as possible. The cross-sectional survey provides:
   a. Bathymetric maps depicting the underwater landscape
   b. Cross sections along the banks to assess the slope stability
   c. Differential models from subsequent surveys, identifying changes over time.

(ii) Flow data indicating the speed of the water movement and its direction. Three types of data are typically collected:
   a. Water levels to determine the range of water levels and potential design water levels.
   b. Float tracks, depicting the speed along the thalweg. Float tracks need to be planned carefully in tidal rivers.
   c. ADCP (acoustic Doppler current profiler) transects provide both speed and three-dimensional direction at different depths. In tidal rivers design data are typically obtained through continuous surveys during the spring tides of dry and flood season. Under certain circumstances, ADCP data can also be used to estimate sediment transport.

(iii) Geotechnical and sediment (bed material) data to understand:
   a. The constituency of the riverbank material for an assessment of its slope stability, and is to be conducted only one time;
   b. The type of material transported in the river for potential modelling, as well as when designing works that is intended to deposit material, and is conducted during the dry season, early and late flood season.

A detailed survey program for the Bhadra river is outlined in Section 5. A survey using DGPS is adequate and is quoted to cost BDT 3,496,250. The details of the survey cost are also outlined in Section 5.

2.2 Available Data

It is understood that some data are available at the two polders:

(i) Bathymetric and flow data, collected by IWM in May 2015, used as an input for their modelling activities[1].

(ii) Cross sectional data collected by the BWDB field office in November 2016. These four cross sections have been processed in the FRERMIP office using triangular interpolation because of the limited data points available. (Figure 2-1). This survey image could be improved with more cross sections; however, this limited survey gives an idea of the elevation of the river bed in the area.

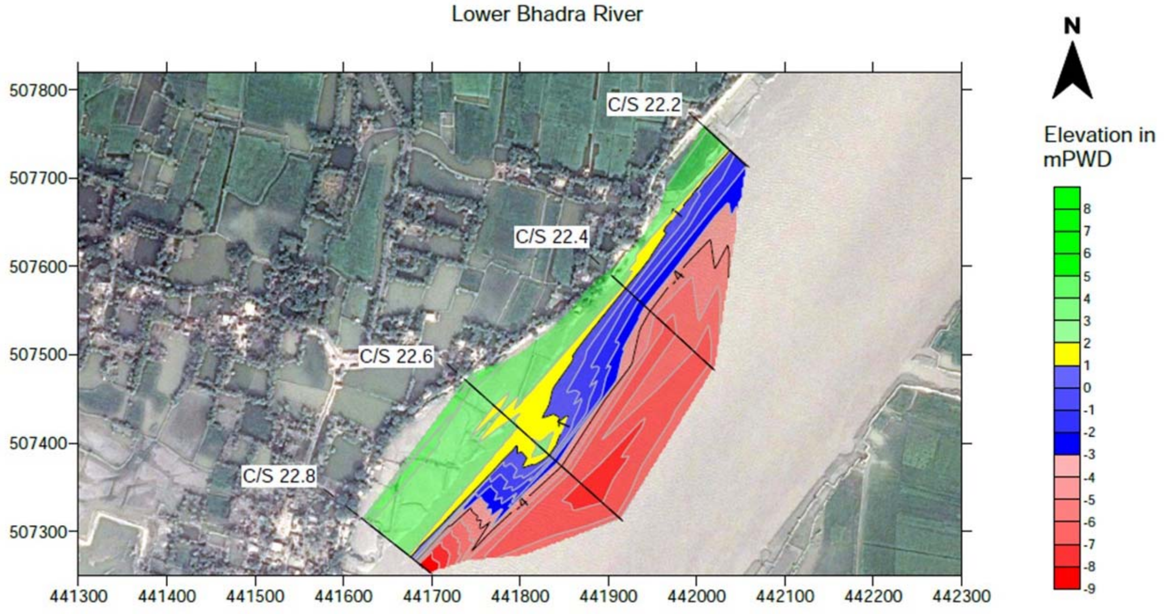

Figure 2-1 Bathymetric map from BWDB cross sectional data of the Lower Bhadra River

We recommend to compare both data sets and show the result in a differential map.

2.3 Monitoring Plan

Good monitoring data provide most of the design data required, and allow for meaningful numerical and physical modelling, and in many cases, limit the numerical modelling efforts to few alternative runs. For the specific case of emergency works, river surveys can provide the key information:

(i) Bank slopes and river cross sections (from echo-sounder surveys),

(ii) Thalweg locations during incoming and outgoing tide (from float tracks)

(iii) Flow velocities (from ADCP)

It is advisable to set up a monitoring plan with one survey during the dry season, one during the early flood season (July) and one during the later flood season (September). All surveys should be conducted during spring tide conditions.

[1] The original e-data is not yet available from IWM, but information will be extracted from the report by Blue Gold for purposes of comparison with the more recent BWDB survey data mentioned below.

3 Emergency Works

3.1 Polder 29

3.1.1 Embankment

The flood embankment has been breached prior to the 2016 flood season and temporarily repaired (Figure 3-1). A new embankment, under construction since June 2016 is expected to close the breach reliably, however the embankment has a number of weaknesses:

(i) Some areas are not constructed to design level, especially the closures of breaches (Figure 3-2).
(ii) In the deep part of the breaches, with bed levels below water level, no berms are constructed, which weakens the cross section substantially and in one place already results in piping, inviting future potential catastrophic failure (Figure 3-3 and Figure 3-4).
(iii) The new embankment is not compacted, which results in potentially 15 to 20% voids (Figure 3-5), and as a consequence the contractor saves this amount of money (payment for air in the cross section).
(iv) The land acquisition process is slow and results in a gap in the cross section where a school is located (Figure 3-6). Here the intergovernmental transfer delays the provision of reliable infrastructure.

Figure 3-1 Temporary flood embankment (left hand side) and new flood embankment (background right)

While the new embankment has some 100m setback distance to the river, the upstream connection with the old embankment is quite close to the eroding bank and situated in a densely populated area (Figure 3-7 and Figure 3-8). This location, together with the poor workmanship of the existing embankment, further aggravated by unfinished sections, results in a high risk of a renewed embankment breach during the 2017 flood season, either due to erosion, piping, or overtopping.

Figure 3-2 partial closure of upstream breach without attaining the final crest level

Figure 3-3 Missing berm at the main breach closure (country side view)

Figure 3-4 Piping through the embankment (riverside view)

Figure 3-5 Uncompacted embankment fill

Figure 3-6 School building (in background) preventing the completion of the new embankment (to the right) with the emergency embankment in the center close to a major drainage khal on the left

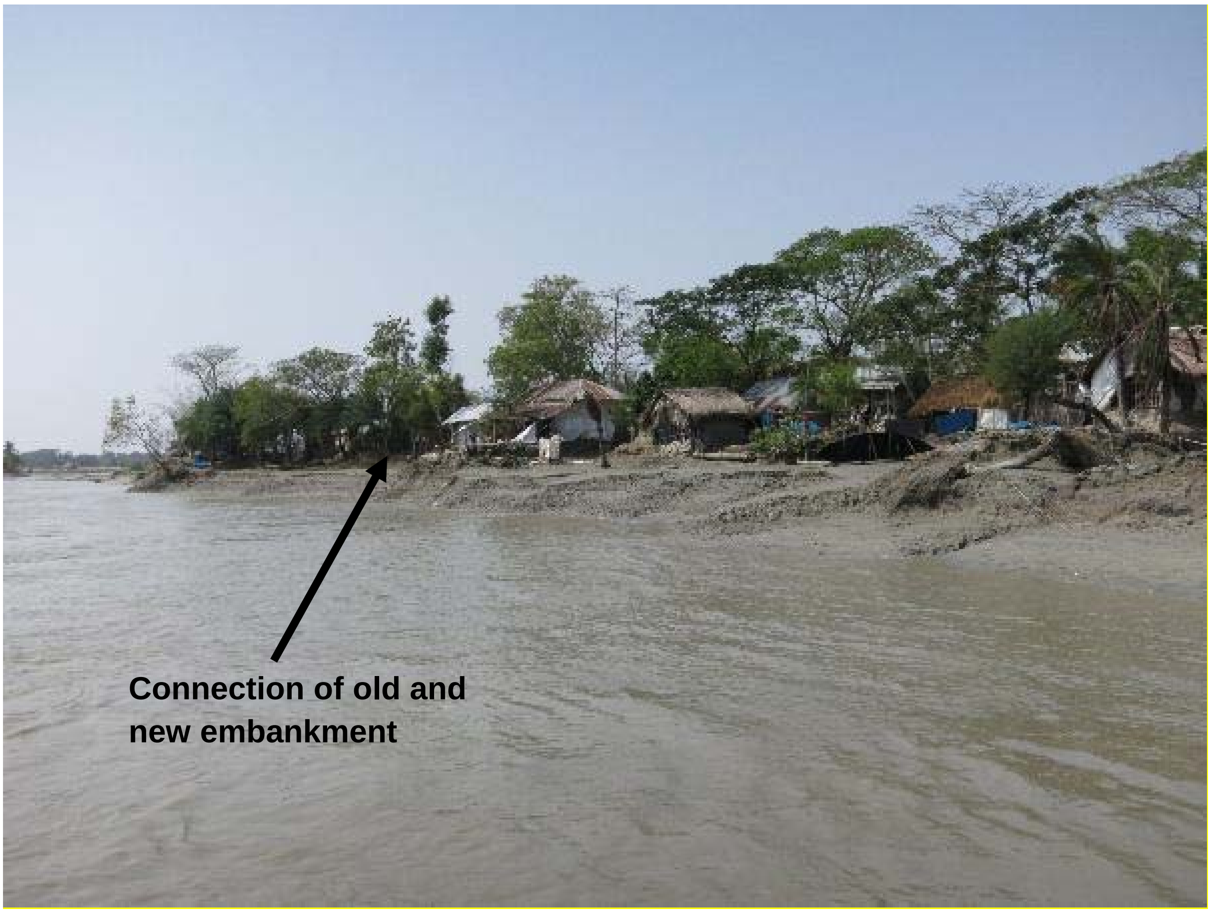

Figure 3-7 Eroding river upstream of the breached embankment (looking downstream)

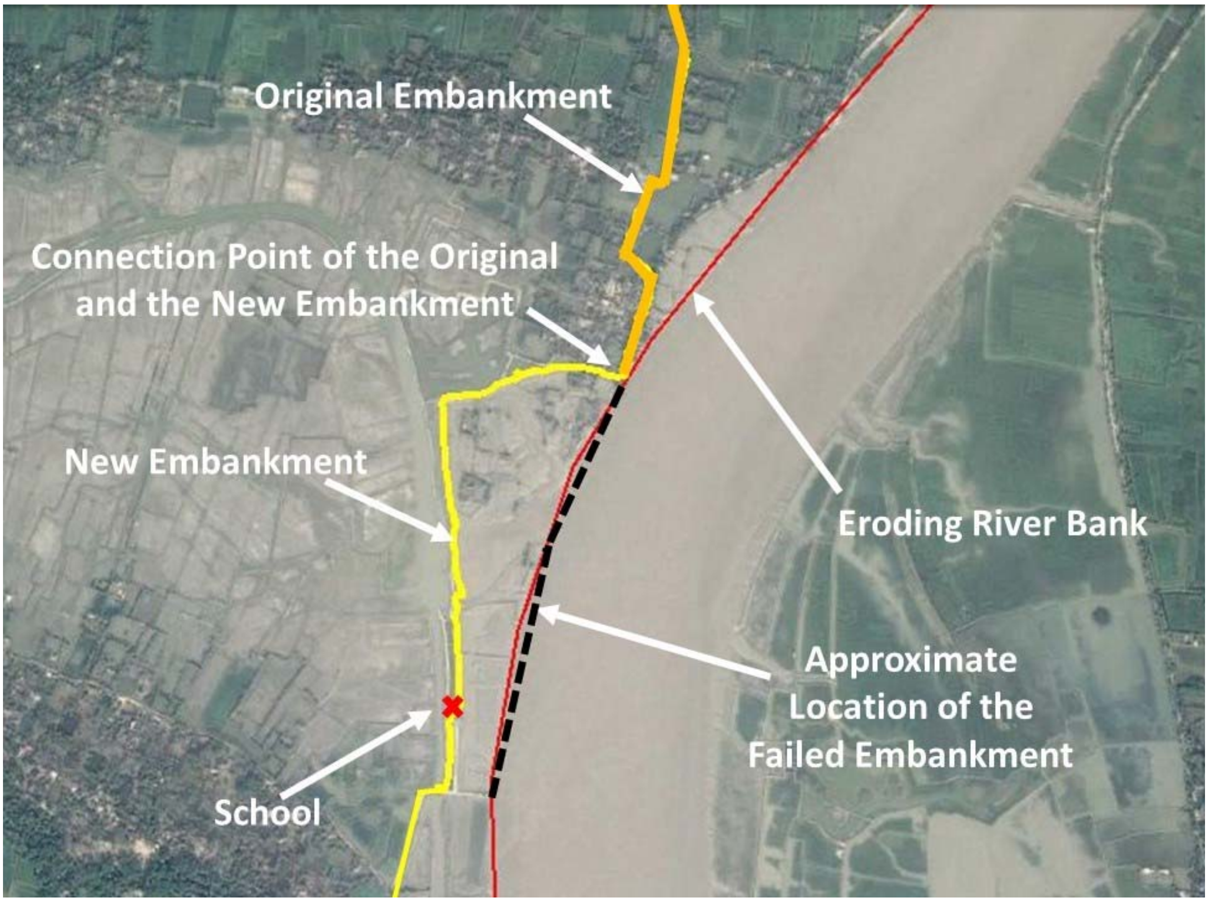

Figure 3-8 Alignment of new and old embankment with upstream connection close to the eroding riverbank (image from Google Earth, November 15th, 2016)

3.1.2 Riverbank Erosion

During the field trip, it could be observed that the thalweg of the incoming spring tide flows close to the riverbank in the area of the breached embankment. Even during the dry season, the flow velocities appeared quite high (Figure 3-9). It was not possible to observe the outgoing flow due to the timing of the visit. We recommend to conduct float track measurements during the next spring tide to get a first grasp on the current flow situation and the location of the thalweg with respect to the bankline.

The overall situation indicates the need for emergency riverbank protection, to control the riverbank. An easy solution is to provide a sufficiently large amount of sand-filled geotextile bags along the bank. These bags, once undercut from erosion slide down the underwater slope and protect the slope against further erosion, as the sand-fill acts as filter against the fine clayey and silty subsoils. Importantly, this type of emergency design has limitations, which need to be further investigated:

(i) The underwater slopes of the eroding banks need to be studied, to assure that the launching process can take place – commonly slopes of around 1V:2H are attained after launching, but could be steeper in case of clay banks, even up to 1V:1H.

(ii) The scour depth needs to be fixed, to correctly calculate the required number of bags.

A tentative rough estimate, assuming a river depth of around 15m with 35m underwater slope length (1V:2H), results in the need of 35 250kg bags per linear meter. This translates into 35,000 bags per km, which at cost of 6 USD per bag, requires 210,000 USD per kilometer. The estimated length, taken during the site visit is around 1 km, shown in Figure 3-10.

Figure 3-9 High flow velocities of incoming tide close to the bankline

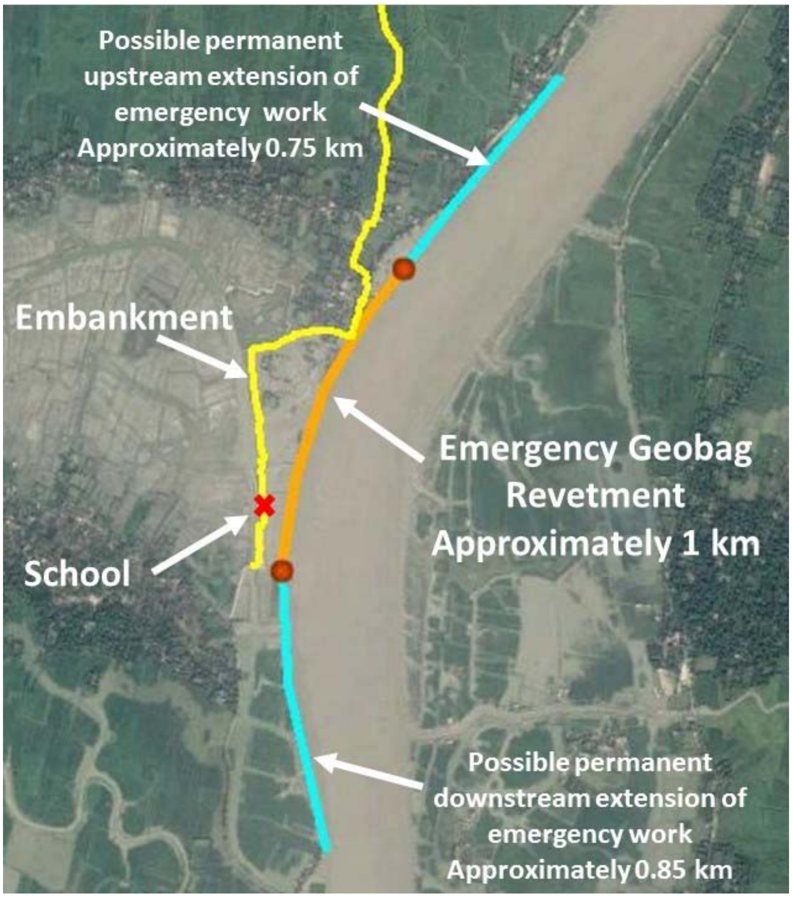

Figure 3-10 Estimated location and length of emergency works (image from Google Earth, November 15th, 2016)

3.2 Polder 22

3.2.1 Embankment

The embankment is partly collapsed and will very likely fail during the coming flood season. Immediately behind the embankment is the Blue Gold training center, currently under renovation (Figure 3-11). The existing embankment alignment indicates a relocation of the embankment in earlier times. The embankment needs to be setback from the river to avoid catastrophic geotechnical failure during the flood season. The highest risk of failure is towards the end of the flood season, when water levels recede quickly, called “rapid draw-down”, and the saturated soil of riverbank and embankment is weakest.

Figure 3-11 Training center of Poder 29 under rehabilitation with earlier realigned embankment

3.2.2 Riverbank Erosion

There was no data collected during the field visit that allowed quantification of the river depth; however, temporary bamboo fencing and the clayey soils indicate that the river could be quite deep and the slopes rather steep at the bank (Figure 3-12). It is advisable to conduct a bathymetric survey with float tracking to understand the river depth, the location of the thalweg, and the flow velocities. We estimate that around 400m emergency riverbank protection could temporarily remediate the situation.

Figure 3-12 eroding riverbank with some temporary bamboo fencing

4 Permanent Works

4.1 Bandaling or “Semi-Permeable Groynes”

While semi-permeable groynes have been tested in numerical models conducted by IWM and were recommended by the RNE, there are a number of issues that raise doubts about their applicability to the site:

(i) The site is located at an outer bend, which does not exhibit depositional characteristics and therefore behaves contrary to the concept of bandals.
(ii) The proposed protected reach does not protect the entire length of bank line that is at risk from erosion, therefore, creating a high chance of the works being outflanked by upstream riverbank erosion
(iii) The site is located in a tidal river, in which bandals are not applicable because of the changing angle of the flow. The effectiveness of bandals is dependent on the angle of the flow.
(iv) The numerical model tests simplify a number of assumptions and raise doubts of having correctly represented the site conditions.
(v) The design, even though it appears sizable, leaves doubts about basic design parameters, specifically on the geotechnical side. Furthermore, the proposed design does not appear to have been tested to an adequate standard in the numerical models. The IWM report detailing the numerical models does not sufficiently test the morphological changes that will result from the structures, for example, they fail to consider the tidal effects on the works and the consequential sedimentation and erosion near the bank

In combination, these factors do not allow an immediate implementation of the proposed bandals, but rather, require further studies to incontrovertibly prove that the concept can work in a river environment contradictory to the typical application. Furthermore, the current design is neither low-cost nor follows the principle of “building with nature”.

4.2 Geobag Revetments

As the temporary protection is recommended to consist of geobags, it is logical to consider permanent works of the same nature, following the successfully implemented adaptive approach as per BWDB Guideline for Riverbank Protection, 2010. This means that more layers of geobags will be dumped over the launched temporary works, with an additional toe apron, able to launch to design scour depth with some safety provision. The resulting slope is geotechnically stable for typical combinations of unfavorable load cases (e.g. earthquake and rapid draw down). The related design and implementation are simple and standard in Bangladesh, implemented in many places by BWDB.

5 Survey Outline

To adequately survey the Bhadra river for analysis and numerical modelling exercises the following program has been devised. The program includes a cost estimate, which has been quoted by Osman Ghani, survey specialist. (contact email: ghani.bd@gmail.com)

5.1 Components

5.1.1 Bathymetric

The bathymetric survey should be conducted along the river with 100m line spacing along the 5.8km long reach indicated in Figure 5-1. The survey should be conducted using a dual frequency, single beam echo sounder (Echotrac CVM or similar), with a record frequency of 0.1s. For georeferencing of the survey boat, a RTK unit with base station, or similar should be used. In total about 59 cross sections of the river are to be surveyed.

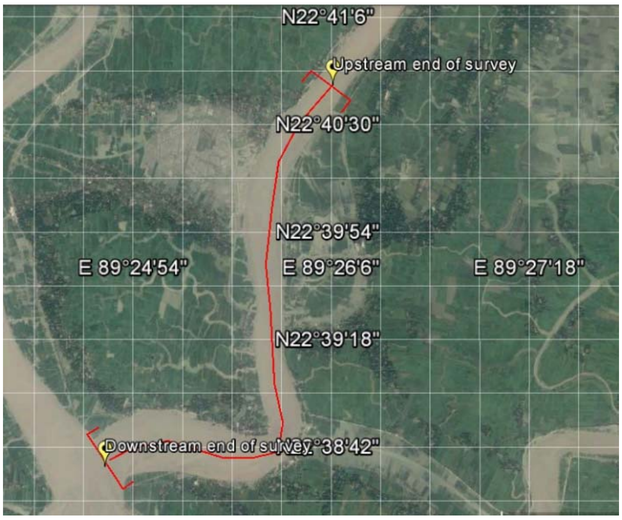

Figure 5-1 River reach to be surveyed

5.1.2 2. ADCP

Flow velocities and discharge should be measured with an ADCP (Riogrande 620 or similar) along the four transects indicated in Figure 5-2. The instruments location should be georeferenced by a RTK unit with base station, or similar. The Base station should be set one hour before the start of the survey. The ADCP measurements should be conducted repeatedly within one day, between 5:30am and 7pm, for a minimum of 13 hours.

Figure 5-2 Location of transects for ADCP surveys

5.1.3 Float tracks

Float tracks should be recorded by tracking floats with a frequency of 3 seconds. The floats should have a fin of a minimum of 0.5m depth. The location should be taken with a handheld GPS system. The floats should be started every hour between 6am and 7pm from the upstream boundary during the receding tide and from the downstream boundary during the incoming tide.

5.1.4 Water level gauges

A total of three water level gauges, connected to know benchmarks in the area, should be installed at the locations indicated in Figure 5-3. The water level gauges shall be set up on the day before the first survey and read and noted twice daily, during high and low tide, until the day after the last survey.

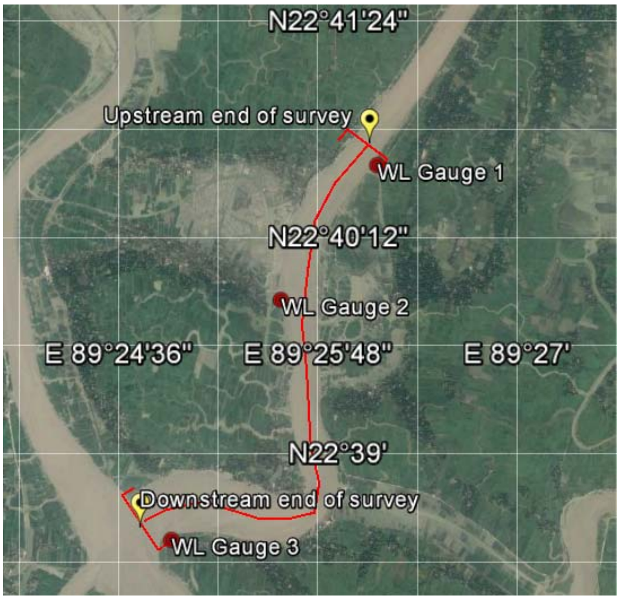

Figure 5-3 WL gauges locations

5.2 Dates

All surveys should be conducted three times, in April, July and September. The float track and ADCP surveys are to be conducted on days with spring tide. The bathymetric surveys should be conducted in the days before the spring tide.

5.3 Cost

Cost outline using a DGPS. A DGPS is deemed acceptable for the area.

Sl. No.	Item	Quantity	Unit	Rate (BDT)	Amount (BDT)	Remarks
1	Mobilization and Demobilization	1	no	40,000.00	40,000.00	
2	**Bathymetric Survey:** The Survey shall be conduted using duel frequency single beam echo sounder with a record frequency of 0.1s and DGPS beacon receiver.	177	No.	4,000.00	708,000.00	April, July & September'2017 each month 59 Sections.
3	**ADCP:** ADCP measurement shall be conducted repeatedly within one day, between 5:30 AM to 7:00 PM, but at least 10 times per transect, use DGPS Beacon for positioning system (4 locations x 10 transect x 3 times) Considering use 2 nos. ADCP.	120	no	12,000.00	1,440,000.00	April, July & September'2017 at least 10 times 4 nos. transect each month.
4	**Float Tracks:** float tracks shall be started every hour between 6:00 AM to 7:00 PM from upstream to uustream during falling tide and from downstream during rising tide. Considering use 4 local boat for float monitoring.	128	km	3,000.00	384,000.00	April, July & September'2017 one in every month.
5	**Water Level Gauges:** Installation of three water level gauges including level fly work for zero value fixing, gauge maintanance etc. work.	3	No.	15,000.00	45,000.00	3 Gauges.
6	**Water Level Gauge:** Total of three gauges shall be set up on the day before the first survey and read and noted twice daily, during high and low tide until the day after the last survey (3 gauges x 5 months).	15	Man month	12,000.00	180,000.00	April to September'2017, total 5 months for 3 Gauges
Sub-total =					2,797,000.00	
VAT & IT (15% + 10%) 25% of work cost =					699,250.00	
Total cost on April, July & September'2017 three times					3,496,250.00	

Cost outline using an RTK.

Sl. No.	Item	Quantity	Unit	Rate (BDT)	Amount (BDT)	Remarks
1	Mobilization and Demobilization	1	no	40,000.00	40,000.00	
2	**Bathymetric Survey**: The Survey shall be conducted using duel frequency single beam echo sounder with a record frequency of 0.1s and RTK-DGPS receiver.	177	No.	9,500.00	1,681,500.00	April, July & September'2017 each month 59 Sections.
3	**ADCP**: ADCP measurement shall be conducted repeatedly within one day, between 5:30 AM to 7:00 PM, but at least 10 times per transect, use RTK-DGPS for positioning system.	120	no	12,000.00	1,440,000.00	April, July & September'2017 at least 10 times 4 nos. transect each month.
4	**Float Tracks**: float tracks shall be started every hour between 6:00 AM to 7:00 PM from upstream to upstream during falling tide and from downstream during rising tide.	128	km	1,200.00	153,000.00	April, July & September'2017 one in every month.
5	**Water Level Gauges**: Installation of three water level gauges including level fly work for zero value fixing, gauge maintenance etc. work.	3	No.	15,000.00	45,000.00	3 Gauges.
6	**Water Level Gauge**: Total of three gauges shall be set up on the day before the first survey and read and noted twice daily, during high and low tide until the day after the last survey.	15	Man month	12,000.00	180,000.00	April to September' 2017, total 5 months for 3 Gauges
Sub Total=					3,540,100.00	
VAT & IT (15% + 10%) 25% of work cost =					885,025.00	
Total cost on April, July & September'2017 three times =					**4,425,125.00**	