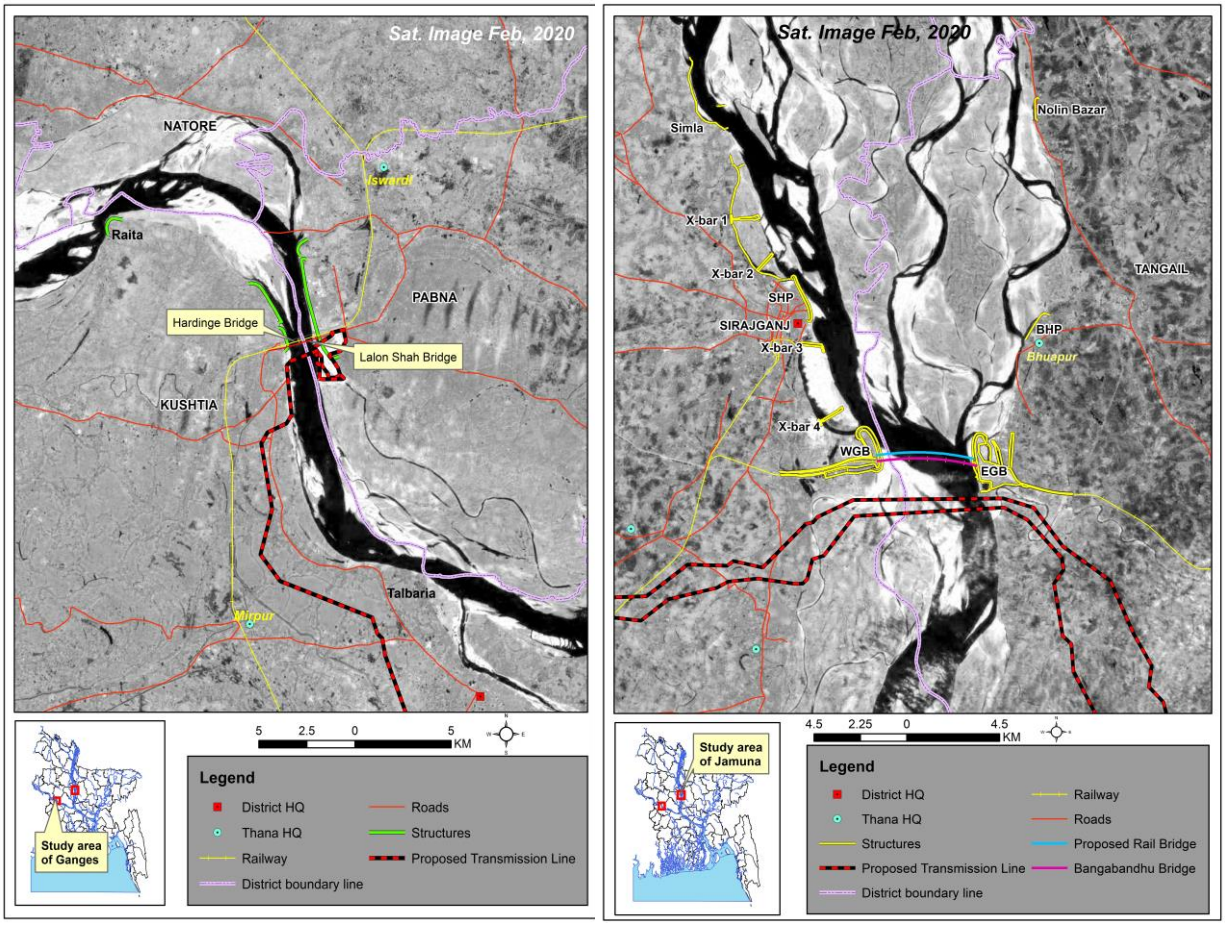
Government of the People's Republic of Bangladesh
Ministry of Power, Energy and Mineral Resources

POWER GRID COMPANY OF BANGLADESH LTD.



Morphological Study of Different River Crossing (Padma River for One Line and Jamuna River for Two Lines) for Infrastructure Development for Power Evacuation Facilities of Rooppur Nuclear Power Plant

FINAL REPORT

February 2021

IWM
Water Environment & Climate

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Memo No. 42.07.016.06.05.2309.2021/0198 Date: 04.02.2021

The Chief Engineer
Project Monitoring
Power Grid Company of Bangladesh Ltd.
PGCB, Dhaka

Sub: Final Report

Ref: Morphological Study of Different River Crossing (Padma River for One Line and Jamuna River for Two Lines) for Infrastructure Development for Power Evacuation Facilities of Rooppur Nuclear Power Plant

Dear Sir,

I am pleased to submit herewith 05 copies of the Final Report, in connection with the study mentioned under reference, for your kind perusal.

Looking forward to continued cooperation,

Yours sincerely,

Sarwat Jahan
Director
River Engineering Division

Encl. As stated

CC: ED/ DED (Opn)/ PS, PL –P52309, IWM

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The Rooppur Nuclear Power Plant will be first nuclear power plant in Bangladesh. The nuclear power plant is being constructed at Rooppur, in the Ishwardi Upazila of Pabna District along the left bank of the Padma River. The power plant will be located approximately 140 km west of Dhaka. With a view to power evacuation facilities of Rooppur Nuclear Power Plant and to be connected with National Grid, Power Grid Company of Bangladesh (PGCB) is going to construct one river crossing of transmission line over the Padma (Ganges) River and two river crossings of transmission lines over the Jamuna River (**Figure E.1**).

Before construction of any hydraulic structure within a dynamic river like the Padma (Ganges) and the Jamuna, it is necessary to assess the response of the river due to the structure that would guide the design engineer to go for safe design. In this present case, River crossing for power transmission would be constructed within the river and anchor tower would be at the riverbanks. Designing a crossing tower is needed to consider the worst possible scenario, which may be experienced by the tower during its lifetime.

This present study, with the application of mathematical modelling of the Ganges and the Jamuna Rivers finalize the alignment of the transmission line as well as positions of the towers (and depths of the tower foundations) and provide outline hydraulic design variables of the river crossings.

OBJECTIVES OF THE STUDY

The objectives of the study, as per the Terms of Reference (Revised), are:

- Geological information of the area including geomorphology, geological structure, etc.
- Observations and data regarding historical channel and bank line movement/shifting for the river/ change of course of river
- Maximum design discharge, maximum velocity, scour depths, slit factor, etc., and history of flood details for mid-stream and river bank locations.

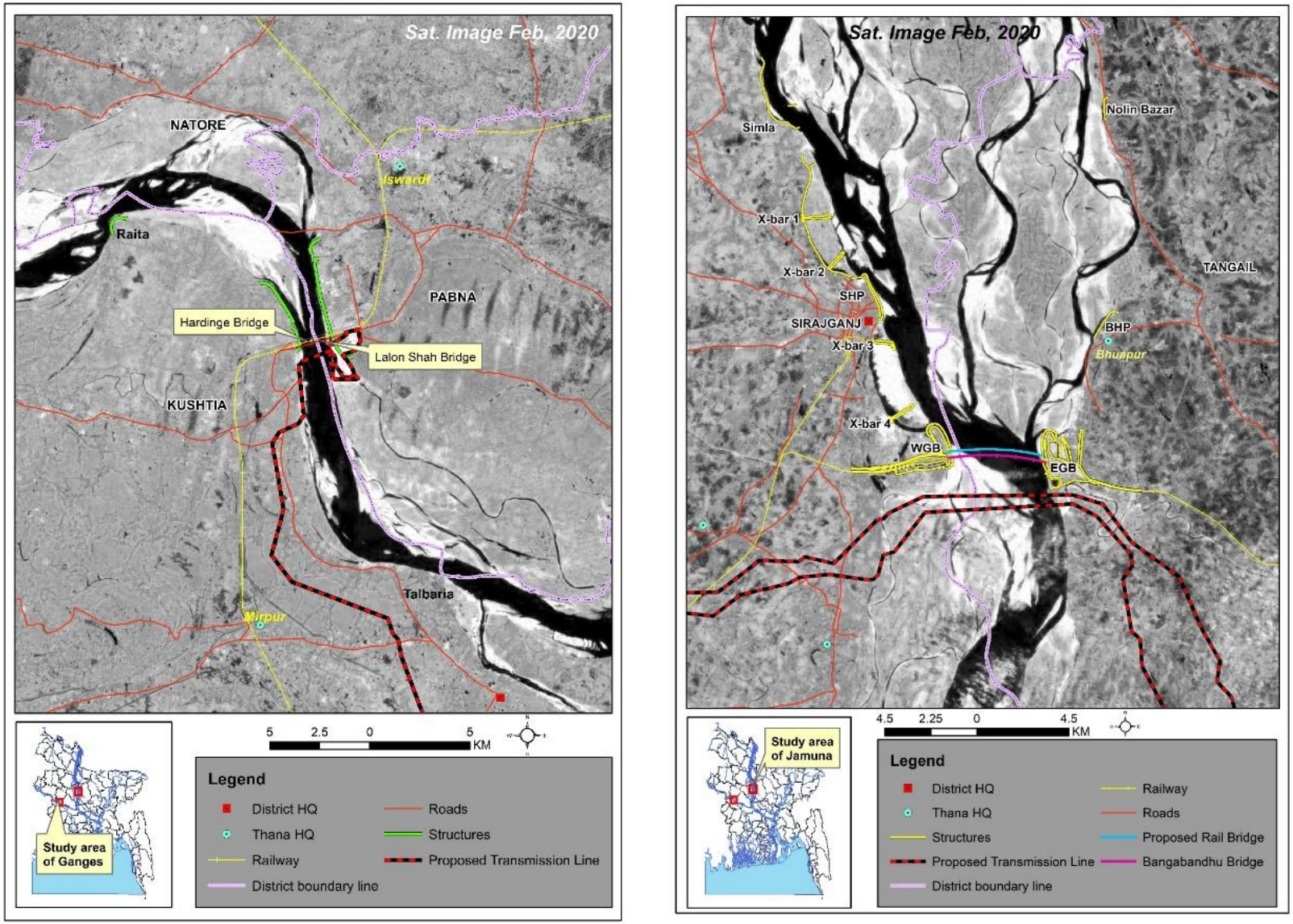


Figure E.1 *The Proposed Crossing location on the Padma (Ganges)and the Jamuna River*

OUTPUTS OF THE STUDY

The outputs of the study are:

- Channel and bankline movement/shifting (quantitative) at and around the tentative river crossing
- Qualitative prediction of possible future development/ shifting of the river (at and around the tentative river crossing) during the next ~20 years (forecast of 50 years is not technically feasible)
- Maximum (design) discharge, maximum velocity, High & Low Flood Levels, seasonal variations in the river (Discharge, Velocity, Depth and Width at the river crossing location)
- Data/information about some past high floods (1987, 1988, 1998, 2004, 2007, 2018) – flood levels and floodplain inundation at and around the tentative river crossing
- Maximum Scour Depths at tower locations (Customarily, only the maximum scour depth is computed, and that value/level is applied for all the piers/towers because in a braided river like the Jamuna, the thalweg/channel shifting is very prominent)
- Bathymetry, and Morphological Data (Suspended Sediment Concentration, river Bed Materials' Grain Size Distribution/Particle Size, Flow Discharge, Velocity)
- Most suitable river crossing alignment (within 0.5km u/s to 0.5km d/s of the tentative crossing alignment)
- Chemical analysis results for water samples: Sulphate content, Calcium Content, Chloride content, Total Dissolved solids.
- Input data required to calculate Velocity attack and Wave attack on the structures in connection with evaluating Ship Impact Load and Water Surge Load.
- Ship Impact Load.
- Impact of river crossing transmission line on nearby existing structures in the river.

APPROACH AND METHODOLOGY

The key approach of the study is to apply two-dimensional hydro-morphological model of the Ganges and the Jamuna River of certain lengths encapsulating the proposed crossing, using available bathymetric and hydrometric data; then simulation of the model for some design hydrological events, and analysis of model results to assess the suitability of the crossing location for the proposed crossing as well as testing the vulnerability of the erosion prone area near the crossing site, and provide suggestion for suitable protective measures.

DATA AND MODEL

Available historical data were collected from secondary sources and IWM database. In order to develop the two-dimensional morphological model, available bathymetric data that was surveyed by IWM survey team during October 2020 has been used. Other relevant data such as water level, discharge, suspended sediment and bed sample data were also collected from IWM database Then, state-of-the-art mathematical modelling exercise has been carried out in determining the probable hydro-morphological changes of the rivers in "with" and "without" project conditions in near future.

STUDY FINDINGS

The findings of the study are described as follows:

Selection of Crossing Locations

From Rooppur Powerplant, one transmission line will be crossed over the Ganges River. This single crossing line over the Ganges River named as Rooppur-Gopalganj 400KV Transmission Line, which will start from Rooppur Nuclear Powerplant territory and crosses over Kushtia, Rajbari, Faridpur and ended at Muksupur upzilla of Gopalganj district. The proposed transmission line will be constructed at about 950 m downstream of Hardinge Bridge

In case of the Jamuna River, two transmission lines will be crossed. These two crossing lines over the Jamuna River named as “Rooppur Nuclear Power Plant to Dhaka Double Circuit 400kV TL” as Transmission Line 1 and “Rooppur to Dhamrai SS Double Circuit 230kV TL” as Transmission Line 2. Both the transmission lines are started at Rooppur Nuclear Power Plant and ended at Dhamrai upzilla of Dhaka district.

Selection of Design Hydrological Event

Using observed flow data from 1934 to 2019 of the Ganges River at Hardinge Bridge station and 1956-2019 of the Jamuna River at Bahadurabad station, frequency analysis has been carried out, in which 1 in 100 year return period flood event and average flood event have been considered for model simulation. For the Ganges River, the maximum flow of these two events are 79059m^3/s and 51000m^3/s for 100 year and average flood event, respectively. For the Jamuna River, the maximum flow of these two events are 105249m^3/s and 68565m^3/s for 100 year and average flood event, respectively.

Channel/ Bankline Shifting at and around the Crossing Location

There was a significant bankline shifting along both banks of Ganges River during 1976 to 2000, at the location of proposed transmission line. The lateral shifting was about 690m along the right bank and 610m along the left bank. However, in the last two decades there were no bankline shifting along the right bank. For the 6km transmission line parallel to the right bank of the Ganges River, it is clearly seen that the right bank was not always stable. After 1980, there was a massive erosion occurred along that bank. However, this bank is being quite stable after the year 2000.

In Jamuna River, the major bankline is shifted along the left bank at the immediate d/s of East Guide Bund. The maximum extent of erosion was about 720m with a rate of 40m/yr. Furthermore, this extent of erosion is found nearly 300m during the period from 2002 to 2020, along the transmission line 2. On the other hand, there was an accretion (maximum extent is about 1km) at the right bank just u/s of Belkuchi.

From model results, it is observed that there is no bank erosion along both the bank of transmission line in Ganges and Jamuna River. However, at 10km u/s and from 5km to 10km d/s of Hardinge Bridge, there might be bank erosion occurred along the right bank, if high flood event passed. In case of Jamuna River, there is no bank erosion at the right bank along the crossings. However, about 10m of erosion might be happened at the left bank of the Jamuna River along the crossing lines.

Chemical Analysis

The measured water sample data in Jamuna and Ganges River at different locations are shown in **Table E.1**. The average value of TDS, Choride, sulphate and calcium are also given in this table.

Table E.1 Measured Water Sample Data in Jamuna and Ganges River

River	Station	Location	TDS, (mg/L)	Chloride, Cl^- (mg/L)	Sulphate, $SO4^{2-}$ (mg/L)	Calcium, Ca(mg/L)
Jamuna	B.U.S	0.6D	59.7	38	6	7.19
	B.D.S	0.6D	61	52	6	6.35
	B.U.S	0.6D	62.7	54	8	6.28
	B.D.S	0.6D	63.2	44	11	6.6
	B.U.S	0.6D	62	40	8	5.87
	B.D.S	0.6D	62.5	50	9	6.99
Average			***61.85***	***46.33***	***8.00***	***6.55***
Ganges	Hatkhola (u/s)	0.6D	111.1	45	7	5.87
		0.6D	122.6	36	6	6.04
		0.6D	111.8	40	59	6.1
	Hardinge (d/s)	0.6D	109.9	41	6	5.86
		0.6D	109	43	6	4.57
		0.6D	111	39	6	6.09
Average			***112.57***	***40.67***	***15.00***	***5.76***

Hydraulic Design Parameters

For the Proposed Transmission Line on the Ganges River

Design Discharge : 79059 m^3/s (model estimated)
Design High Water Level (HFL) : 15.22 mPWD, 14.76 MSL (model estimated)
Standard High Water Level : 14.87 mPWD, 14.41 MSL
Minimum Water Level : 4.20 mPWD, 3.74 MSL (observed data using slope analysis)
Maximum average velocity : 4.22 m/s (2D model estimated)
Minimum Bed Level : -0.97mPWD, -1.43 MSL (surveyed)
General Scour : 27.18 m (model estimated)
Constriction Scour : 3.28 m (model estimated)
Local Scour : 28.46 m
Total Scour : 58.92 m
Scour Level : -59.89 mPWD, -60.35 MSL
Minimum Vertical Navigation Clearance : 5 m (according to BIWTA Guideline)
Minimum Horizontal Navigation Clearance : 20 m (according to BIWTA Guideline)
Angle of attack, Θ : 18.43˚
Mean Diameter, d_{50} : 0.15 mm
Type of river bed material : fine sand

Max depth of flow :16.19 m
Max span length or max distance between tower :557.2 m

For the Proposed Transmission Line 1 on the Jamuna River

Design Discharge : 102436 m^3/s (model estimated)
Design High Water Level (HFL) : 14.00 mPWD, 13.54 MSL (model estimated)
Standard High Water Level : 14.083 mPWD, 13.623 MSL
Minimum Water Level : 5.292 mPWD, 4.83 MSL (observed data using slope analysis)
Maximum average velocity : 2.90 m/s (2D model estimated)

Minimum Bed Level	: -34.37mPWD, -34.83 MSL (surveyed)
General Scour	: 0 m (model estimated)
Constriction Scour	: 6.95 m (model estimated)
Local Scour	: 39.52 m
Total Scour	: 46.47 m
Scour Level	: -80.84 mPWD, -81.3 MSL
Minimum Vertical Navigation Clearance	: 7.62 m (according to BIWTA Guideline)
Minimum Horizontal Navigation Clearance	: 30.48 m (according to BIWTA Guideline)
Angle of attack, Θ	: 25.5˚
Mean Diameter, d_{50}	: 0.18 mm
Type of river bed material	: fine sand
Max depth of flow	: 48.37 m
Max span length or max distance between tower	: 848 m

For the Proposed Transmission Line 2 on the Jamuna River

Design Discharge	: 102436 m^3/s (model estimated)
Design High Water Level (HFL)	: 13.89 mPWD, 13.43 MSL (model estimated)
Standard High Water Level	: 14.048 mPWD, 13.588 MSL
Minimum Water Level	: 5.256 mPWD, 4.79 MSL (observed data using slope analysis)
Maximum average velocity	: 3.25 m/s (2D model estimated)
Minimum Bed Level	: -17.44 mPWD, -17.9 MSL (surveyed)
General Scour	: 17.88 m (model estimated)
Constriction Scour	: 5.17 m (model estimated)
Local Scour	: 38.85 m
Total Scour	: 61.9 m
Scour Level	: -79.34 mPWD, -79.8 MSL
Minimum Vertical Navigation Clearance	: 7.62 m (according to BIWTA Guideline)
Minimum Horizontal Navigation Clearance	: 30.48 m (according to BIWTA Guideline)
Angle of attack, Θ	: 52.64˚
Mean Diameter, d_{50}	: 0.18 mm
Type of river bed material	: fine sand
Max depth of flow	: 31.33 m
Max span length or max distance between tower	: 874 m

RECOMMENDATIONS

The following recommendations have been made based on the study results:

- As Ganges or Jamuna River are so dynamic in nature, the thalweg of the rivers may shift from one bank to another. So, every tower/ pier should be designed considering the maximum scour.
- Monitoring of hydro-morphological conditions of the river at upstream, downstream and along the crossings are suggested to arrest any unaccountable situation after construction of the crossings.
- To save the foundation cost at right bank of Ganges River, the 6km of transmission line (Rooppur-Gopalganj) parallel to the river can be shifted about 200m towards the country side (by observing the bank erosion from the long term simulation).

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ABBREVIATIONS

2D	Two-dimensional
ADCP	Acoustic Doppler Current Profiler
BTM	Bangladesh Transverse Mercator
BBA	Bangladesh Bridge Authority
BHP	Bhuapur Hard Point
BIWTA	Bangladesh Inland Water Transport Authority
BR	Bangladesh Railway
BWDB	Bangladesh Water Development Board
BSMRBCP	Bangabandhu Sheikh Mujib Railway Bridge Construction Project
CEGIS	Centre for Environmental and Geographic Information Services
DGPS	Differential Global Positioning System
DHI	Danish Hydraulic Institute, Denmark
EVA	Extreme Value Analysis
EGB	East Guide Bund
FAP	Flood Action Plan
FHWA	Federal Highway Administration
GK	Ganges-Kobadak
GIS	Geographic Information System
GPS	Global Positioning System
HB	Hardinge Bridge
HFL	Highest Flood Level
IWM	Institute of Water Modelling
JMBA	Jamuna Multipurpose Bridge Authority
K-S	Kolmogorov–Smirnov
MW	Mega Watt
MSL	Mean Sea Level
MIKE 21C	Two-dimensional Curvilinear Modelling System of DHI
NEDECO	Netherlands Engineering Consultants
PWD	Public Works Department
RL	Reduced Level
RTK	Real Time Kinematic
RTW	River Training Works
RHD	Roads and Highway Department
SHP	Sirajganj Hard Point
SWMC	Surface Water Modelling Centre (Now IWM)
TRDI	Teledyne RD Instruments
ToR	Terms of Reference
USGS	United States Geological Survey
WGB	West Guide Bund
YREC	Yellow River Commission

1. INTRODUCTION

1. INTRODUCTION

1.1 General

The Rooppur Nuclear Power Plant will be first nuclear power plant in Bangladesh. The nuclear power plant is being constructed at Rooppur, in the Ishwardi Upazila of Pabna District along the left bank of the Padma River. The power plant will be located approximately 140 km west of Dhaka. With a view to power evacuation facilities of Rooppur Nuclear Power Plant and to be connected with National Grid, Power Grid Company of Bangladesh (PGCB) is going to construct one river crossing of transmission line over the Padma (Ganges)[1] River (**Figure1.1**) and two river crossings of transmission lines over the Jamuna River (**Figure1.2**). The River Crossing site should be selected judiciously and carefully. It is desirable to cross the river which is stable or tamed by structures and riverbanks at the crossing point are at a level higher than the highest flood level to ensure safety of the crossing towers during flood. Besides, highest scour level is also necessary for the design of the foundation of the crossing towers. Padma (Ganges) and Jamuna are the two major rivers of Bangladesh which are morphologically very dynamic and active. So, construction of transmission tower over such dynamic rivers for a nationally important project needs detail investigation of the hydro-morphological condition of the rivers mentioned.

1.2 Background of the Study

Before construction of any hydraulic structure within a dynamic river like the Padma (Ganges) and the Jamuna, it is necessary to assess the response of the river due to the structure that would guide the design engineer to go for safe design. In this present case, River crossing for power transmission would be constructed within the river and anchor tower would be at the riverbanks. Designing a crossing tower is needed to consider the worst possible scenario, which may be experienced by the tower during its lifetime. So, detail comprehensive hydraulic study is pre-requisite before finalizing the design, and with this view PGCB approached IWM considering its reputation in the field of hydraulics and experience in dealing with the dynamic nature of the rivers of Bangladesh. In this regard, a formal contract agreement was signed between Power Grid Company of Bangladesh Ltd (PGCB) and Institute of Water Modelling on 06 September 2020.

PGCB is looking forward to construct one river crossing of transmission line over the Padma (Ganges) River and two river crossings of transmission lines over the Jamuna River. In addition, there is about 6 kilometers of transmission line running parallel and close to the Padma (Ganges) river just after the crossing point.

This present study, with the application of mathematical modelling of the Ganges and the Jamuna Rivers finalize the alignment of the transmission line as well as positions of the towers (and depths of the tower foundations) and provide outline hydraulic design variables of the river crossings.

1.3 Study Objectives

The objectives of the study, as per the Terms of Reference (Revised), are:

- Geological information of the area including geomorphology, geological structure, etc.
- Observations and data regarding historical channel and bank line movement/shifting for the river/ change of course of river
- Maximum design discharge, maximum velocity, scour depths, slit factor, etc., and history of flood details for mid-stream and river bank locations.

1.4 Scope of Work

The Scope of Works of the study, as per the Terms of Reference (Revised), are as follows:

1. Study area should cover at least 2 (two) kilometers in upstream and 2 (two) kilometers in downstream stream from the proposed transmission line and portion of proposed transmission line running parallel to river;
2. Collection and processing of historical data & maps, satellite images, hydrological data (water level, discharge), including the Highest Flood Level (HFL) of the rivers (within the study area) for at least past 20 years;
3. Prediction about possible future development/shifting of the rivers within the study area (forecast for at least 50 years);
4. Assessment of erosion-accretion over time and sedimentation processes of the rivers;
5. Analysis and Identification of riverbank erosion vulnerable areas;
6. Bathymetric survey shall be covered at least 0.5 kilometers in upstream and 0.5 kilometers in downstream stream from the proposed transmission line;
7. Maximum design discharge, maximum water velocity, particle size of river bed, silt factor, width of rivers at crossing locations, depth of river bed, Highest & lowest water level at tower locations, Nature of river flow (perineal or non-perineal) and seasonal variations of the river (Discharge, Velocity, depth and width);
8. Reduced Level (RL) of existing ground, highest water level and maximum scour depth for every finally proposed tower location shall be mentioned with respect to Mean Sea Level (MSL);
9. Maximum scour depth shall be calculated: i) mathematically, following IRC:78-2014 or updated guideline at each finally proposed tower location and ii) by modeling, following any standards and/or any code & practices.;
10. Ship impact loads should be provided;
11. Necessary input data required to calculate velocity attack and wave attack on the structures;
12. Chemical analysis of water samples (Sulphate content, Calcium Content, Chloride content, Total Dissolved solids in water);
13. Past observations and historical data, if available, for the area or for near other areas with soil profile, or with similar structures in the surrounding areas;
14. Effect of river crossing transmission line on nearby existing structures in the rivers.

1.5 Output of the Study

Understanding the Objectives and Scope of Works of the study, the outputs of the study are as follows:

1. Channel and bankline movement/shifting (quantitative) at and around the tentative river crossing
2. Qualitative prediction of possible future development/ shifting of the river (at and around the tentative river crossing) during the next ~20 years (forecast of 50 years is not technically feasible)
3. Maximum (design) discharge, maximum velocity, High & Low Flood Levels, seasonal variations in the river (Discharge, Velocity, Depth and Width at the river crossing location)
4. Data/information about some past high floods (1987, 1988, 1998, 2004, 2007, 2018) – flood levels and floodplain inundation at and around the tentative river crossing
5. Maximum Scour Depths at tower locations (Customarily, only the maximum scour depth is computed, and that value/level is applied for all the piers/towers because in a braided river like the Jamuna, the thalweg/channel shifting is very prominent)

6. Bathymetry, and Morphological Data (Suspended Sediment Concentration, river Bed Materials' Grain Size Distribution/Particle Size, Flow Discharge, Velocity)
7. Most suitable river crossing alignment (within 0.5km u/s to 0.5km d/s of the tentative crossing alignment)
8. Chemical analysis results for water samples: Sulphate content, Calcium Content, Chloride content, Total Dissolved solids.
9. Input data required to calculate Velocity attack and Wave attack on the structures in connection with evaluating Ship Impact Load and Water Surge Load.
10. Ship Impact Load.
11. Impact of river crossing transmission line on nearby existing structures in the river.

1.6 Structure of the Report

This document is the Final Report of the present study.

This Final Report consists of 9 (nine) chapters, as described below:

Chapter 1 Introduces the background, objective, scope of works, and expected output.
Chapter 2 Provides execution on the study area focusing the Hydro-morphological aspects of the Padma (Ganges) and the Jamuna River.
Chapter 3 Summarizes data collection with their detail analysis;
Chapter 4 Development of 2D morphological model of the Ganges and Jamuna River
Chapter 5 Provides probable hydro-morphological changes near the Crossing Location
Chapter 6 Contains assessment of scour around the Transmission Line/ Pier;
Chapter 7 Contains Ship Impact Load, Input data required to calculate Velocity attack and Wave attack;
Chapter 8 Provides study findings and recommendations;
Chapter 9 References.

This Final Report also includes four appendices:

Appendix A: Computation of Local scours and Typical Transmission Tower Foundation Layout
Appendix B: Terms of Reference (ToR)
Appendix C: Wind Speed Data
Appendix D: Response on DFR

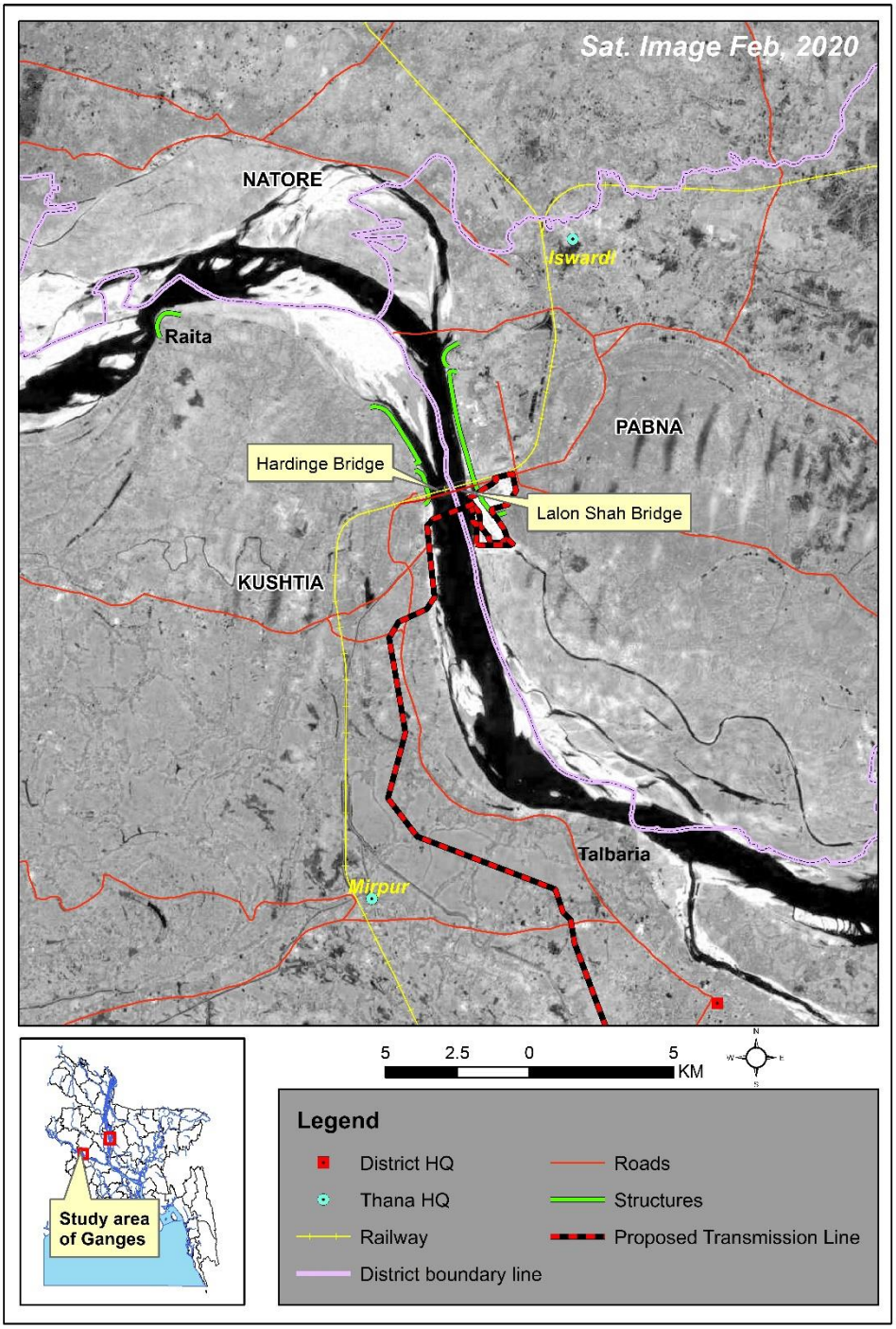


Figure 1.1 *The Proposed Crossing location on the Padma (Ganges) River*

Note:

1 *As per the ToR, the proposed transmission line near Rooppur Powerplant is located on Padma River. The local name of this river is Padma. However, according to Bangladesher Nod Nodi, (BWDB, 2005 and 2011), the river name is Ganges. So, the river name is written as Ganges River instead of Padma River in this report.*

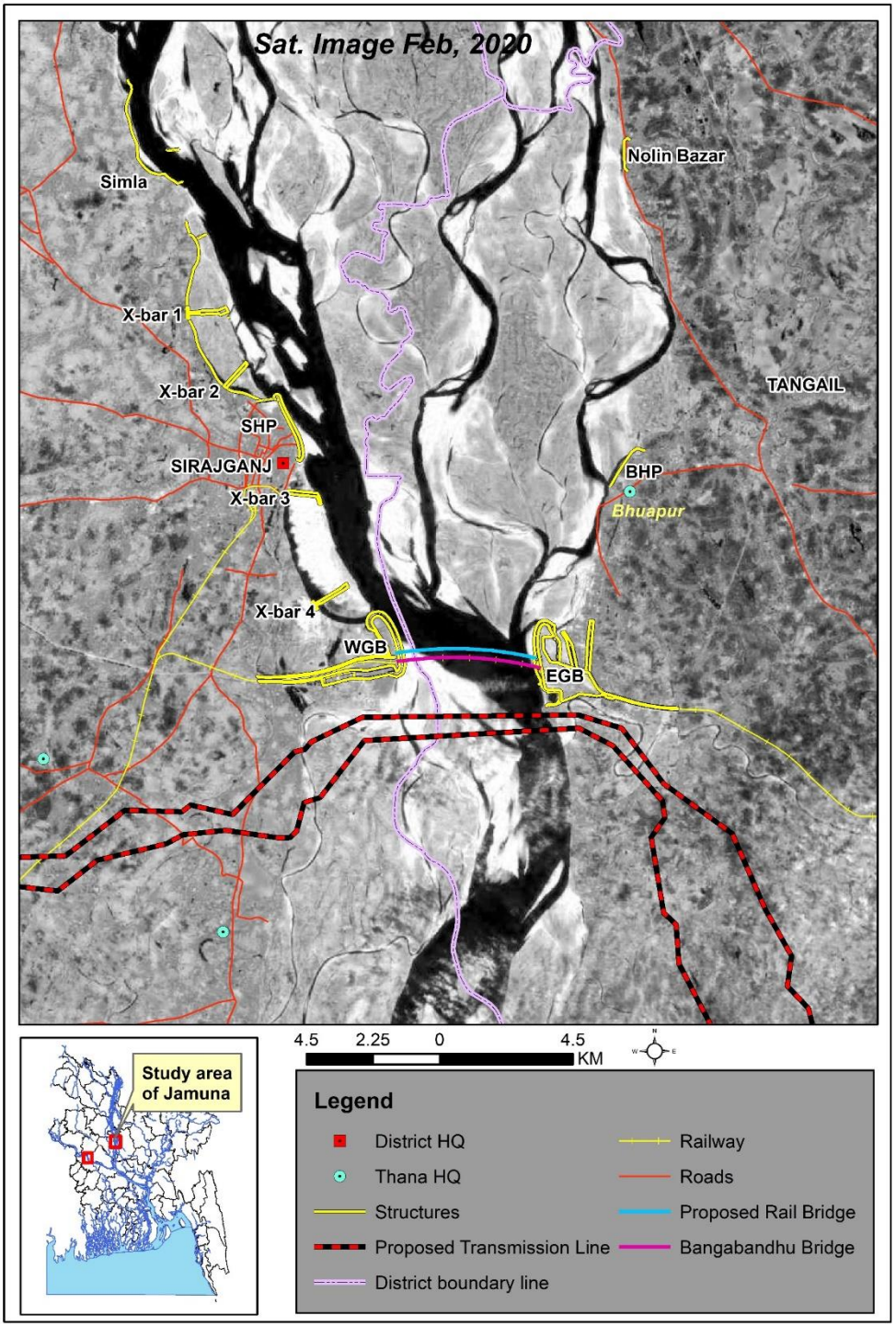


Figure 1.2 *The Proposed two Crossings location on the Jamuna River*

2. EXECUTION OF THE STUDY

2. EXECUTION OF THE STUDY

2.1 Description of the Study Area

The study area covers two major rivers, the Ganges and the Jamuna. Since the key approach of this present study is the use of mathematical modelling, 30 km of the Jamuna and the Ganges have been considered for model development and detail hydro-morphological investigation is limited to this domain of the rivers.

2.1.1 The Ganges-Padma River System

The Ganges-Padma is one of the major rivers in Bangladesh. It has a length of approximately 2,200 km from its source in the Himalayas in Nepal to its confluence with the Jamuna River in Bangladesh. The lowermost reach of the Ganges at the downstream from the Farakka Barrage to the Jamuna confluence at Aricha, is referred to here as the Ganges River, **Figure 2.1**. Locally, the river in this reach is known as a part of the Padma River. In fact, the Padma River can be divided into two distinct reaches, which are hydrologically and morphologically quite different from each other. The upstream reach is from the Farakka Barrage to Aricha. The downstream reach extends from Aricha to Chandpur and carries the combined flow of the Ganges and Jamuna rivers. In technical literature, the upstream reach is generally referred to as the Ganges River to distinguish it from the much larger Padma River at the downstream.

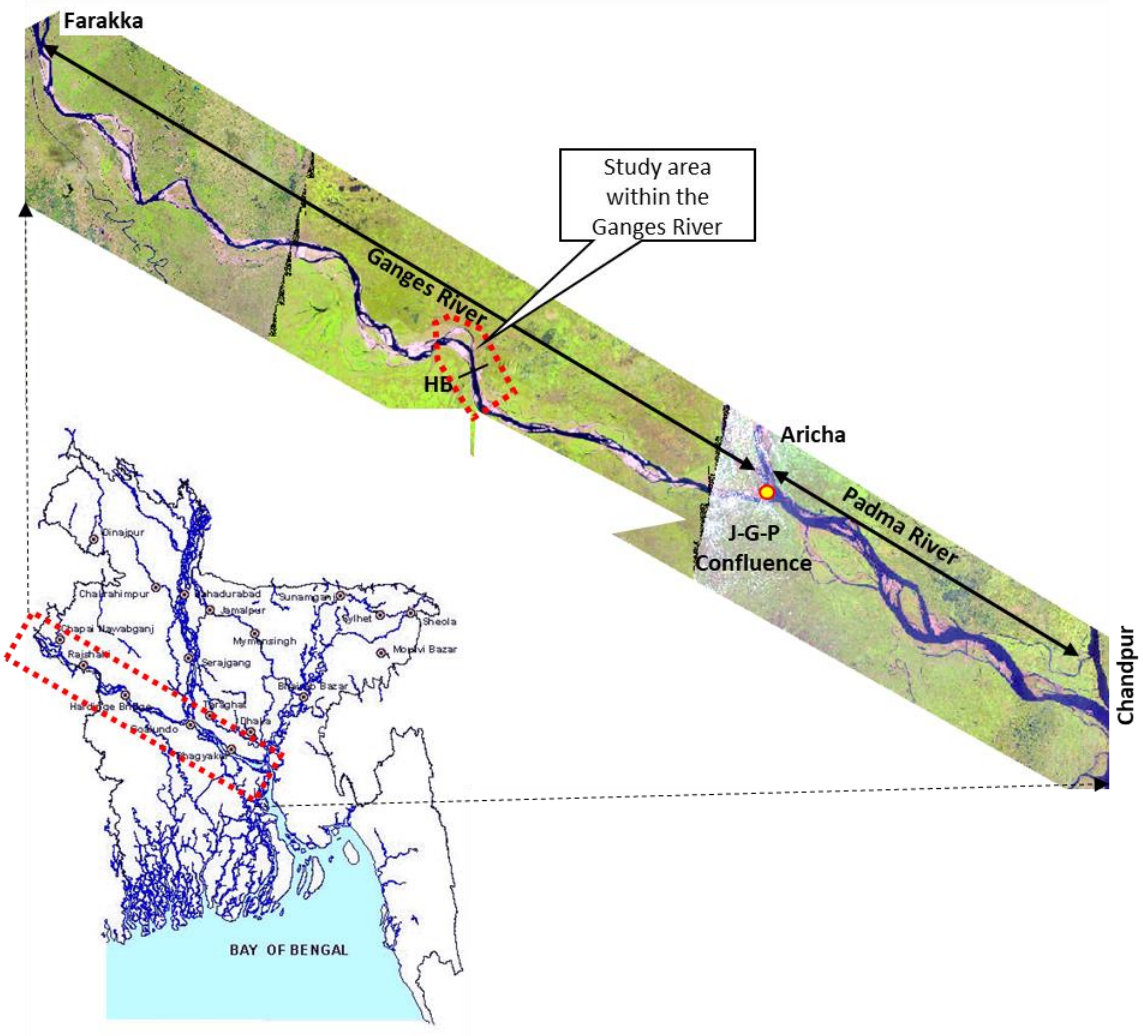


Figure 2.1 *Extent of Ganges-Padma River System of Bangladesh*

2.1.2 The Brahmaputra-Jamuna River System

The Brahmaputra-Jamuna river system is one of the renowned river systems in the world. In its origin from Tibet, it is called Tsangpo River where it flows towards east and then turn right side and enters North-East Region of India. Inside India, the river is named as the Brahmaputra and flowing over relative flat terrain and passing through Assam, it finally enters Bangladesh at Noonkhawa. Within Bangladesh, the Brahmaputra is called Jamuna after it crosses the Old Brahmaputra offtake at Kholabarirchar of Jamalpur district. Following southward direction, the Jamuna river merges with the Ganges at Aricha to form the Padma river on the way to fall into the Bay of Bengal along with the Meghna River. **Figure 2.2** shows the entire Brahmaputra-Jamuna river in Bangladesh.

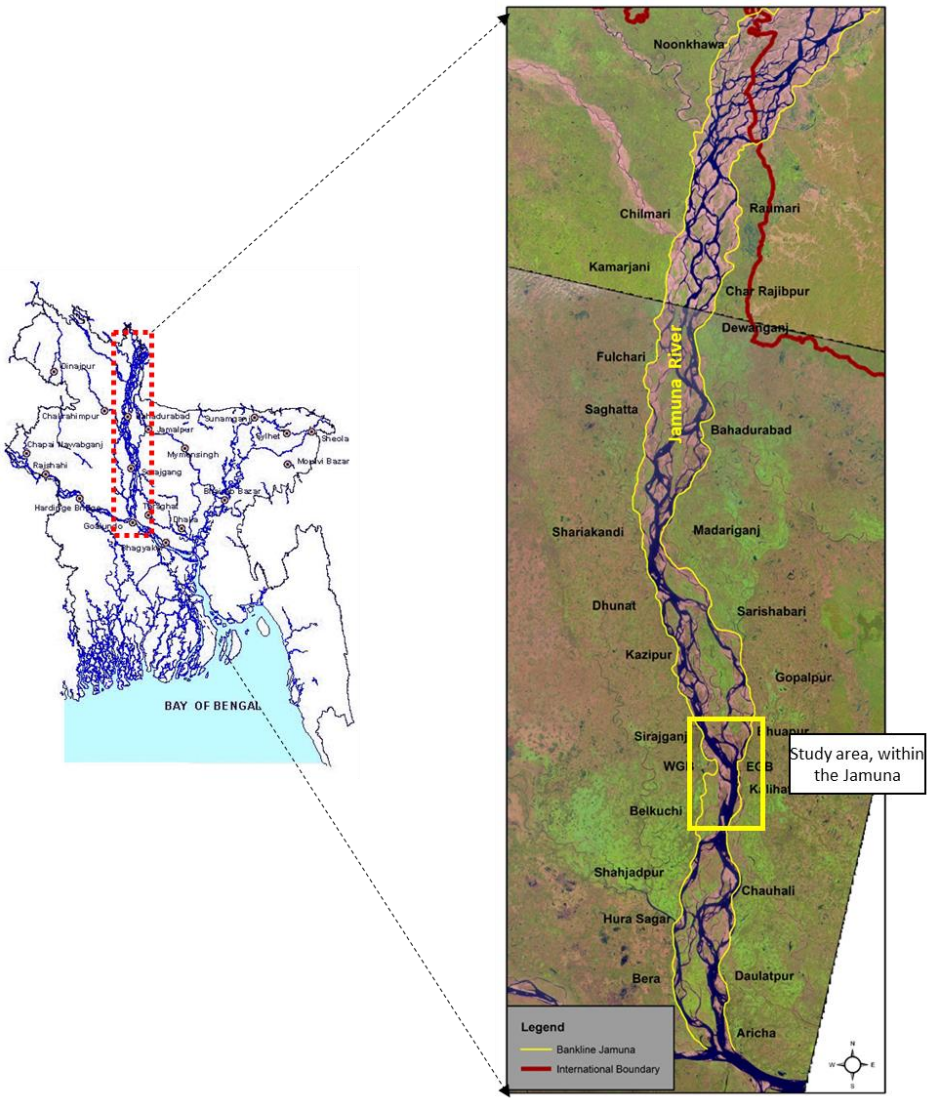


Figure 2.2 *Extent of Brahmaputra-Jamuna River System of Bangladesh*

2.1.3 Historical Development of Ganges and Brahmaputra-Jamuna River

Ganges River

The Ganges is one of the largest river systems in the world. It rises south of the main Himalayan and divides near Gangotri (elevation 4500 m) in Uttar Pradesh, India. On its way towards the sea, numerous tributaries join the Ganges River from India and Nepal. The river divides into two channels below Farakka. The right arm continues to flow south in

West Bengal as the Bhagirathi-Hooghly on which Calcutta Port is situated. The left main arm enters Bangladesh 18 km below Farakka and joins the Brahmaputra River at Goalundo. In Bangladesh, the Gorai River is the main distributary which leaves the Ganges River about 65 km above the confluence of the Ganges and Brahmaputra Rivers. The total catchment area of Ganges is about 1087300 Km^2 and only 46300 Km^2 lies within the Bangladesh (**Table 2.1**).

Brahmaputra-Jamuna River

The Brahmaputra, the largest river in Bangladesh, originates at the snout of a glacier in the Kailas Range of the Himalayas, south of the Gunkyud Lake in southwestern Tibet. The river rises at an elevation of about 5300 m (Goswami, 1998) and then flows 1100 km eastward across the Tibetan Plateau as Tsangpo River, before turning south to cross the east-west trending ranges of the Himalayas. The ranges crossed include the Greater Himalaya (average elevation 6000 m), Middle Himalayas (average elevation 3000-5000 m) and the Sub-Himalayas (average elevation 1000-2000 m). The river breaks through these ranges via a series of deep, narrow gorges before entering the Valley of Assam in India. After travelling 700 km in a southwesterly direction in the Assam valley, the river turns south again to enter Bangladesh. Inside Bangladesh (ref. Noor et al 2014), the Brahmaputra river covers 240 km from Noonkhawa to Aricha where the existing Bangabandhu Bridge is located at around 160 km chainage started from Noonkhawa.The total catchment area of Brahmaputra is about 552000 Km^2 and only 39100 Km^2 lies within the Bangladesh, **Table 2.1**.

Figure 2.3 shows the catchment area of Ganges-Padma and Brahmaputra-Jamuna River.

Table 2.1 Catchment areas of major rivers of Bangladesh (Source: IWM, 2011)

River Basin	Total catchment area (km^2)	Catchment area (km^2)				
		India	Nepal	Bhutan	China	Bangladesh
Brahmaputra-Jamuna	552000	195000	-	47000	270900	39100
Ganges	1087300	860000	147480	-	33520	46300
Meghna	82000	47000	-	-	-	35000
	1721300 (100%)	1102000 (64.02%)	147480 (8.57%)	47000 (2.73%)	304420 (17.69%)	120400 (7%)

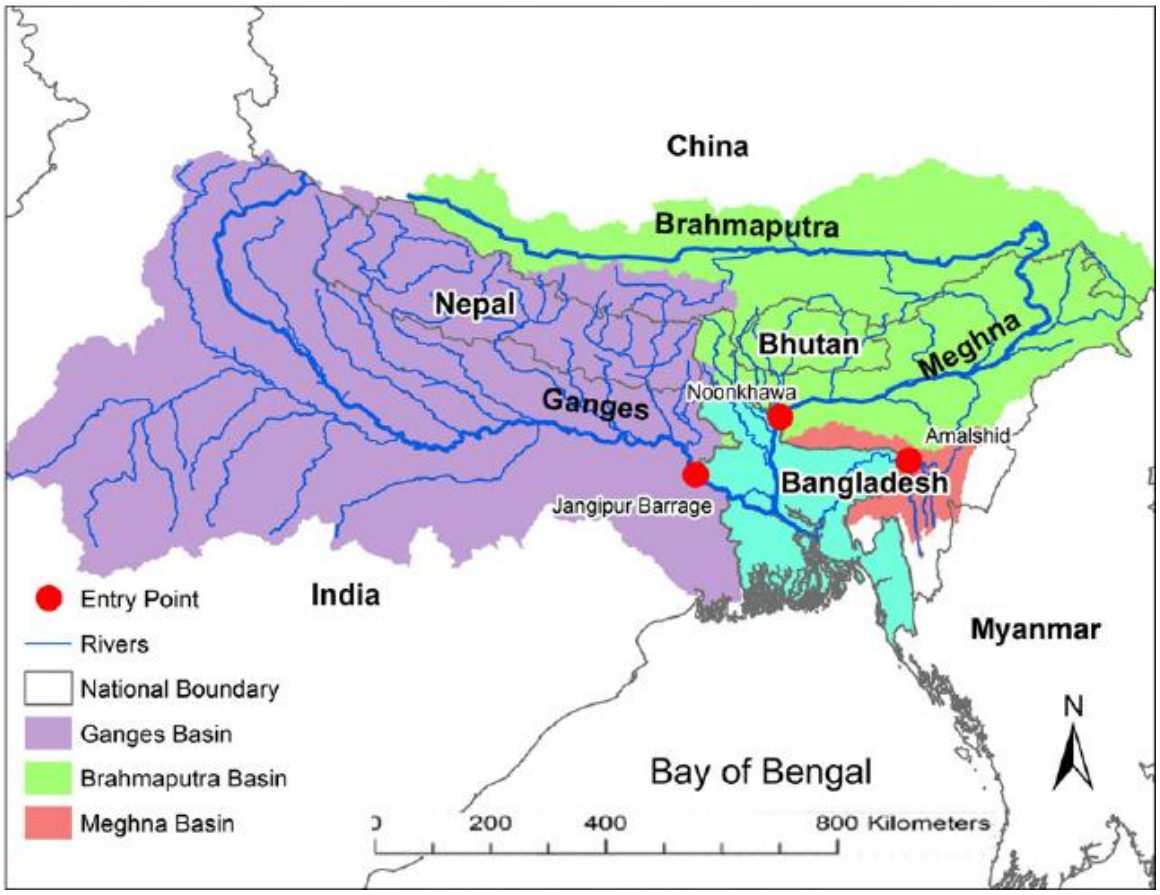


Figure 2.3 *The Ganges-Brahmaputra-Meghna River Basin of South Asia*

2.2 Location of the Study Area

Ganges River

The proposed tentative transmission line over Ganges River is located at approximately 1 km d/s from Hardinge Bridge location. In order to carry out the mathematical modelling study of Ganges River, a study area has been selected from 18km u/s of Hardinge Bridge to 12km d/s of the bridge location, shown with yellow line in **Figure 2.4** (right). The study area starts from Lalpur Upzilla at Natore district along left bank and Bheramara Upzilla at Kushtia district along right bank and ends at Ishwardi Upzilla, Pabna district. Within the study area, most of the time the channel persists along the left bank near Natore bend to the right bank up to Gorai offtake (blue color, shown in **Figure 2.4**, left).

Significant Features near the Study Area of Ganges River

There are some significant features within the study area of Ganges River. Hardinge Bridge (Rail bridge) and Lalon Shah Road Bridge are two of the most important existing structures in this location. Both the bridges are approximately 1.8 km in length. There is another existing transmission line at 3.5 km u/s of Hardinge Bridge (HB) location. At 1.9km d/s of HB, the mouth of canal of Ganges-Kobadak Irrigation Project (known as G-K project) along the right bank is situated. Two powerplants are also present within the study area, one is along the right bank named Bheramara 410 MW Combined Cycle Power Plant and another one is under-construction Rooppur Nuclear Power Plant along the left bank.

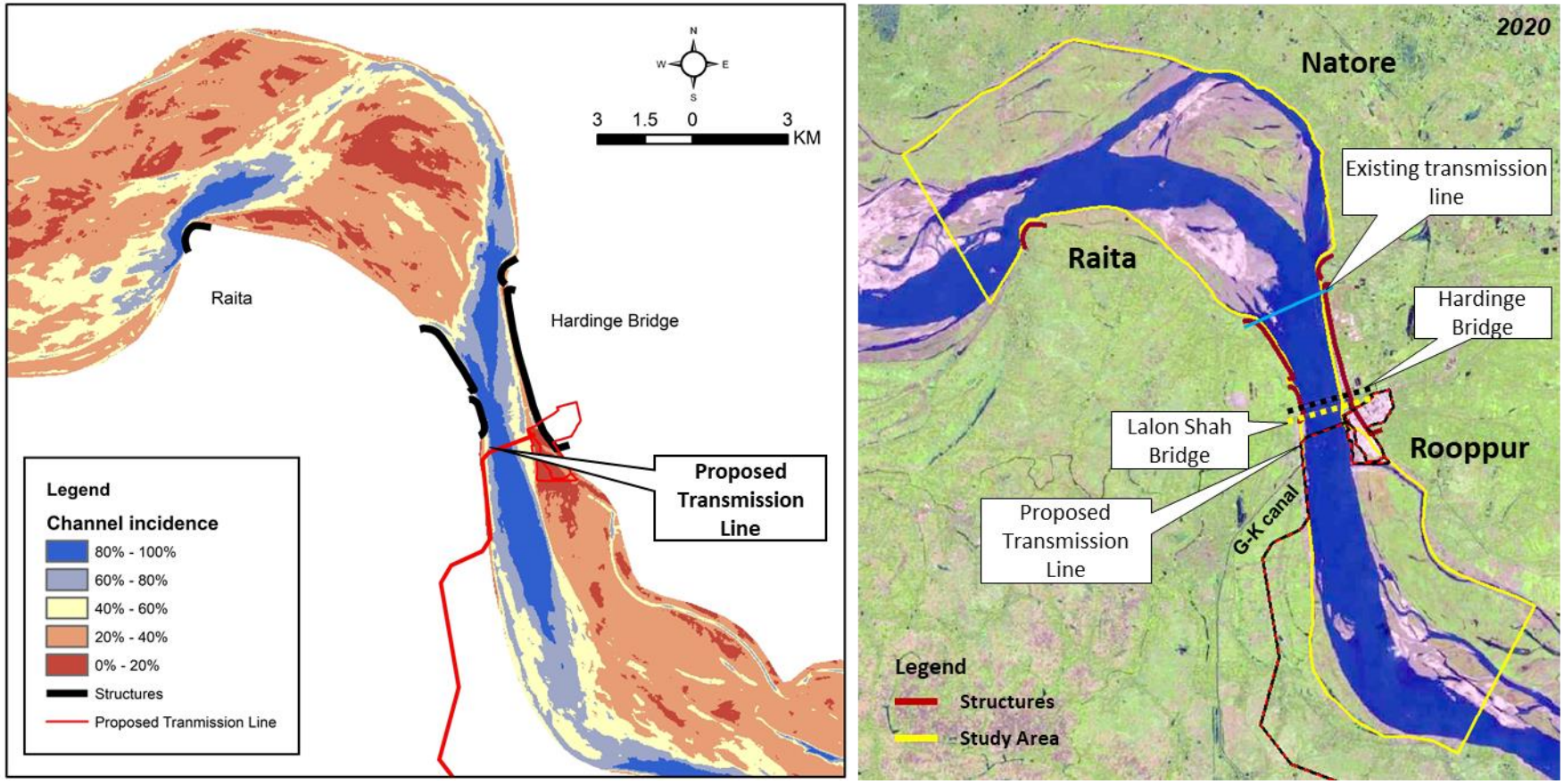


Figure 2.4 *Channel incidence map of Ganges River (left) and location of study area in Ganges River (right)*

Jamuna River

The proposed two tentative transmission line over Jamuna River is located almost 2km and 2.6km d/s from Bangabandhu Bridge location, shown in **Figure 2.5**. In this regard, a study area has been selected (blue line in **Figure 2.5**, right) to carry out the mathematical modelling of Jamuna River to observe the response of the river. The study reach lies within the districts of Sirajganj and Tangail from E465800m to E471800m and N688100m to N718000m (BTM coordinate) and covers about 30km reach of the Jamuna River (20km upstream and 10km downstream of Bangabandhu Bridge). The channel incidence map that has been prepared by superimposing the satellite image from 1973-2019, suggests that channel near the EGB persists more (80-100%) than the channel along the WGB (60-80%). However, recent satellite image reflects the presence of vegetative land along the right side of the proposed transmission lines.

Significant Features near the Study Area of Jamuna River

The river training works on the Jamuna River in connection with Bangabandhu Bridge are East Guide Bunds, West Guide Bund, Bhuapur Hard Point and Sirajganj Hard Point. Among the RTWs first three are under Bangladesh Bridge Authority (BBA) and the fourth one is under Bangladesh Water Development Board (BWDB) constructed under FAP1. The following are the lengths of Bangabandhu Bridge River Training Works:

Length of East Guide Bund	: 3100 m
Length of West Guide Bund	: 3260 m
Length of Sirajganj Hard Point	: 2550 m
Length of Bhuapur Hard Point	: 1700 m

Hydraulic design parameters of guide bunds

The following hydraulic and morphological design parameters were used for design of guide bund (Rendel Palmer & Triton, NEDECO, BCL, Design Report-Volume II, May 1990).

Design High Water level	:	+15.00 mPWD
Standard High water Level	:	+12.90 mPWD
Standard Low Water Level	:	+ 6.20 mPWD
Design Velocity	:	3.30 m/sec
Design Wave Height	:	1.00 m
Design Scour Depth	:	45.00 m
Design Scour Level	:	- 30.00 mPWD

In 2011 BWDB undertook dredging at two locations of the Jamuna stretching from Sirajganj Hard Point to WGB and along left bank near Nalin Bazar covering different lengths during different periods from 2011 to 2013. Main purpose of the dredging was to divert the flow from the right bank to save Sirajganj and West Guide Bund (WGB) and Nalin Bazar Road. Dredged spoil from these dredging works were utilized to build cross bars along right banks of the Jamuna from immediate upstream of Sirajganj Hard Point to immediate upstream of WGB and near Nalin Bazar. Within this period, BWDB constructed four numbers of cross-bars. Dredging associated with the construction of cross-bars in the vicinity of the bridge area has certainly brought changes in the regime within the period from 2011 to 2013. During monsoon 2014, some part at the head of cross-bar 3 and toe of cross-bar 4 were washed out. Afterwards, the damaged parts were rehabilitated by BWDB in 2015 and made those permanent. Hence, construction of those cross-bars are playing a vital role to keep the main channel away from the right bank.

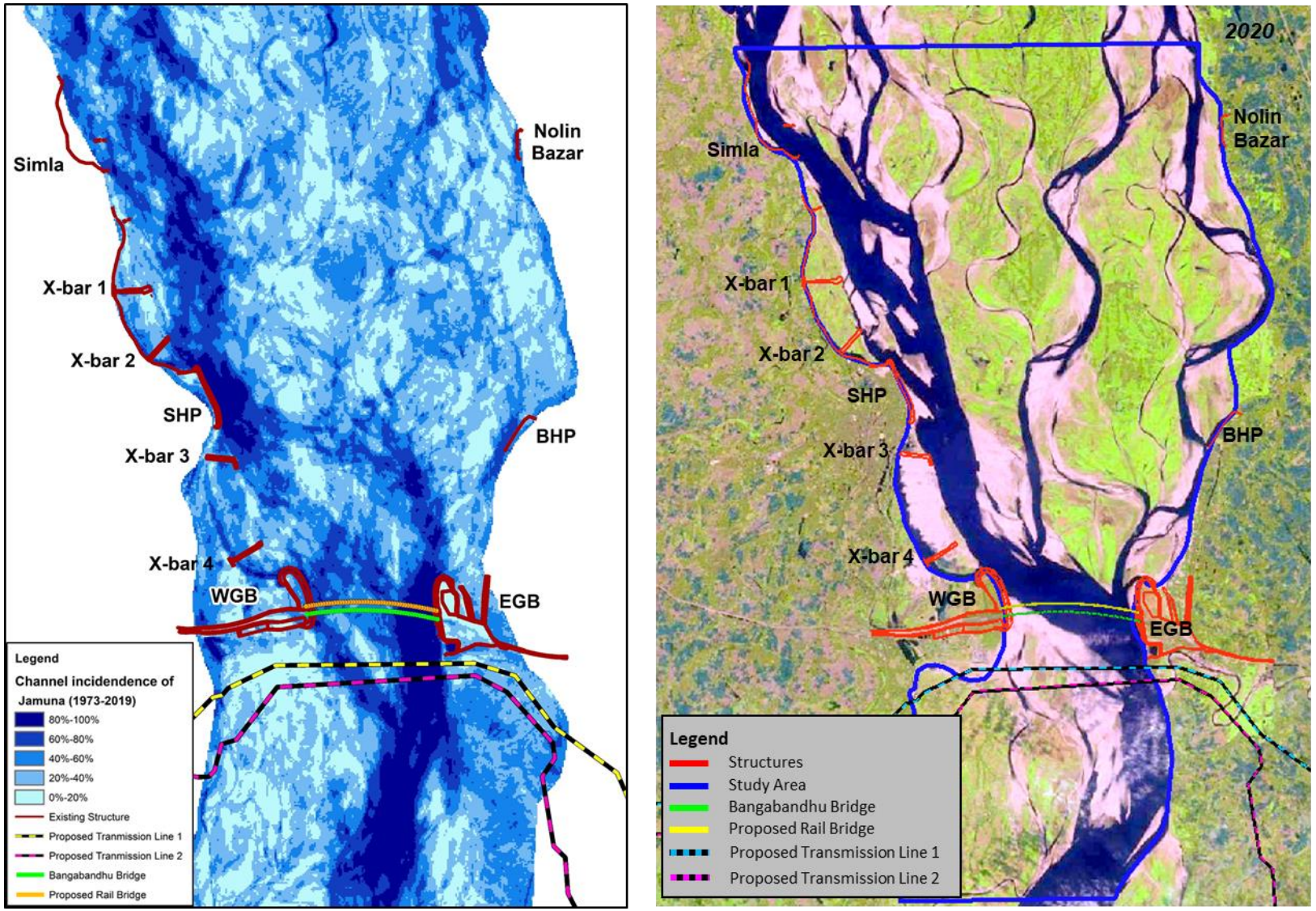


Figure 2.5 *Channel incidence map of Jamuna River (left) and location of study area in Jamuna River (right)*

2.3 Hydro-morphological Features of the Ganges River

The Ganges River has few numbers of distributary channels flowing towards south-east direction such as Gorai, Chandana, Hisna etc. Among these, only Gorai river now carries significant flow from the Ganges during monsoon.

The average flood discharge of the Ganges is approximately 50,000 m^3/s. The calculated dominant discharge and bankfull discharge is found about 42000 m^3/s (IWM, 2017a). The mean annual discharge is around 11000 m^3/s (FAP 24, 1996a and IWM, 2017a). The discharge is mainly contributed by the snowmelt of the Himalayas and monsoon rainfall. In general, the flood peak occurs between the end of August and early September. The bed material of the river consists of fine sand. The grain size diameter of Ganges River near Hardinge Bridge is found 0.15mm (IWM, 2017). The river is very dynamic and the channel of the river shifts between meandering and braided. The average water surface slope of Ganges is found 5 cm/km (FAP 24, 1996a).

Before mid-1970s the river flowed without any major intervention along its course. Through the implementation of the Farakka Barrage in 1975, India started to divert a part of dry season flow of the Ganges River through the Hoogly River. During the post-Farakka period major changes have occurred in the dry season flow, especially between January and May. During the pre-Farakka period the minimum yearly average flow was 1,500 m^3/s, which reduced nearly 600 m^3/s in post-Farakka period, **Figure 2.6**. The recorded minimum monthly average flow was 182 m^3/s in March 1997. Historical daily discharge and water level of Ganges at Hardinge bridge are shown in **Figure 2.7** and **Figure 2.8**.

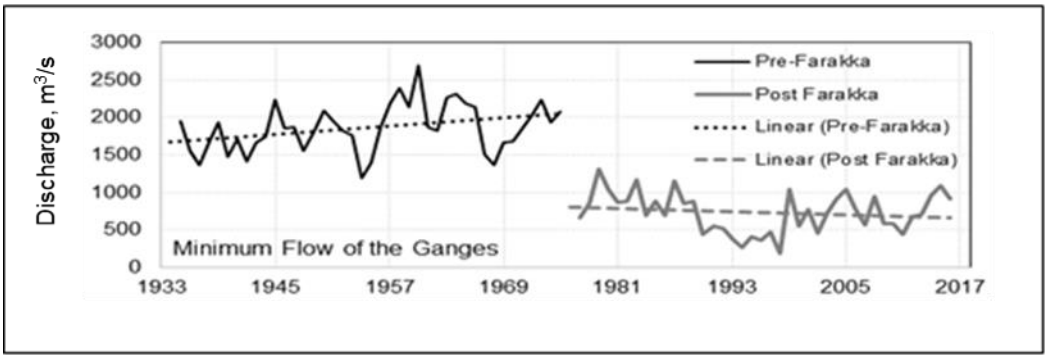


Figure 2.6 *Minimum flow of the Ganges during pre- and post-Farakka barrage operation*

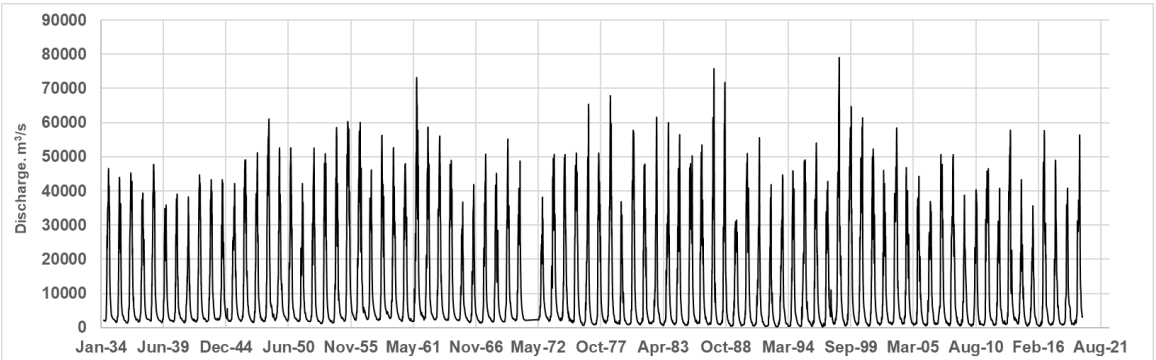


Figure 2.7 *Historical Daily Discharge of Ganges River at Hardinge Bridge from 1934 to 2019*

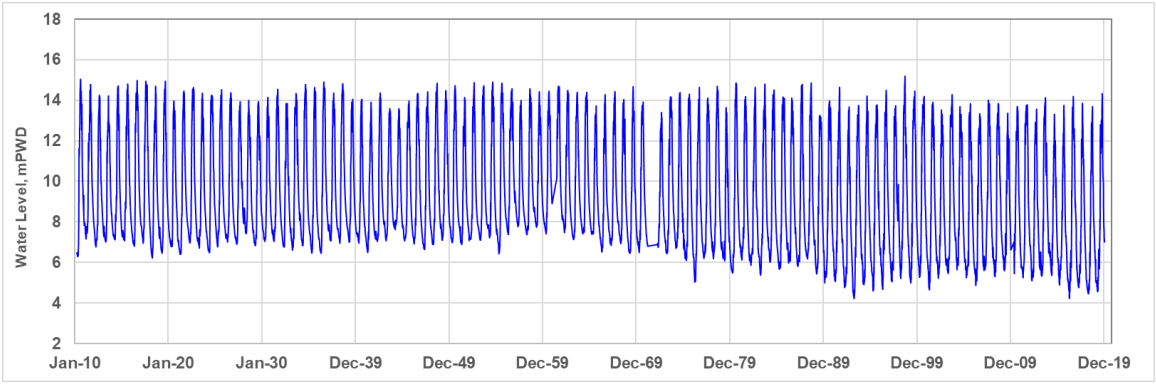


Figure 2.8 *Historical Daily Water Level of Ganges River at Hardinge Bridge from 1910 to 2019*

2.4 Hydro-morphological Features of the Jamuna River

The Jamuna River has some major tributaries as well as distributaries flowing towards the south direction. Teesta, Dharla, Dudhkumar are some major tributaries and Old Brahmaputra, Dhaleswari are the major distributaries of Jamuna River.

The calculated dominant discharge of Jamuna is found about 45000 m^3/s (IWM, 2020). The mean annual discharge is around 20000 m^3/s (FAP 24, 1996a, IWM 2019). In Jamuna River, peak discharge generally occurs between July and September and the lowest discharge is observed in February-March of a year. The discharge of the Jamuna River shows significant seasonal variation with snowmelt in the Himalayas accounting for the sources of flow, whilst rainfall in Assam and Bangladesh contributes significantly. The daily discharge hydrographs of the Jamuna River at Bahadurabad station from 1962 to 2019 is shown in **Figure 2.9**. The available daily water level hydrographs from 1962-2019 at Bahadurabad station is also shown in **Figure 2.10**.

The Jamuna River carries a heavy sediment load, estimated to be over 650 million tonnes annually (FAP 24, 1996b). However, in recent decade this annual sediment load decreases around 273 million tonnes (YREC, 2019). Most of this is in the silt size class (suspended load) but around 15 to 25 percent is sand (bed load). This sand is deposited along the course of the river and the clay fraction is transported to the delta region. The banks of the Jamuna River consist of fine cohesion less silty sand. For the Jamuna River the angle of internal friction is approximately 30° (IWM, 2019). It is, however, dependent on the mica contents. Because of the varying location of the river branches, much of the sediment has been eroded and accreted many times. The sand size sediment is relatively uniformly graded. The range of d_{50} values vary between 0.23 mm and 0.17 mm (FAP 24, 1996c).

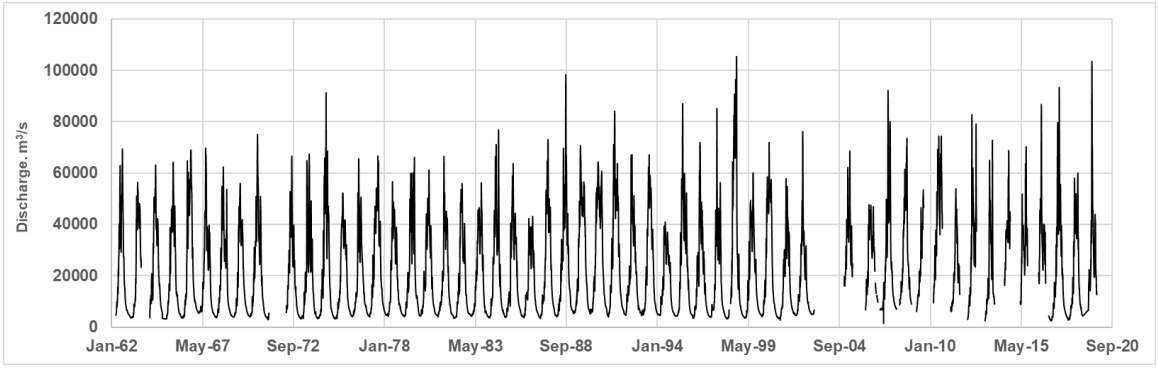


Figure 2.9 *Historical Daily Discharge of Jamuna River at Bahadurabad from 1962 to 2019*

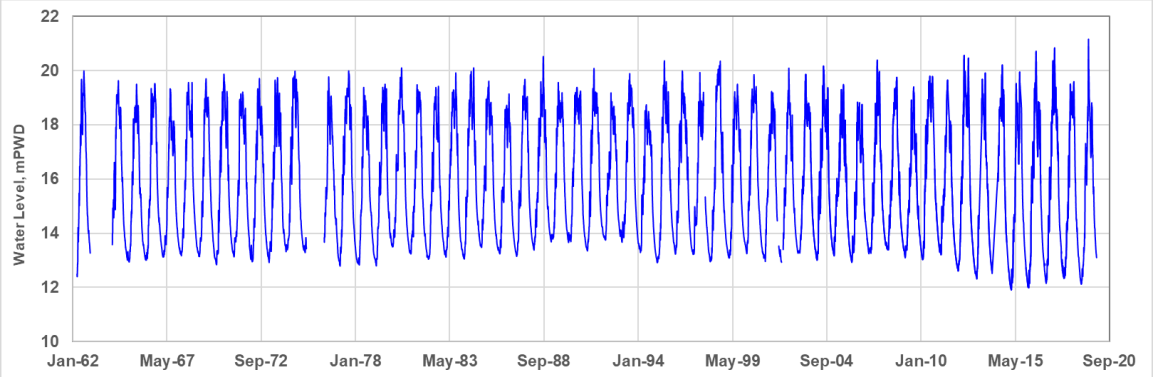


Figure 2.10 *Historical Daily Water Level of Jamuna River at Bahadurabad from 1962 to 2019*

2.5 Site Selection of Transmission Line

Ganges River

From Rooppur Powerplant, one transmission line will be crossed over the Ganges River. These single crossing line over the Ganges River named as Rooppur-Gopalganj 400KV Transmission Line, which will start from Rooppur Nuclear Powerplant territory and crosses over Kushtia, Rajbari, Faridpur and ended at Muksupur upzilla of Gopalganj district (**Figure 2.11)**. The proposed transmission line will be constructed at about 950 m downstream of Hardinge Bridge, **Figure 2.12** (left). As the Rooppur Powerplant is located along this area, there is no any other option for this transmission line to shift. In this regard, the morphological adverse impact of this crossing line is provided for the design of the transmission tower.

Jamuna River

In case of the Jamuna River, two transmission line will be crossed. These two crossing lines over the Jamuna River named as “Rooppur Nuclear Power Plant to Dhaka Double Circuit 400kV TL” as Transmission Line 1 and “Rooppur to Dhamrai SS Double Circuit 230kV TL” as Transmission Line 2. Both the transmission lines are started at Rooppur Nuclear Power Plant and ended at Dhamrai upzilla of Dhaka district. As downstream of Bangabandhu Bridge is the narrowest point of the Jamuna River as well as flow is moving in a controlled way, this site is chosen for these two transmission lines. The proposed transmission line 1 and 2 will be constructed at about 2km and 2.6km d/s of Bangabandhu Bridge, respectively, shown in **Figure 2.12,** right.

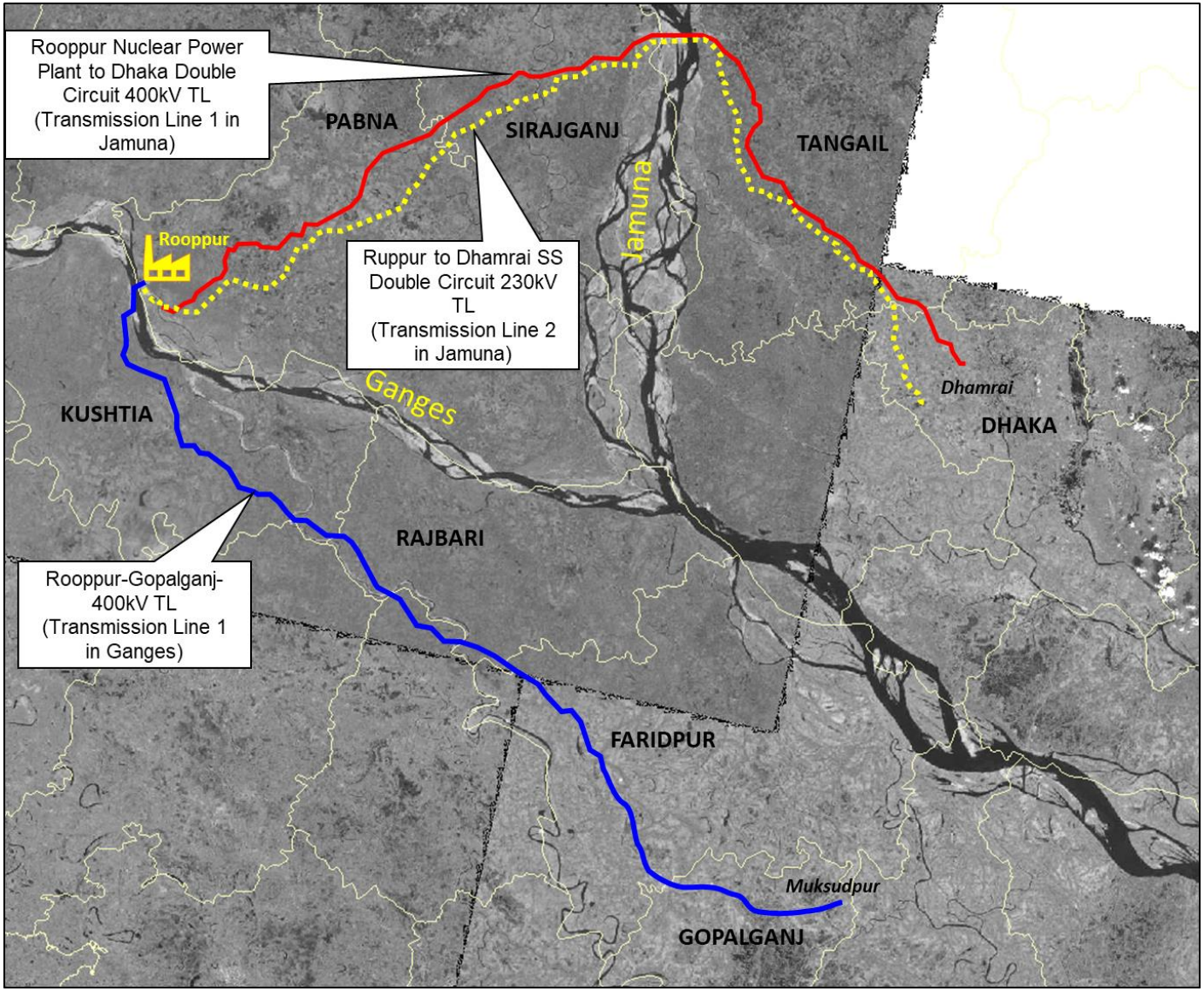


Figure 2.11 *Route Map of Proposed Transmission Lines started from Rooppur Powerplant*

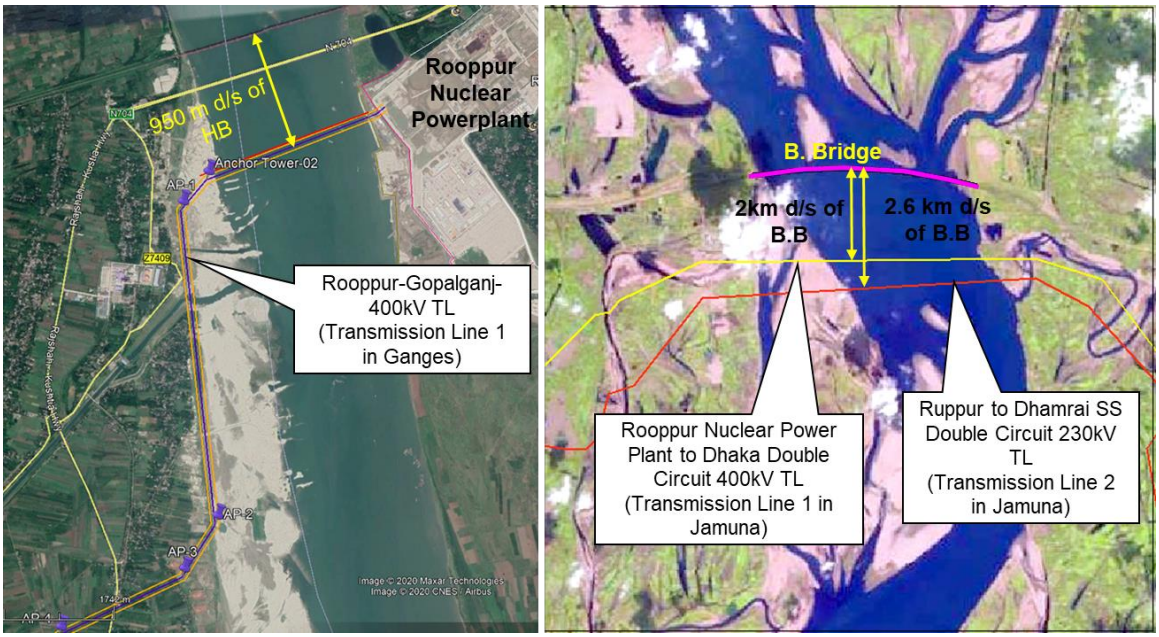


Figure 2.12 *Locations of Proposed Transmission Lines in Ganges (left) and Jamuna (right) River*

Transmission Pier/ Tower Position

The position of transmission towers for both the rivers are given in tabular form (**Table 2.2** and **Table 2.3**). The locations are also shown in **Figure 2.13** and **2.14**.

Table 2.2 Transmission Tower Position for Ganges River

Transmission Line	Anchor	Chainage from Left Bank, m	X_UTM	Y_UTM	Bed Level (mPWD)	Bed Level (MSL)
TL-1 (Ganges)	1	90	707154.7	2662562	13.05	12.59
	2	540.28	706736.7	2662394	-0.15	-0.61
	3	1097.73	706219.2	2662187	0.22	-0.24
	4	1534.76	705813.5	2662025	6.52	6.06

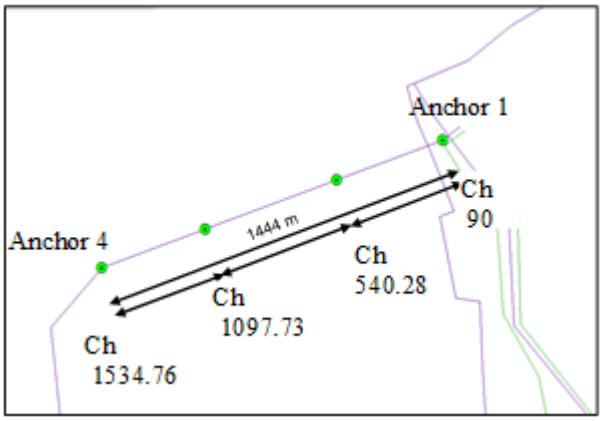


Figure 2.13 *Position of Proposed Transmission Pier/ tower in Ganges River*

Table 2.3 Transmission Tower Position for Jamuna River

Transmission Line	Anchor	Chainage from Right Bank, m	X_UTM	Y_UTM	Bed Level (mPWD)	Bed Level (MSL)
TL-1 (Jamuna)	1	0	778164.5	2699234	12.69	12.23
	2	400.39	778564.7	2699246	11.63	11.17
	3	1242.79	779406.7	2699272	9.50	9.04
	4	2090.21	780253.8	2699298	12.29	11.83
	5	2920.84	781084	2699323	6.71	6.25
	6	3746.62	781909.4	2699348	4.98	4.52
	7	4575.5	782737.9	2699374	5.23	4.77
	8	5324.61	783486.7	2699397	4.43	3.97
	9	6101.2	784262.9	2699420	-5.94	-6.40
	10	6853.32	785014.7	2699443	Main land	Main land
	11	7264.02	785425.2	2699456	Main land	Main land
TL-2 (Jamuna)	1	0	778217	2698441	12.16	11.70
	2	353.69	778569.5	2698470	12.37	11.91
	3	1128.83	779342.2	2698531	11.77	11.31
	4	1961.5	780172.2	2698597	10.68	10.22
	5	2804.8	781012.9	2698665	12.81	12.35
	6	3679.93	781885.2	2698734	5.64	5.18
	7	4499.42	782702.1	2698799	7.92	7.46
	8	5311.52	783511.6	2698864	7.15	6.69
	9	6118.7	784316.3	2698928	-15.09	-15.55
	10	6863.77	785059	2698987	Main land	Main land
	11	7263.89	785457.8	2699019	Main land	Main land

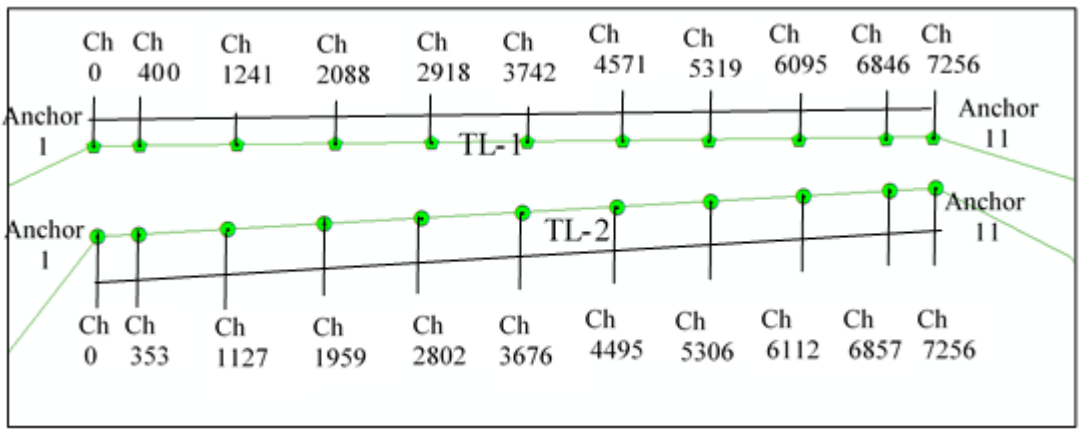


Figure 2.14 *Position of Proposed Transmission Piers/ towers in Jamuna River*

Existing Cross-section at Transmission Line

The surveyed cross-section along the transmission lines over the Ganges and Jamuna River are presented in **Figure 2.15** to **2.17**.

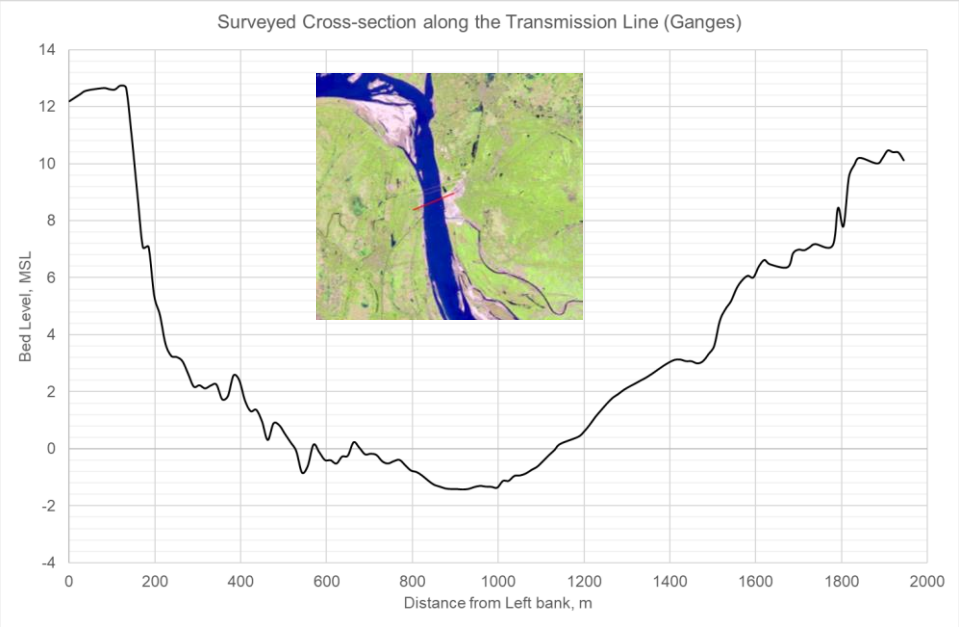


Figure 2.15 *Surveyed Cross-section along the proposed Transmission line on the Ganges River*

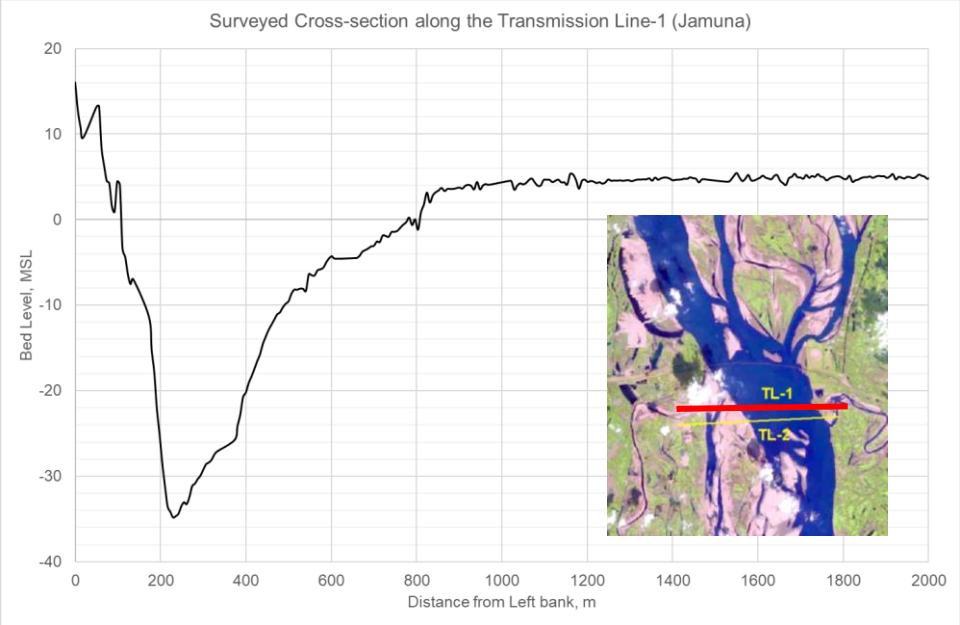


Figure 2.16 *Surveyed Cross-section along the proposed Transmission line -1 on the Jamuna River*

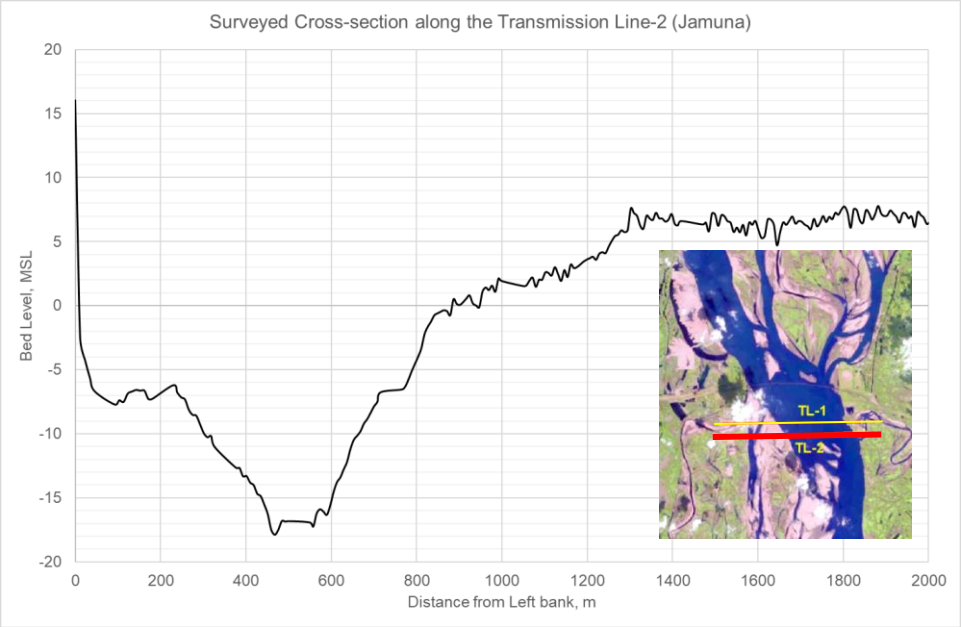


Figure 2.17 *Surveyed Cross-section along the proposed Transmission line -2 on the Jamuna River*

Feasible location for 3 new Transmission Lines parallel of the Ganges River

There are 3 more proposed transmission lines at the left bank (Rooppur power plant side) to the downstream of Hardinge Bridge, running 2-3km parallel of the Ganges River, shown in **Figure 2.18**. These are:

1. Rooppur-Aminbazar 400kV Transmission line, approximately 910m d/s from Hardinge Bridge,
2. Rooppur-Dhamrai 230kV Transmission line, approximately 1070m d/s from Hardinge Bridge, and
3. Rooppur-Baghabari 230kV Transmission line, approximately 1100m d/s from Hardinge Bridge.

These transmission lines are located within the river boundary of Ganges River. The satellite image of 1973, 1978 and 1980 show that there was an existence of river at the proposed sites for these 3 transmission lines, **Figure 2.19**. Construction of these transmission lines parallel of the river, needs extra precaution otherwise piers should be design considering the maximum scour of the river.

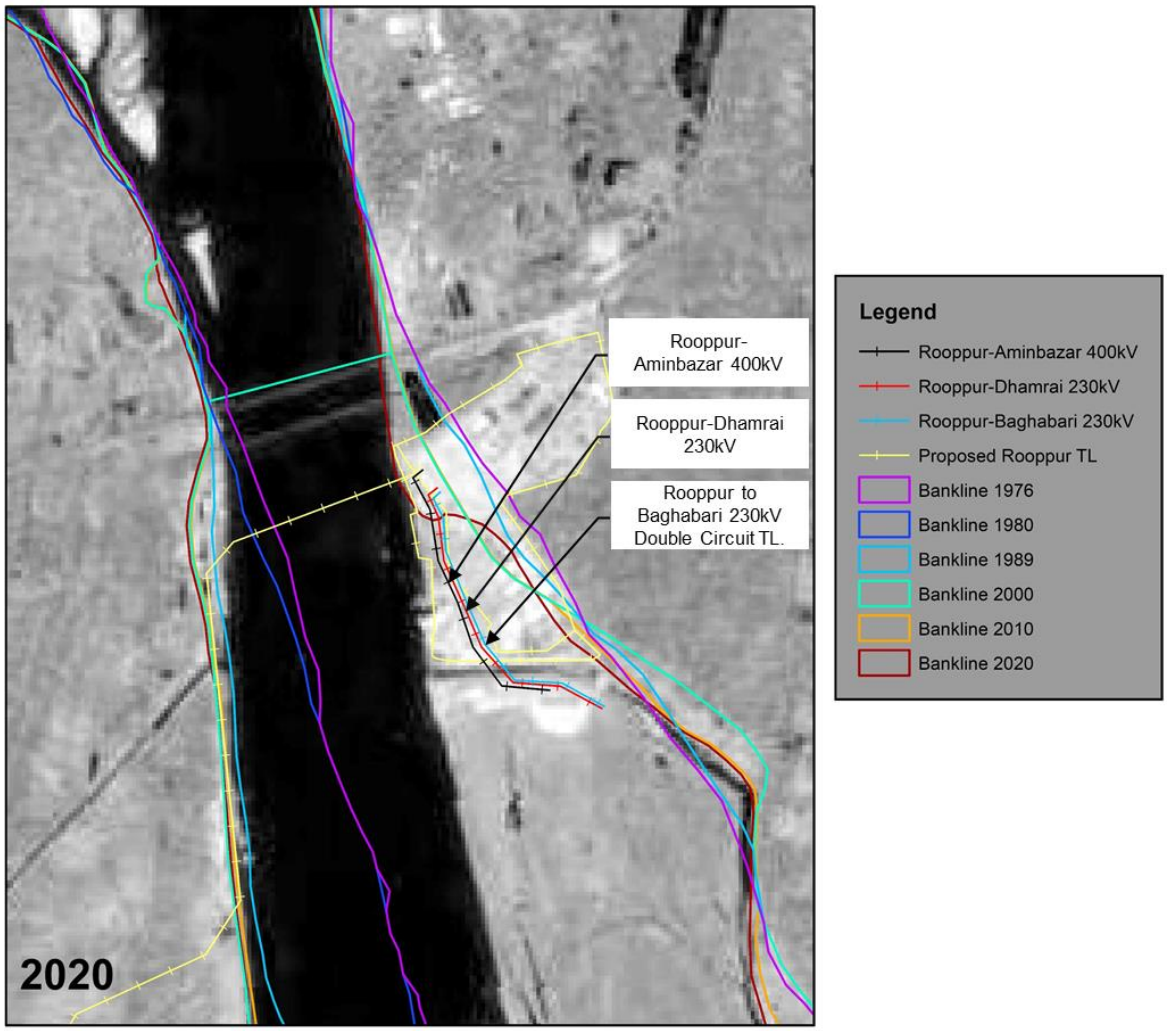


Figure 2.18 *Location of three new transmission lines parallel of the Ganges River*

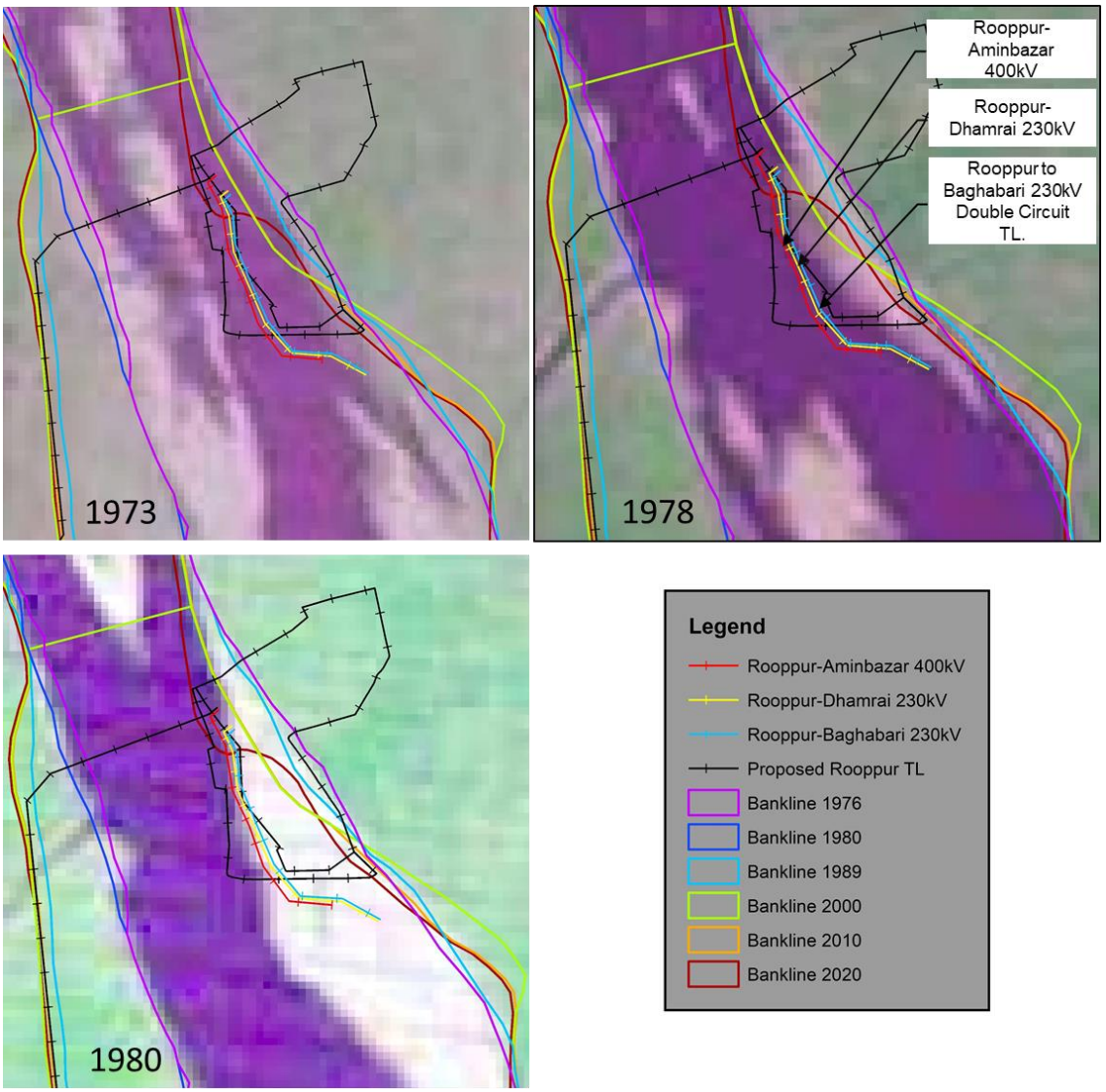


Figure 2.19 *Location of three new transmission lines parallel of the Ganges River on different satellite images*

2.6 Study Approach and Methodology

The main goal of the study is to finalize the suitable crossing alignment and position of the anchor towers/piers. In addition, outline hydraulic design variables of the crossing towers is also provided. To achieve that, following approach and methodology has been followed.

Compilation and Analysis of Available Data and Information

In order to develop fair understanding of the problems/ issues concerned of the study area, collection and analysis of available data, information and satellite imagery are one of the important tasks of the study. Relevant hydrometric and hydrographic data, satellite images and other information have been collected from different organizations and sources. The data, which have been collected from various sources, are:

- Discharge, water level and sediment data, source: IWM, BWDB
- Satellite images, source: IWM, USGS
- Bankline data, source: IWM, USGS
- Cross-section data, source: IWM, BWDB

Review of Relevant Past Study Reports

The study reports having relevance to the study area have been reviewed. Among these, FAP studies, previous IWM studies on the study area have been reviewed and noted to develop the knowledge on the Jamuna and Ganges River and adjacent areas.

Field Visit, Reconnaissance Survey and Consultation with Local Stakeholders

In order to have a fair understanding of the existing situation of the Jamuna and Ganges River within the project area, field visits were undertaken. Field visits along with reconnaissance survey were accomplished during the inception phase of the study. During the field visits, professionals of the study team interacted with the local people as well as inhabitants around the bridge site areas.

Field Survey and Acquisition of Primary Data for Development of the Models

In order to develop the model, primary data have been collected through field measurement in these two major rivers. These data include bankline data, bathymetry/ cross-section data, water level, discharge, bed material and suspended sediment data. In addition, to check the water quality along the transmission line, few samples have been collected to check the Sulphate content, Calcium content, Chloride content and Total Dissolved Solids in water.

Analysis of Secondary Data

Secondary data such as historical hydrometric data (discharge and water level) and morphological data (sediment and cross-sections data) have been collected from BWDB. These hydrometric data have been used for frequency analysis using suitable extreme value methods to identify the design hydrological events for two rivers. In this present case, flow and water level data of two BWDB hydrometric monitoring stations; Bahadurabad station (for Jamuna River) and Hardinge Bridge station (for Ganges River) have been used. Moreover, historical satellite images have also been collected from USGS for planform analysis that facilitates in perceiving the changes in the river-course with time.

Development of 2D Morphological Model

In the present study, two sets of models have been generated. One is for the Ganges River and another is for the Jamuna River. For developing two-dimensional model, MIKE 21C

has been chosen from advanced mathematical modelling suite of MIKE series, developed by the DHI, Denmark. These two models have been developed using the bathymetry/bankline data of year 2020 and calibrated against the monsoon data of 2020. The developed 2D morphological models have been applied for simulating different hydrological events.

The morphological model describes the large-scale movement of bed material due to scour or deposition causing changes to the bathymetry. The hydrodynamic part of the model solves the velocity and water depth at each grid cell which is provided to the continuity equation for sediment in the morphological model to solve the changes in bed level at the grid cells at every time step. The changed bed level information is returned back to the hydrodynamic model to simulate for the next time steps.

Selection of Design Hydrological Event

As the proposed transmission lines will have to face different flow in its design period, different types of flood events have been selected for the bridge design. These events represent the hydrological event having a particular return period. Based on these events, the hydro-morphological assessment of the rivers/channels has been done. In the present case, 1 in 100-year return period flood event have been selected for Jamuna and Ganges River, and applied to the 2D models considering the severity of the flood event. In addition, 2.33 year flood event, an average flood event, has also been considered to investigate the hydro-morphological behavior of the river. The reason is, according to Federal Highway Administration (FHWA), that there may have chance to occur severe hydraulic incidents (i.e. erosive velocity, bed degradation of river, etc.) due to average/2.33 year flood event.

Hydrological and Morphological Assessment

The existing hydraulics and morphology of the river near the crossing sites have been analyzed on the basis of historical and recent hydro-morphological data and satellite images. The probable hydraulic conditions and morphology of the river near the crossing area have been assessed based on the results of the 2D morphological model. The model has been applied to establish the flow situation of the river and also to identify the erosion prone areas nearby as it is very essential for the planning of a structure like crossings. In this regard, number of simulations have been carried out under different flow events. Examining the river response for different flow conditions different hydraulic parameters in relation to the river crossing have been extracted from the models. These parameters are mainly include flow velocity and bed scouring at and around the towers.

Computation of Design Water Level, Design Flow Discharge and Design Scour at the crossing Sites

Statistical analysis that have been done earlier with the historical water levels and flow discharges at/near the crossing's location, is used to compute the highest and lowest water levels and flow discharges corresponding to different flow events having distinct return period.

To identify the scour at/ around the pier, the results from the 2D morphological model has been used. The 2D morphological model (MIKE 21C) is capable of generating morphological changes due to construction of towers/ piers as well as river training/ bank protection works. It is possible to compute constriction scour due to channel constriction, and bend and confluence scour from the depth-integrated flow and sediment transport model. However, the local scour around the tower/ pier is also computed using standard empirical equations using the results to be obtained from the 2D morphological models.

Scour Analysis

The flow around a pier sheds vortex on the sides of the pier. Sediment deposition occurs in the wake area downstream of the pier. There are many factors that influence the magnitude of pier scour, which has been computed using empirical formulae. HEC-18 (FHWA 2012b) includes several Pier Scour equations (FHWA, Laursen, Breuser Type I and II, etc.) for various conditions. Hydraulic parameters to be used in the empirical formulae has been taken from the output of 2D morphological model. The details of scour computation for pier considering maximum depth of flow is also provided in the report.

Besides the above scour computation methodology, scour values have been also computed following the guidelines of IRC:78-2014.

Impacts Due to Construction of the Transmission Towers

The impact of the proposed construction of the towers on the Jamuna and the Ganges rivers' hydraulics and morphology has been assessed with 2D morphological model results. The outputs are comprised of: Flow Pattern, Magnitude and Extent of Backwater Effect and Effects on River Morphology and Hydrology, especially on the existing structures like piers and guide bunds of the Bangabandhu Bridge and Hardinge Bridge.

Chemical Analysis of Water Samples

Total six samples have been collected (three samples from the Jamuna River, and three samples from the Ganges River) along the finalized alignments of transmission lines, viz. near left bank, deepest vertical and near right bank. The depth of sampling was 0.6d ('d' is the depth of the sampling location). The samples have been tested for Sulphate content, Calcium content, Chloride content and Total Dissolved Solids in water. These tests have been done at the laboratory of IWM.

Ship Impact Load, Wave Attack and Velocity Attack Assessment

Ship impact load, wave attack and velocity attack will be evaluated in line with available standard methods. In this regard, expert opinions have sought from the Roads & Highways Department (RHD) and Bangladesh Water Development Board (BWDB) and Bangladesh Inland Water Transport Authority (BIWTA).

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Qualitative and Quantitative Prediction of Possible Future Developments/Shifting of the River (at and around the Tentative River Crossing)

A qualitative prediction of possible future development/ shifting of the river (at and around the tentative river crossing) during the next 20 years have been assessed by simulating the 2D morphological model. In addition, a quantitative prediction of possible future development/ shifting of the river for 2-3 years has also been provided using 2D morphological mathematical model.

The entire approach and methodology of this study is also showing in the flow chart given below:

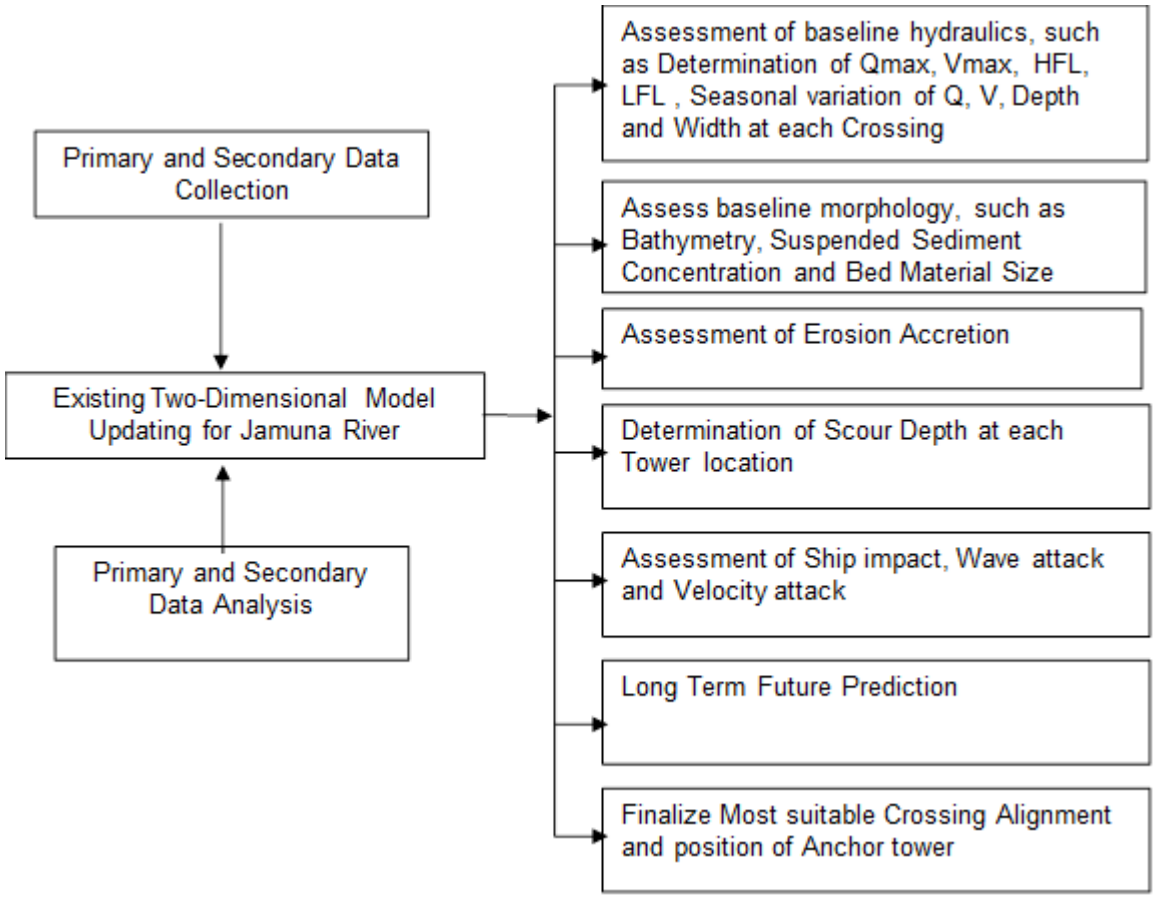


Figure 2.20 *Flow chart showing Study Approach*

3. DATA COLLECTION AND ANALYSIS

3. DATA COLLECTION AND ANALYSIS

3.1 General

In order to assess the hydro-morphological condition of the Jamuna and Ganges River, various kinds of hydrometric, hydrographic and morphological data of recent and previous years have been collected and compiled. These data also form the basis for further analysis and interpretation of the model results. Follows here is a brief discussion about the collected data and field of application of the same.

3.2 Data Collection

In order to support the two-dimensional morphological modelling, secondary data as well as primary data have been collected from different sources. In connection with this study, the field survey was carried out by IWM survey team during September-November 2020, i.e. post-monsoon 2020. The field survey campaign included bathymetry, measurement of water level and discharge, and collection of bed sample, water sample and suspended sediment sample data. The field survey was carried out mainly for Ganges River. Data for Jamuna River was collected from another study conducted by IWM in January 2020.

3.2.1 Hydrological Data

Hydrometric data

The hydrometric data includes water level and discharge data. Hydrometric data are necessary to understand present hydro-morphological condition of the river. Besides, these data are needed to define model boundary and to compare the model generated results with the observed data.

Discharge Data

The primary discharge data in the Ganges River has been measured in two different locations, Hatkhola (at the u/s boundary of the model) and old Ferry Ghat (immediate d/s of HB), given in **Table 3.1**. The data were collected on 29 and 30 September 2020. The locations of the discharge stations are shown in **Figure 3.1**.

Table 3.1 Discharge data (primary) in the Ganges River measured by IWM

Locations	Discharge, m^3/s	Date
Hatkhola	32135.76	29.09.2020
Old Ferry Ghat	30480.49	30.09.2020

Historical discharge data in Jamuna and Ganges River at Bahadurabad and Hardinge Bridge location is collected from BWDB and IWM archive and compiled, shown in **Table 3.2**.

Table 3.2 Available discharge data (secondary) in the Jamuna and Ganges River

Data Type	River	Location	Station ID	Data Coverage	Source
Discharge	Jamuna	Bahadurabad	46.9 L	1962-2019	BWDB, IWM
	Ganges	Hardinge Bridge	90	1934-2019	BWDB, IWM

Water Level Data

Water level data has been taken for one month starting from 19 September 2020 to 19 October 2020 in the Ganges River. The location of the water level stations in Ganges River is also shown in **Figure 3.1**. Measured water surface slope found from these primary water level data varies from 6 to 8 cm/km within this reach.

Historical water Level data at Bahadurabad, Sirajganj and EGB in Jamuna River and Hardinge Bridge and Talbaria station in Ganges River are collected from BWDB and IWM archive. **Table 3.3** shows the collected water level data from different sources.

Table 3.3 Available Water level data (secondary) of the Jamuna and Ganges River

Data Type	River	Location	Station ID	Data Coverage	Source
Water Level	Jamuna	Bahadurabad	46.9 L	1962-2019	BWDB, IWM
		Sirajganj	49	1950-2019	BWDB, IWM
		EGB	-	1994-2019	BBA
	Ganges	Hardinge Bridge	90	1910-2019	BWDB
		Talbaria	91	1950-2019	BWDB

3.2.2 Morphological Data

Bathymetry Data

The proposed two transmission lines in Jamuna River are located at about 2km and 2.6km d/s from the existing Bangabandhu Bridge. Bathymetry data of the Jamuna at immediate downstream of the B. Bridge for approximately 1 km strip @50m interval have been taken. These data have been incorporated in the developed model of Jamuna. The data was collected in the month of October 2020. The rest of the bathymetry data has been collected from IWM database, which was surveyed during January 2020. The spacing of these data varied from 100 m to 250 m.

Similarly, the proposed transmission line in the Ganges River are located at about 950m d/s from the existing Hardinge Bridge. The bathymetry data have been taken with a spacing of 250m from 5km u/s and d/s of Hardinge Bridge and rest of the bathy data of 20km stretches have been collected with a spacing of 500m interval. Bathy data for 1km strip @50m interval has also been taken at the 0.5km u/s and d/s of the proposed transmission line in Ganges River. These data were collected in the month of October-November 2020.

Figure 3.1 shows the transect lines of the surveyed bathymetric data in Ganges and Jamuna River.

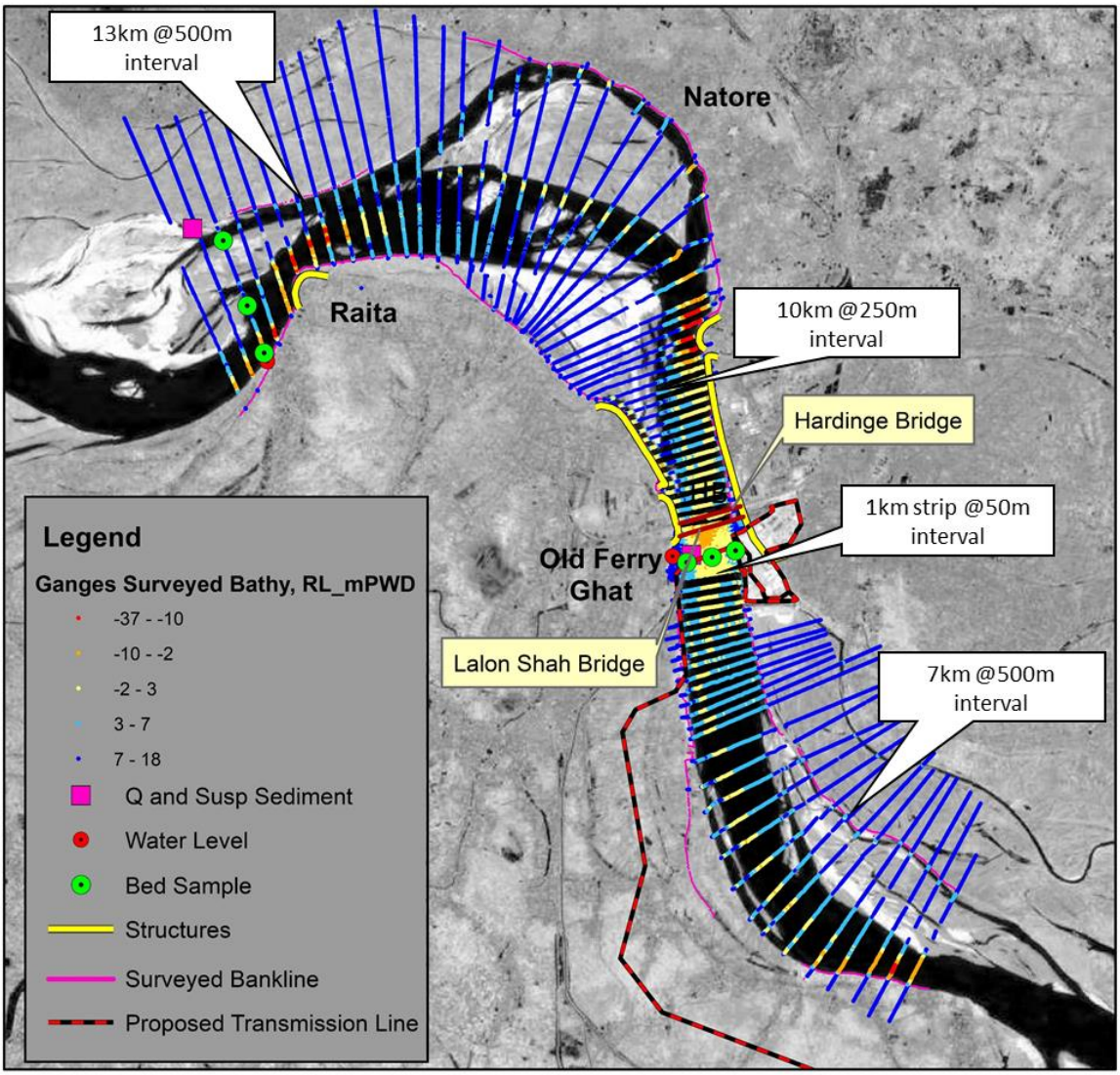


Figure 3.1 *Transect lines of the surveyed bathymetry and gauge locations installed by IWM in the Ganges River*

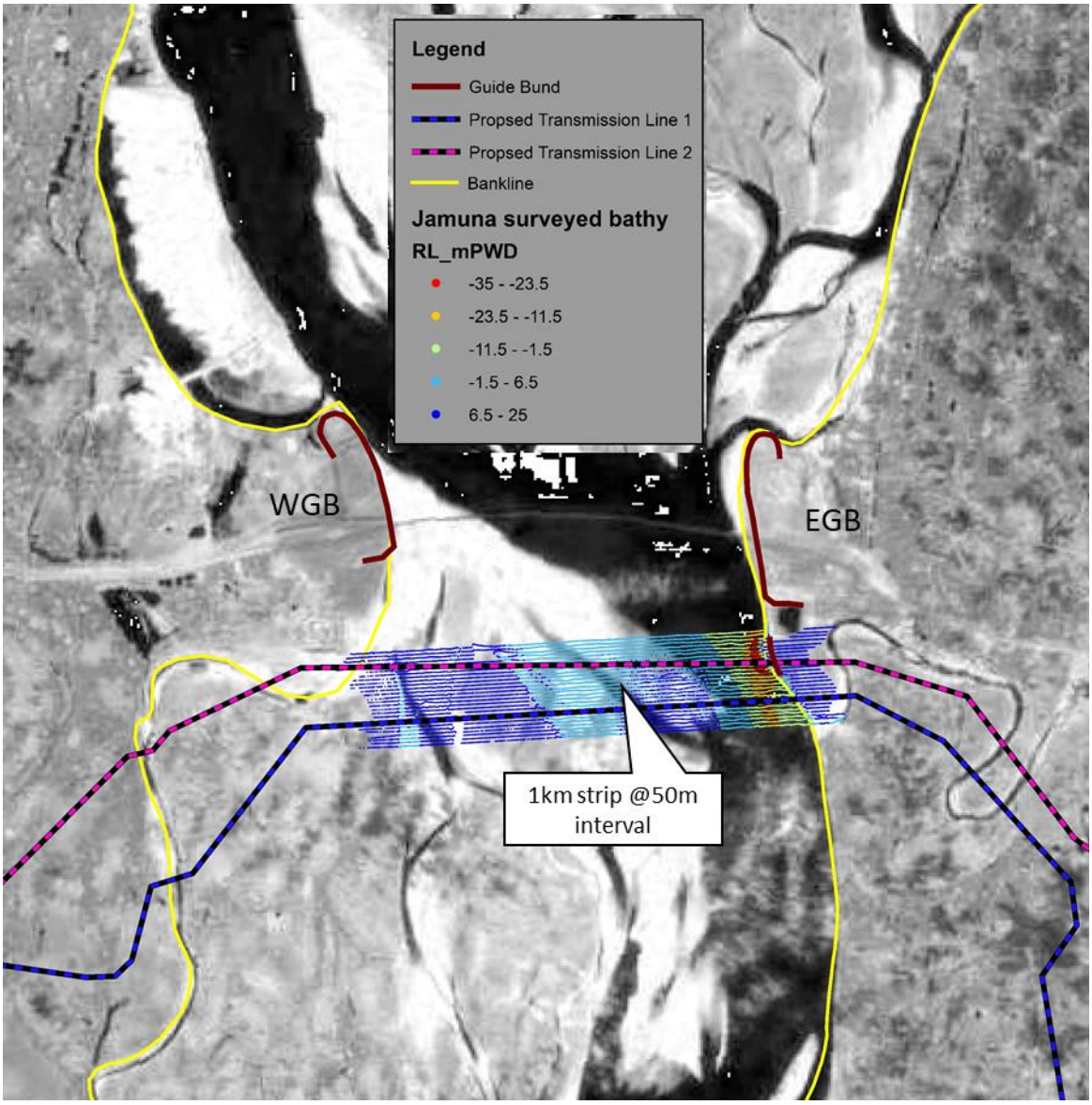


Figure 3.2 *Transect lines of the surveyed bathymetry within 1km strip near Transect Lines in the Jamuna River*

Bankline Data

Approximately 60km length of bankline for both the banks of the Ganges River have been surveyed by IWM survey team. The surveyed bankline in Ganges River is shown in **Figure 3.1**. The surveyed bankline of Jamuna River is also shown in **Figure 3.2**.

Bed Sample Data

Total six bed samples, three bed samples at the upstream of study area and three samples at the immediate downstream of Hardinge Bridge (at left bank, at channel and at right bank) have been collected from each of the two locations of Ganges River. The grain size diameters (d_{50}) at the different locations in the Ganges River are given in **Table 3.4**

After collecting the data, the samples were processing in the laboratory and the grain size parameters of all samples were determined using the grain size distribution curve.

Table 3.4 Measured Median Grain Size Diameter in Ganges and Jamuna River

Date	River	Location		d_{50} (mm)
13-Oct-2020	Ganges	Hatkhola	u/s Left Bank	0.066
			Channel	0.087
			u/s Right Bank	0.087
14-Oct-2020	Ganges	d/s of HB	Left Bank	0.049
			Channel	0.135
			Right Bank	0.055
29-Oct-2020	Jamuna	d/s of BB	Left Bank	0.27
			Channel	0.18
			Right Bank	0.20

Suspended Sediment Concentration Data

From the IWM field measurements, it is found that the average sediment concentrations in Ganges River varies from 604 mg/l to 1002 mg/l along the study area. The measured sediment concentration values are shown in **Table 3.5**.

On the other hand, secondary suspended sediment data in Jamuna and Ganges River have been collected from BWDB and IWM archive. The inventory of secondary sediment data is shown in **Table 3.6**.

Table 3.5 Measured Suspended Sediment Concentrations in Ganges River

Date	Concentration, mg/L	Location	River
30/09/2020	687.9	Hatkhola	Ganges
06/10/2020	669.04		
30/09/2020	1002.14	d/s of HB	Ganges
06/10/2020	604.14		
03/10/2020	731.55	d/s of BB	Jamuna
05/11/2020	337.54		

Table 3.6 Available Suspended Sediment data (secondary) of the Jamuna and Ganges River

Data Type	River	Location	Station ID	Data Coverage	Source
Suspended Sediment	Jamuna	Bahadurabad	46.9 L	1968-1995; 1999;2000-2017	BWDB
		Sirajganj	49	1998 and 2002 2013-2020	BWDB, IWM
		Bangabandhu Bridge area	-	2013-2020	IWM
	Ganges	Hardinge Bridge	90	1966-2016	BWDB

BWDB Cross-section Data

Historical observed cross-sections along the study area in Jamuna and Ganges River have been collected from BWDB. The locations of those cross-sections are shown in **Figure 3.3**. Details of cross-sections analysis has been described in Section 3.3.6.

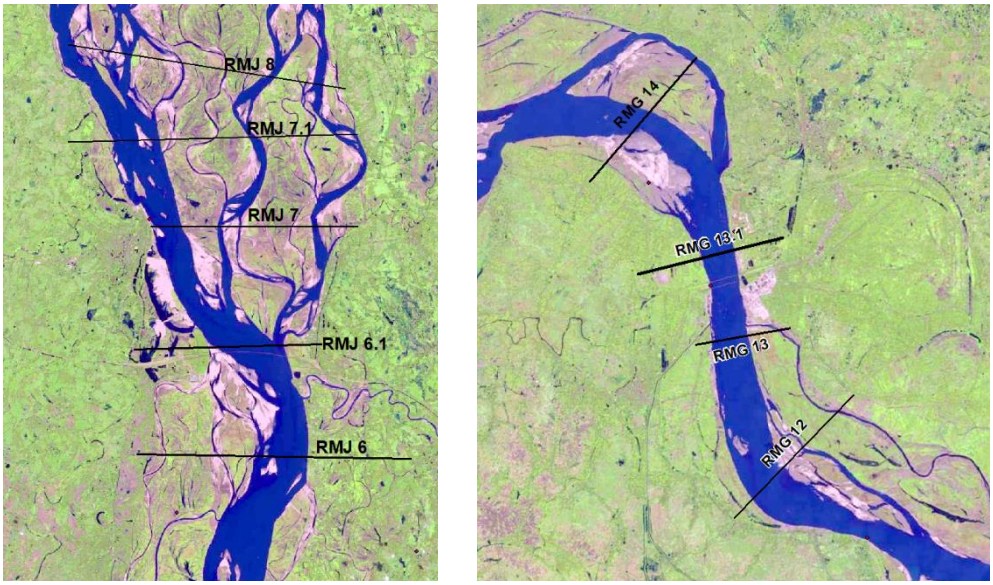


Figure 3.3 *BWDB Cross-section locations along the study area of Jamuna (left) and Ganges River*

Data inventories of the last 20 years cross-section data are presented in **Table 3.7**.

Table 3.7 Available BWDB cross-section data of the Jamuna and Ganges Rivers

River	X-sec No	Period
Jamuna	RMJ 6	2001, 2002, 2003, 2005, 2006, 2008, 2010-2019
	RMJ 6.1	2005, 2006, 2008, 2010-2019
	RMJ 7	2001, 2002, 2003, 2005, 2006, 2008, 2010-2019
	RMJ 7.1	2005, 2006, 2008, 2010-2019
	RMJ 8	2001, 2002, 2005, 2006, 2008, 2010-2019
Ganges	RMG 12	2001, 2002, 2003, 2005, 2006, 2008-2014, 2016-2019
	RMG 13.1	2009-2014, 2016-2019
	RMG 14	2001, 2002, 2003, 2005, 2006, 2008-2014, 2016-2019

Satellite Images

Historical time series satellite images have been collected from the source, USGS. Most of the images are captured by LANDSAT satellite with a resolution varies from 30m to 60m. The inventories of the available satellite images are shown in **Table 3.8**.

Table 3.8 Inventory of historical satellite images

River	Year	Month	Resolution	Satellite	Source
Ganges - Jamuna	1973	February	60m	LANDSAT 1	USGS
	1976	January	60m	LANDSAT 2	
	1977	February	60m	LANDSAT 2	
	1978	February	60m	LANDSAT 2	
	1979	February	60m	LANDSAT 3	
	1980	February	60m	LANDSAT 3	
	1989	January	30m	LANDSAT 4	
	1993	January	30m	LANDSAT 5	
	2000	February	30m	LANDSAT 7	
	2002	February	30m	LANDSAT 7	
	2003	March	30m	LANDSAT 7	
	2005	January	30m	LANDSAT 5	
	2006	January	30m	LANDSAT 5	
	2007	May	30m	LANDSAT 5	
	2008	May	30m	LANDSAT 5	
	2009	January	30m	LANDSAT 5	
	2010	February	30m	LANDSAT 5	
	2011	March	30m	LANDSAT 7 (SLC Off)	
	2011	November	30m	LANDSAT 5	
	2012	March	30m	LANDSAT 7 (SLC Off)	
	2012	October	30m	LANDSAT 7 (SLC Off)	
	2013	February	30m	LANDSAT 7 (SLC Off)	
	2013	November	30m	LANDSAT 8	
	2014	March	30m	LANDSAT 8	
	2014	November	30m	LANDSAT 8	
	2015	March	30m	LANDSAT 8	
	2015	October	30m	LANDSAT 8	
	2015	December	30m	LANDSAT 8	
	2016	February	30m	LANDSAT 8	
	2016	April	30m	LANDSAT 8	
	2016	October	30m	LANDSAT 8	
	2016	November	30m	LANDSAT 8	
	2017	Mach	30m	LANDSAT 8	
	2017	November	30m	LANDSAT 8	
	2018	February	30m	LANDSAT 8	
	2019	January	30m	LANDSAT 8	
	2020	February	30m	LANDSAT 8	
	2020	November	30m	LANDSAT 8	

The detail inventory of primary data collection is provided in **Table 3.9**.

Table 3.9 Inventory of Primary Data Collection

Datatype	Location	Position		Collection Period		Remarks
		BTM-X	BTM-Y	Start	End	
Water Level	Hatkhola	390815	665596	19/09/2020	20/10/2020	Continuous Data
	Old Ferry Ghat	400789	660797	18/09/2020	19/10/2020	
Discharge & Suspended Sediment	Hatkhola	388976	668854	29/09/2020	-	Dis-continuous Data
	Old Ferry Ghat	401255	660829	30/09/2020	-	
Bed Material	Hatkhola	389726	668559	13/10/2020		Left Bank
		390318	666959			Center
		390733	665795			Right Bank
	Old Ferry Ghat	402342	660933	14/10/2020		Left Bank
		401759	660773			Center
		401142	660642			Right Bank
Bathymetry	Hatkhola to u/s of HB Guide Bund (13 km)	-		October-November 2020		Bathymetry & Land Topography @500 m spacing
	5km u/s and d/s of Hardinge Bridge (10 km)	-				Bathymetry @250 m spacing
	5 km d/s of HB to Talbaria (7km)	-				Bathymetry & Land Topography @500 m spacing
	0.5km strip at u/s and d/s of Transmission Line (1 km)	-				Bathymetry @50 m spacing
Bankline Survey	60km			30/09/2020		Both banks of the Ganges River

3.3 Data Analysis

The data that was collected from primary and secondary sources have been analyzed in this section. Analysis include determination of maximum discharge, maximum water level (HFL), frequency analysis, channel/ bankline shifting, cross-section, scour etc.

3.3.1 Discharge

Ganges River

Flow analysis of Ganges River has been carried out with the discharge data of Hardinge Bridge location, since this is the only discharge measurement station maintained by BWDB in this river. The rated discharge hydrographs of the Ganges River at HB for the years 1978, 1987, 1998, 2016 and 2020 have been shown in **Figure 3.4**.

The annual maximum, minimum and mean flow values are also shown in **Figure 3.5**. This figure shows that the maximum magnitude of the flow of the Ganges was in 1998 and the magnitude was 79,059 m^3/s. The annual minimum discharge, **Figure 3.6** is showing a decreasing trend after the construction of Farakka Barrage in 1975. Annual minimum flow fluctuates around 700 m^3/s and annual average flow fluctuates around 10,000 m^3/s. The dominant discharge corresponds to the largest volume of sediment discharge and for the Jamuna River the dominant discharge is found 42,000 m^3/s (IWM 2017a).

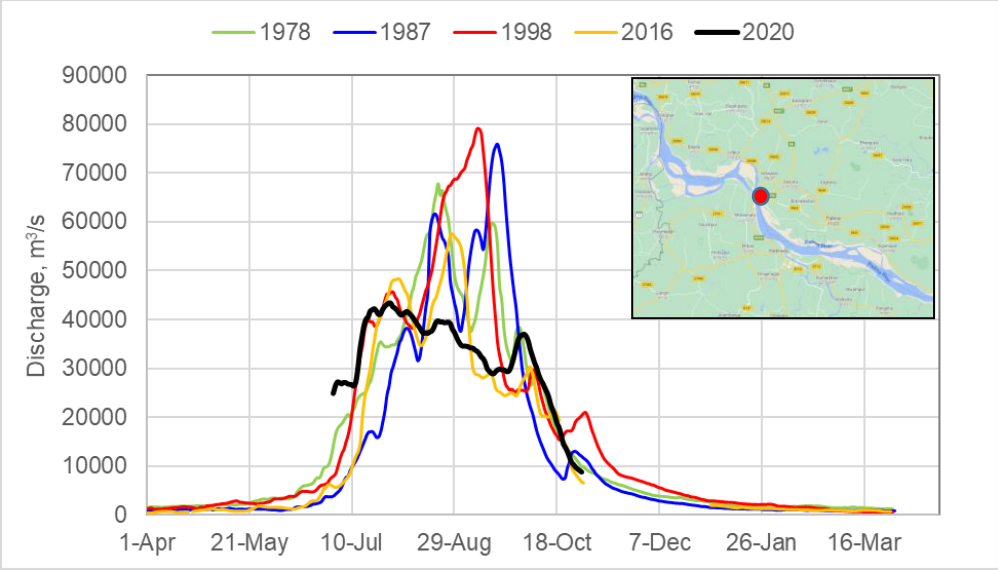


Figure 3.4 *Flow Discharge Hydrographs of the Ganges at Hardinge Bridge*

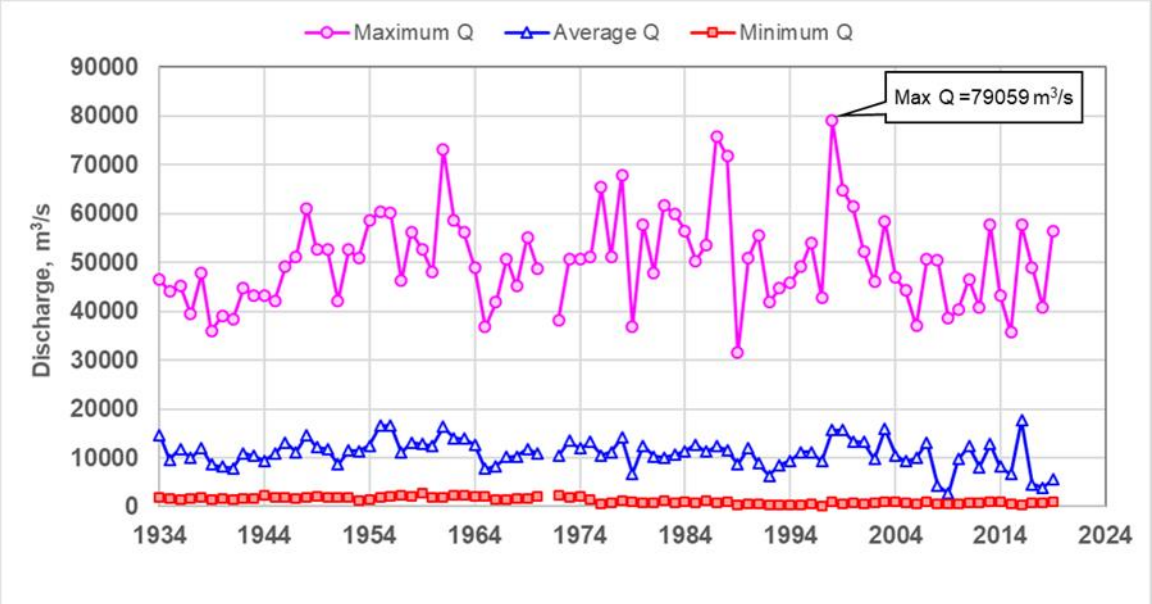


Figure 3.5 *Maximum, average and minimum discharge in Ganges River at Hardinge Bridge station from 1934-2019*

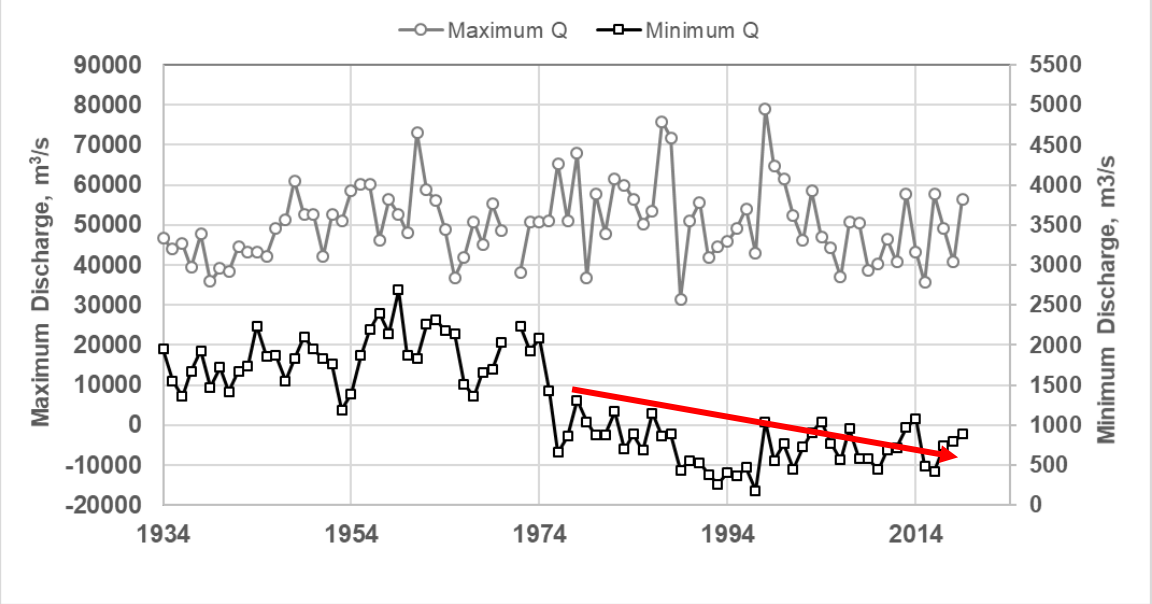


Figure 3.6 *Maximum and minimum discharge in Ganges River at Hardinge Bridge station from 1934-2019*

Jamuna River

Similarly, flow analysis of the Jamuna River has been done with the data of Bahadurabad. This is also the only discharge measurement station maintained by BWDB. There is no significant tributaries and distributaries of the Jamuna from Bahadurabad to Bridge area. The discharge of the Jamuna River shows significant seasonal variation with snowmelt in the Himalayas accounting for the sources of flow, whilst rainfall in Assam and Bangladesh contributes significantly. The rated discharge hydrographs of the Jamuna River at Bahadurabad for the years 1988, 1994, 1995, 1998, 2016 and 2020 have been shown in **Figure 3.7**.

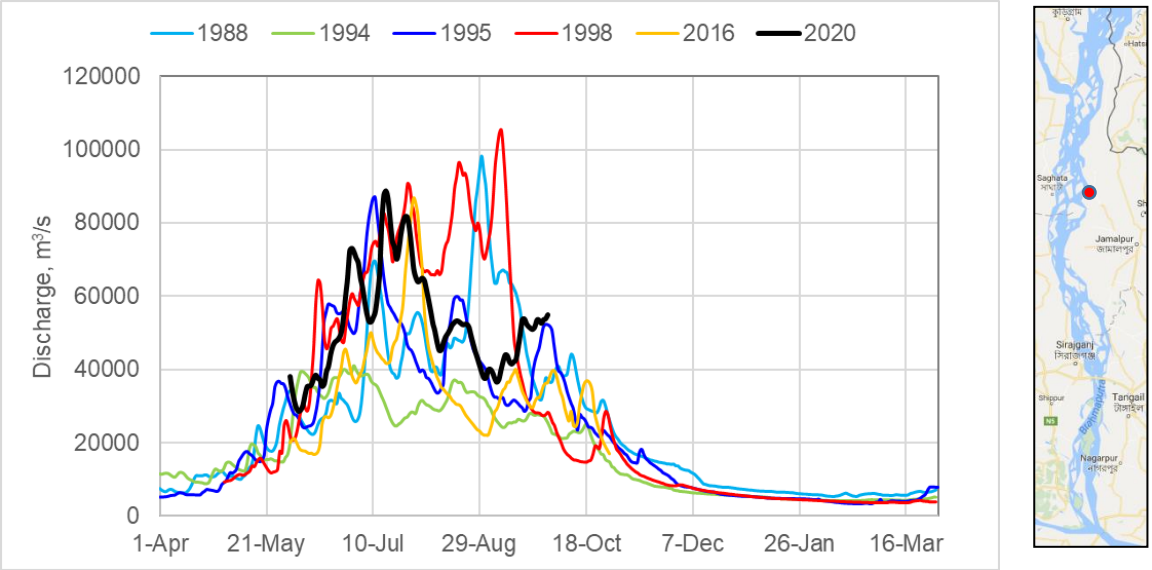


Figure 3.7 *Flow Discharge Hydrographs of the Jamuna at Bahadurabad*

Figure 3.7 shows that the minimum of the maximum is 40900 cumec (in 1994). This figure also shows the maximum magnitude of the flow of the Jamuna was in 1998 and the magnitude was 105,249 m^3/s. Annual maximum, minimum and mean flow values are shown in **Figure 3.8**. The annual mean and the annual minimum discharges are showing more or less a stable trend. Annual minimum flow fluctuates around 4,000 m^3/s and annual average flow fluctuates around 20,000 m^3/s. The dominant discharge corresponds to the largest volume of sediment discharge and for the Jamuna River the dominant discharge is found 45,000 m^3/s (IWM 2020).

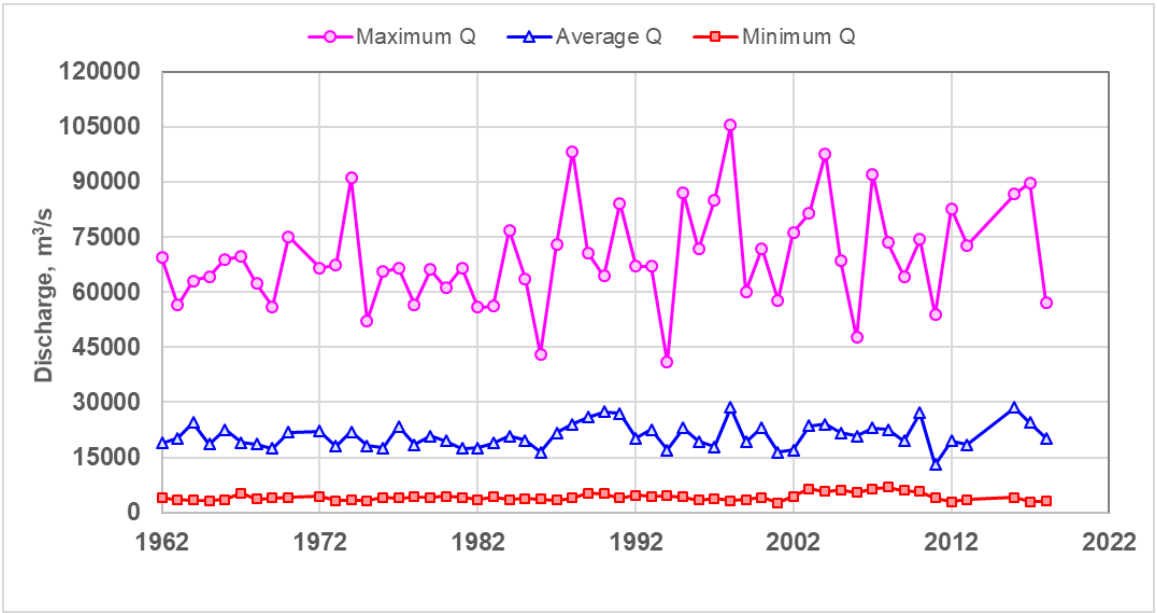


Figure 3.8 *Maximum, average and minimum discharge in Jamuna River at Bahadurabad station from 1962-2019*

3.3.2 Frequency Analysis

Ganges River

To identify the discharge events of different return period, frequency analysis of annual maximum discharges of Ganges River has been updated with the discharge data of year 2019. Probabilistic analysis of hydrometric data was carried out with the aid of EVA (Extreme Value Analysis) tool of MIKE, an advanced tool for frequency analysis developed by DHI. Using yearly maximum discharge data of Hardinge Bridge from 1934 to 2019 (**Figure 3.9**), three distributions (Gumbel EV1, Log-Normal and Log-Pearson-III) have been used. **Table 3.10** presents predicted values for several return periods based on Gumbel, Log-Normal and Log-Pearson-III distribution. The best frequency analysis curve for the data has been selected based on goodness of fit tests (Chi square test and K-S test) (**Table 3.11**). Among the three distributions, **Log-Pearson-III** came out as the best fit for the discharge data according to Goodness test (**Table 3.11**). The distribution plots are shown in **Figure 3.10** to **Figure 3.12**.

Table 3.10 Ganges Discharge data based on different distributions

Return Period	Q at Hardinge Bridge, m^3/s			Corresponding Hydrological Year for Log-Pearson-III	Actual Discharge of the corresponding year, m^3/s
	Gumbel EV1	Log-Normal	Log Pearson-III		
2	48869	49533	49300	1995	49100
2.33	50553	51179	50954	1990	51000
5	57870	57788	57753	2016	57716
10	63830	62637	62902	1982	61600
25	71361	68257	69041	1978	67900
50	76947	72153	73406	1961	73200
100	82493	75847	77626	1998	79059

Table 3.11 Goodness of fit test among three distributions for Ganges River

Est	Gumbel EV1 Distribution	Log-Normal Distribution	Log-Pearson-III Distribution
Chi Square Test	8.059	2.647	2.647
K-S Test	0.066	0.052	0.049

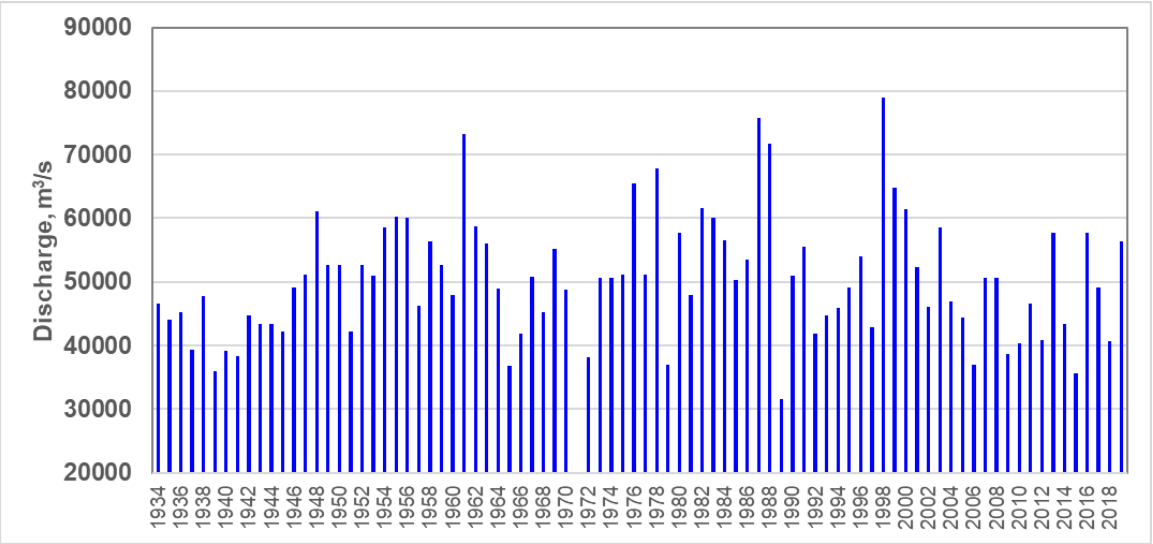


Figure 3.9 *Yearly maximum Discharge of the Ganges River at Hardinge Bridge Location*

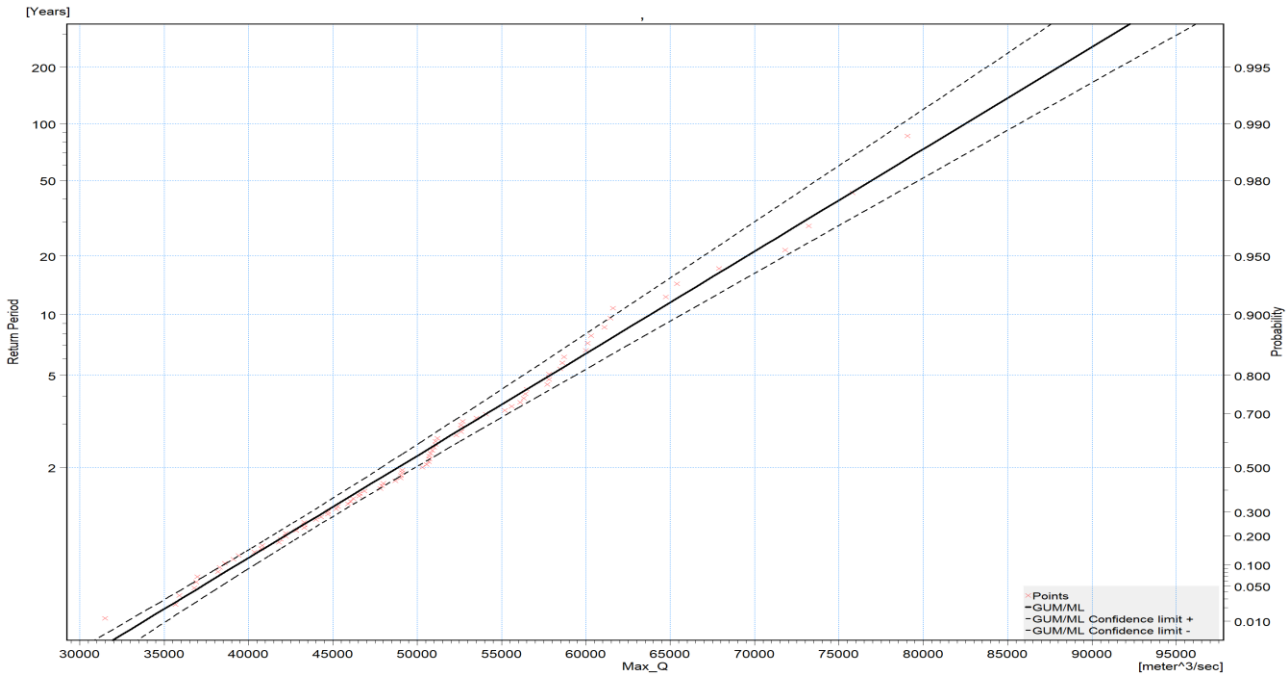


Figure 3.10 *Frequency Analysis of Gumbel EV1 Distribution*

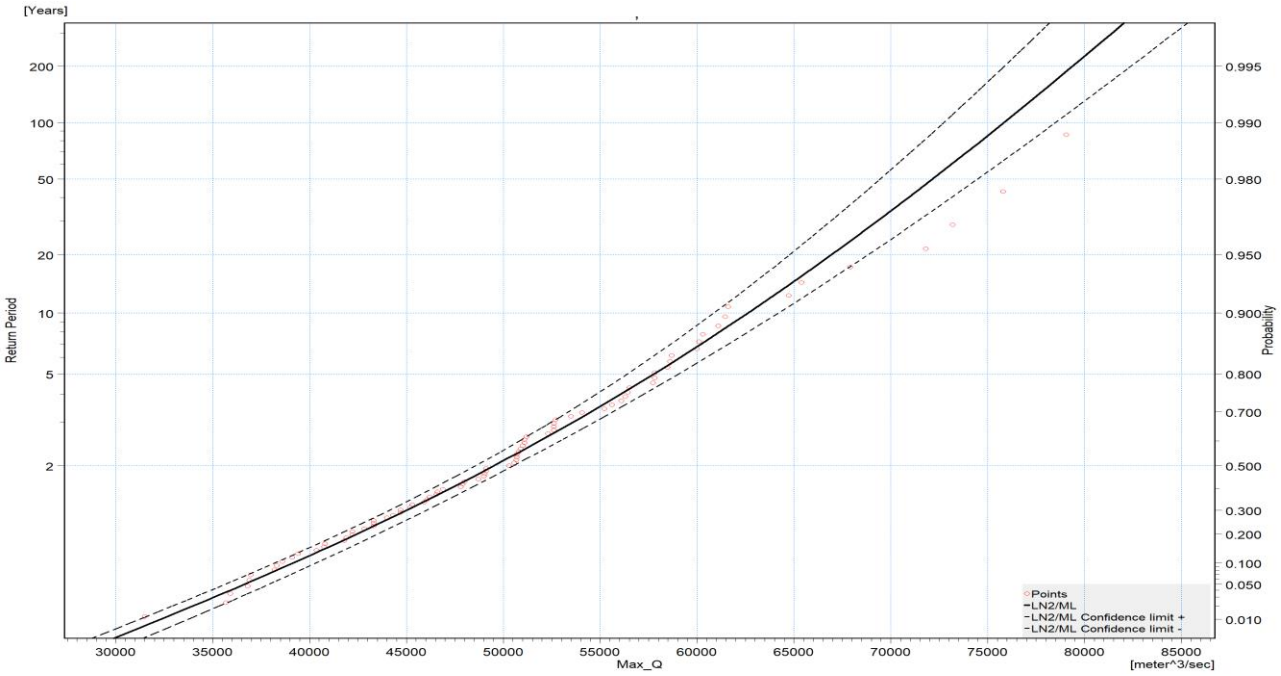


Figure 3.11 *Frequency Analysis of Log-Normal Distribution*

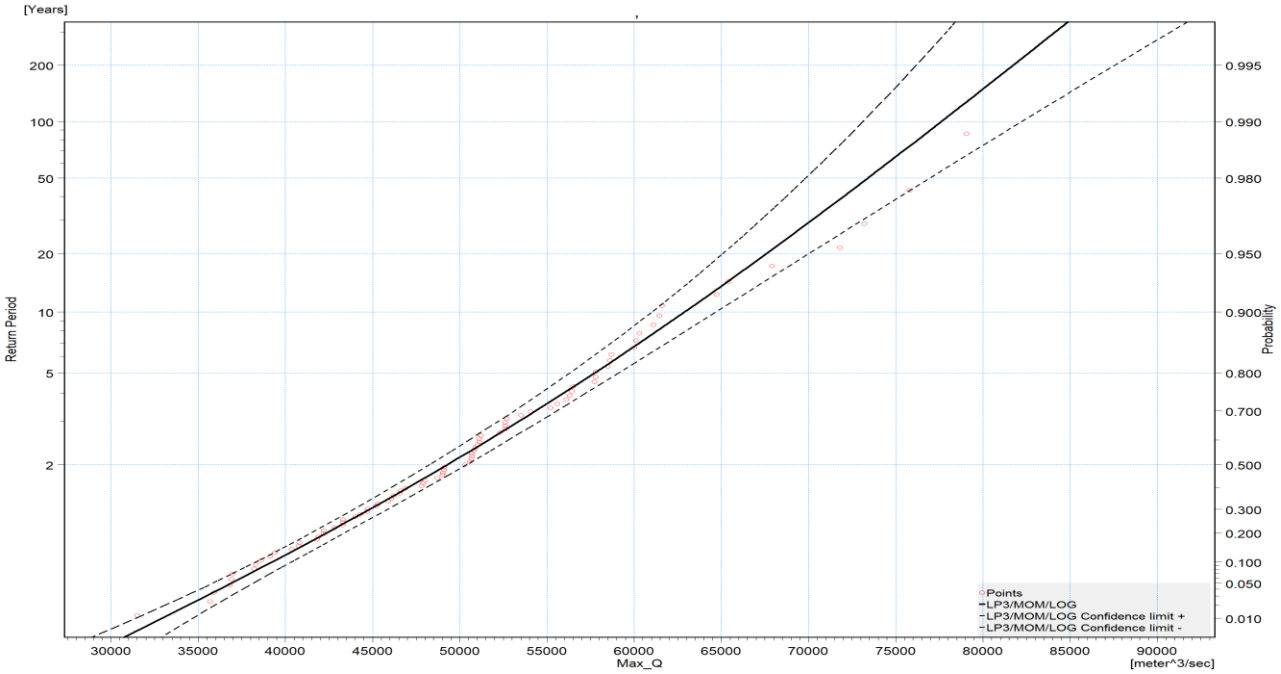


Figure 3.12 *Frequency Analysis of Log Pearson-III Distribution*

Jamuna River

In a similar way, frequency analysis of Jamuna River has also been done using the annual maximum discharge data of Bahadurabad station. The probabilistic analysis of hydrometric data was carried out with the aid of EVA (Extreme Value Analysis) tool of MIKE. Using yearly maximum discharge data of Bahadurabad from 1956 to 2019 (**Figure 3.13**), three distributions (Gumbel EV1, Log-Normal and Log-Pearson-III) have been plotted in **Figure 3.14** to **Figure 3.16**. **Table 3.12** presents predicted values for several return periods based on Gumbel, Log-Normal and Log-Pearson-III distribution for Jamuna River. The best frequency analysis curve for the data has been selected based on goodness of fit tests

(Chi square test and K-S test) (**Table 3.13**). Among the three distributions, Log Normal came out as the best fit for the discharge data according to Goodness test (**Table 3.13**).

Table 3.12 Jamuna Discharge data based on different distributions

Return Period	Q at Bahadurabad, m^3/s			Corresponding Hydrological Year for Log-Normal	Actual Discharge of the corresponding year, m^3/s
	Gumbel EV1	Log-Normal	Log Pearson-III		
2.33	69976	70551	70764	2005	68565
5	80812	79966	80130		
10	89639	86895	86899	1997	85090
25	100791	94947	94633	-	-
50	109064	100541	99927	1988	98300
100	117276	105854	104895	1998	105249

Table 3.13 Goodness of fit test among three distributions for Jamuna River

Est	Gumbel EV1 Distribution	Log-Normal Distribution	Log-Pearson-III Distribution
Chi Square Test	12.397	9.54	10.492
K-S Test	0.087	0.076	0.082

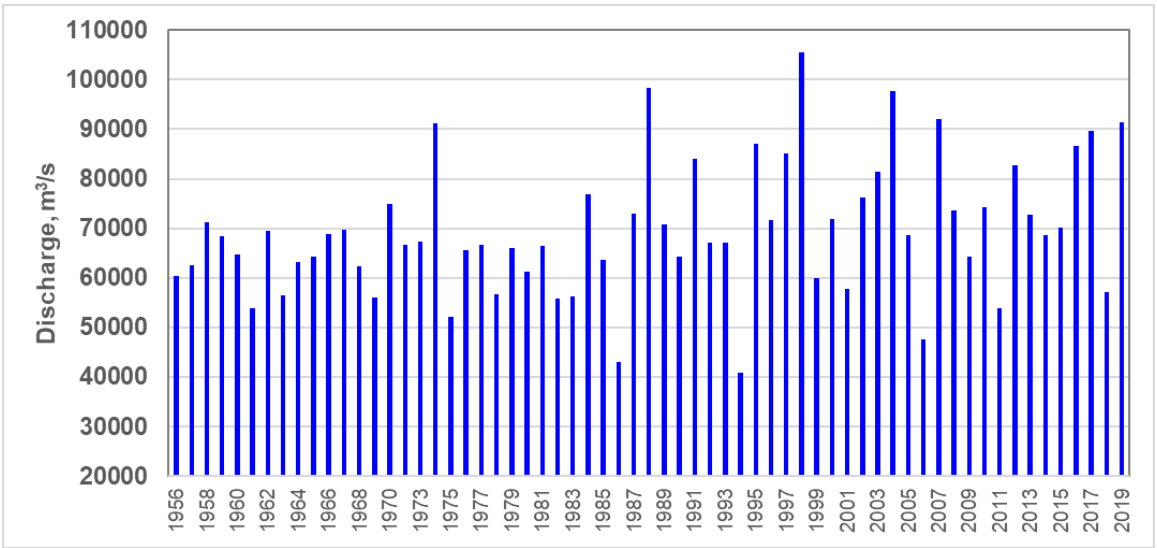


Figure 3.13 *Yearly maximum Discharge of the Jamuna River at Bahadurabad*

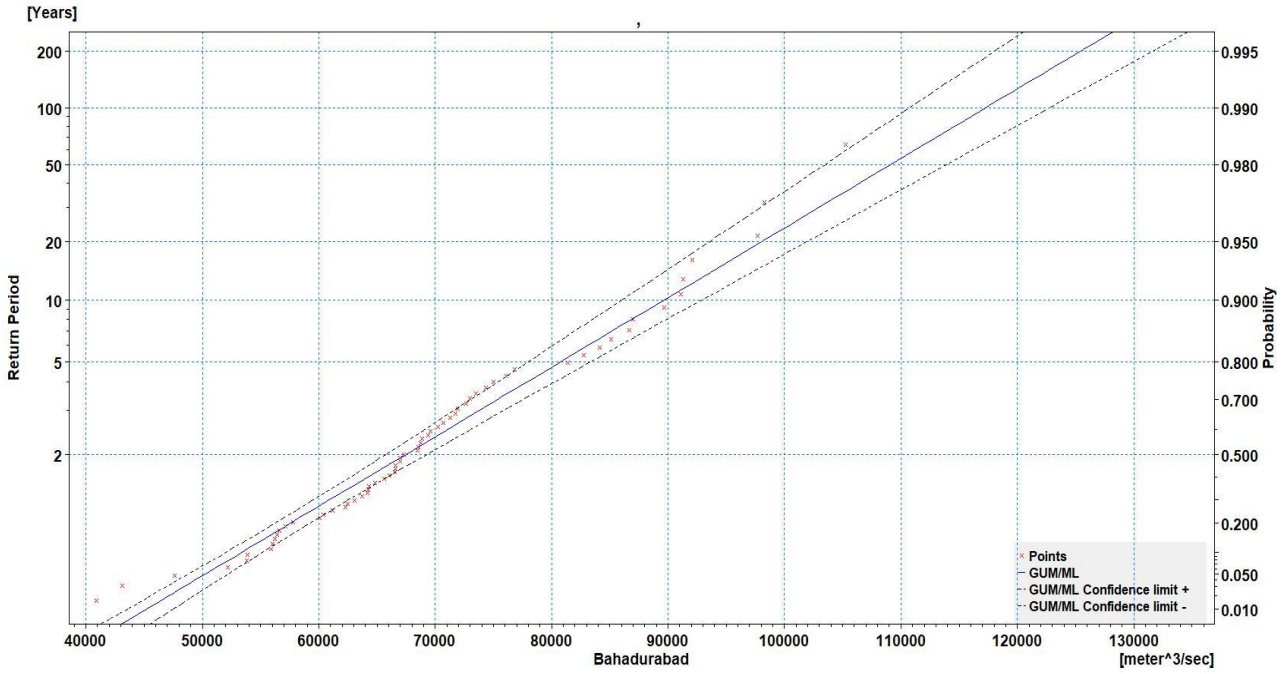


Figure 3.14 *Frequency Analysis of Gumbel EV1 Distribution*

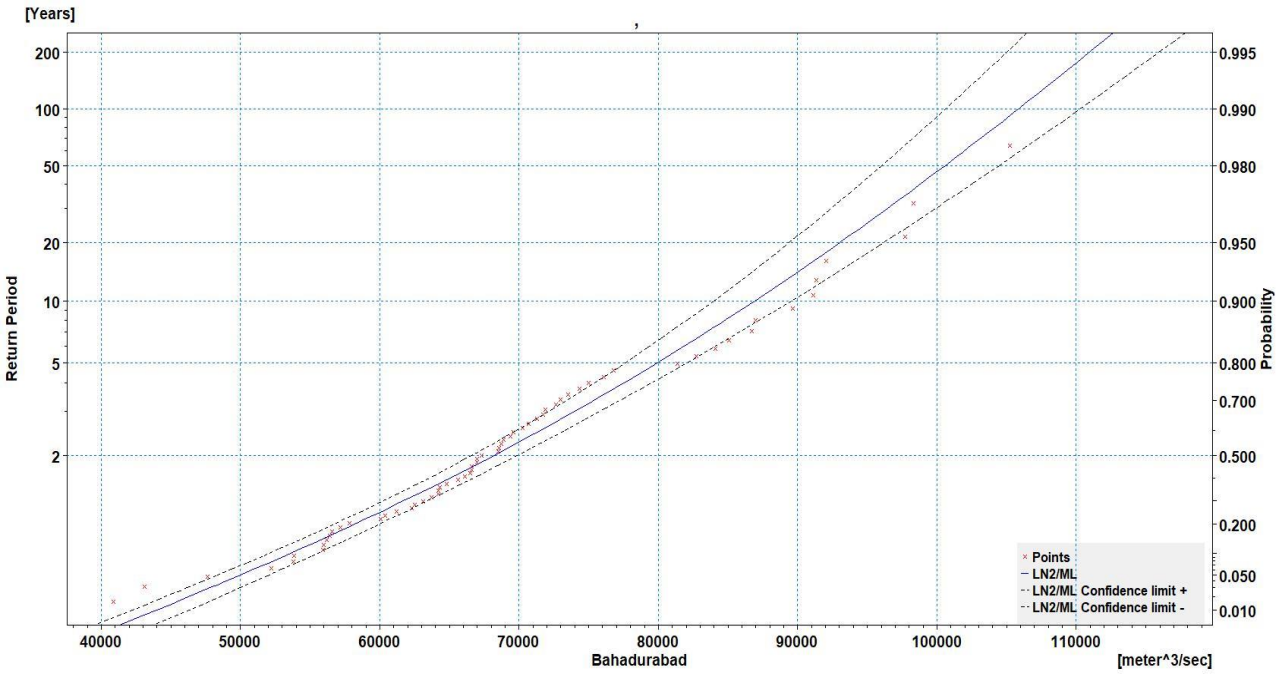


Figure 3.15 *Frequency Analysis of Log-Normal Distribution*

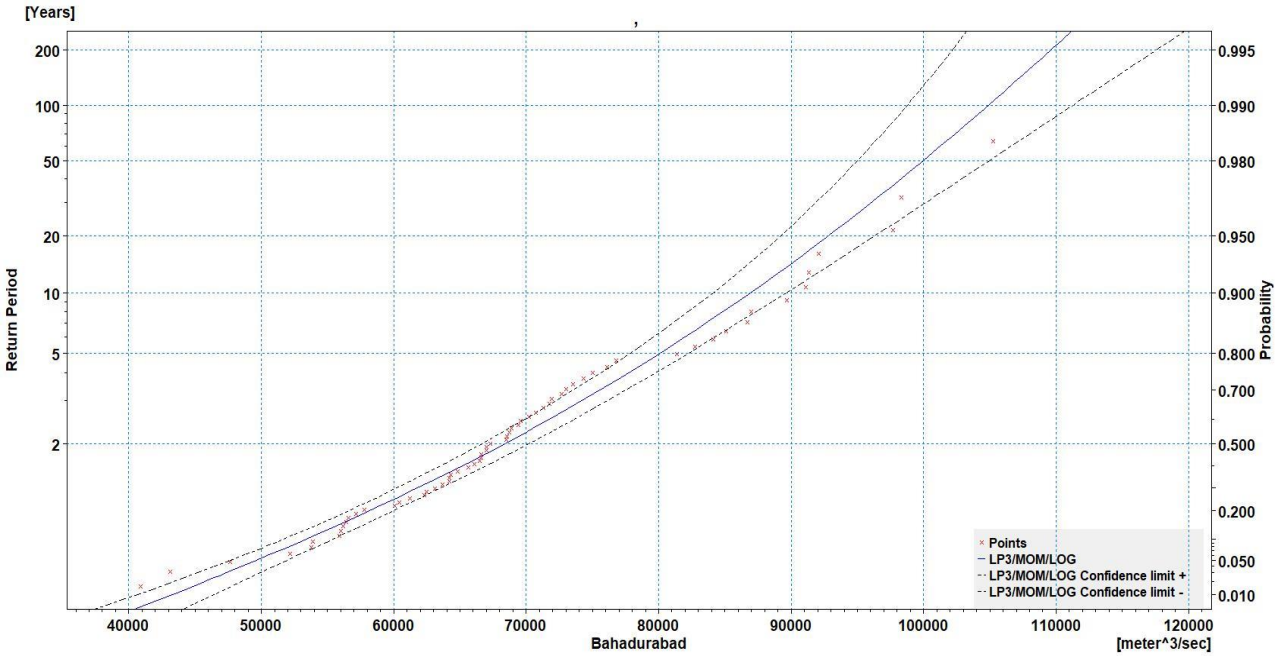


Figure 3.16 *Frequency Analysis of Log Pearson-III Distribution*

3.3.3 Water Level

Ganges River

Water level data at Hardinge Bridge station in the Ganges River were compiled and analyzed to figure out annual maximum, minimum and average water level and presented in **Figure 3.17**. Analyzing the data, maximum water level was found as 15.19 mPWD whereas minimum was 4.22 mPWD. Maximum water level was recorded in 1998 (9th September).

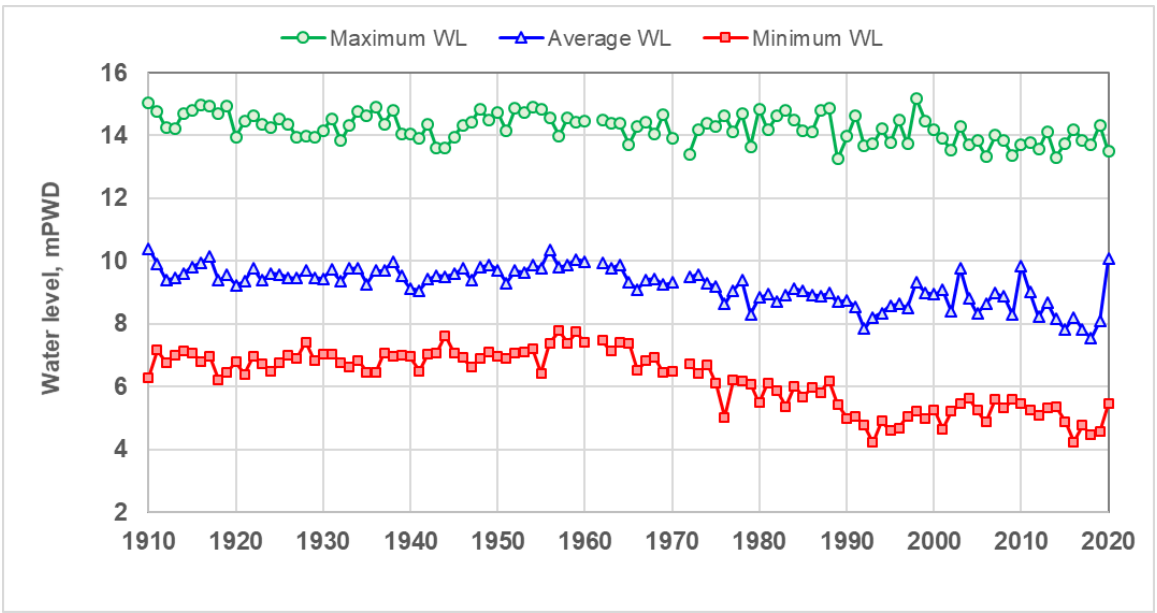


Figure 3.17 *Maximum, average and minimum water level of the Ganges River at Hardinge Bridge station from 1910-2020*

Jamuna River

Water level data at Bahadurabad, Sirajganj and EGB station in the Jamuna River were compiled and analyzed to figure out annual maximum, minimum and average water level and presented in **Figure 3.18** to **Figure 3.20**. Among these stations, Bahadurabad and Sirajganj stations are maintained by BWDB and EGB water level station is maintained by BBA. Analyzing the data, maximum water level at EGB (as EGB is near the transmission lines) was found as 14.12 mPWD whereas minimum was 5.41 mPWD. Maximum water level at EGB was recorded in 1998 (8th September).

The maximum (HWL) and minimum (LWL) water level at Hardinge Bridge station in Ganges River and Sirajganj and EGB stations in Jamuna River are given in **Table 3.14**.

Table 3.14 Maximum (HFL) and minimum (LWL) water level at different stations in Ganges and Jamuna River

Year	HB		Sirajganj		EGB	
	HFL	LFL	HFL	LFL	HFL	LFL
1980	14.85	5.48	14.49	6.55	-	-
1981	14.18	6.12	13.87	6.63	-	-
1982	14.64	5.86	13.73	6.71	-	-
1983	14.8	5.37	14.19	6.9	-	-
1984	14.51	6.02	14.61	6.12	-	-
1985	14.16	5.67	14.14	6.68	-	-
1986	14.11	5.97	13.66	6.85	-	-
1987	14.79	5.81	14.57	6.71	-	-
1988	14.86	6.18	15.1	6.97	-	-
1989	13.26	5.44	13.65	7.38	-	-
1990	13.97	4.99	13.96	7.61	-	-
1991	14.64	5.06	14.36	7.61	-	-
1992	13.67	4.76	13.25	7.56	-	-
1993	13.74	4.22	13.76	7.56	-	-
1994	14.21	4.91	13.04	7.43	-	-
1995	13.77	4.6	14.69	7.03	13.57	5.92
1996	14.49	4.68	14	7.3	12.97	6.255
1997	13.73	5.05	13.58	6.62	12.7	6.255
1998	15.19	5.21	14.76	7.02	14.115	6.36
1999	14.45	4.99	14.1	6.52	13.319	5.916
2000	14.19	5.27	14.03	6.78	13.4425	5.79
2001	13.9	4.65	13.44	6.63	12.9555	5.9875
2002	13.52	5.22	14.36	7.18	13.728	5.7535
2003	14.28	5.46	14.32	7.33	13.58	5.7485
2004	13.69	5.64	14.81	7.36	13.905	5.7525
2005	13.83	5.25	13.31	7.05	13.155	6.01
2006	13.34	4.87	12.93	6.19	12.33	5.875
2007	14	5.6	14.94	6.59	13.97	5.96
2008	13.83	5.31	14.32	6.71	13.48	5.825
2009	13.36	5.59	13.68	6.39	12.81	5.58
2010	13.69	5.45	13.83	6.22	12.91	5.41

Year	HB		Sirajganj		EGB	
	HFL	LFL	HFL	LFL	HFL	LFL
2011	13.78	5.25	13.41	6.69	12.65	5.86
2012	13.56	5.1	13.97	6.68	13.35	5.7
2013	14.13	5.33	13.49	6.35	13.075	6.06
2014	13.31	5.36	13.78	6.03	13.43	5.92
2015	13.75	4.89	14.13	6.13	13.4	5.69
2016	14.19	4.23	14.24	5.37	13.89	5.67
2017	13.85	4.76	14.87	5.78	14.01	5.51
2018	13.69	4.46	13.34	6.37	12.98	5.67
2019	14.33	4.56	14.34	5.75	14	5.44
2020	13.5	5.45	14.36	6.19	-	-

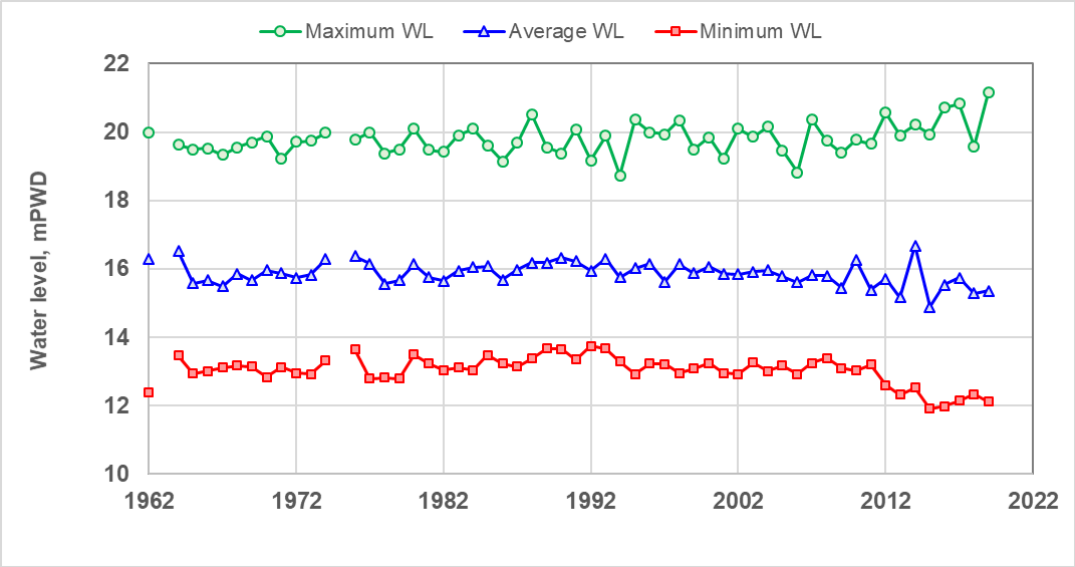


Figure 3.18 *Maximum, average and minimum water level of the Jamuna River at Bahadurabad station from 1962-2019*

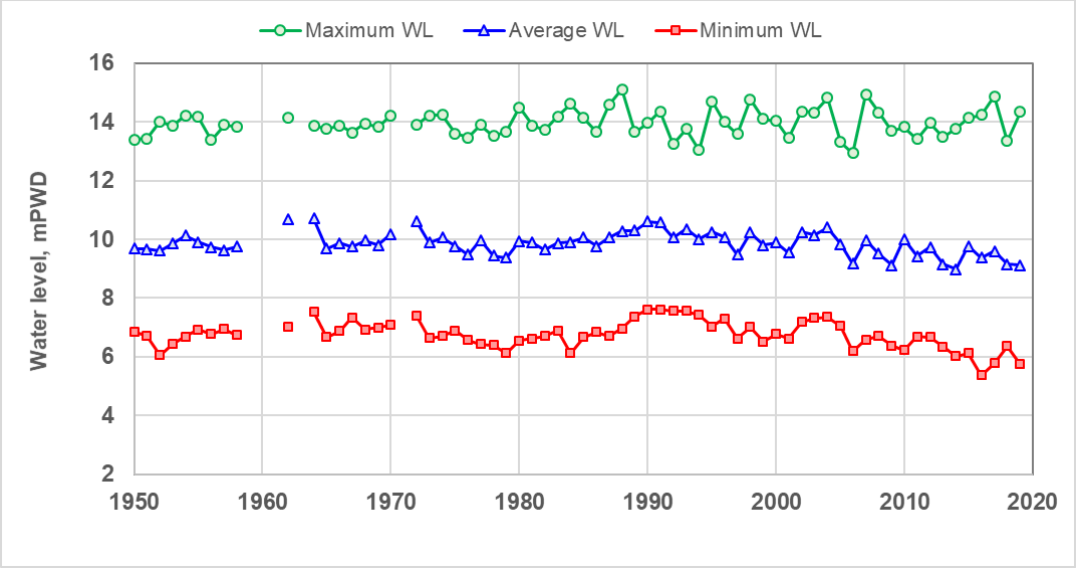


Figure 3.19 *Maximum, average and minimum water level of the Jamuna River at Sirajganj station from 1950-2019*

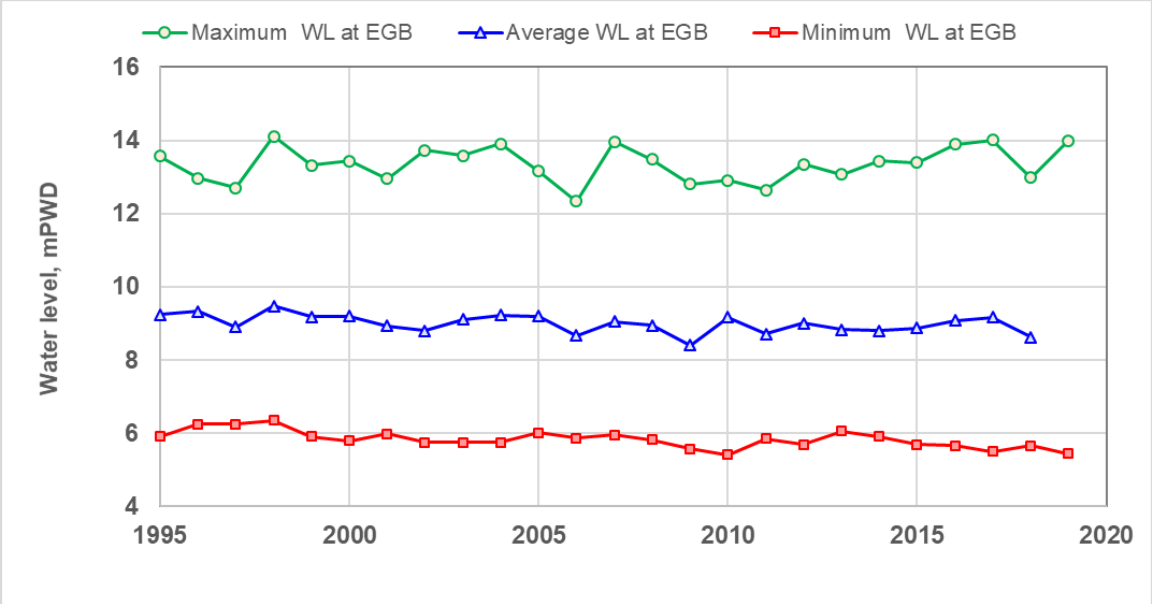


Figure 3.20 *Maximum, average and minimum water level of the Jamuna River at EGB station from 1995-2019*

3.3.4 Sediment Data

The historical sediment data in Ganges and Jamuna River that was collected from BWDB are represented in **Figure 3.21** and **Figure 3.22**. The sediment rating curve for these two rivers is also shown in **Figure 3.23**. The data period has been divided in to two segments, before and after of the year 2000. It is noticed that the sediment transport is decreasing in Jamuna River and increasing in Ganges River, after the year of 2000.

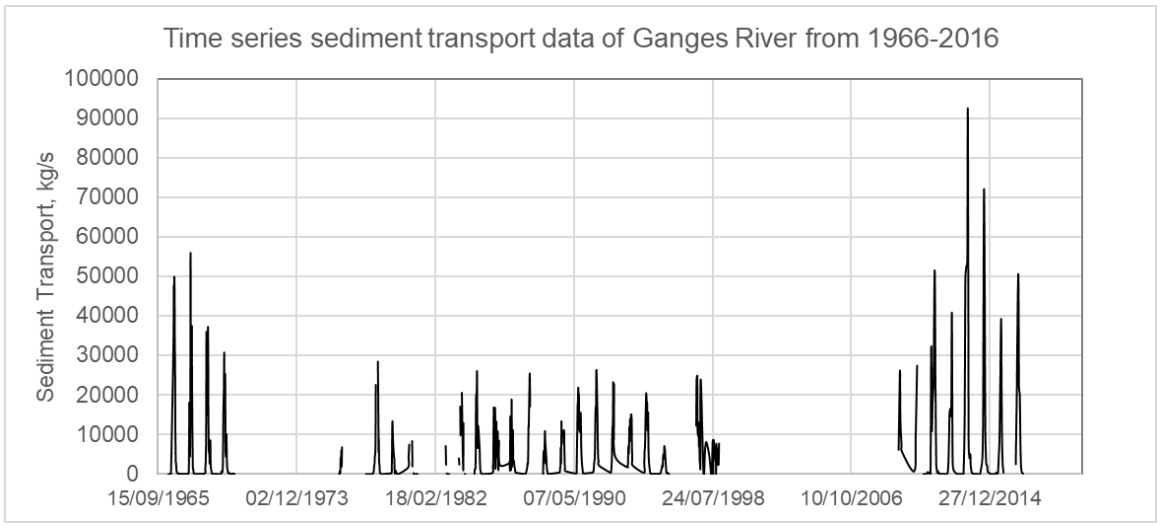


Figure 3.21 *Available Suspended Sediment Transport Data in Ganges River measured at Hardinge Bridge station*

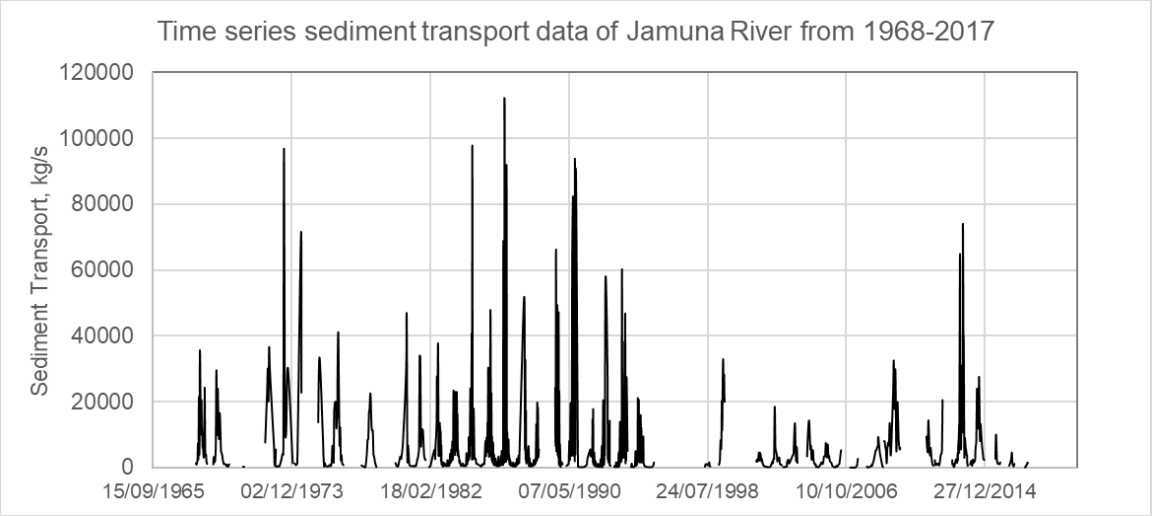


Figure 3.22 *Available Suspended Sediment Transport Data in Jamuna River measured at Bahadurabad station*

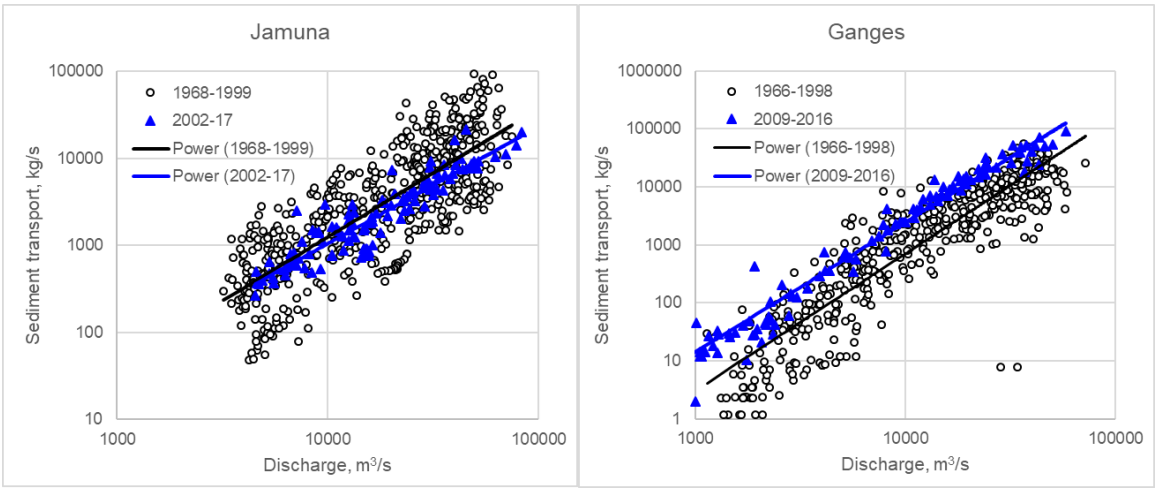


Figure 3.23 *Sediment Rating Curve in Jamuna and Ganges River*

3.3.5 Channel/ Bankline Shifting at and around the Crossing Location

Ganges River

In order to observe the bankline shifting in the Ganges River within the study area, the bankline has been delineated from the available satellite images of 1976-2020 and shown in **Figure 3.24**. The plot exhibits that there was a major shifting of bankline along the left bank near the bend of Natore and along the right bank at the d/s of HB. The lateral extent of erosion during the last four decades is found about 2350m and 1485m near the bend of Natore and at the d/s of HB, respectively.

There was a significant bankline shifting along both banks during 1976 to 2000, at the location of proposed transmission line, shown in **Figure 3.24** (zoomed view). The lateral shifting was about 690m along the right bank and 610m along the left bank. However, in the last two decades there were no bankline shifting along the right bank.

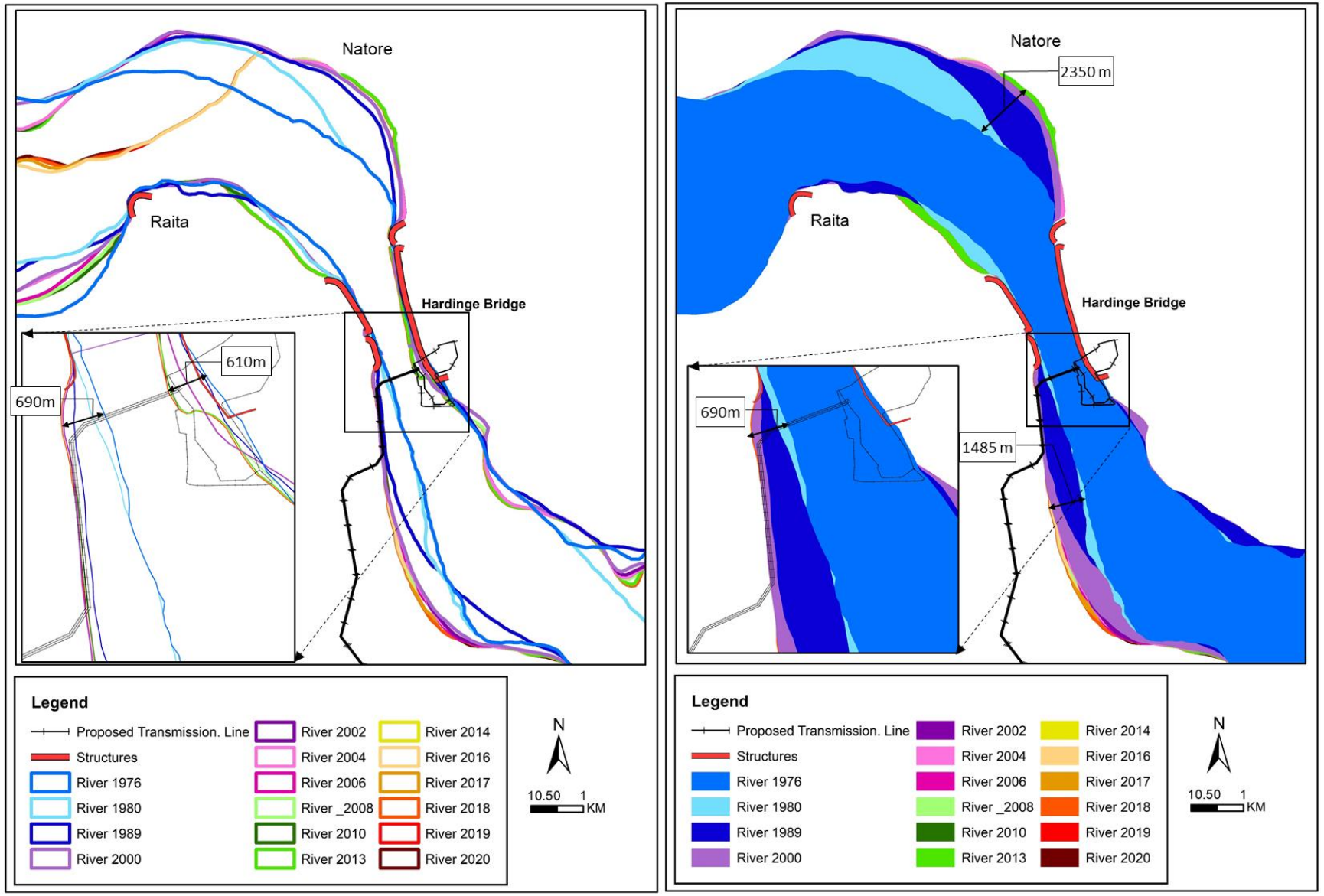


Figure 3.24 *Bankline shifting in Ganges River within the study area*

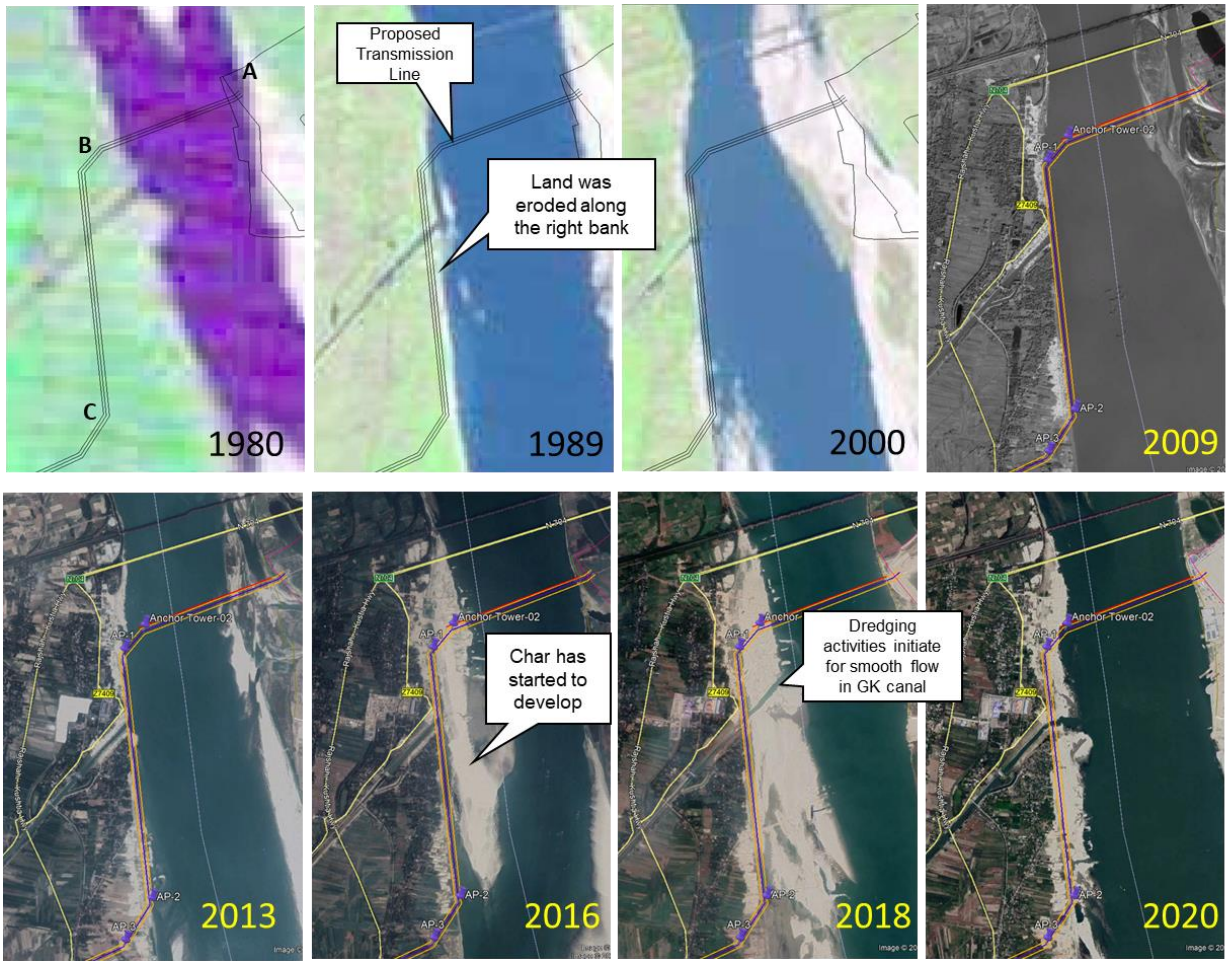


Figure 3.25 *Time series Satellite Images neat the Crossing Location in Ganges River*

The historical time series satellite images of Ganges River near the proposed transmission line exhibits in **Figure 3.25**, shows that the portion of transmission line (BC) is situated nearly along the right bank near GK project. Analyzing the sat. images, it is clearly seen that the right bank was not always stable. After 1980, there was a massive erosion occurred along that bank. However, this bank is being quite stable after the year 2000. There was a revetment along this right bank, see **Figure 3.26**. In satellite image of 2016, a newly developed char is visible along this right bank, which is again started to diminish in the recent year. Construction of 6km transmission line parallel to the right bank should be design considering this fact.



Figure 3.26 *Right bank of Ganges River near Proposed Location of the Crossing*

Jamuna River

The time-series satellite images of Jamuna near the two-crossing line shows the changes of channel layout in Jamuna River within the last four decades. **Figure 3.27** is showing the series of satellite images of Jamuna River. Prior to the construction of Bangabandhu Bridge, in 1980 and 1989, the river was maintaining a single channel near the crossing line. However, due to the construction of the bridge, the river has turned into multi-threaded channel (termed as braided) at the d/s of bridge. A minor channel was also existing along the right bank at the d/s of WGB. After a couple of years, this channel was abandoned, and the char became permanent in 2005. In 2015, there was initiating a new sand bar along the right bank, immediate d/s of the transmission line 2, which is disconnected from the main land in 2020.

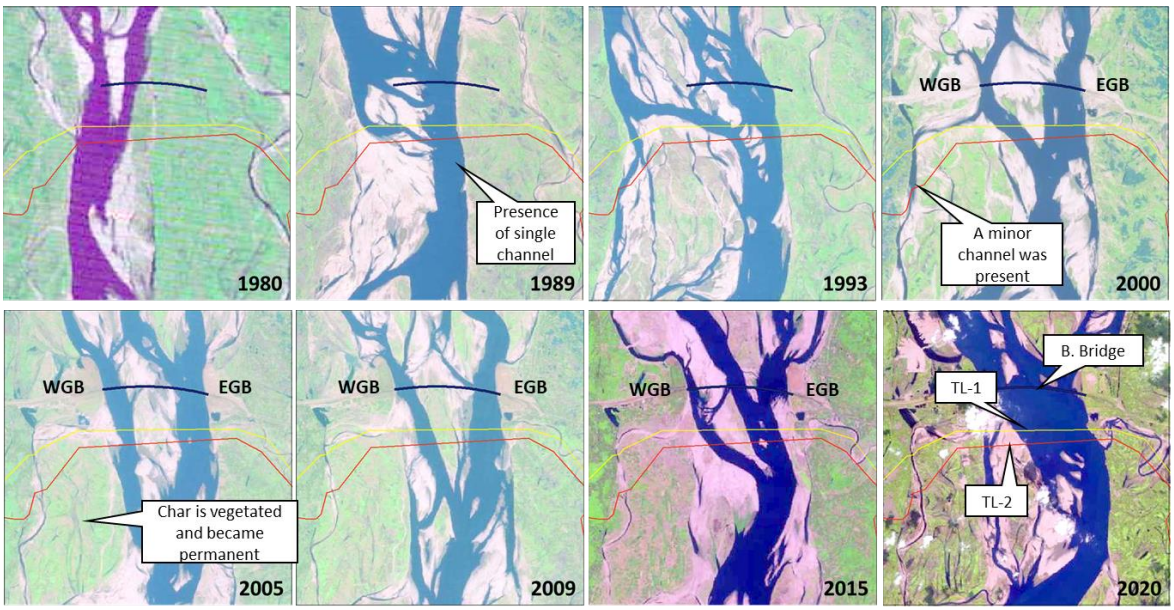


Figure 3.27 *Time series Satellite Images neat the Crossing Location in Jamuna River*

The bankline shifting within the study area of Jamuna River is also done in a similar way like Ganges. The plot of these bankline shifting is shown in **Figure 3.28**. In Jamuna River, the major bankline is shifted along the left bank at the immediate d/s of EGB. The maximum extent of erosion was about 720m with a rate of 40m/yr. Furthermore, this extent of erosion is found nearly 300m during the period from 2002 to 2020, along the transmission line 2. On the other hand, there was an accretion (maximum extent is about 1km) at the right bank just u/s of Belkuchi.

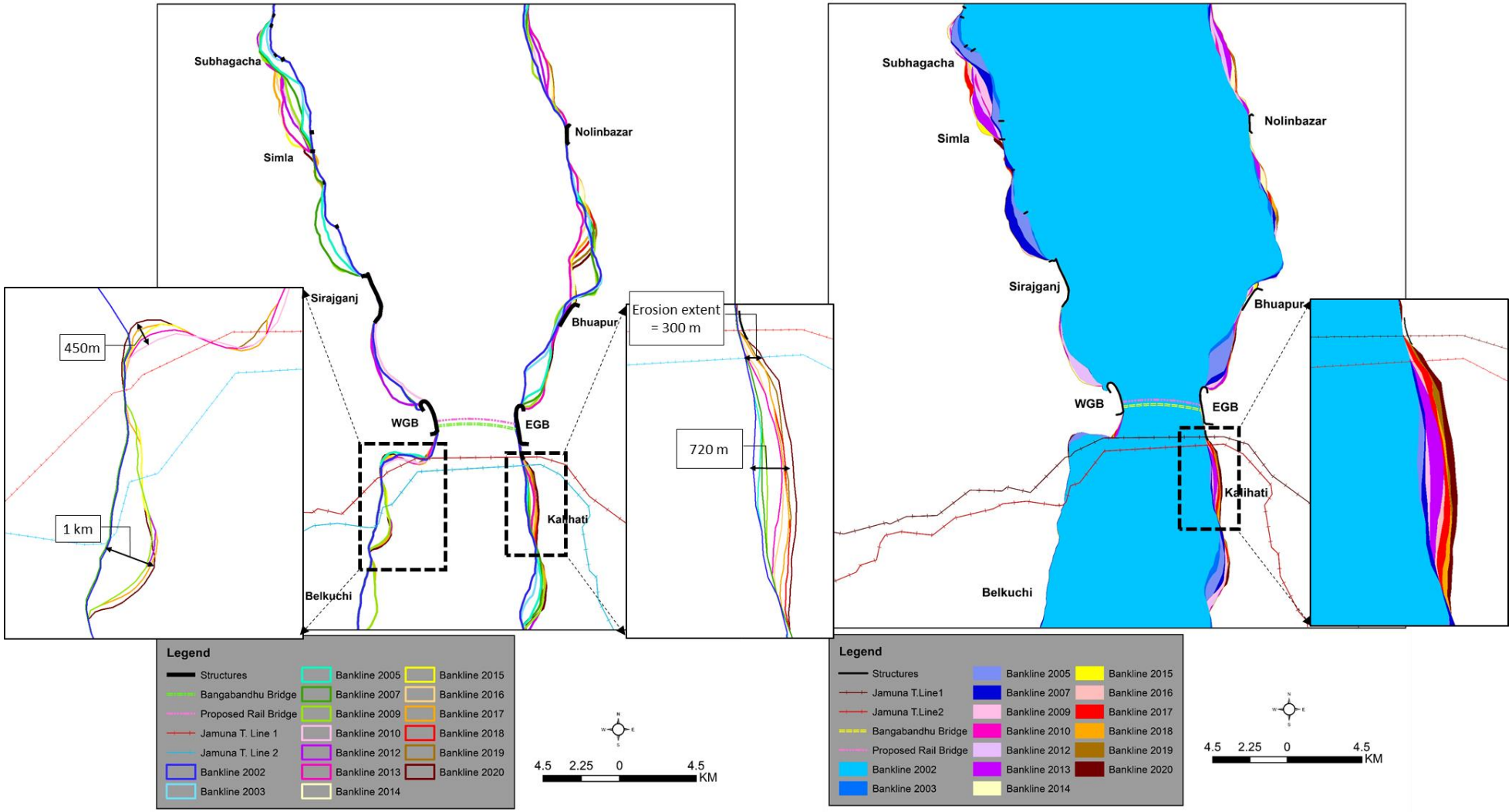


Figure 3.28 *Bankline shifting in Jamuna River within the study area*

3.3.6 Cross-section Analysis

BWDB has been collecting cross-section data on the Jamuna River from 1965 and in Ganges River from 1972. In connection with this study, cross-section data have been plotted for the last 20 years from 2000 to 2019 as per Scope of Works.

Ganges River

The cross-section data of Ganges River within the study area for section RMG 12, RMG 13.1 and RMG 14 has been collected from BWDB and shown in **Figure 3.29** to **Figure 3.31.** The cross-section at RMG 12 is about 9km d/s from HB, whereas RMG 13.1 and RMG 14 is about 1.1km and 8.5km u/s from HB.

The cross-section at RMG 12 shows that the main channel was present along the right bank during the last two decades, **Figure 3.29**. The channel width was found nearly 3200m up to the year 2014, which has been reduced to 1700m in 2019. The deepest scour within this section during the last two decades is found -11.58 mPWD (in 2013).

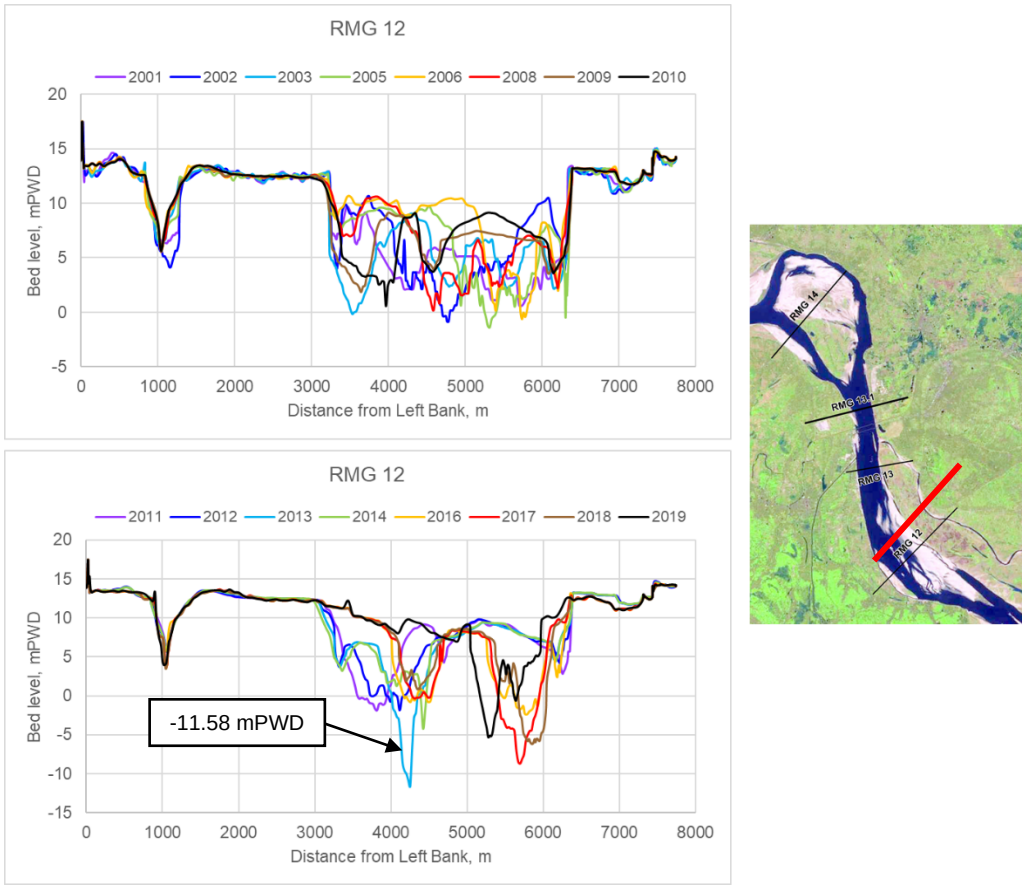


Figure 3.29 *BWDB available Cross-section data at RMG 12 in Ganges River from 2001-2019*

The cross-section at the immediate u/s of HB (RMG 13.1) shows that there is always a presence of deep single channel at this location, **Figure 3.30**. The channel was along the right bank where the maximum scour was found to be -13.82 mPWD (in 2010). Within few years the channel has shifted about 770m towards the left side and finally within last 2-3 years, the channel has been silted up about 12m.

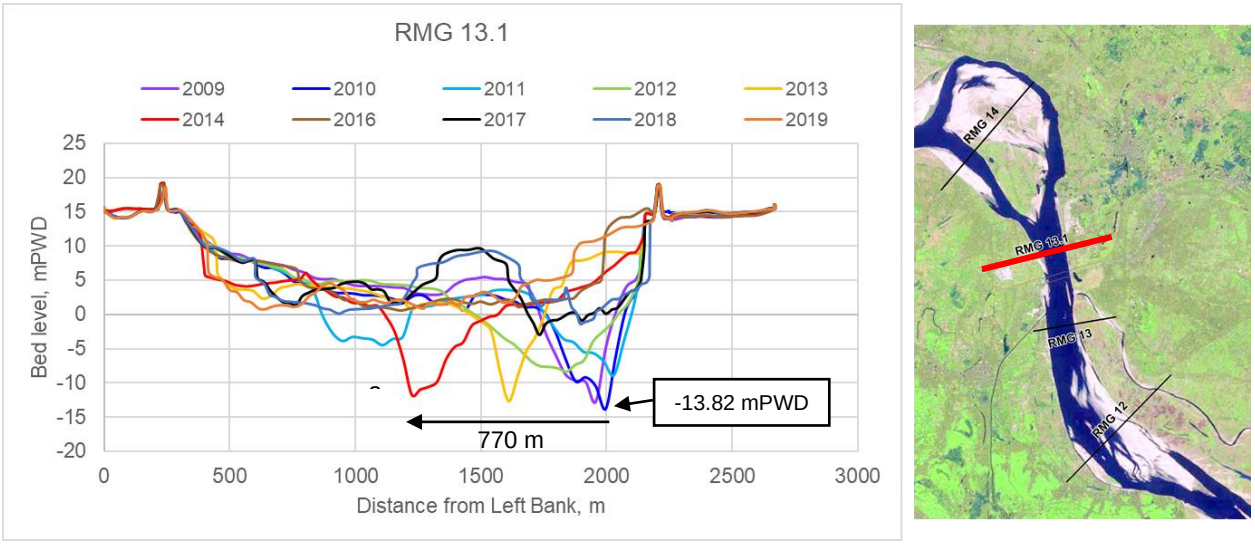


Figure 3.30 *BWDB available Cross-section data at RMG 13.1 in Ganges River from 2009-2019*

The cross-sections at RMG 14 from the year 2001 to 2019 have been plotted in **Figure 3.31**. The plot shows that during the first decade (2001-2010) the channel was entirely along the left bank. The deepest scour (-5.89 mPWD) was observed in 2009, which slightly reduced to -5.08 mPWD in 2014. Afterwards, in 2016 the channel planform along this location has totally changed and three different channels were formed. In 2019, the main channel was prominent along the right side and the left channel was abandoned.

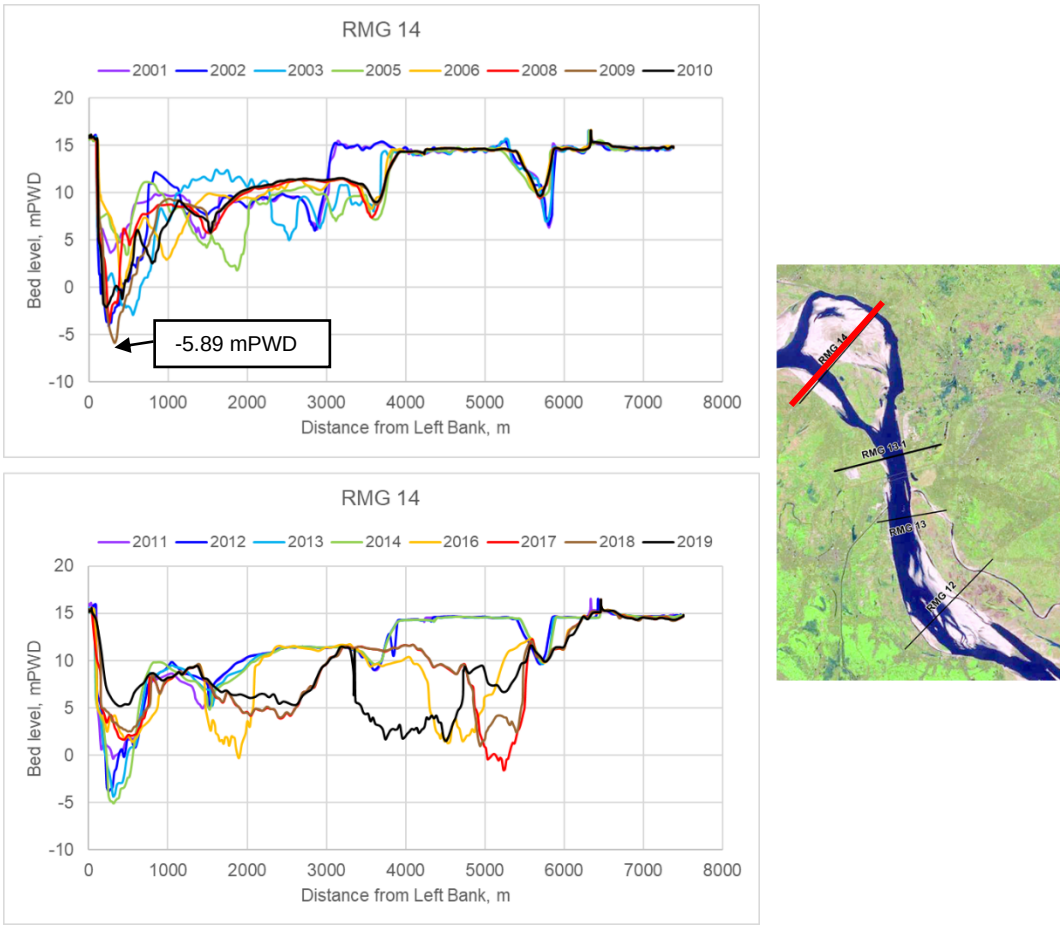
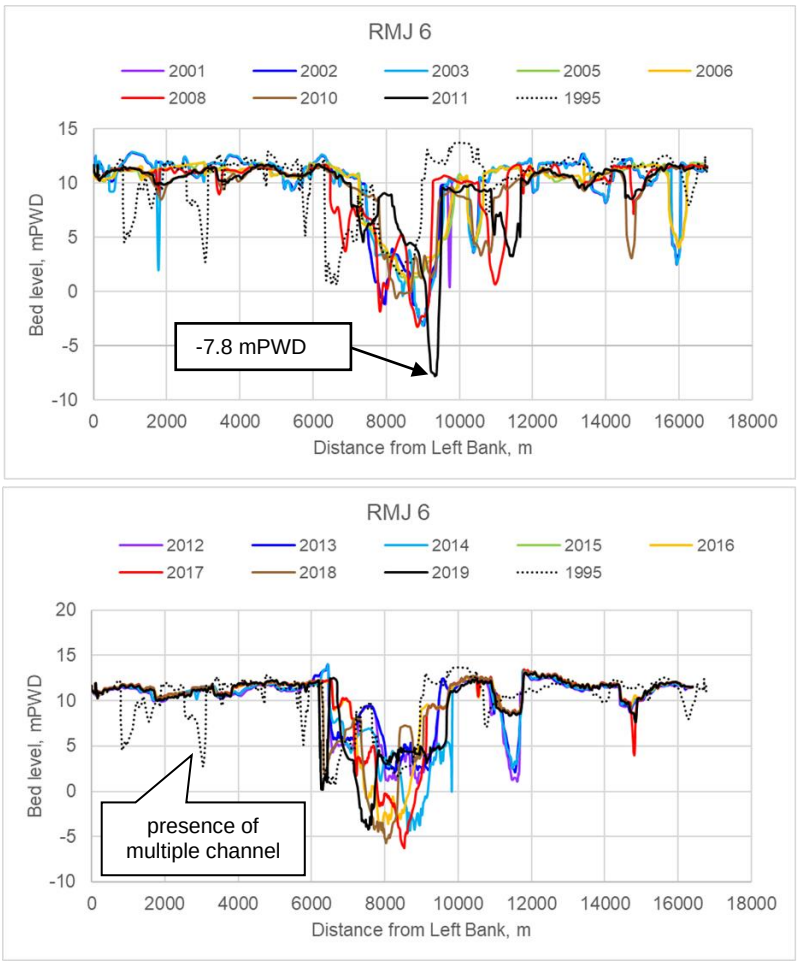


Figure 3.31 *BWDB Cross-section data at RMG 14 in Ganges River from 2001-2019*

Jamuna River

Similarly, the cross-section data within the study area of Jamuna River, for section RMJ 6, RMJ 6.1, RMJ 7, RMJ 7.1 and RMJ 8 has been collected from BWDB and shown in **Figure 3.32** to **Figure 3.36**. The cross-section at RMG 6 is about 6.2km d/s from B. Bridge, whereas RMJ 6.1, RMJ 7, RMJ 7.1 and RMJ 8 is about 345m, 7.5km, 12.8km and 16.8km u/s from B. Bridge.



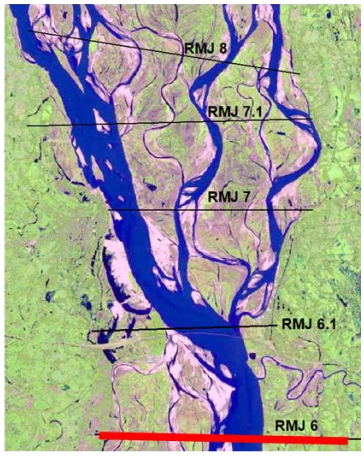


Figure 3.32 *BWDB available Cross-section data at RMJ 6 in Jamuna River from 2001-2019*

The cross-section at RMJ 6 plotted in **Figure 3.32** shows that during the last 20 years, a single channel was always dominated in this location. This is most probably due to the construction of Bangabandhu Bridge in 1998. The cross-section for the period of 1995 shows the presence of multiple channels along this section.

The cross-section at RMJ 6.1 is located very near to the existing bridge site. The lowest bed level during the last 20 years is found about -8.3 mPWD in 2010 along the EGB, see **Figure 3.33**. Considering the last 50 years, the lowest bed level was found -12.7 mPWD in 1998 along this section.

The cross-section plot for RMJ 7, RMJ 7.1 and RMJ 8 are also provided in **Figure 3.34** to **Figure 3.36**. The plots show that multiple channels were existed along these sections, as it is a braided river. These cross-sections are located more upstream from the proposed transmission lines.

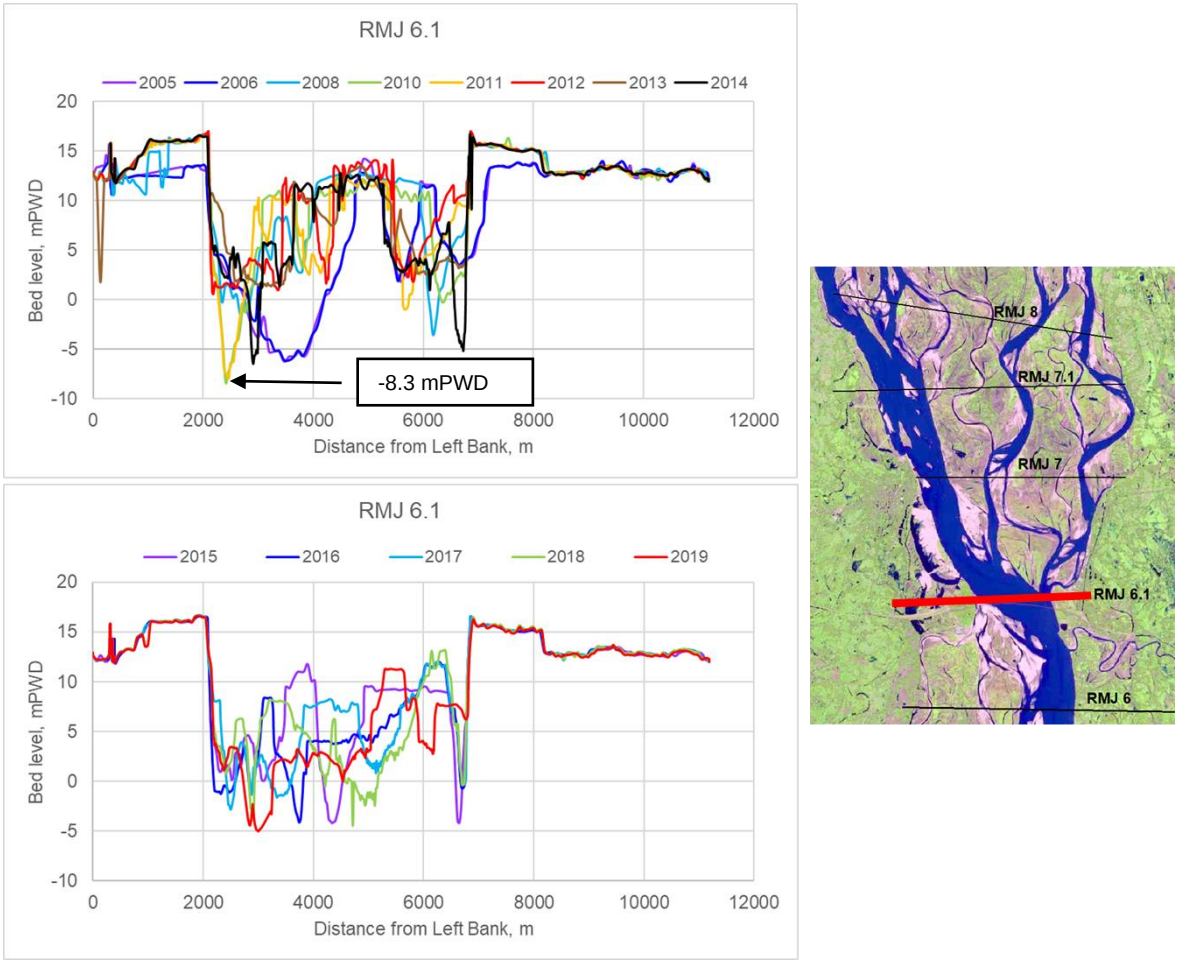


Figure 3.33 *BWDB available Cross-section data at RMJ 6.1 in Jamuna River from 2005-2019*

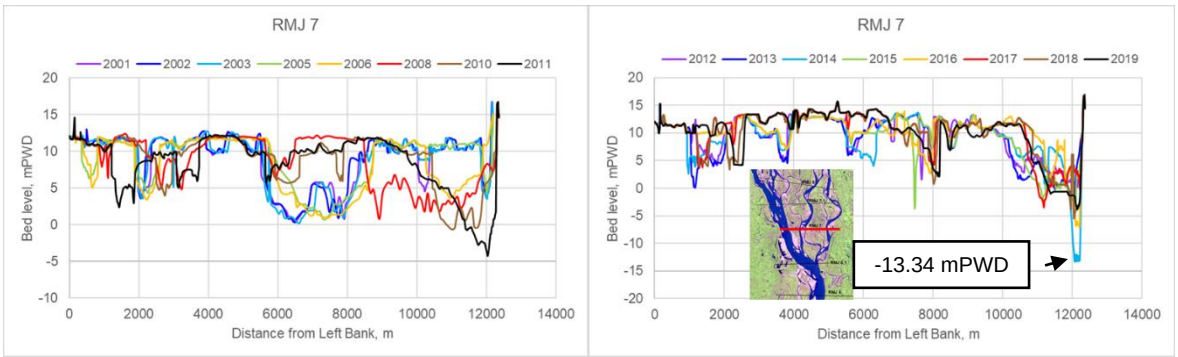


Figure 3.34 *BWDB available Cross-section data at RMJ 7 in Jamuna River from 2001-2019*

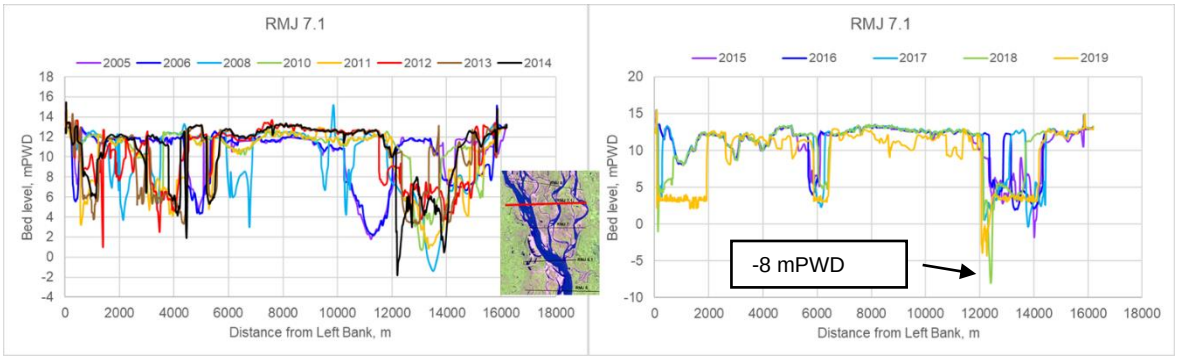


Figure 3.35 *BWDB available Cross-section data at RMJ 7.1 in Jamuna River from 2005-2019*

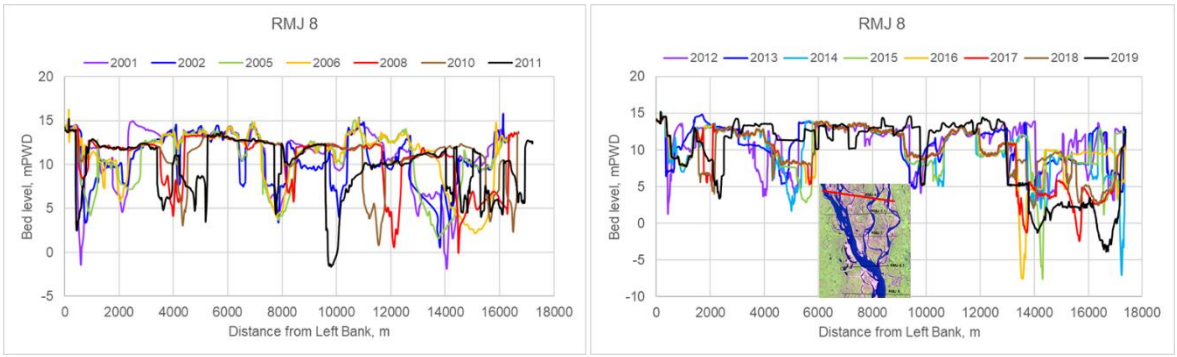


Figure 3.36 *BWDB available Cross-section data at RMJ 8 in Jamuna River from 2001-2019*

3.3.7 Scour Analysis from Observed Data

The lowest scour level is the minimum bed elevation observed in one cross-section of a river. BWDB has been taken cross-section data along certain locations in Ganges and Jamuna River. **Figure 3.37** shows the locations of cross-section surveyed by BWDB in Ganges and Jamuna River within the study area.

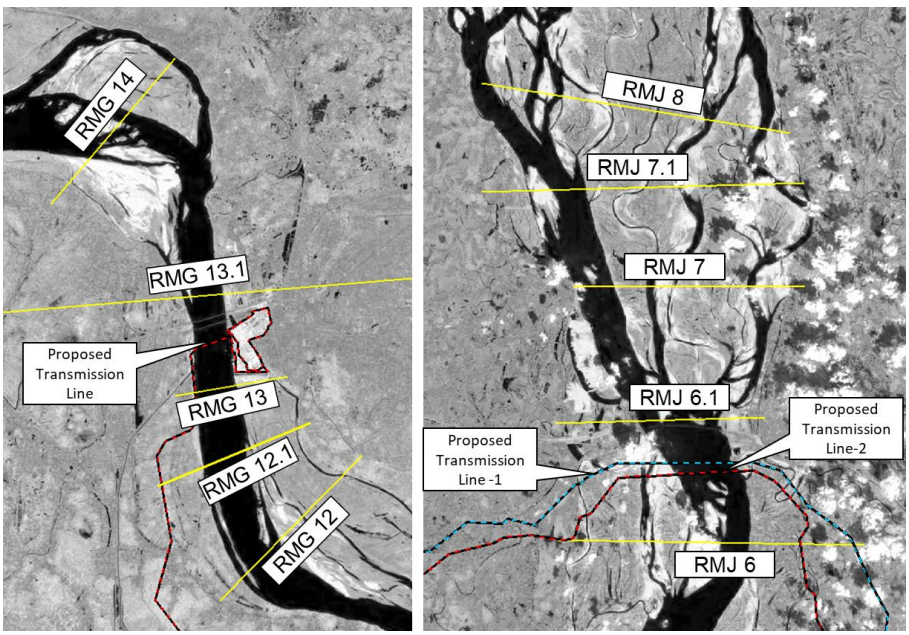


Figure 3.37 *Locations of BWDB Cross-sections in Jamuna (left) and Ganges (right) River*

Ganges River

The lowest scour level within the study area of Ganges River during the last 40 years (1980-2020) is plotted and shown in **Figure 3.38**. It is seen that the minimum bed level was about -13.82 mPWD in 2010 along the cross-section of RMG 13.1. **Table 3.15** summarizes the lowest, highest and average scour level observed along these BWDB cross-sections. It is mention worthy that the proposed Rooppur 400KV transmission line in Ganges River is in between of RMG 13 and RMG 13.1.

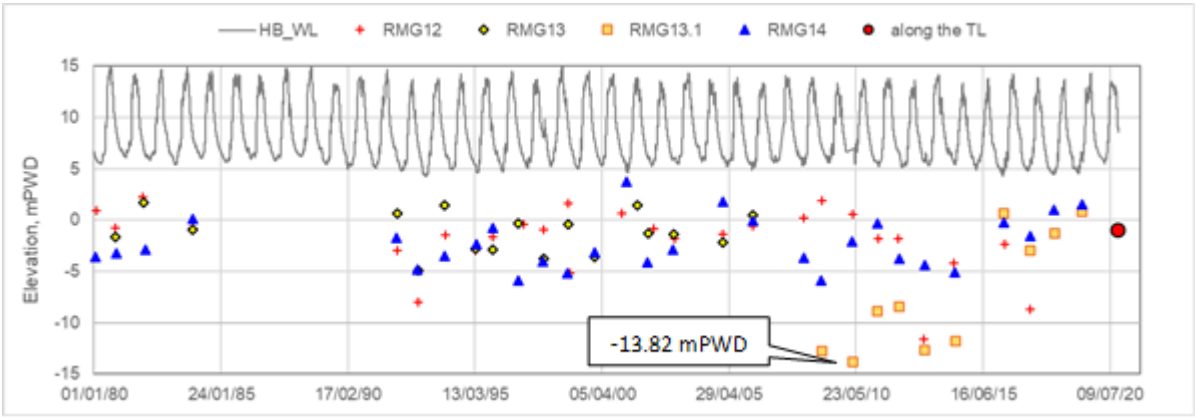


Figure 3.38 *Observed Maximum Scour Level in Ganges River within the study area*

Table 3.15 Lowest, highest and average scour level along BWDB Cross-section in Ganges River

Scour Level, mPWD	RMG 12	RMG 13	RMG 13.1	RMG 14
Lowest	-11.58	-4.9	**-13.82**	-5.89
Highest	2.23	1.71	0.79	3.71
Average	-1.92	-1.2	-7.128	-2.37

Moreover, cross-sections along the transmission line is also extracted from the available survey data and shown in **Figure 3.39**. These data were retrieved from IWM archive. The data period covers from 2010-2020. The graph suggests that the main channel was along the right bank during 2010-2013, which clearly shifted towards left bank within the period from 2014-2017. The deepest scour level along this transmission line is observed -11.9 mPWD in 2010 that was aggraded almost 11m within ten years. In 2020, the cross-section is showing very uniform pattern and the lowest scour level is found -0.97mPWD. **Figure 3.40** is showing the lowest scour level surveyed by IWM during the period from 2010-2020.

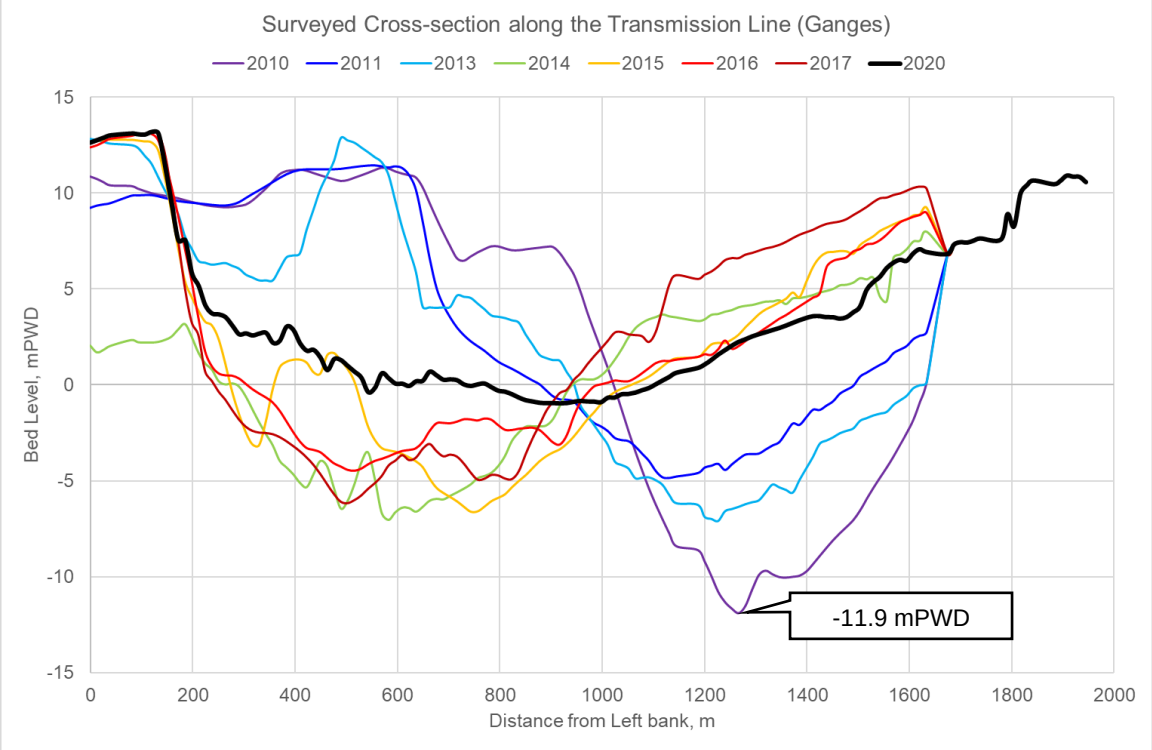


Figure 3.39 *Surveyed Cross-section in Ganges River along the Rooppur 400KV Transmission Line*

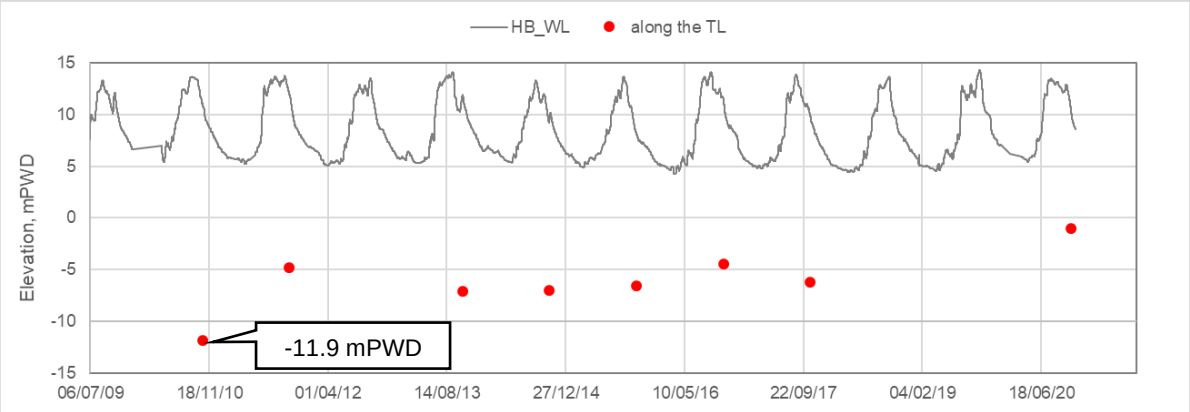


Figure 3.40 *Observed Maximum Scour Level along the Transmission Line in Ganges River*

Jamuna River

The lowest scour levels within the study area of Jamuna River is also plotted for available BWDB cross-sections plot and represented in **Figure 3.41**. The recent surveyed value of the deepest scour level is also included in this plot. It is seen that the minimum bed level is found -34.36 mPWD in Jamuna River within the study area, which is found along the proposed Rooppur 400KV transmission line (TL 1). This is the deepest scour which is observed during the last four decades in Jamuna River. The lowest, highest and average scour level along the BWDB cross-section in Jamuna River in summarized in **Table 3.16**.

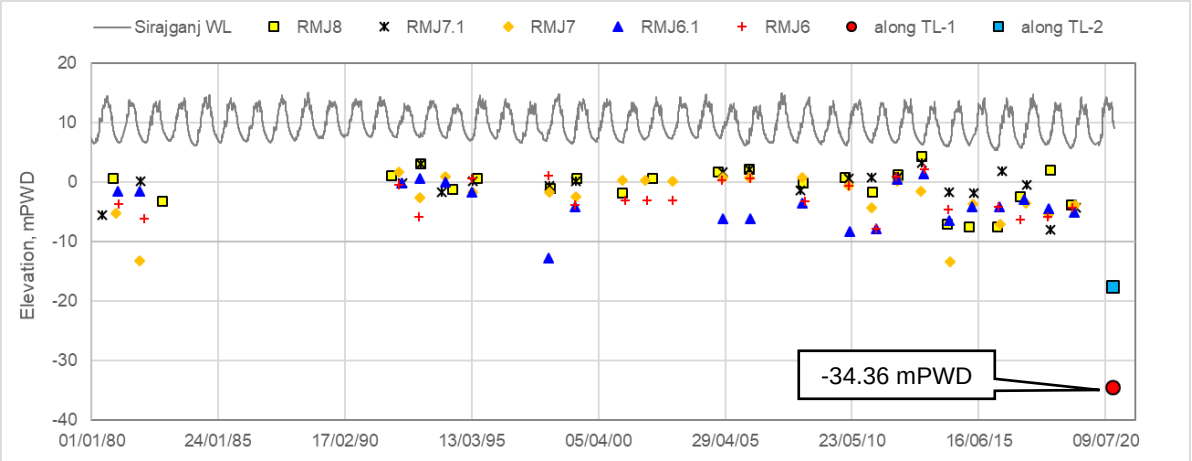


Figure 3.41 *Observed Maximum Scour Level in Jamuna River within the study area*

Table 3.16 Lowest, highest and average scour level along BWDB Cross-section in Jamuna River

Scour Level, mPWD	RMJ 6	RMJ 6.1	RMJ 7	RMJ 7.1	RMJ 8
Lowest	-7.8	-12.69	**-13.34**	-8	-7.55
Highest	2.12	1.35	1.72	3.31	4.3
Average	-2.56	-4.02	-3.14	-0.59	-0.718

The observed maximum scour level in Jamuna River at Sirajganj Hardpoint, East Guide Bund and West Guide Bund are plotted for the available data period from 2004-2020, shown in **Figure 3.42**. These observed data are also retrieved from IWM archive. From the available data, it is seen that the maximum scour level is found -33.04 mPWD in 2006 along the WGB.

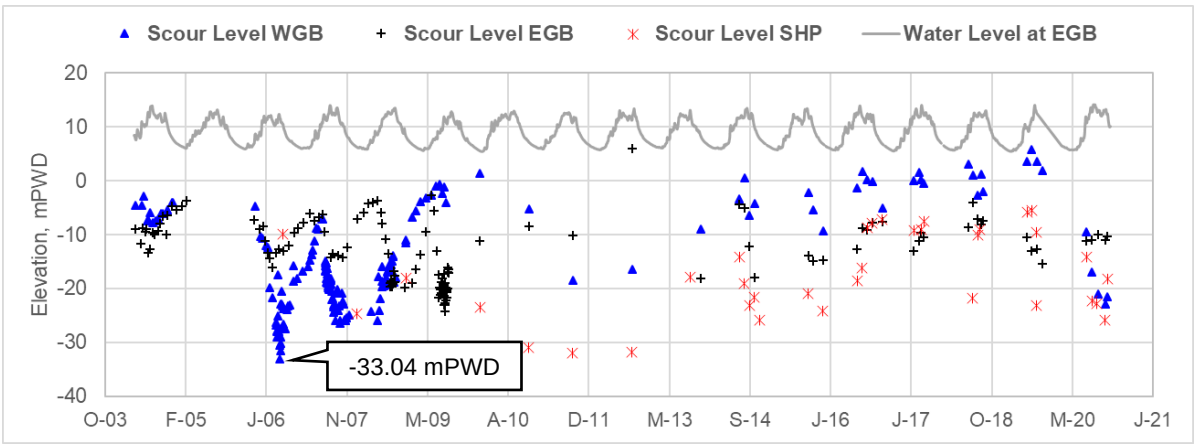


Figure 3.42 *Observed Maximum Scour Level in Jamuna River at SHP, EGB and WGB of Bangabandhu Bridge from 2004-2020*

3.3.8 Chemical Analysis

The measured water sample data in Jamuna and Ganges River at different locations are shown in **Table 3.17**. The average value of TDS, Choride, sulphate and calcium are also given in this table.

Table 3.17 Measured Water Sample Data in Jamuna and Ganges River

River	Station	Location	TDS, (mg/L)	Chloride, Cl^- (mg/L)	Sulphate, $SO4^{2-}$ (mg/L)	Calcium, Ca(mg/L)
Jamuna	B.U.S	0.6D	59.7	38	6	7.19
	B.D.S	0.6D	61	52	6	6.35
	B.U.S	0.6D	62.7	54	8	6.28
	B.D.S	0.6D	63.2	44	11	6.6
	B.U.S	0.6D	62	40	8	5.87
	B.D.S	0.6D	62.5	50	9	6.99
Average			***61.85***	***46.33***	***8.00***	***6.55***
Ganges	Hatkhola (u/s)	0.6D	111.1	45	7	5.87
		0.6D	122.6	36	6	6.04
		0.6D	111.8	40	59	6.1
	Hardinge (d/s)	0.6D	109.9	41	6	5.86
		0.6D	109	43	6	4.57
		0.6D	111	39	6	6.09
Average			***112.57***	***40.67***	***15.00***	***5.76***

3.4 Information on Past High Floods at and around the Crossing Location

In past, there were some major floods (1987, 1988, 1998, 2004 and 2007) occurred in Ganges and Jamuna River. Among all these flood events, 1987, 1988 and 1998 are the most severe one. The number of days that the water level was above the danger level in Ganges and Jamuna River are calculated (**Table 3.18**) to understand the severity and flood inundation situation along the study area. The water level hydrograph of different flood events and danger level (marked as red line) are plotted in **Figure 3.43** and **3.44**. It is seen that the severity is higher in Jamuna River rather than Ganges River. In 2018, the maximum water level did not cross the danger level. So, the inundation map is not done for this flow event.

The flood inundation map for these flood events are plotted and shown from **Figure 3.45** to **Figure 3.49**.

Table 3.18 No of days the water level was above the danger level in Ganges and Jamuna River near the study area

Flood Event	No. of days the water level was above the danger level	
	Sirajganj	Hardinge Bridge
1987	63	24
1988	53	22
1998	69	26
2004	32	0
2007	55	0
2018	0	0

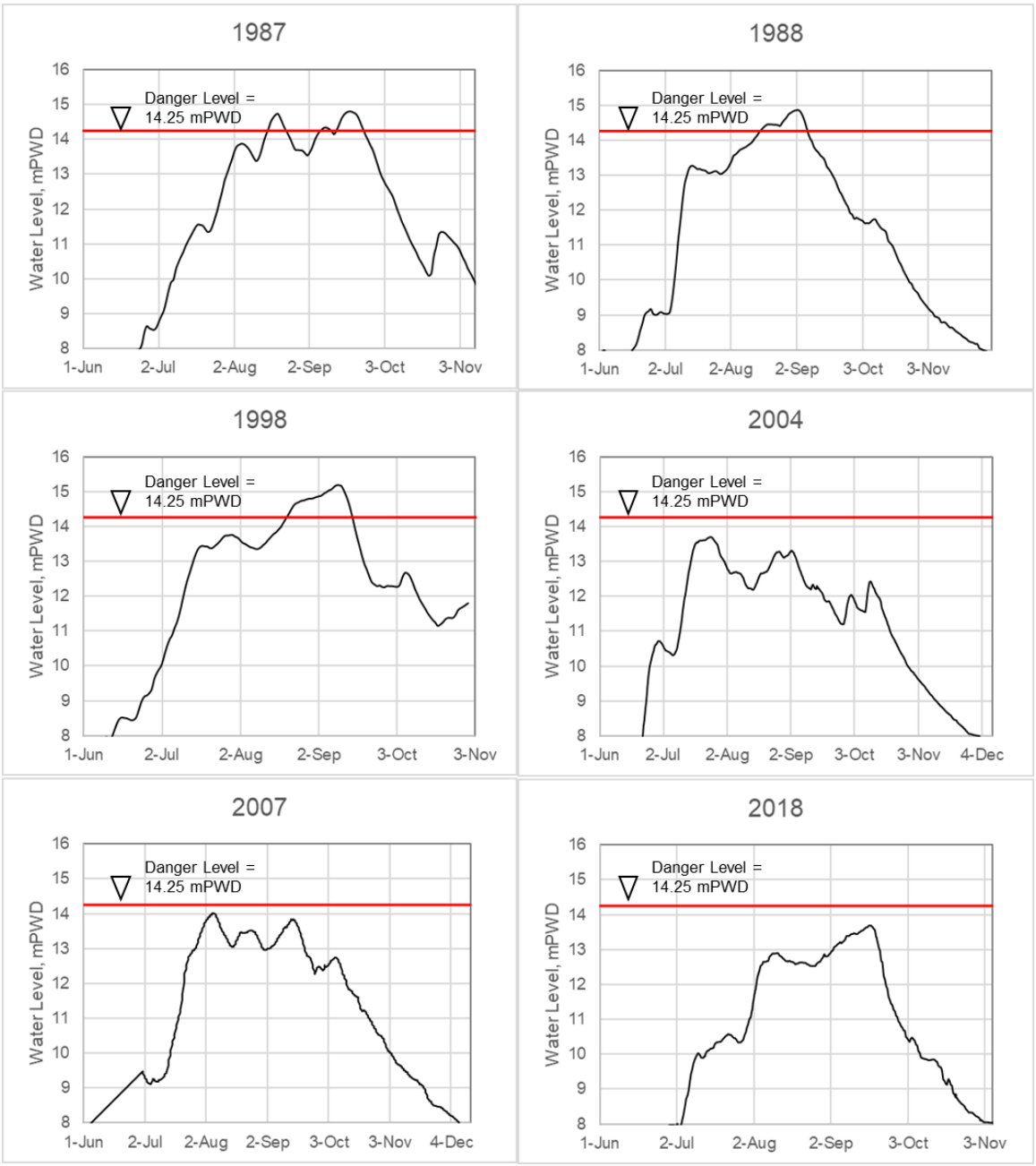


Figure 3.43 *Water Level Hydrograph of 1987, 1988, 1998, 2004, 2007 and 2018 of Ganges River at Hardinge Bridge station*

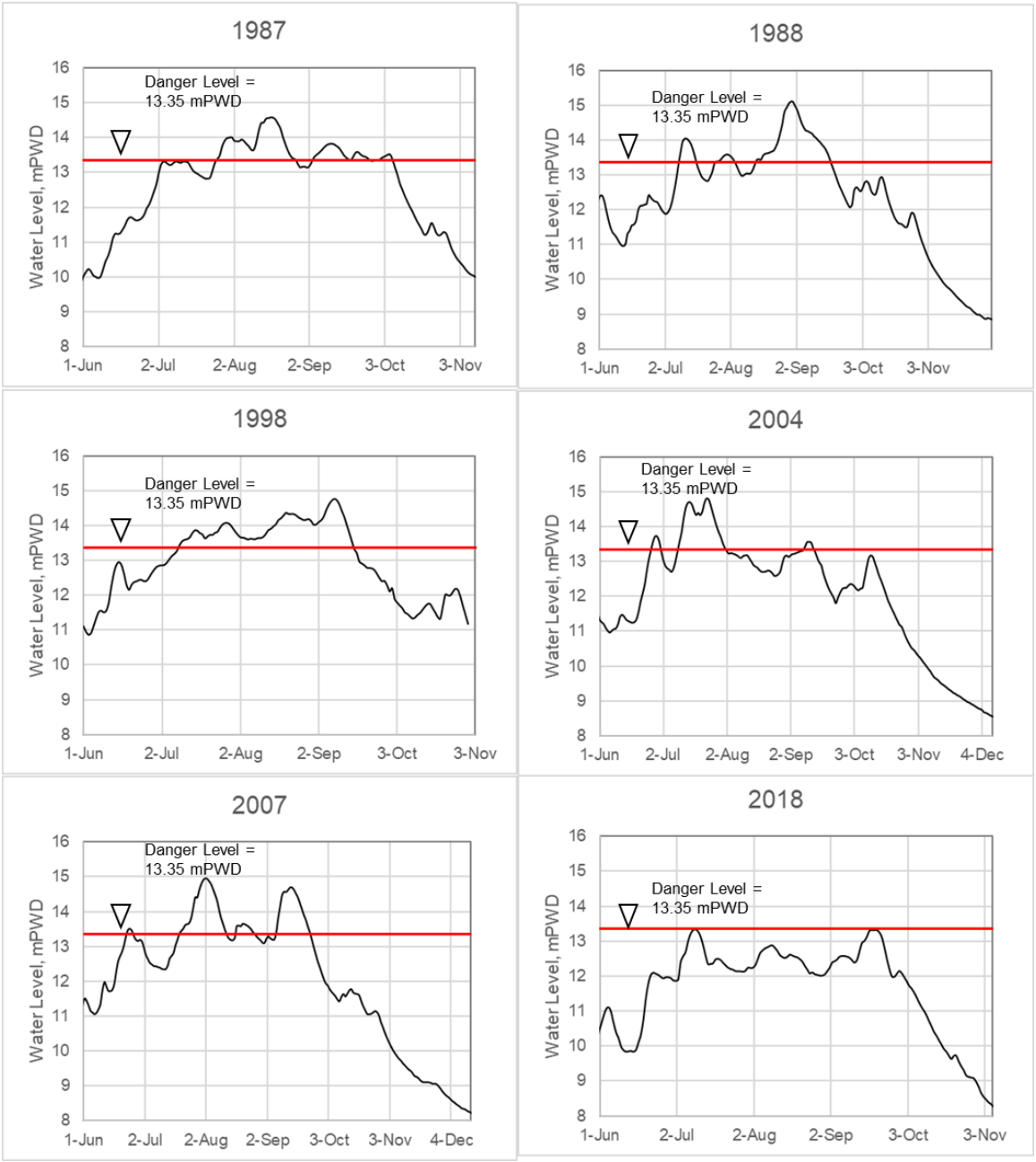


Figure 3.44 *Water Level Hydrograph of 1987, 1988, 1998, 2004, 2007 and 2018 of Ganges River at Hardinge Bridge station*

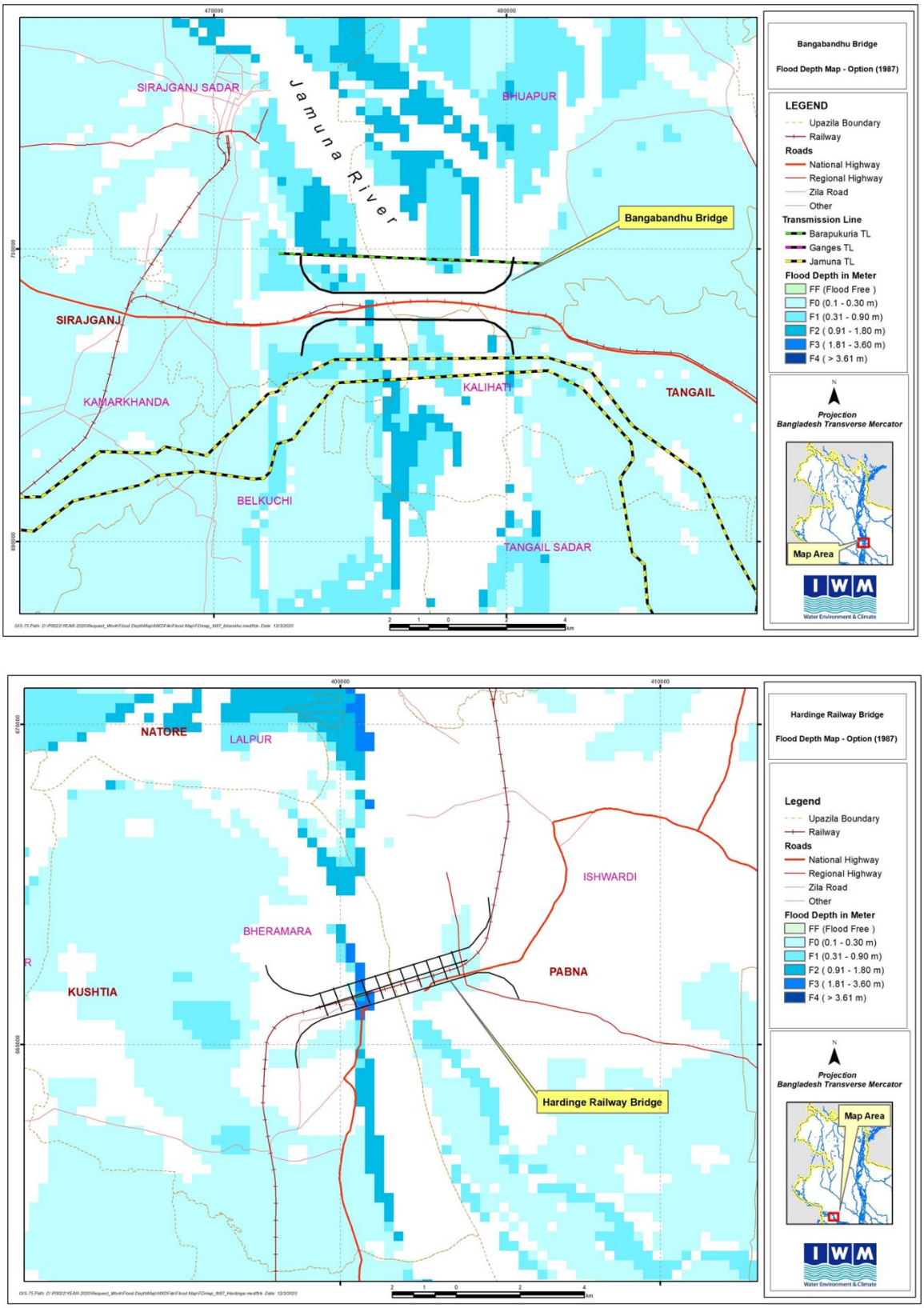


Figure 3.45 *Floodplain Inundation Map of the Jamuna (top) and the Ganges (bottom) River for 1987 flood event*

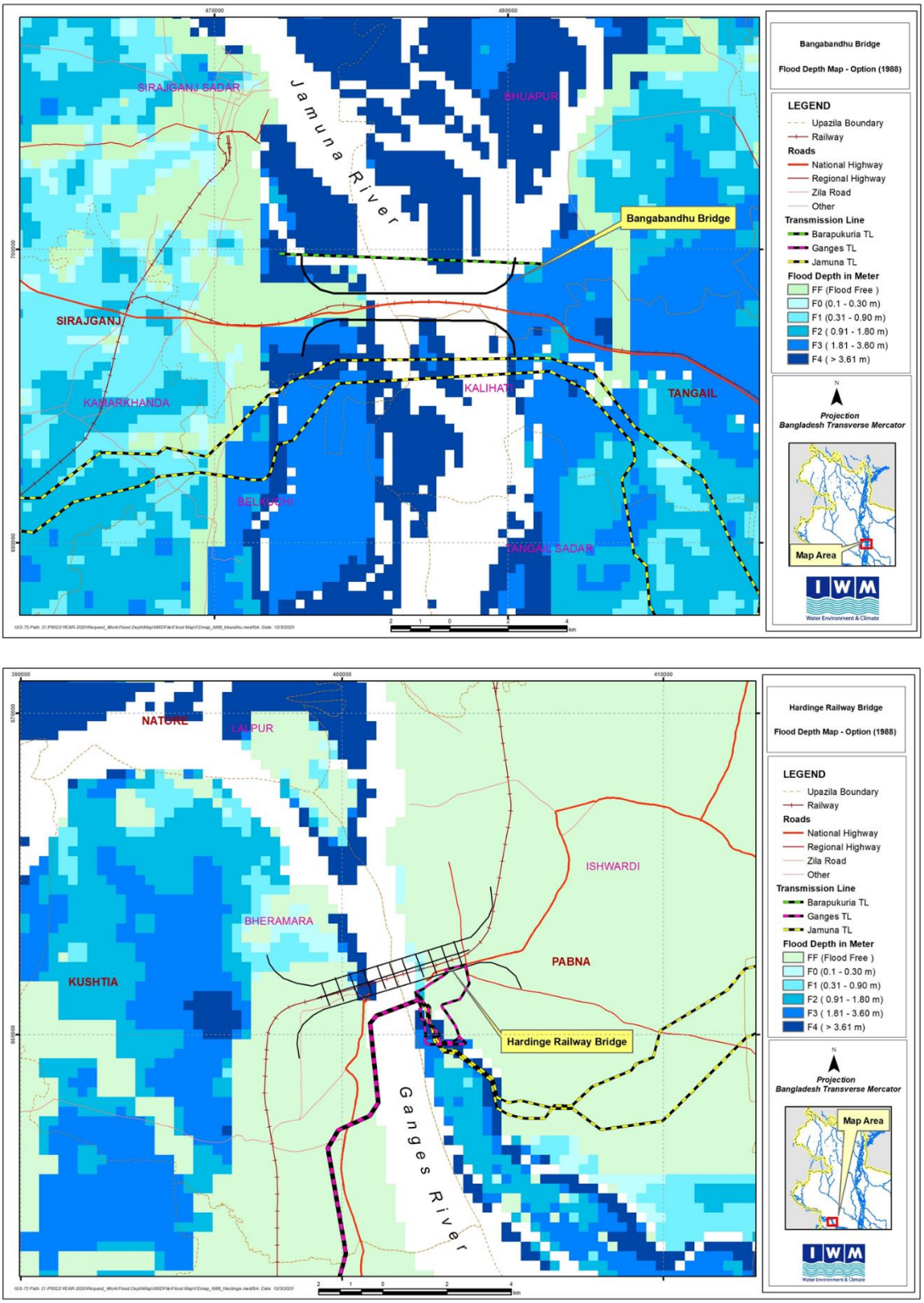


Figure 3.46 *Floodplain Inundation Map of the Jamuna (top) and the Ganges (bottom) River for 1988 flood event*

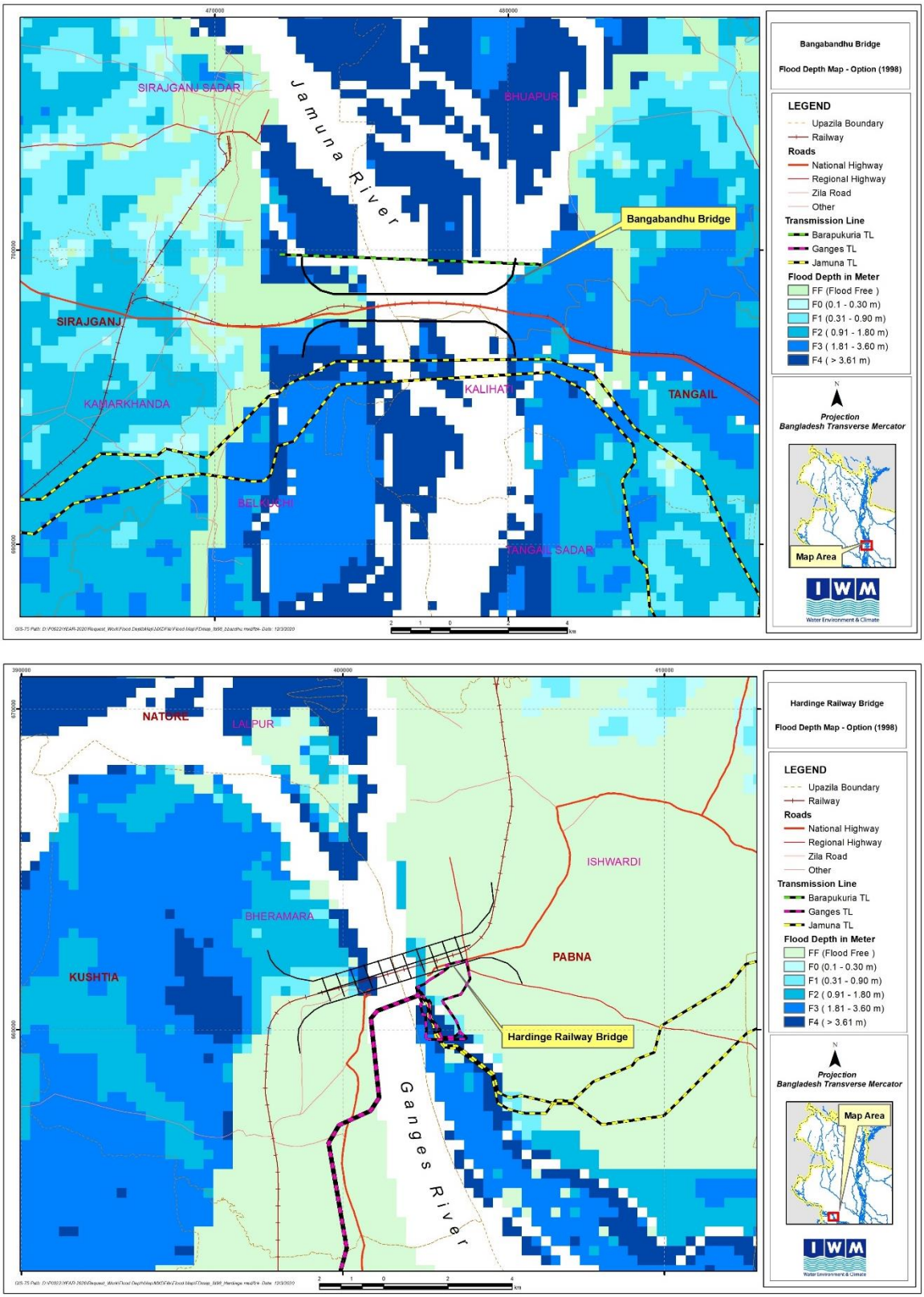


Figure 3.47 *Floodplain Inundation Map of the Jamuna (top) and the Ganges (bottom) River for 1998 flood event*

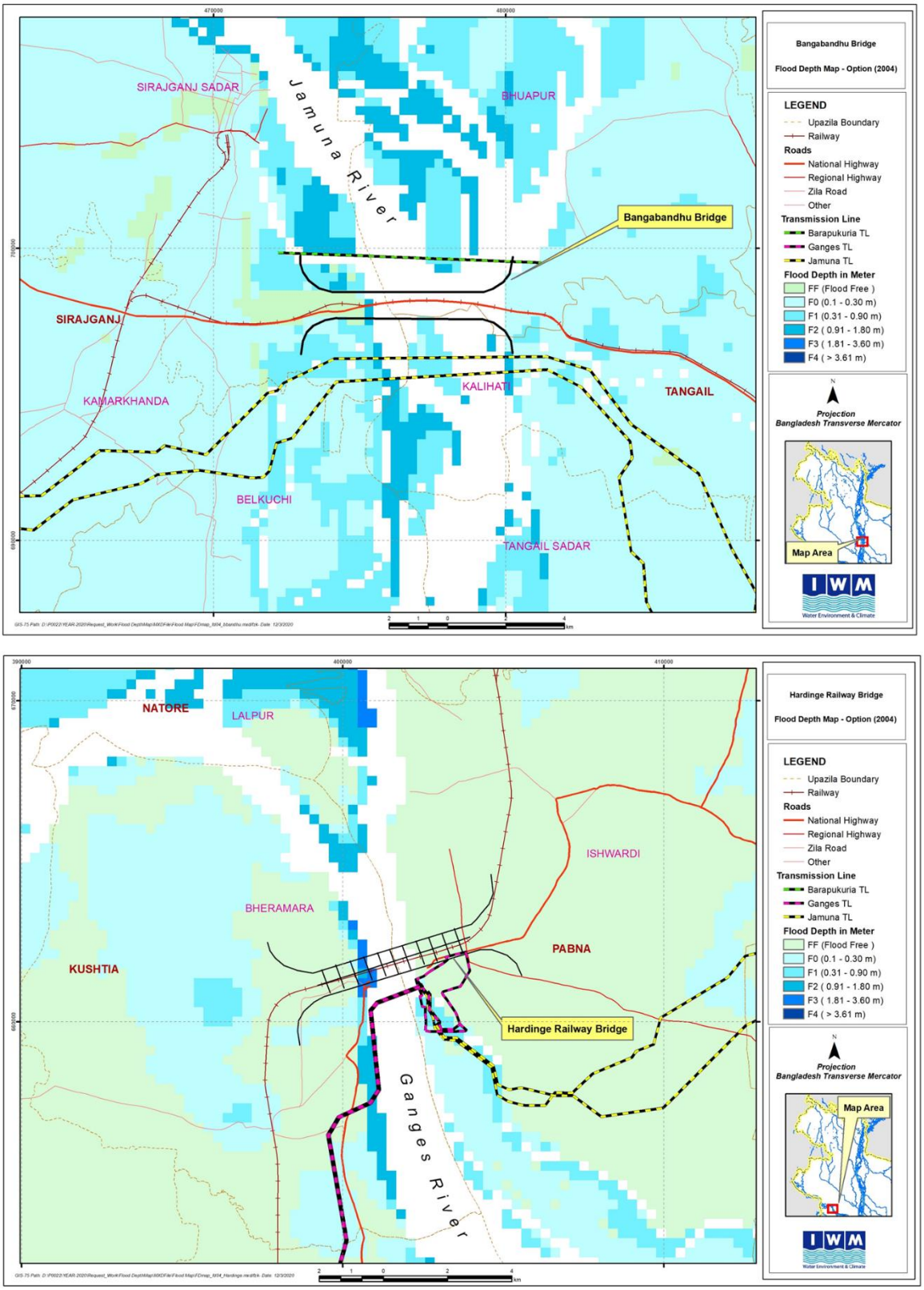


Figure 3.48 *Floodplain Inundation Map of the Jamuna (top) and the Ganges (bottom) River for 2004 flood event*

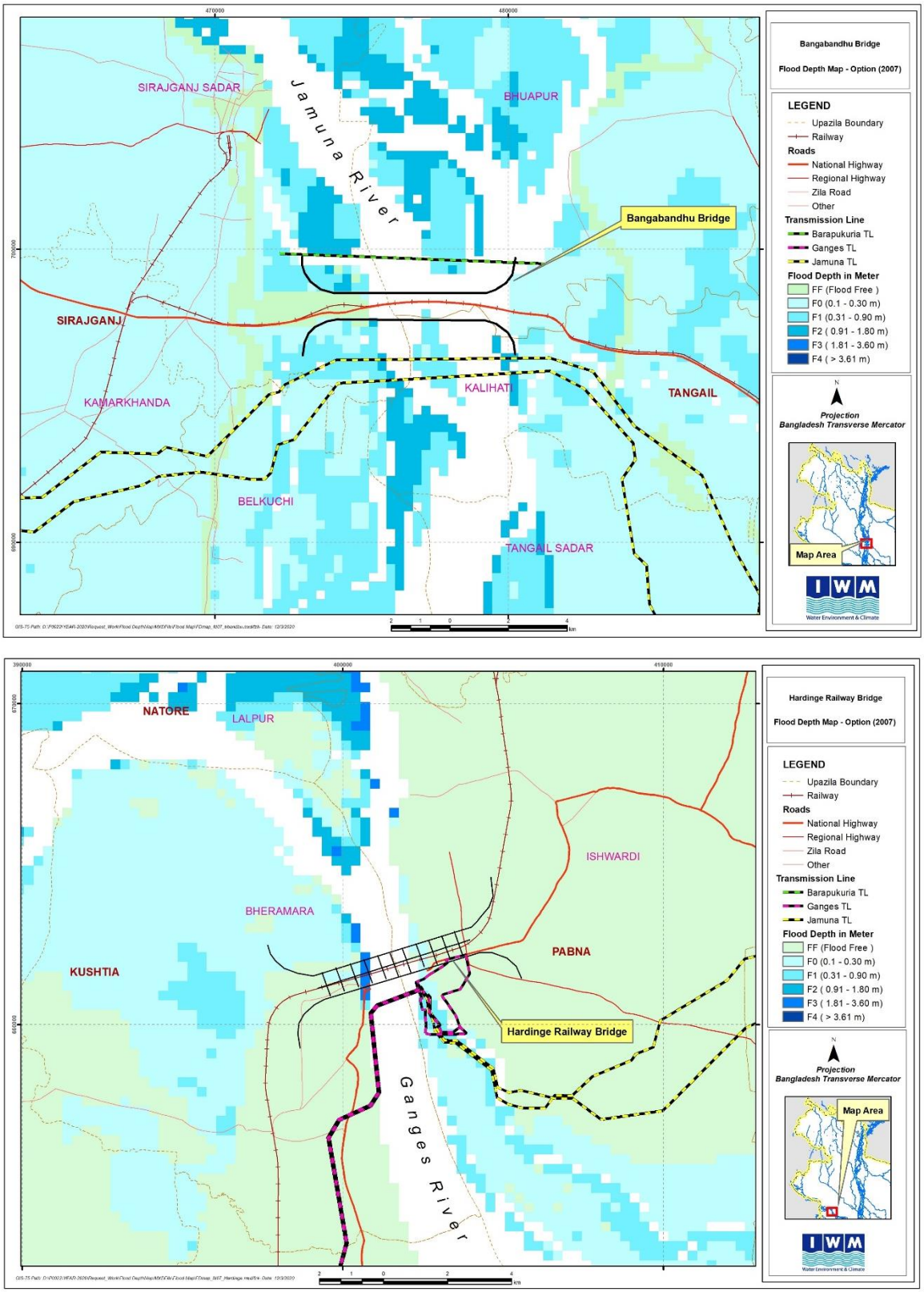


Figure 3.49 *Floodplain Inundation Map of the Jamuna (top) and the Ganges (bottom) River for 2007 flood event*

4. DEVELOPMENT OF 2D MORPHOLOGICAL MODEL

4. DEVELOPMENT OF 2D MORPHOLOGICAL MODEL

For the present study, MIKE 21C, two-dimensional modeling tool (hydrodynamic and morphological), has been used that simulates full hydrodynamic and morphological processes of erosion/sedimentation of rivers with movable bed. MIKE 21C applies curvilinear grid incorporating fully unsteady flow, bed load as well as suspended load including dynamic bed level changes through simple continuity, and updates the planform through bank erosion model considering the secondary currents.

The two-dimensional (2D) model used in this study is based on a fine grid, which allows for a detailed spatial resolution. The model is applied to simulate base condition as well as "with project" condition. In short, application of the 2D morphological model developed in this study covers mainly the followings:

- Identify the maximum scour near the crossing area due to "with project" condition
- Assessment of maximum velocity around the crossing area due to construction of transmission lines
- Assessment of the probable maximum water level at the crossing line
- Identification of vulnerable locations having the threat of bank erosion along both the bank of rivers
- Provide Hydraulic Parameters for Designing Transmission Line/ Pier
- Impact of river crossing transmission line on nearby Existing Structures in the river.

4.1 Model Extent

Two-dimensional model of the Jamuna River prepared for this present study extends from 20 km upstream to 10 downstream of the Bangabandhu Bridge, and for Ganges River it extends from 18km upstream to 12 downstream of the Harding Bridge. Two models cover about 30 km length of Jamuna and Ganges River.

4.2 Generation of Curvilinear Grid

Grid is the main framework needed to construct at first in developing a 2D model with MIKE 21C. Therefore, a curvilinear grid was generated covering entire model extent using "Curvilinear Grid Generator" tool of MIKE 21C. **Table 4.1** summarizes the model extent and computational grid dimensions of the developed 2D morphological model of Ganges and Jamuna. **Figure 4.1 and 4.2** presents part of the computational grid of Ganges and Jamuna, respectively.

Table 4.1 Model Extent and Computational Grid Resolution used in 2D Model of Jamuna and Ganges River

River	Model Extent	Grid Nos.		Total Computational Points
		Along the river	Across the river	
Ganges	30Km	319	202	64438
Jamuna	30Km	557	822	457854

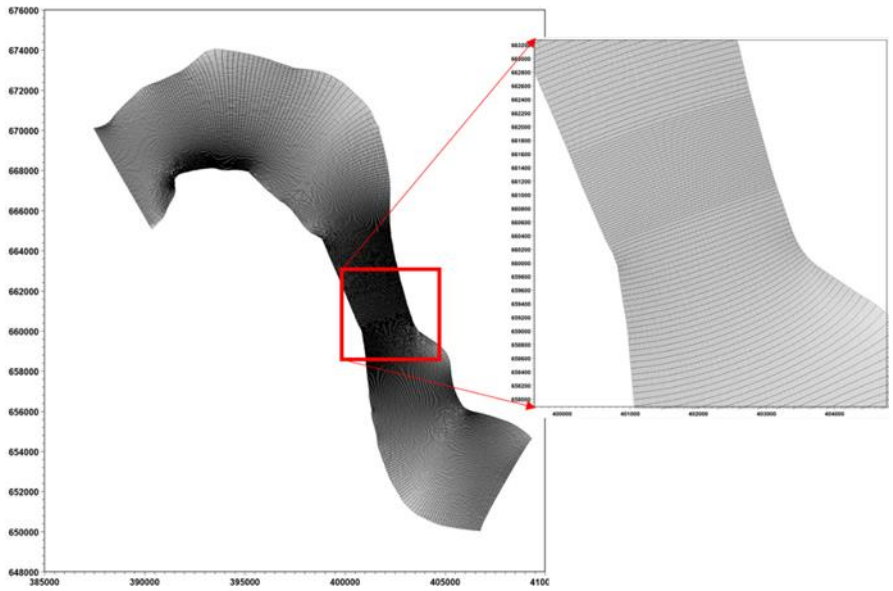


Figure 4.1 *Part of Curvilinear Grid of 2D Morphological Model of the Ganges River*

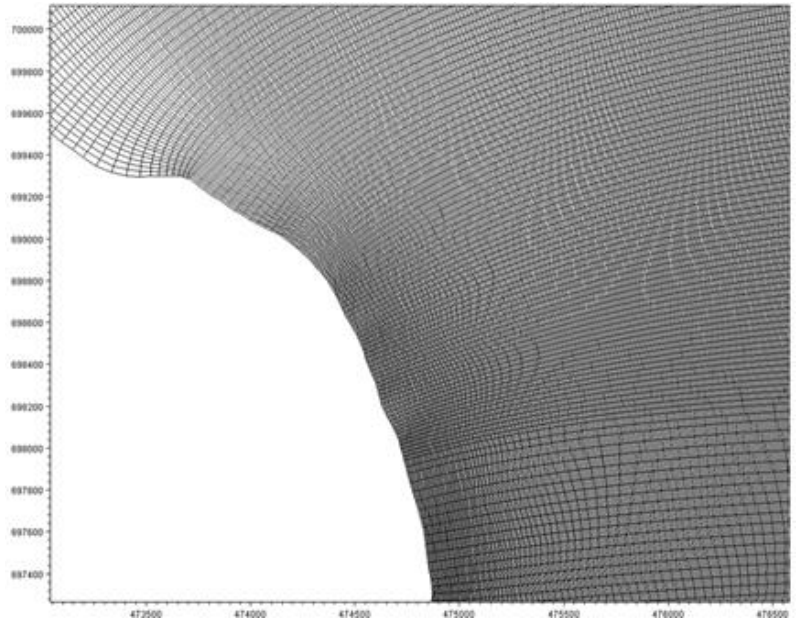


Figure 4.2 *Curvilinear Grid of 2D Morphological Model of the Jamuna River*

4.3 Preparation of Bathymetry

Bathymetry is the bed level contour which is supposed to be given in the model simulation as an input for the entire model area. In MIKE 21C modelling system, this contour map is prepared by giving a bed level value in each of the grid cell. The bathymetry of Jamuna River has been prepared using the available data collected during January 2020 in connection with the project "Bangabandhu Sheikh Mujib Railway Bridge Construction Project (BSMRBCP)" of Bangladesh Railway (BR). Similarly, the bathymetry of Ganges River has been prepared using the available data surveyed during October 2020. Interpolation method was used to fill up each grid cell with bed level data. **Figure 4.3 and 4.4** shows the completed bathymetry of Ganges and Jamuna River, respectively.

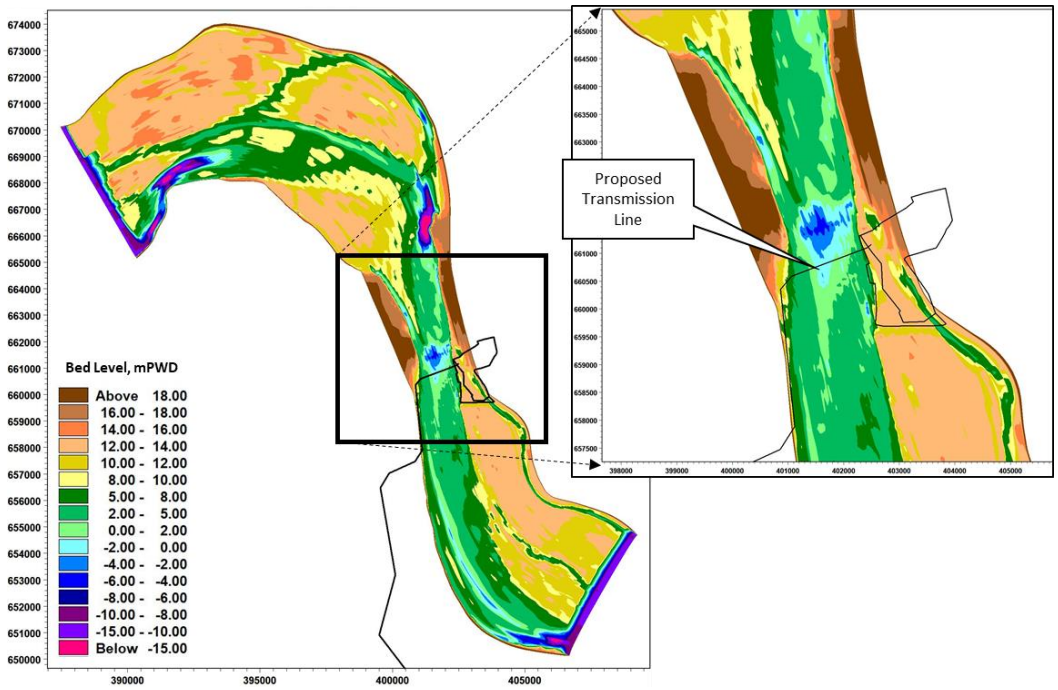


Figure 4.3 *Prepared Base Bathymetry for Ganges River*

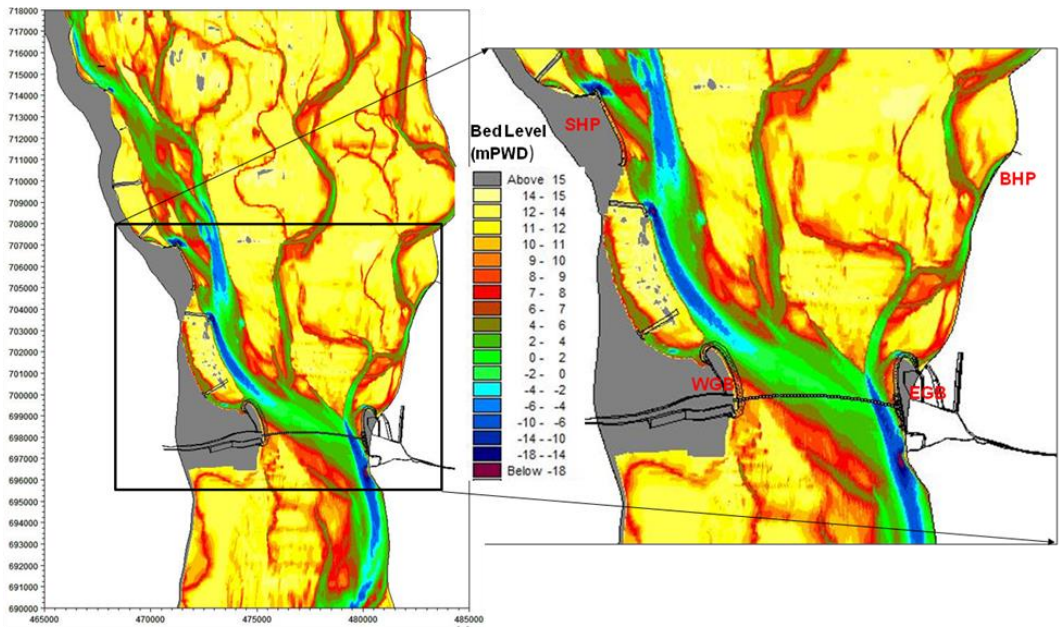


Figure 4.4 *Prepared Base Bathymetry for Jamuna River*

Bathymetry is also prepared for the “with project” condition for Ganges and Jamuna River incorporating the transmission piers. **Figure 4.5** is showing the bathymetry for “with project” condition for both the rivers.

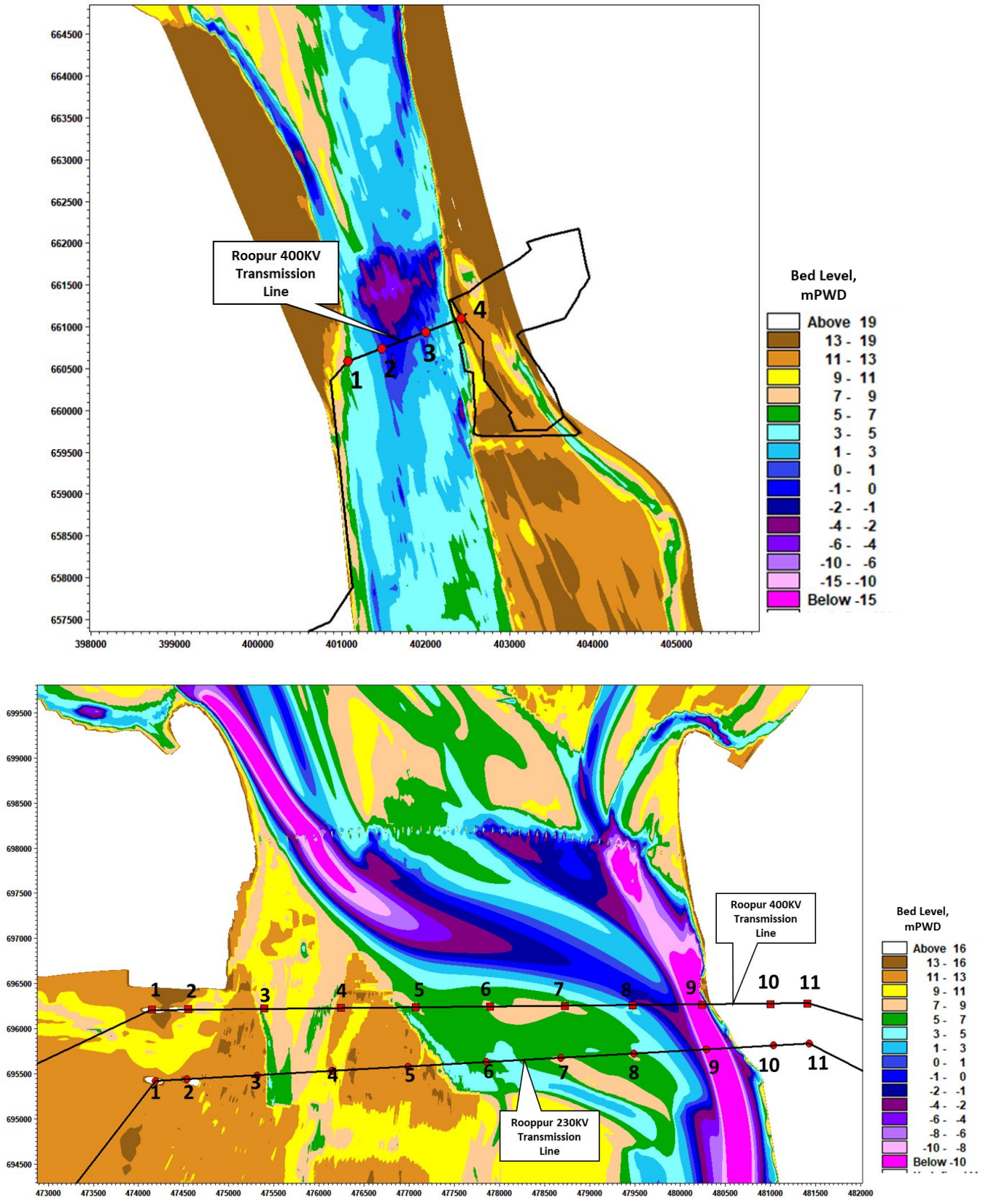
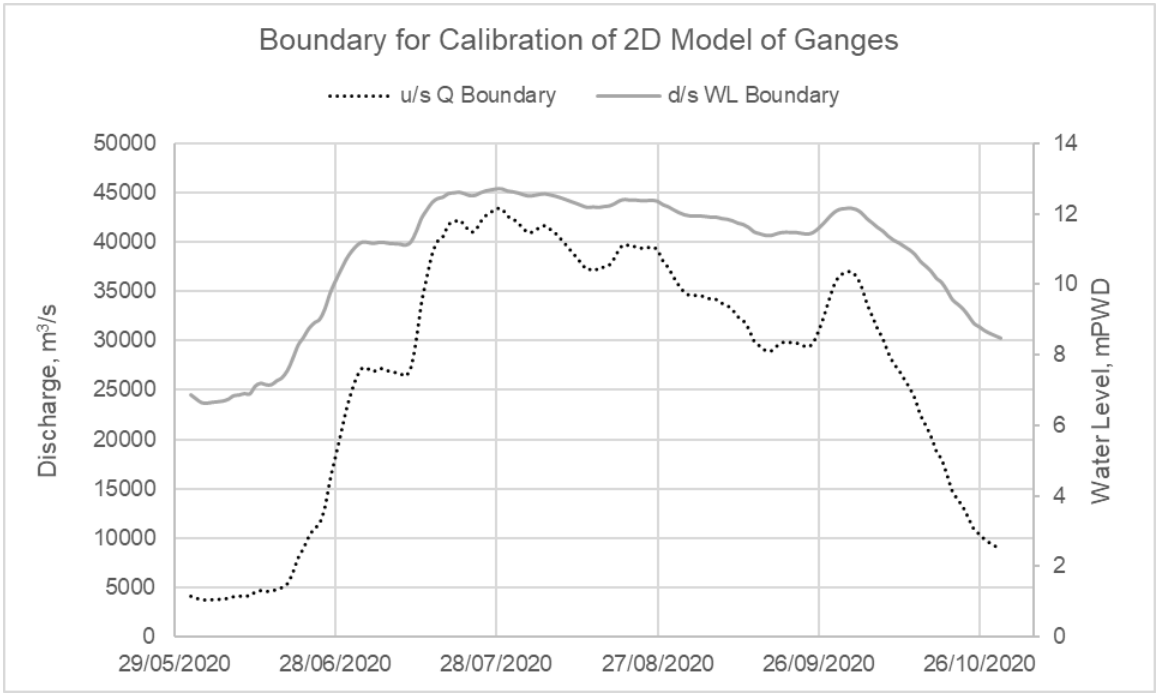


Figure 4.5 *Bathymetry after incorporating transmission piers in Ganges (top) and Jamuna (bottom)River*

4.4 Boundary for 2D Model Simulations

For Ganges River, the model has one upstream discharge boundary and one downstream water level boundary. On the other hand, for Jamuna River, along with these boundaries, there is a side discharge boundary for Dhaleshwari River. The model has been calibrated using the hydrographs of 2020, shown in **Figure 4.6**. The boundaries for High Flood Event and Average Flood Event are shown in **Figure 4.7 and 4.8**.

From the available data and previous model studies, it is observed that most of the morphological developments take place during the monsoon period. Therefore, all model simulations (calibration/verification, simulation for "without" and "with project" condition) mainly concentrated for a five-months monsoon flood period (typically from June to October).



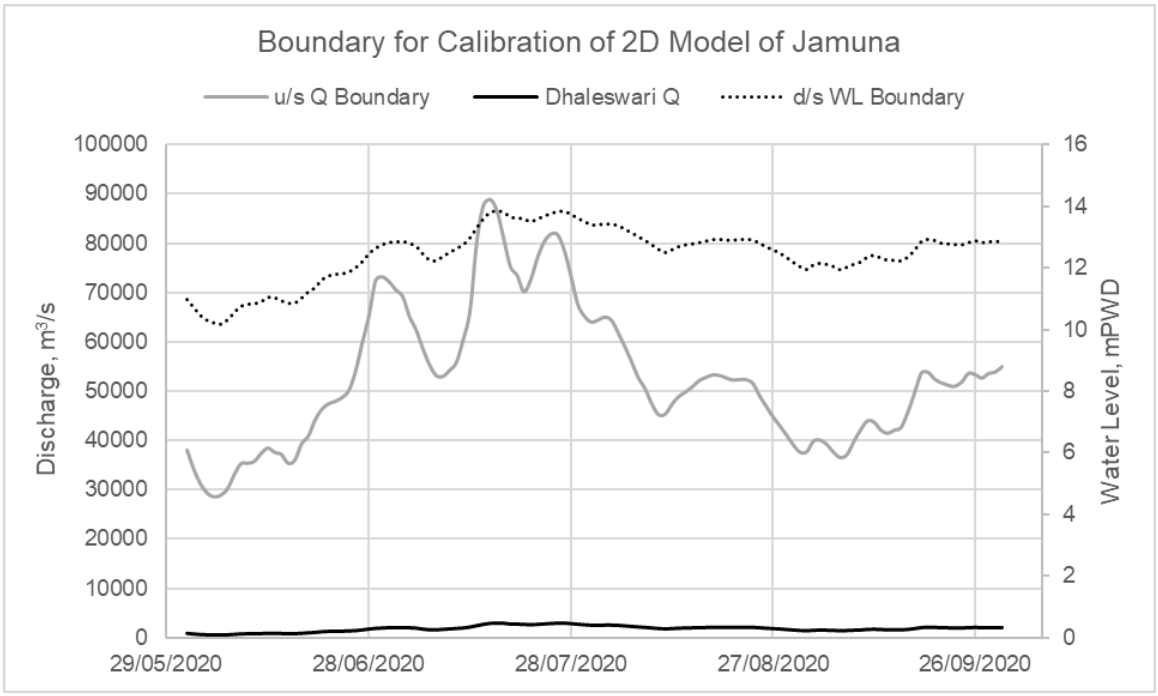


Figure 4.6 *Hydrological Model Boundary for Calibration Purpose*



Figure 4.7 *Hydrological Model Boundary for High Flood Event*

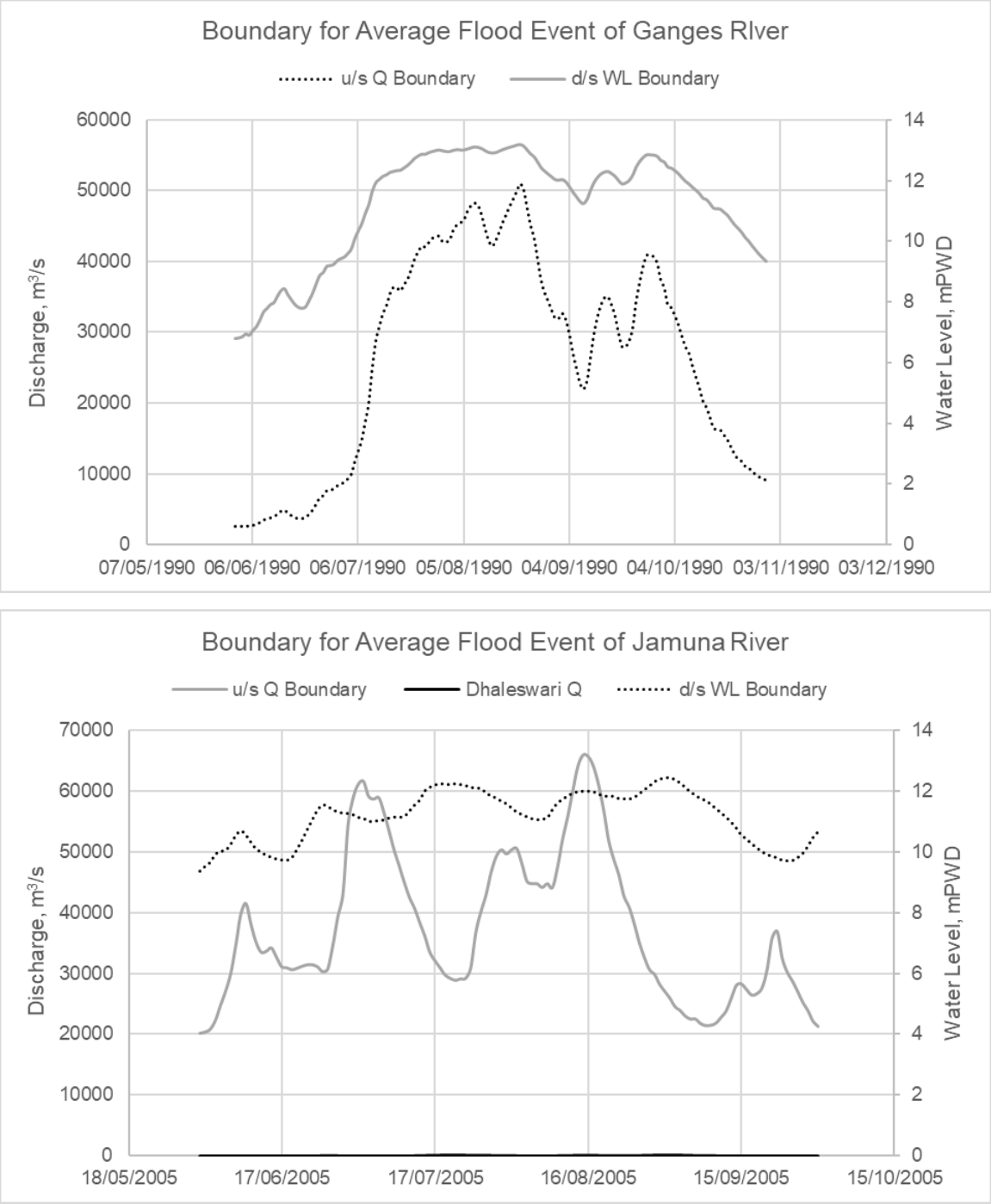


Figure 4.8 *Hydrological Model Boundary for Average Flood Event*

4.5 Calibration of the Model

Hydrodynamic Calibration

Hydrodynamic calibration of 2D model was accomplished comparing observed water level with 2D model generated data at some salient locations within the model domain by tuning parameters like chezy value 'C' and Eddy Viscosity. **Figure 4.9** to **Figure 4.10** shows comparison of model generated water levels with the observed data at Hardinge Bridge of Ganges River and EGB of Jamuna River. These figures show satisfactory agreement between 2D model generated water level and discharge with observed data for 2020.

Morphological Calibration

The 2D morphological model has been calibrated with observed sediment transport of the study reach. Sediment transport formula along with measured median grain size of the sediment and calibrating parameters are tabulated in **Table 4.2**. Plot of suspended sediment transport calibration have been shown in **Figure 4.11** to **Figure 4.12** for Ganges and Jamuna River, respectively. The calibration has been done plotting the sediment transport load against flow discharge.

Table 4.2 Sediment Transport Formula, Physical Parameters and Calibrating Parameters

River Name	Sediment Transport Formula used		d_{50} (mm)	Alluvial Resistance, $C = aH^b$ ($m^{1/2}/s$)		Eddy viscosity (m^2/s)
	Bed Load	Suspended Load		A	b	
Ganges	0.4 Engelund-Hansen	1.6 Engelund-Hansen	0.15	27 to 34	0.5	5
Jamuna	Van Rijn	Van Rijn	0.18	14 to 30	0.5	6

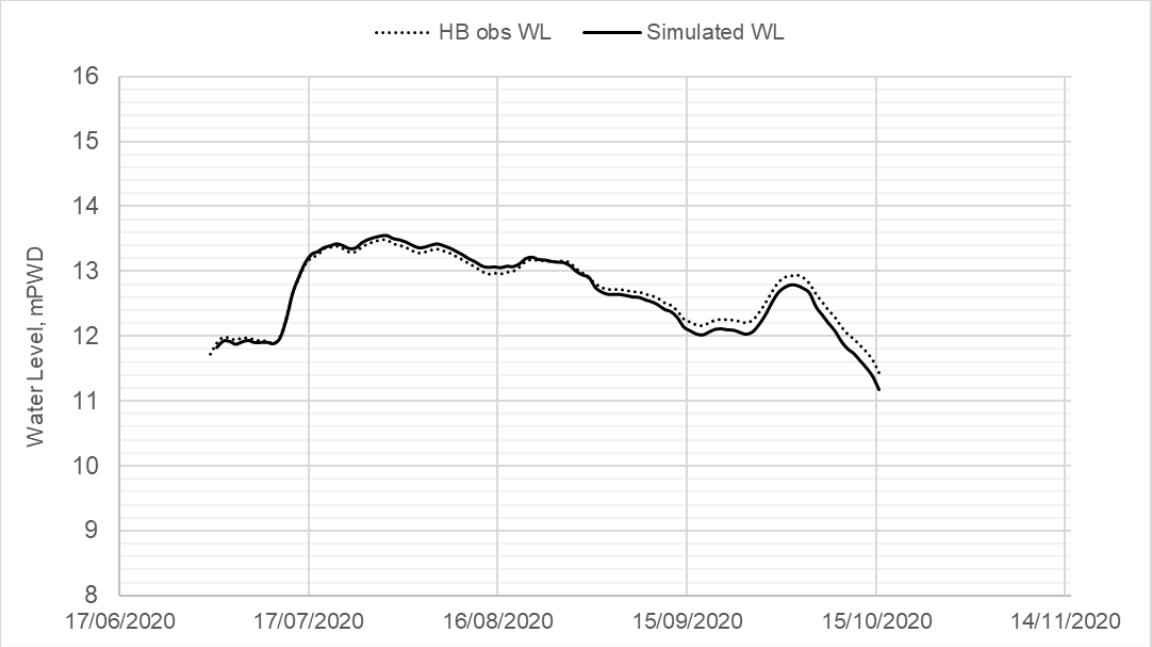


Figure 4.9 *Water level calibration of 2D model of the Ganges River at Hardinge Bridge*

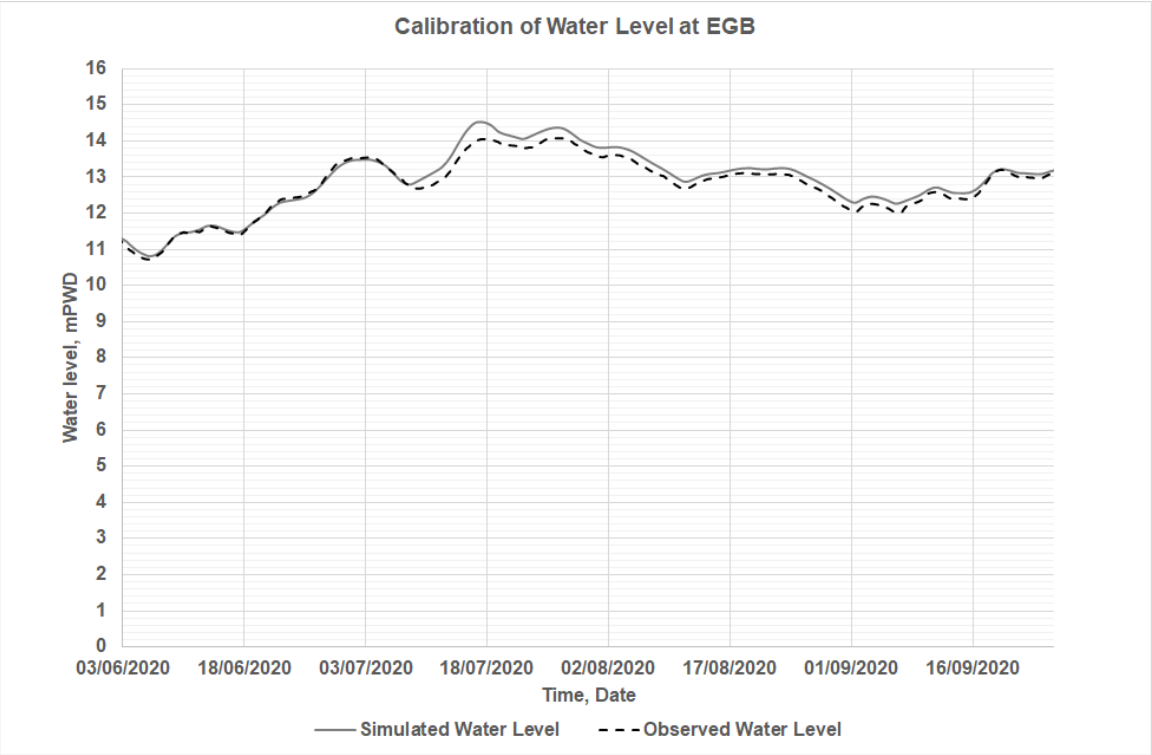


Figure 4.10 *Water level calibration of 2D model of the Jamuna River at EGB*

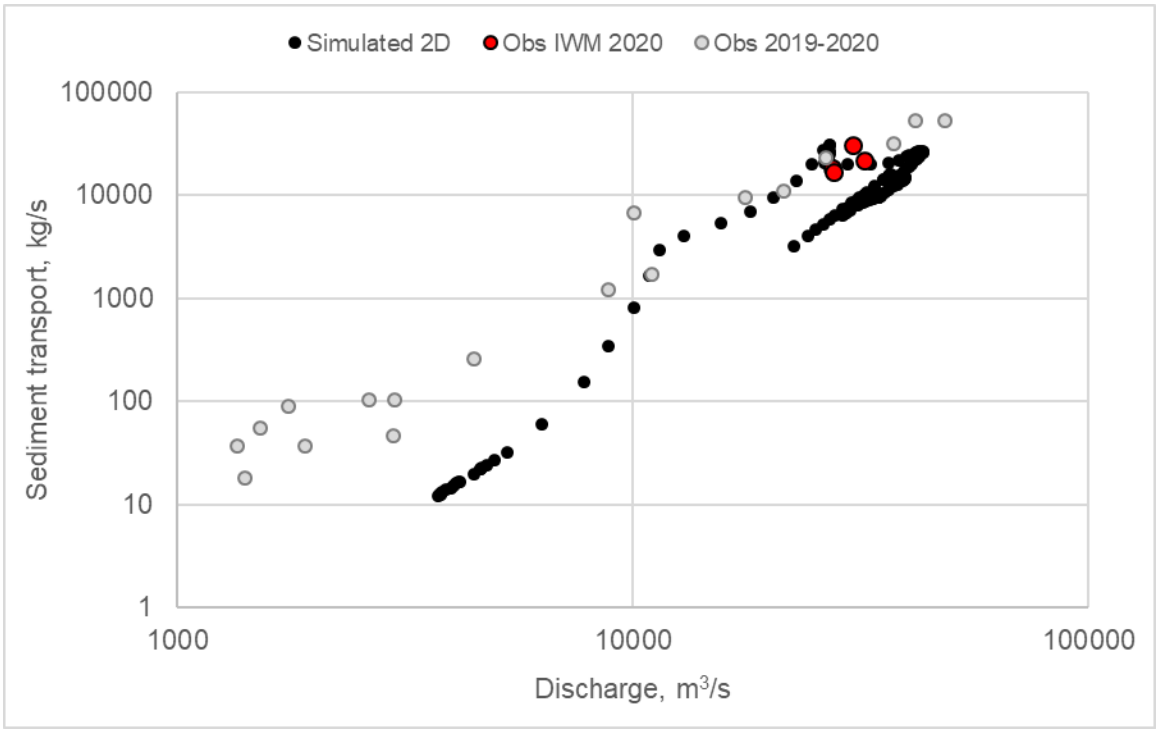


Figure 4.11 *Sediment calibration result near Hardinge Bridge*

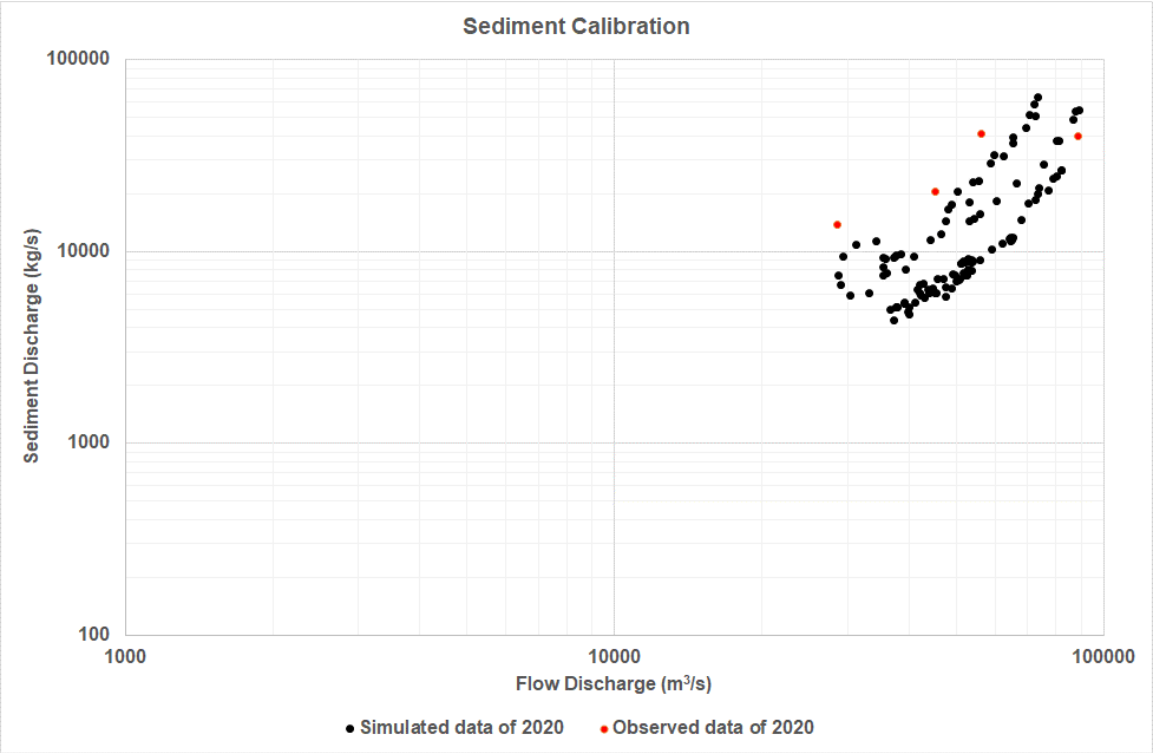


Figure 4.12 *Sediment calibration result near Bangabandhu Bridge*

5. SIMULATED HYDRO-MORPHOLOGICAL CHANGES NEAR THE CROSSING LOCATION

5. SIMULATED HYDRO-MORPHOLOGICAL CHANGES NEAR THE CROSSING LOCATION

5.1 General

The simulated hydro-morphological performance of the Ganges and the Jamuna River for "without project" and "with project" condition is described in this chapter. The maximum velocity and scour (general and constriction) near the pier, changes of river bed erosion and sedimentation and the bank erosion near the transmission lines are predicted from the simulated model results.

5.2 Existing Hydro-Morphological Condition near the Crossing Area

The two-dimensional morphological model, developed in the present study, has been used to predict the hydro-morphological conditions of the river, if the existing condition prevails. 1 in 2.33 year (average flow condition) and 1 in 100 year (High flood event) have been simulated for this prediction.

Flow Velocity Distribution

Model generated velocity (flow field) during the peak of 1 in 2.33 and 1 in 100 year flood events over the stretch of Ganges and Jamuna River near the crossing area for "without project" condition are plotted in **Figure 5.1 and Figure 5.2**. The bed profile and velocity profile across the transmission line on Ganges and Jamuna River at peak discharges of different flood events are also shown in from **Figure 5.3** to **Figure 5.5**. It appears from the velocity vectors (flow field) that the velocity distribution is nearly uniform across the channel at the peak of flood events. The simulated maximum velocity along the transmission lines is also provided in **Table 5.1**.

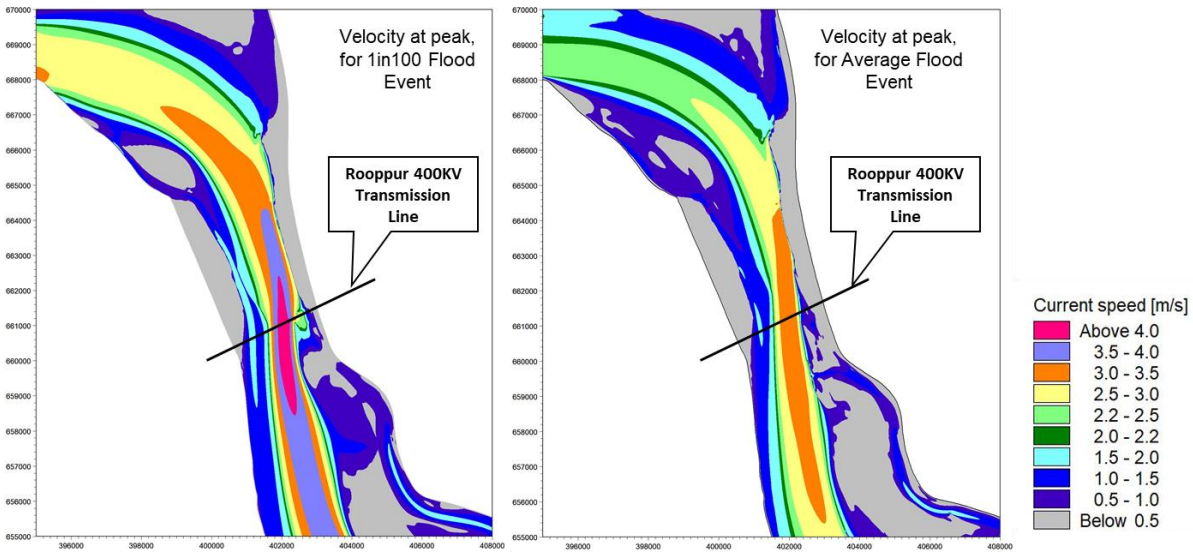


Figure 5.1 *Simulated Depth Average Velocity Distribution of Ganges River along the crossing line during the peak of 1 in 2.33 and 1 in 100 year Flood Events for "without project" condition*

Table 5.1 Simulated Maximum Velocity along the transmission line of Ganges and Jamuna River for "without project" condition

Transmission Line	River	Return Period	Max. Velocity (m/s)
Rooppur 400KV	Ganges	2.33	3.40
		100	4.25
Rooppur 400KV	Jamuna	2.33	2.59
		100	3.62
Rooppur 230KV	Jamuna	2.33	3.01
		100	3.73

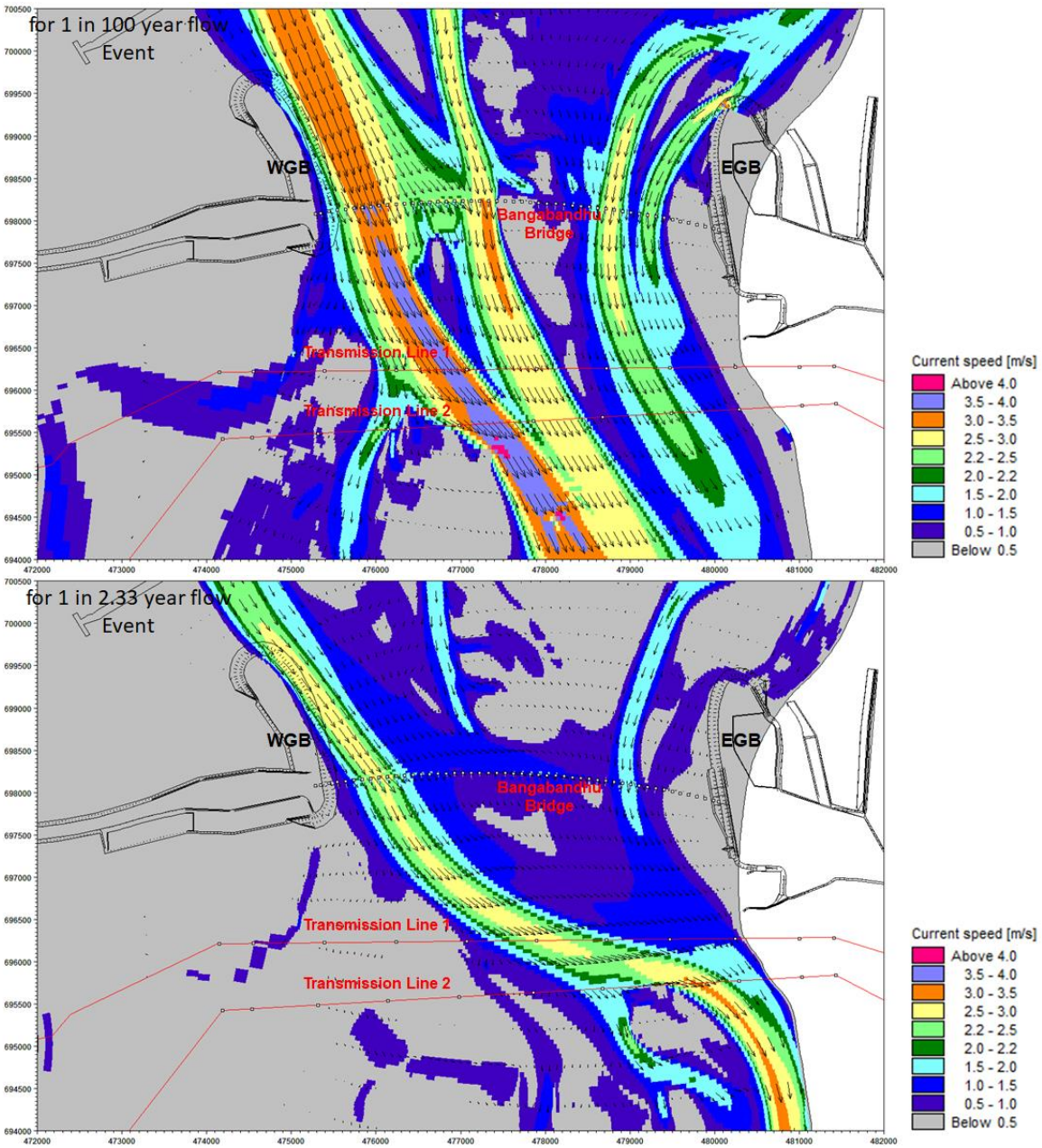


Figure 5.2 *Simulated Depth Average Velocity Distribution of Jamuna River along the crossing lines during the peak of 1 in 2.33 and 1 in 100 year Flood Events*

The profiles of velocity during peak of 1 in 2.33 and 1 in 100 year flood event along the crossing line of Ganges and Jamuna River are shown in **Figure 5.3** to **5.5**.

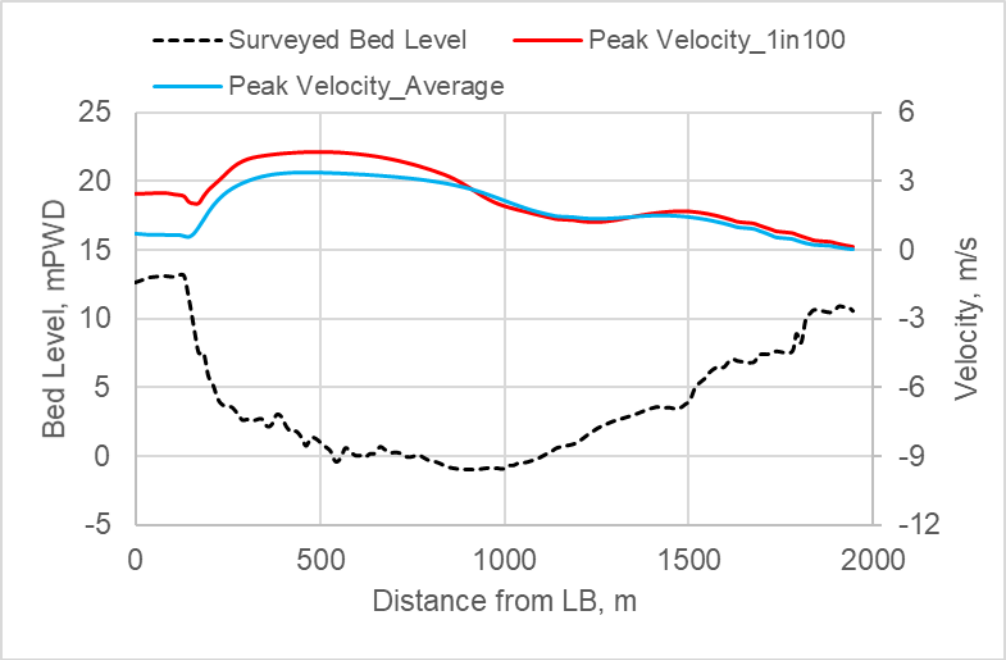


Figure 5.3 *Bed Profile and Velocity Profile across the Transmission Line on Ganges River at Peak Discharges of different Flood Events for "without project" condition*

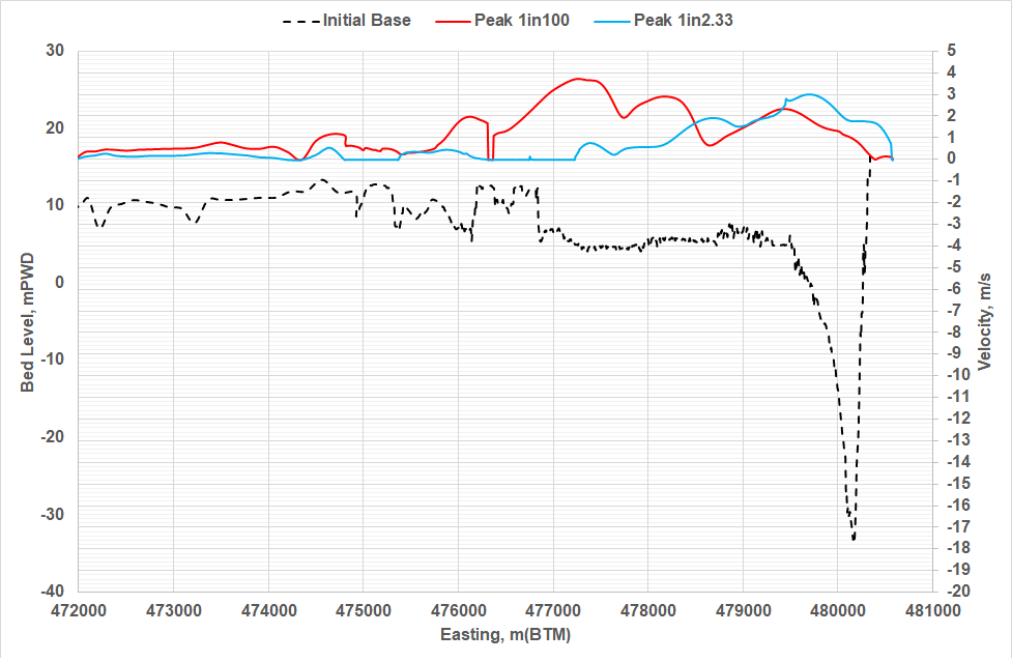


Figure 5.4 *Bed Profile and Velocity Profile across the Transmission Line-1 on Jamuna River at Peak Discharges of different Flood Events for "without project" condition*

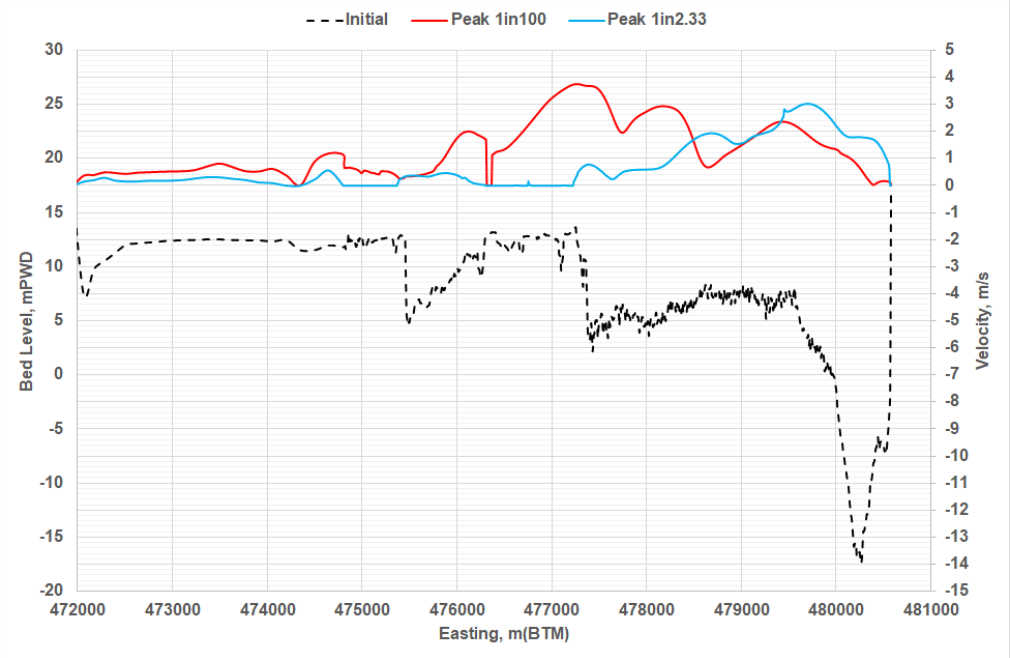


Figure 5.5 *Bed Profile and Velocity Profile across the Transmission Line-2 on Jamuna River at Peak Discharges of different Flood Events for "without project" condition*

Probable Bed Erosion and Sedimentation Process

The planform view of simulated channel layout of Ganges River for base condition or "without project" condition near the crossing area for high and average flood events are shown in **Figure 5.6**. The simulated results exhibit that the channel is fully shifted along the left bank near Hardinge Bridge location for both the flood events. The maximum bed level at the end of simulation along the transmission line may reach at about -24.32 mPWD for 1 in 100 year flood event and -14.26 mPWD for average flood event. Considering this model results, the general scour is found 27.18m, see **Figure 5.8** and **Figure 5.9**.

In case of the Jamuna River the planform view of simulated channel layout of the Jamuna River for "without project" condition near the crossing area for high and average flood events are shown in **Figure 5.7**. Near the crossing locations of the Jamuna River, the single channel is transformed into double channel after passing the both flood event. The maximum bed level at the end of simulation along the transmission line-1 moves to -30.31 mPWD for 1 in 100 year flood event and -28.08 mPWD for average flood event from -34.37 mPWD. Considering this model results, the general scour is found 0.0m, see **Figure 5.10** and **Figure 5.11**.

On the other hand, the maximum bed level at the end of simulation along the transmission line-2 moves to -26.11 mPWD for 1 in 100 year flood event and -26.46 mPWD for average flood event. Considering this model results, the general scour is found 17.46m, see **Figure 5.12** and **Figure 5.13**.

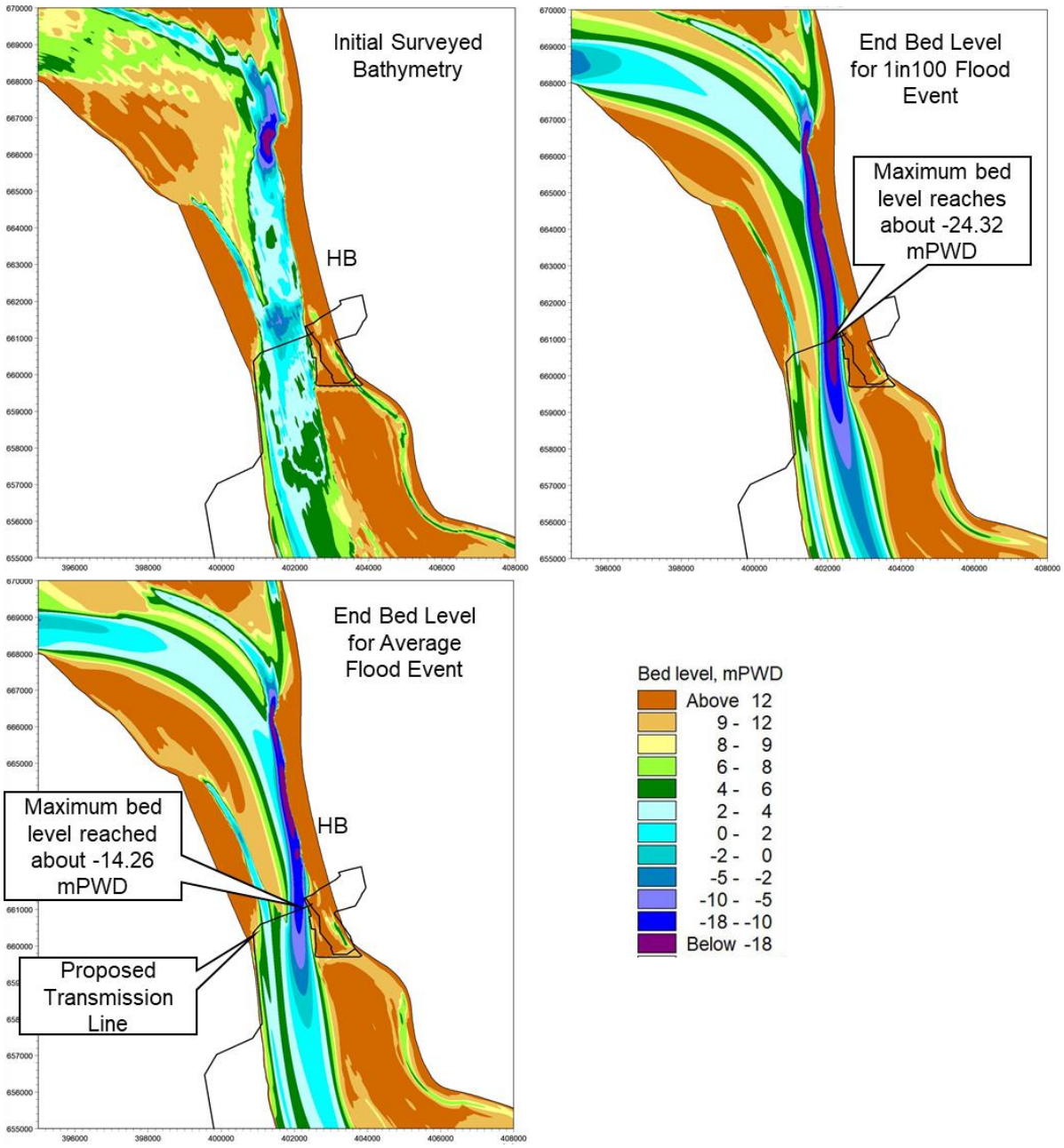


Figure 5.6 *Simulated Bed Level Change in the Ganges River for different flood events for "without project" condition*

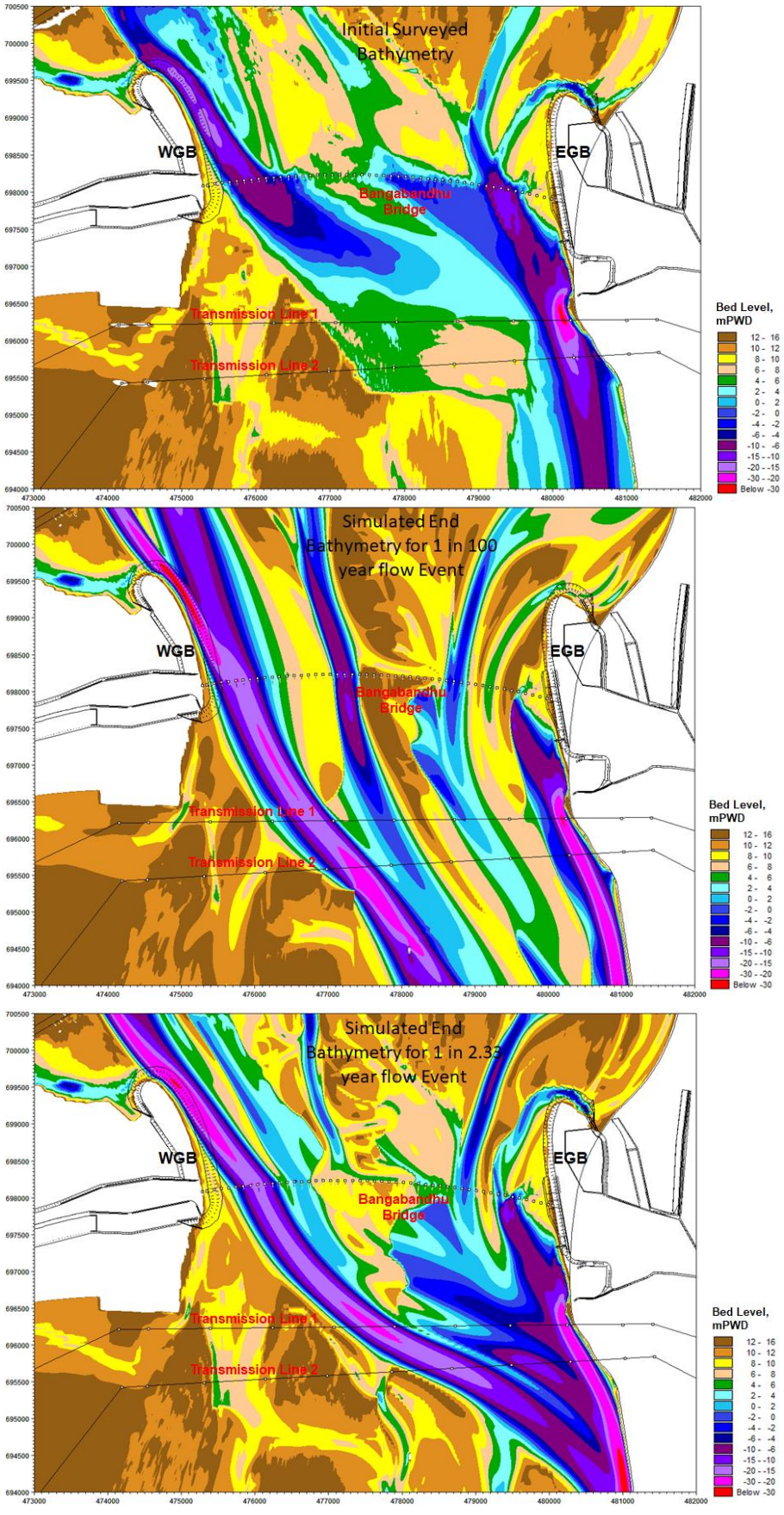


Figure 5.7 *Simulated Bed Level Change in the Jamuna River for different flood events for "without project" condition*

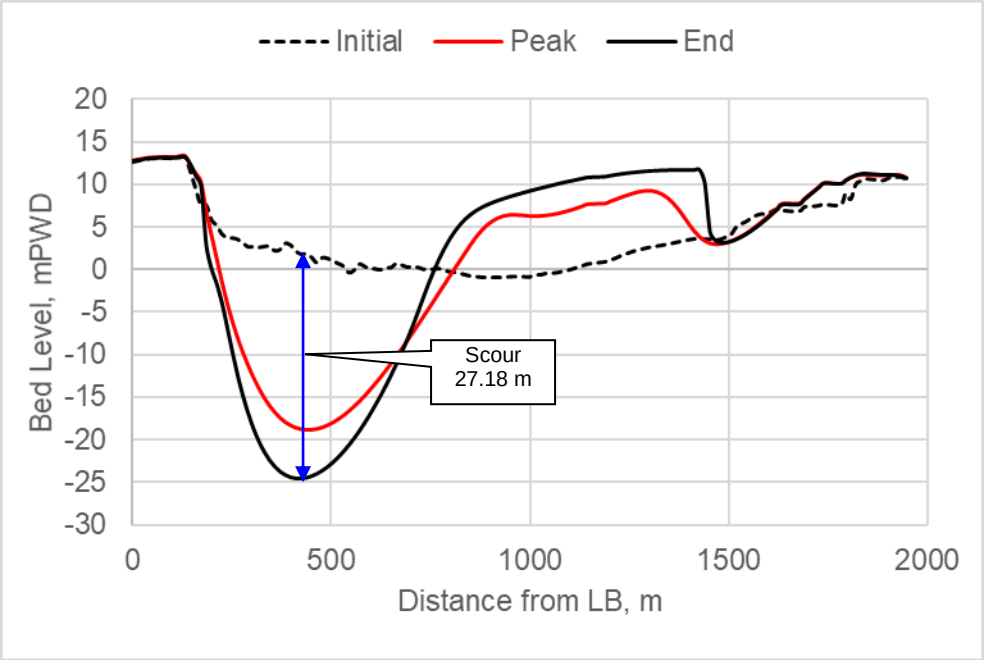


Figure 5.8 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line on the Ganges River for 1in100 year flood event for "without project" condition*

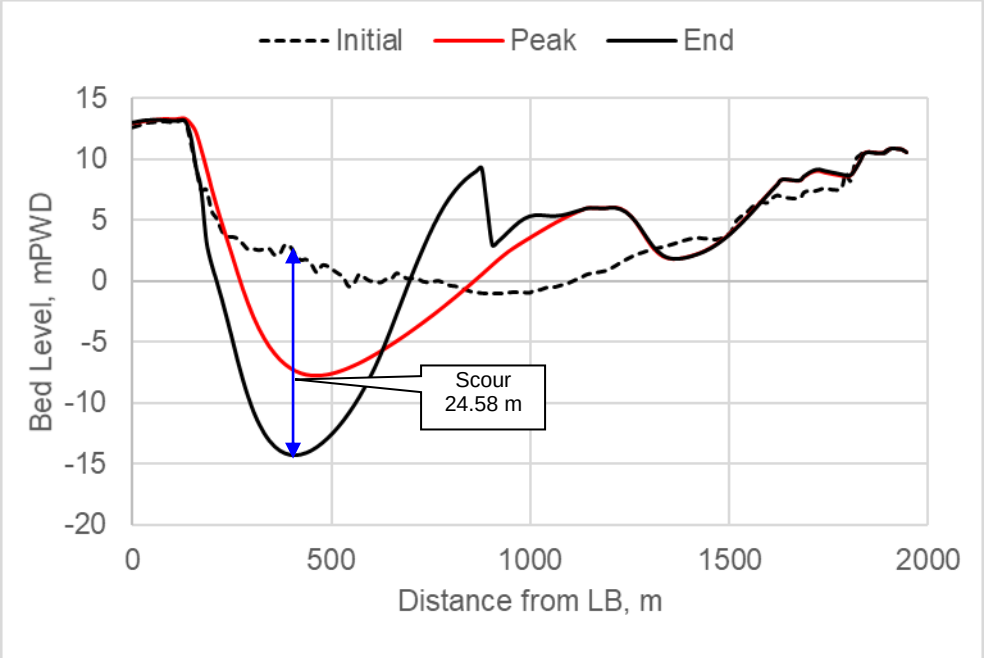


Figure 5.9 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line on the Ganges River for Average Flood Event for "without project" condition*

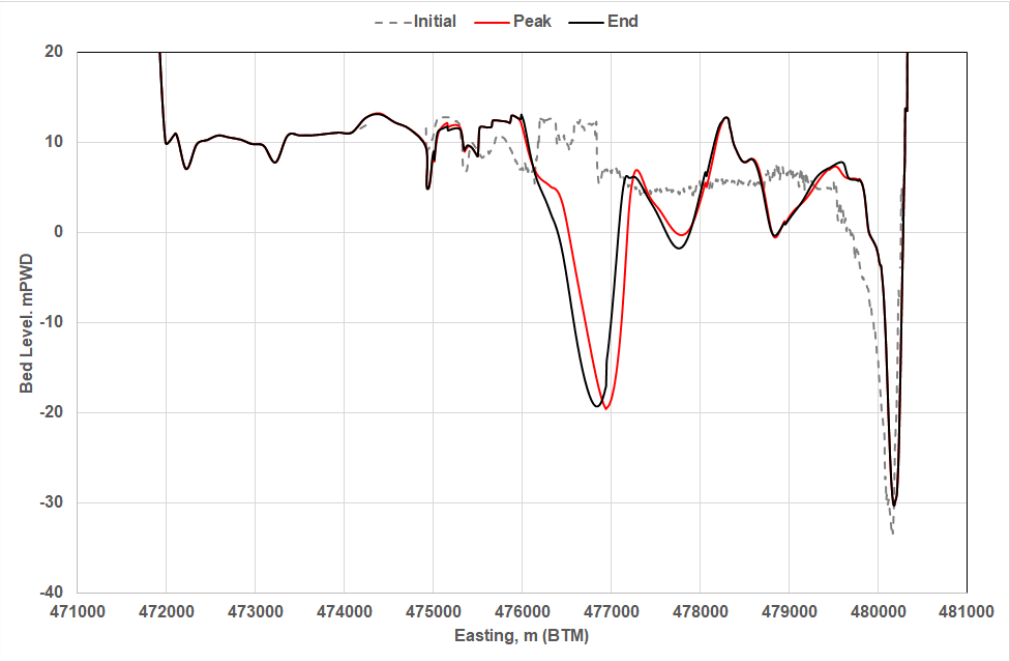


Figure 5.10 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line 1 (Rooppur 400KV) on the Jamuna River for 1in100 year flood event for "without project" condition*

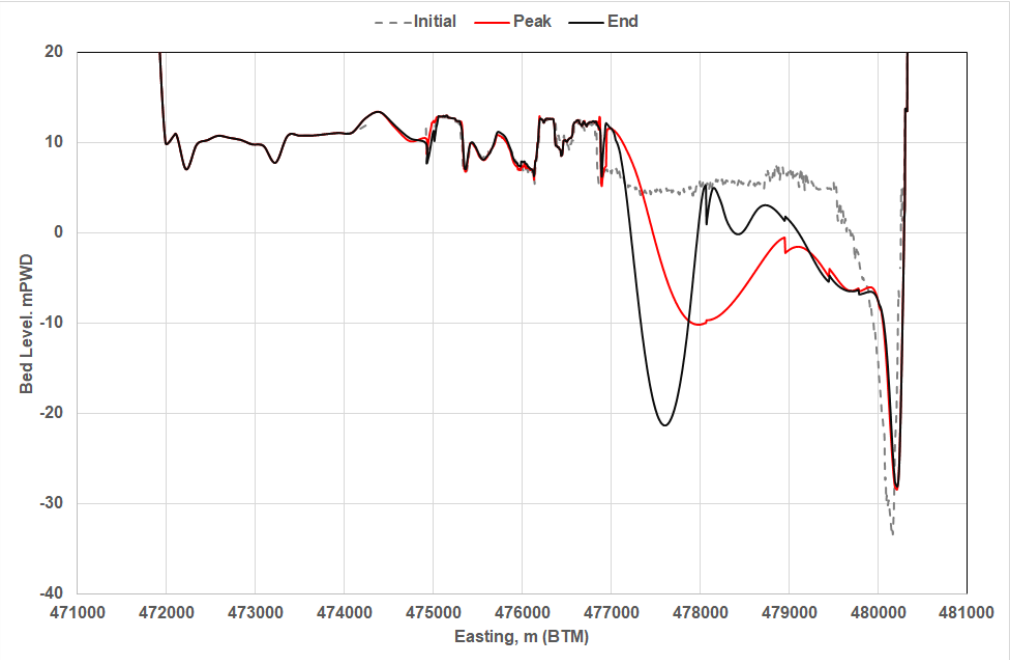


Figure 5.11 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line 1 (Rooppur 400KV) on the Jamuna River for Average Flood Event for "without project" condition*

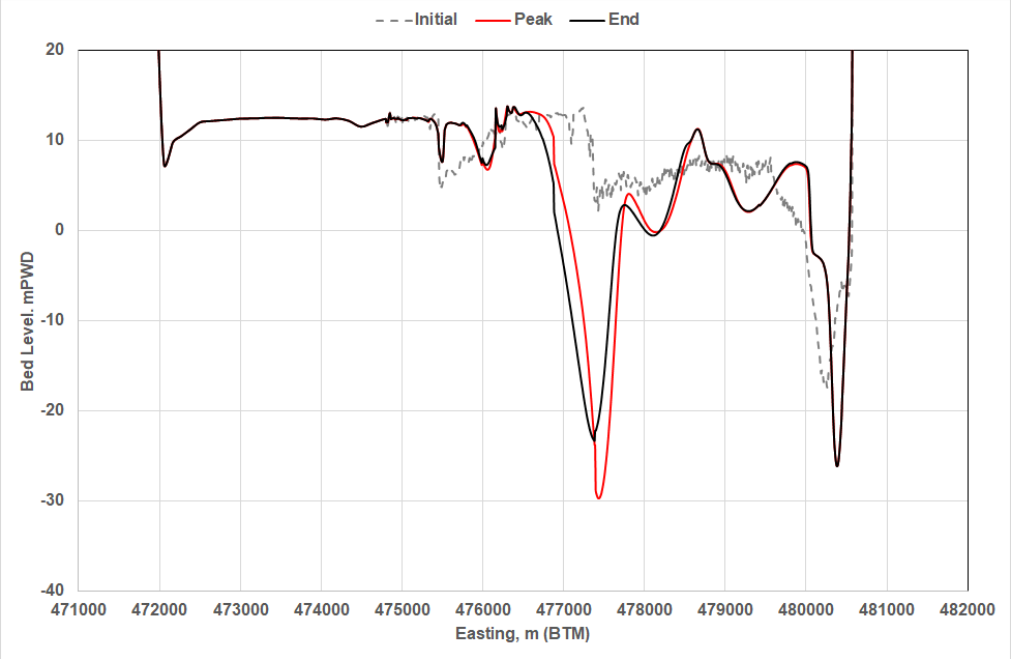


Figure 5.12 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line 2 (Rooppur 230KV) on the Jamuna River for 1in100 year flood event for "without project" condition*

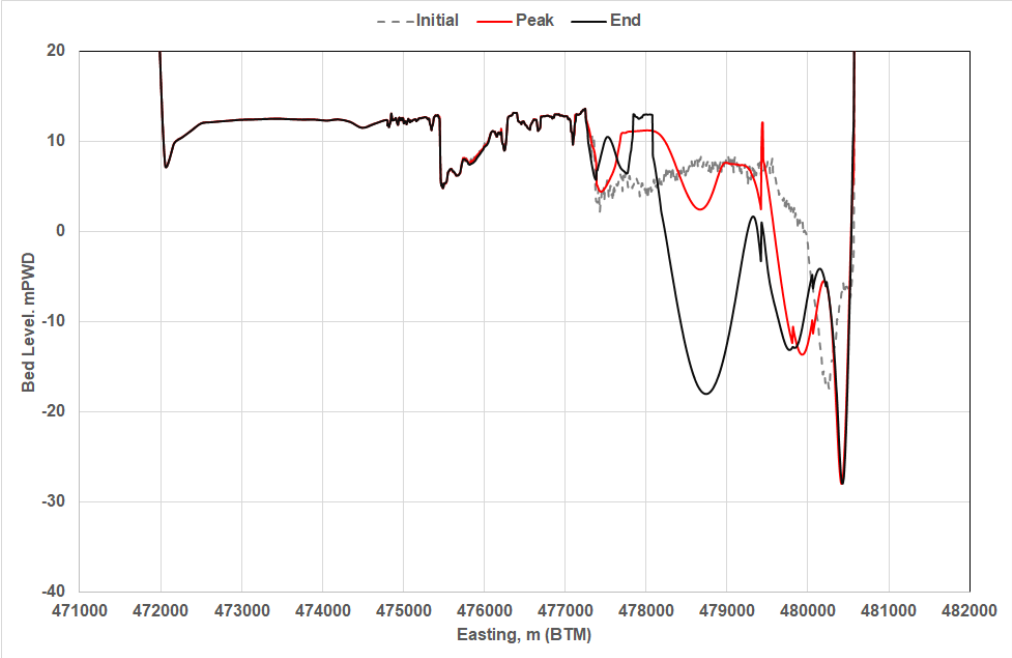


Figure 5.13 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line 2 (Rooppur 23000KV) on the Jamuna River for Average Flood Event for "without project" condition*

Probable Highest Water Level

The probable maximum water level along the transmission line on Ganges River for "without project" condition is extracted from model results as well as from frequency analysis of maximum water level. **Table 5.2** shows that both values are very close and the maximum water level along the 400KV Rooppur Transmission Line is found 15.22 mPWD, comparing with the extreme value analysis.

Table 5.2 Probable Maximum Water Level along the transmission line of Ganges and Jamuna River for "without project" condition

Transmission Line	River	Return Period	Probable Max. Water Level, mPWD	
			Simulation	Extreme value Analysis
Rooppur 400KV	Ganges	2.33	14.06	14.06
		100	15.22	15.12
Rooppur 400KV	Jamuna	2.33	12.53	13.18
		100	13.73	14.8
Rooppur 230KV	Jamuna	2.33	12.42	13.14
		100	13.70	14.76

Identification of River Bank Erosion Vulnerable Areas

The simulated bank erosion that has been extracted from model results are represented in **Figure 5.14 and Figure 5.15**. It is observed that there is no bank erosion along both the bank of transmission line in Ganges and Jamuna River. However, at 10km u/s and from 5km to 10km d/s of Hardinge Bridge, there might be bank erosion occurred along the right bank, if high flood event passed. It is mention worthy that there is a proposed transmission line parallel along the Ganges River at right bank, shown in **Figure 5.14**. This location might face about 25m bank erosion for high flood event. Thus, the location of this anchor tower/ pier of transmission line should be shifted considering this bank erosion. In case of Jamuna River, there is no bank erosion at the right bank along the crossings. However, about 10m of erosion might be happened at the left bank of the Jamuna River along the crossing lines.

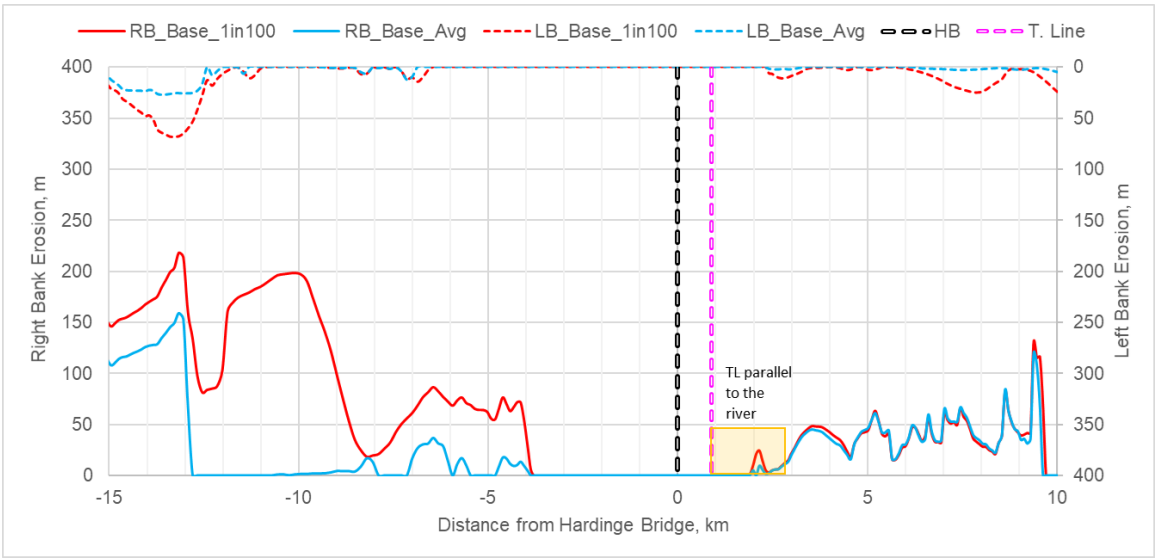


Figure 5.14 *Bank Erosion along the Ganges River near the Crossing Site for different flood events for "without project" condition*

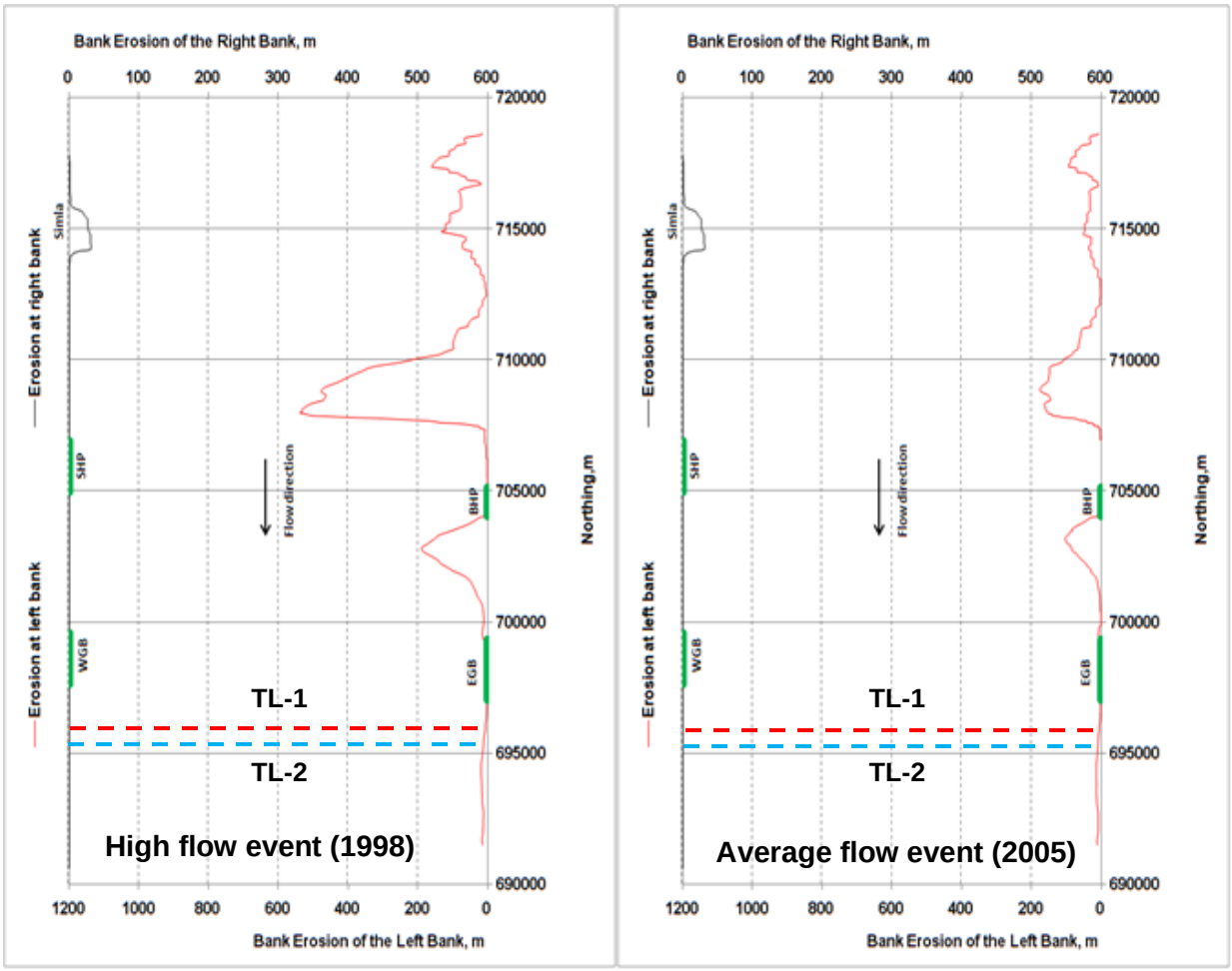


Figure 5.15 *Bank Erosion along the Jamuna River near the Crossing Site for different flood events for "without project" condition*

5.3 Model Results "With Project" Condition near the Crossing Area

To predict the hydro-morphological conditions of the rivers due to construction of transmission pier, two-dimensional morphological model has been simulated for high and average flood events. The velocity distribution, river bed erosion and sedimentation, maximum water level and bank erosion are the main concern for "with project" condition. The detail model analysis for "with project" condition is described below:

Flow Velocity Distribution

Model generated velocity vector (flow field) during the peak of 1 in 2.33 and 1 in 100 year flood events over the stretch of Ganges and Jamuna River near the crossing area for "with project" condition are plotted in **Figure 5.16 and 5.18**. It appears from the figure that the maximum velocity is 4.22m/s that attacks at Pier # 3 in Ganges River, see **Figure 5.17**.

The model simulated peak velocities along the transmission lines for the base and "with" project conditions for different flood events are tabulated in **Table 5.3** for Ganges and Jamuna River. It is observed that maximum velocity is found 4.22 m/s for base condition during 1 in 100 year flood event in case of Ganges River. Again, for the Jamuna River, the maximum velocity along the transmission line-1 is found 3.8 m/s. Along the transmission line-2 velocity is found to be 3.74 m/s.

Table 5.3 Simulated Maximum Velocity along the transmission line of Ganges and Jamuna River

Transmission Line	River	Return Period	Max. Velocity (m/s)	
			Without Project	With Project
Rooppur 400KV	Ganges	2.33	3.40	3.16
		100	4.22	4.01
Rooppur 400KV	Jamuna	2.33	2.59	2.62
		100	3.62	3.80
Rooppur 230KV	Jamuna	2.33	3.01	3.74
		100	3.73	2.81

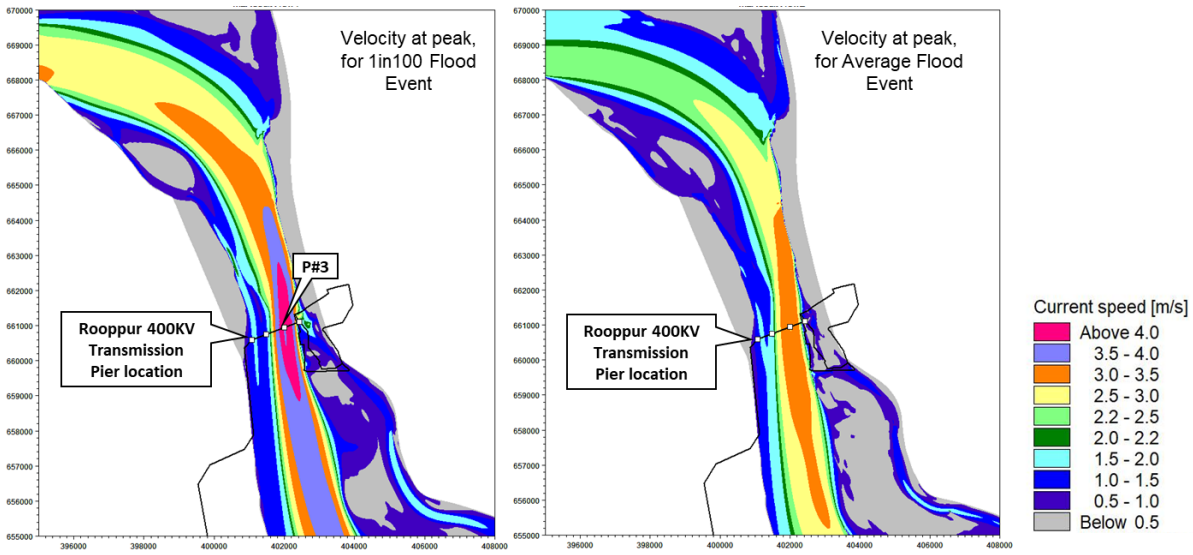


Figure 5.16 *Simulated Depth Average Velocity Distribution of Ganges River along the crossing line during the peak of 1 in 2.33 and 1 in 100 year Flood Events for "with project" condition*

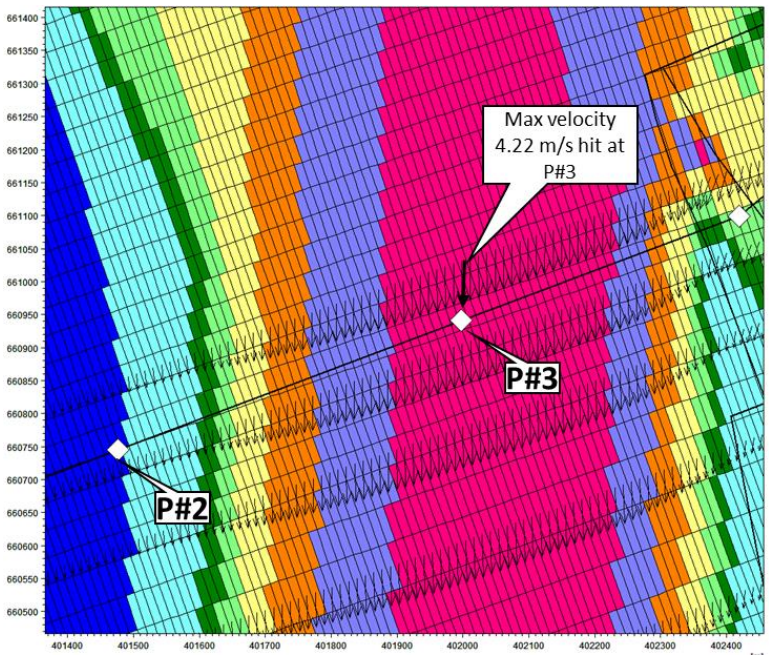


Figure 5.17 *Simulated Depth Average Velocity Distribution of Ganges River shows maximum velocity attacks at Pier#3*

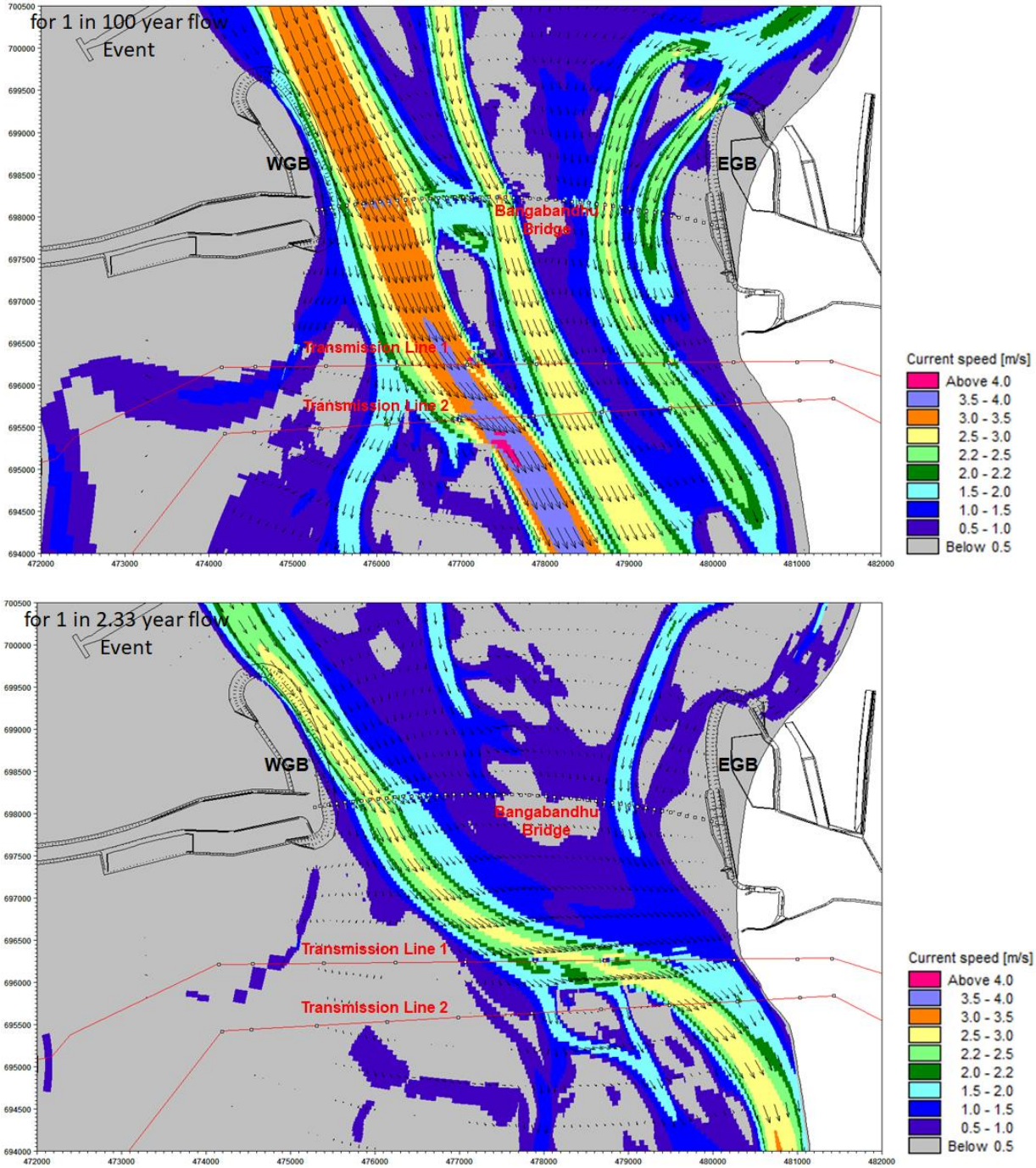


Figure 5.18 *Simulated Depth Average Velocity Distribution of Jamuna River along the crossing line during the peak of 1 in 2.33 and 1 in 100 year Flood Events for "with project" condition*

The profiles of velocity during peak of 1 in 2.33 and 1 in 100 year flood event along the crossing line of Ganges and Jamuna River are shown in **Figure 5.19** to **5.21**. The velocity distribution is nearly uniform across the channel at the peak of flood events.

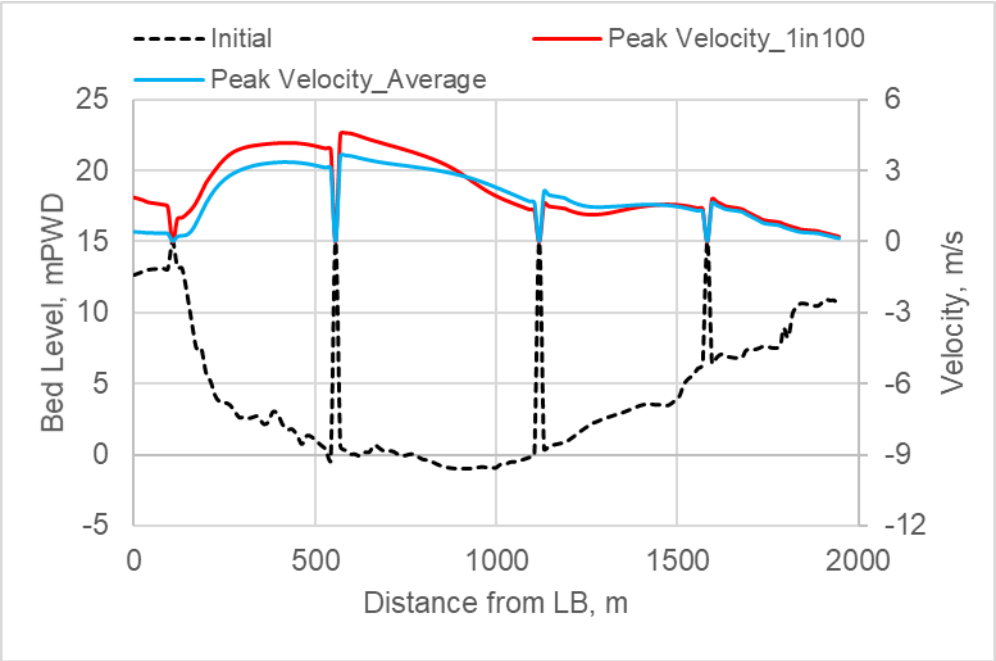


Figure 5.19 *Bed Profile and Velocity Profile across the Transmission Line on Ganges River at Peak Discharges of different Flood Events for "with project" condition*

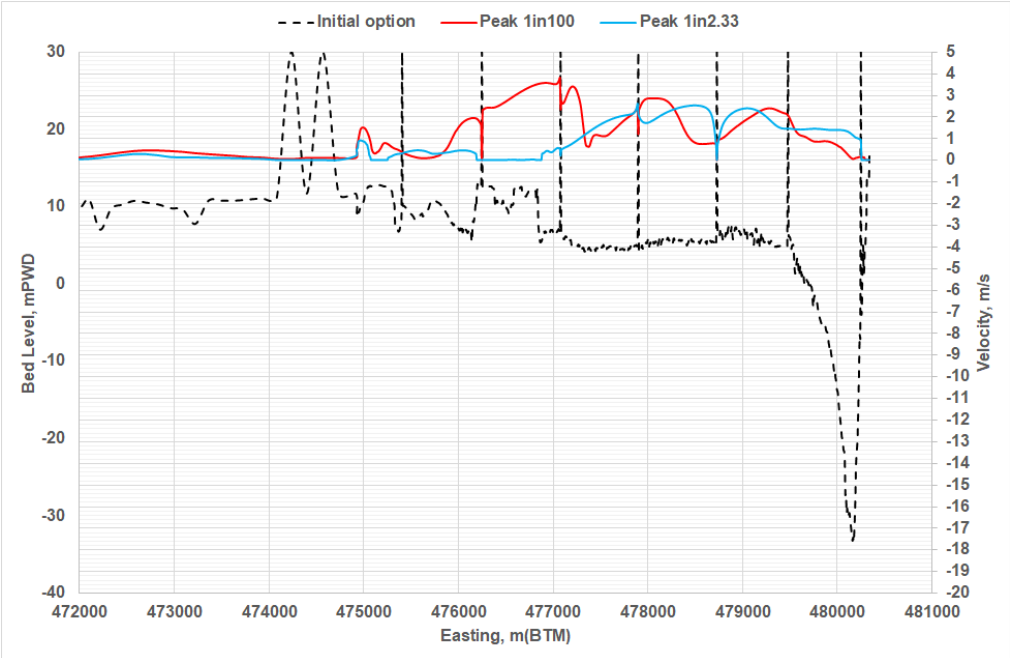


Figure 5.20 *Bed Profile and Velocity Profile across the Transmission Line 1 on Jamuna River at Peak Discharges of different Flood Events for "with project" condition*

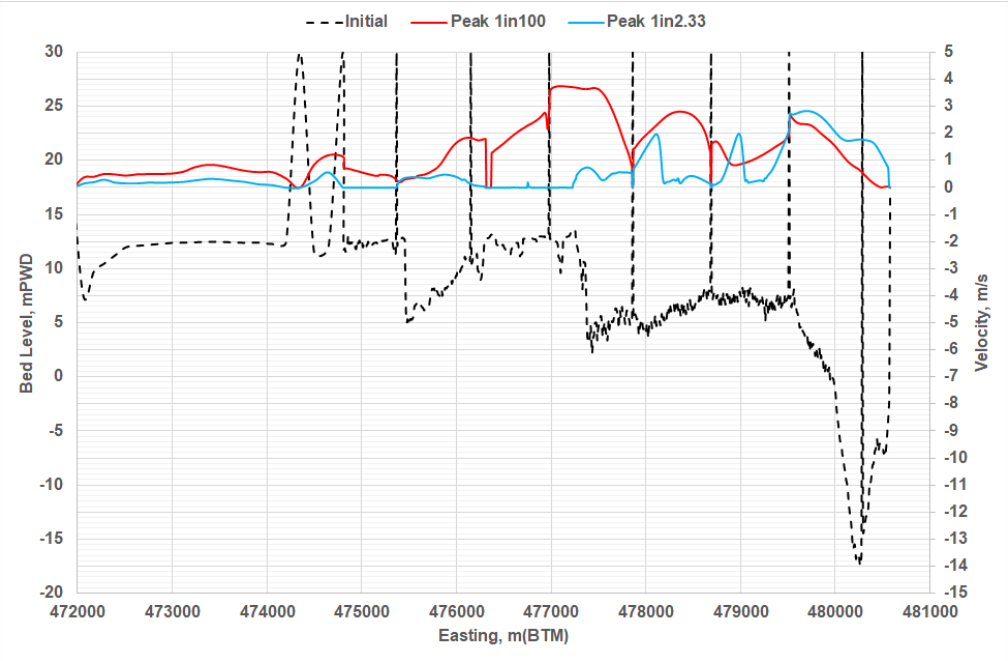


Figure 5.21 *Bed Profile and Velocity Profile across the Transmission Line 2 on Jamuna River at Peak Discharges of different Flood Events for "with project" condition*

Probable Bed Erosion and Sedimentation Process

The planform view of simulated channel layout of Ganges River for "with project" condition near the crossing area for high and average flood events are shown in **Figure 5.22**. The simulated results exhibit that the channel is fully shifted along the guide bund of left bank near Hardinge Bridge location for both the flood events, like base condition. The maximum bed level at the end of simulation along the transmission line may reach at about -21.68 mPWD for 1 in 100 year flood event and -13.28 mPWD for average flood event, **Figure 5.24** and **Figure 5.25**.

In case of the Jamuna River the planform view of simulated channel layout of the Jamuna River for "with project" condition near the crossing area for high and average flood events are shown in **Figure 5.23**. Near the crossing locations of the Jamuna River, the single channel might be transformed into double channel after passing the both flood event. The maximum bed level at the end of simulation along the transmission line-1 moves to -29.72 mPWD for 1 in 100 year flood event and -29.11 mPWD for average flood event from -34.37 mPWD (**Figure 5.26** and **Figure 5.27)**.

On the other hand, the maximum bed level at the end of simulation along the transmission line-2 moves to -26.46 mPWD for 1 in 100 year flood event and -27.72 mPWD for average flood event, see **Figure 5.28** and **Figure 5.29**.

The lowest bed levels for "with" and "without project" condition along the transmission lines during all the flood events have been shown in **Table 5.4.**

Table 5.4 Lowest Bed Level (in mPWD) for different flood events along the transmission lines of Ganges and Jamuna River

Transmission Line	River	Return Period	Initial Bed Level, mPWD	Lowest Bed Level (in mPWD)	
				Without Project	With Project
Rooppur 400KV	Ganges	2.33	-0.97	-14.26	-13.28
		100		-24.48	-21.68
Rooppur 400KV	Jamuna	2.33	**-34.37**	-28.08	-29.11
		100		-30.31	29.72
Rooppur 230KV	Jamuna	2.33	**-17.37**	-26.11	27.43
		100		-26.46	26.46

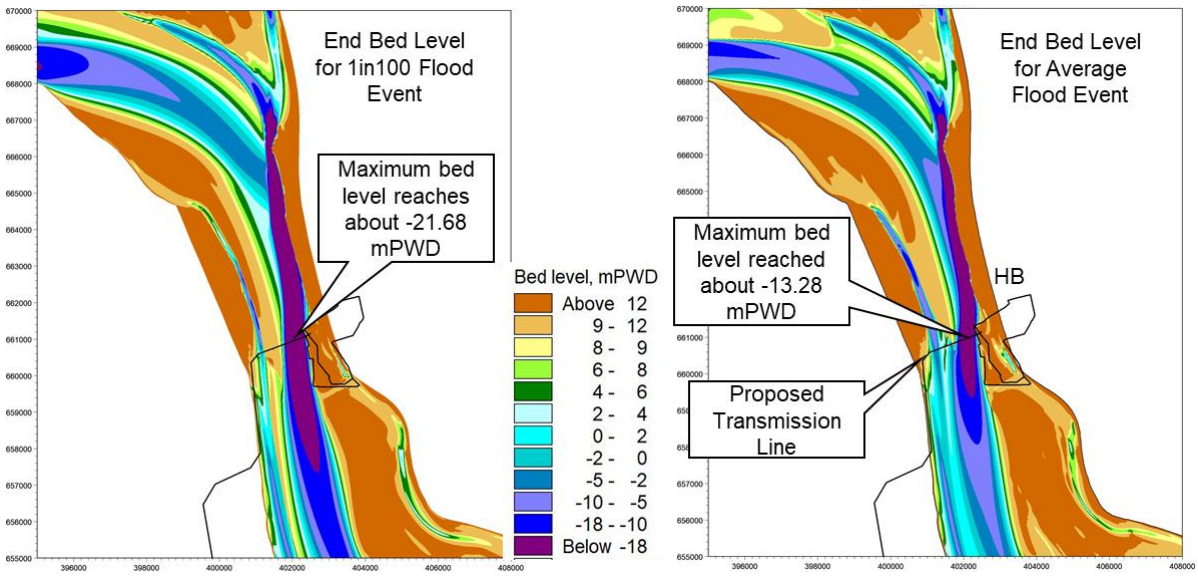


Figure 5.22 *Simulated Bed Level Change in the Ganges River in different flood events for "with project" condition*

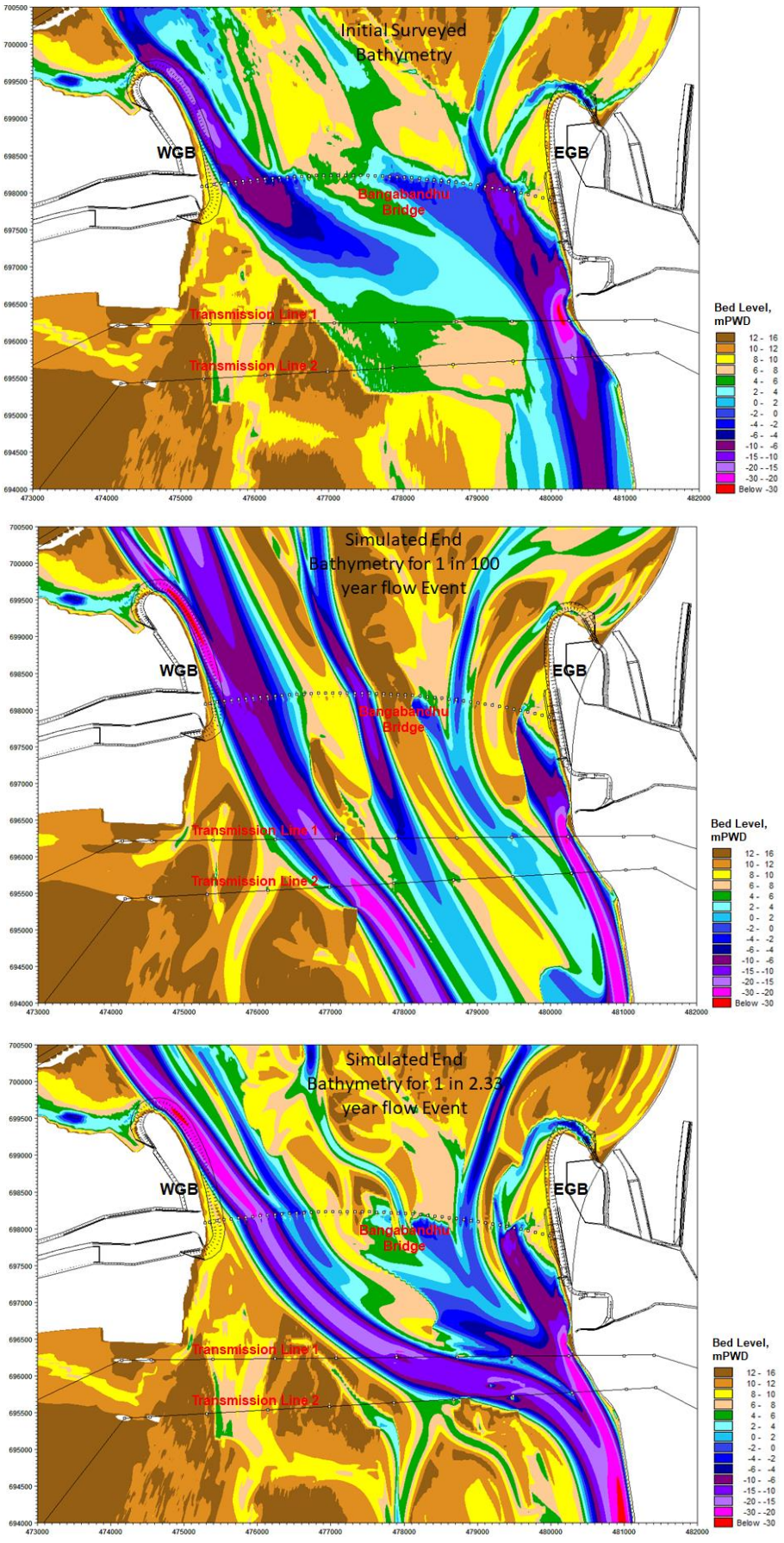


Figure 5.23 *Simulated Bed Level Change in the Jamuna River for different flood events*

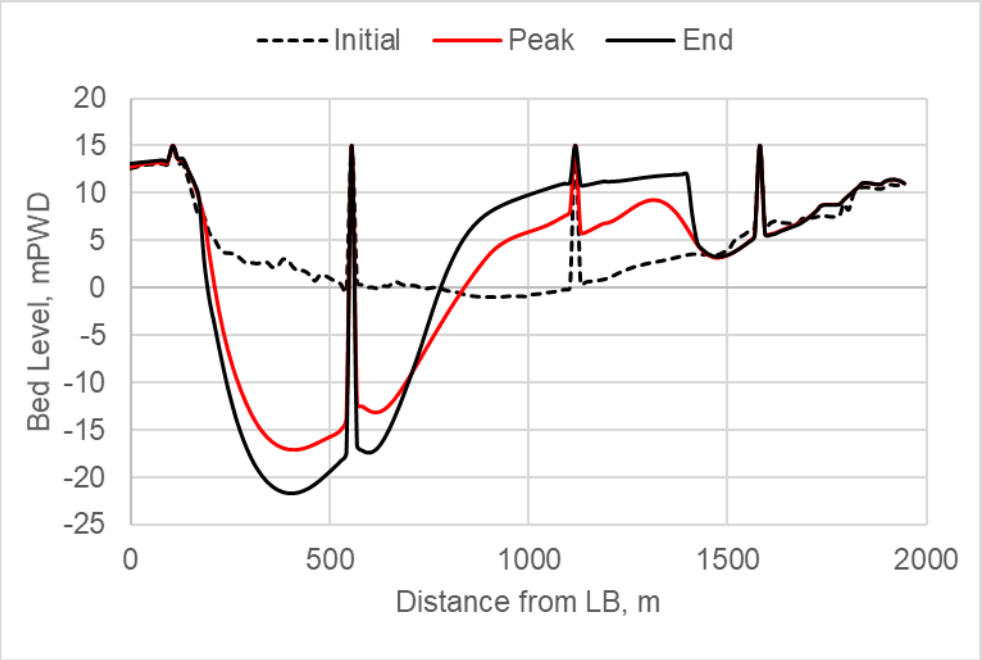


Figure 5.24 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line on the Ganges River for 1in100 year flood event for "with project" condition*

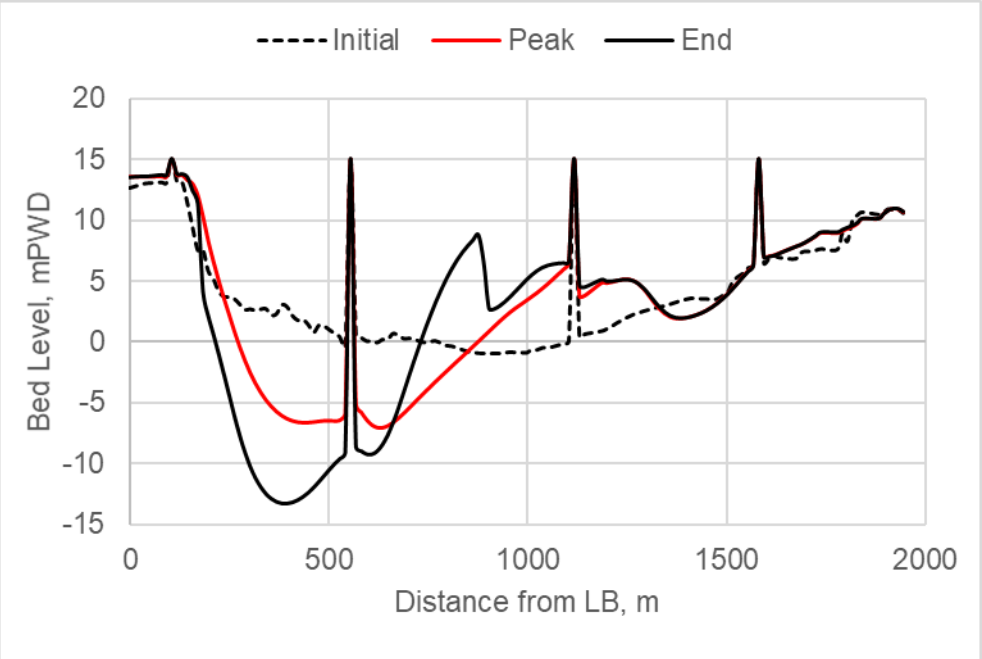


Figure 5.25 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line on the Ganges River for Average Flood Event for "with project" condition*

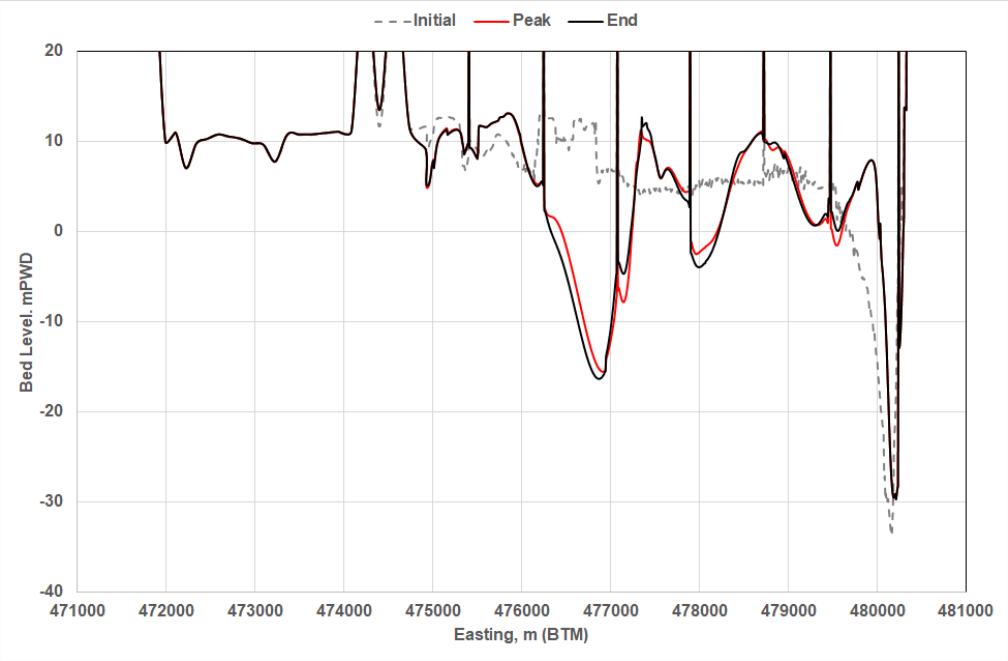


Figure 5.26 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line-1 on the Jamuna River for 1in100 year flood event for "with project" condition*

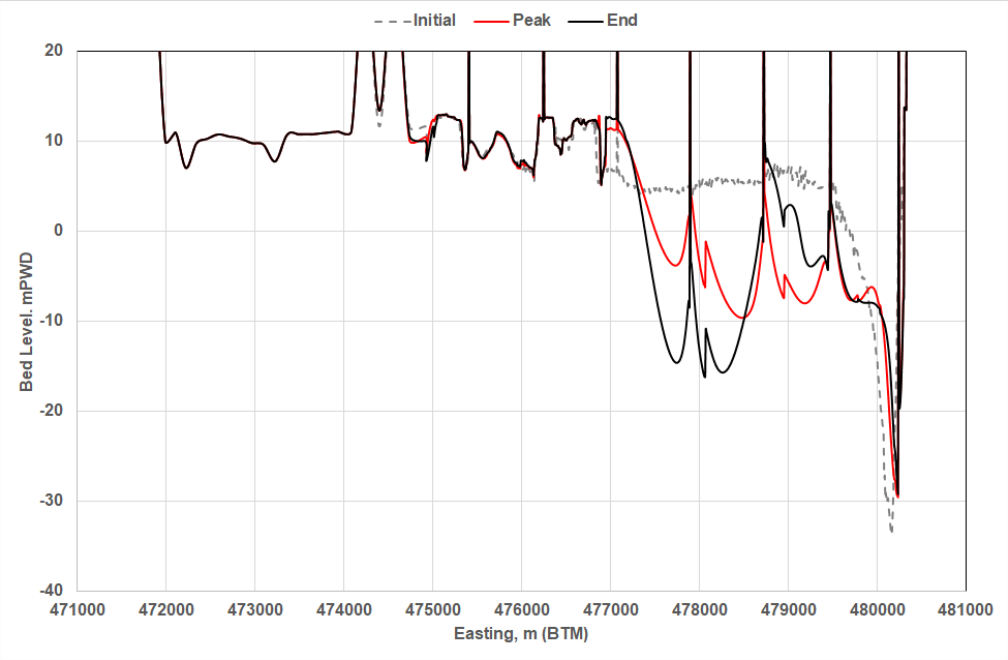


Figure 5.27 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line-1 on the Jamuna River for Average Flood Event for "with project" condition*

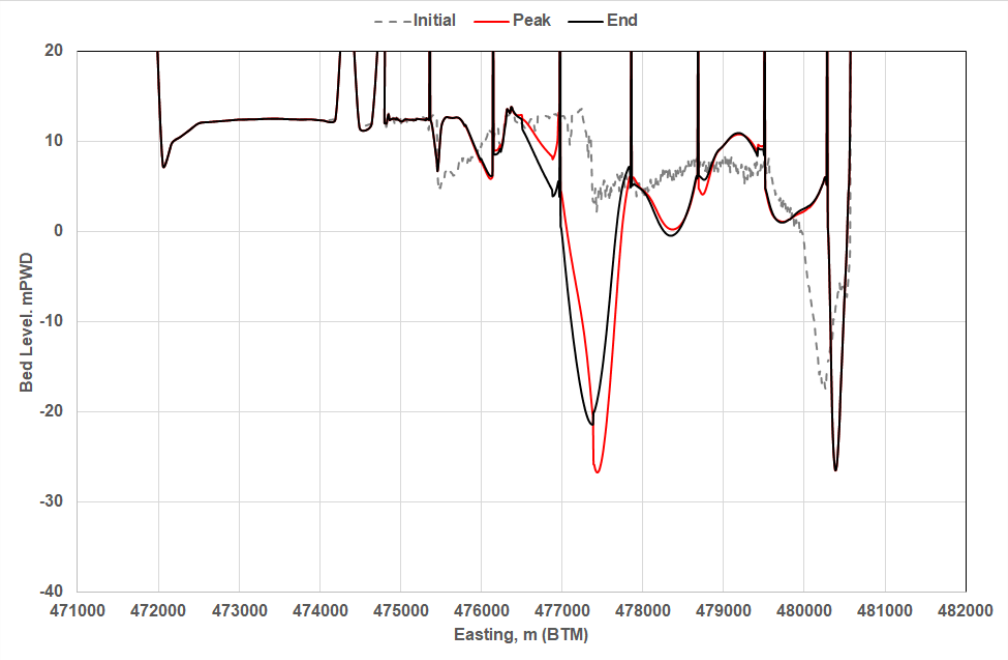


Figure 5.28 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line-2 on the Jamuna River for 1in100 year flood event for "with project" condition*

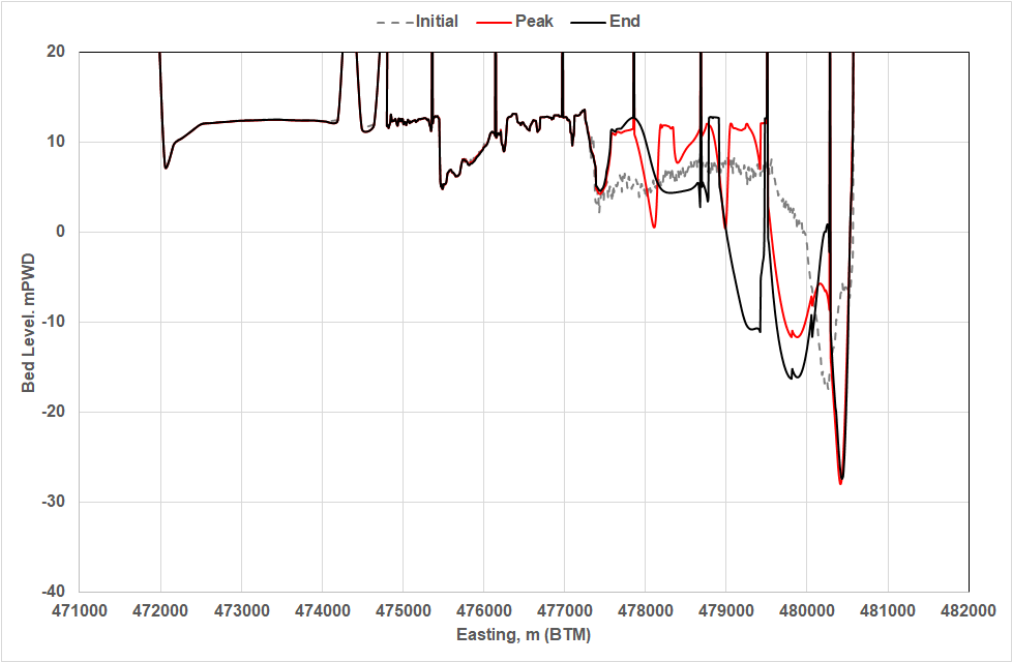


Figure 5.29 *Cross-sections at the peak and end of simulation along the Proposed Transmission Line-2 on the Jamuna River for Average Flood Event for "with project" condition*

Probable Highest Water Level

The probable maximum water level along the transmission line on Ganges and Jamuna River for "with" and "without project" condition is tabulated in **Table 5.5**.

Table 5.5 Simulated Maximum Water Level along the transmission line of Ganges and Jamuna River for "with" and "without project" condition

Transmission Line	River	Return Period	Probable Max. Water Level, mPWD	
			Without Project	With Project
Rooppur 400KV	Ganges	2.33	14.06	14.14
		100	15.22	15.19
Rooppur 400KV	Jamuna	2.33	12.53	12.74
		100	13.73	13.77
Rooppur 230KV	Jamuna	2.33	12.42	12.53
		100	13.70	13.76

Identification of River Bank Erosion Vulnerable Areas

The bank erosion plot displays that there is no bank erosion in Ganges River along both the bank of transmission line, **Figure 5.30**. However, there might have chance of bank erosion at the 5km to 10 km u/s and d/s of Hardinge Bridge, like base condition. The anchor tower/ pier of transmission line parallel of the right bank of Ganges River will face mild erosion. Therefore, location of these piers should be relocated. The vulnerable locations along the Ganges River are identified in the satellite image and shown in **Figure 5.31.**

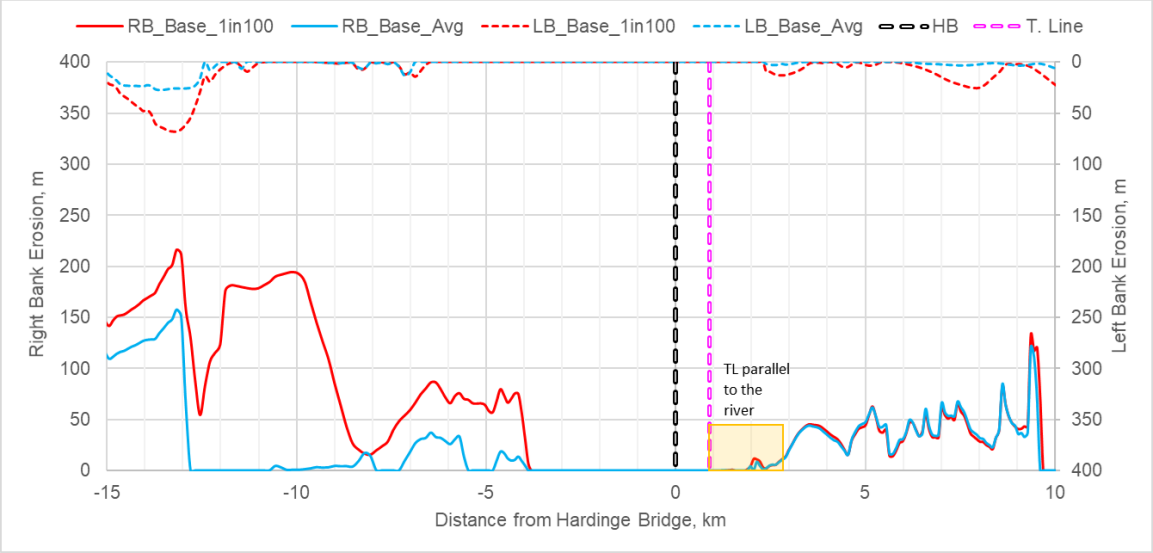


Figure 5.30 *Bank Erosion along the Ganges River near the Crossing Site for different flood events for "with project" condition*

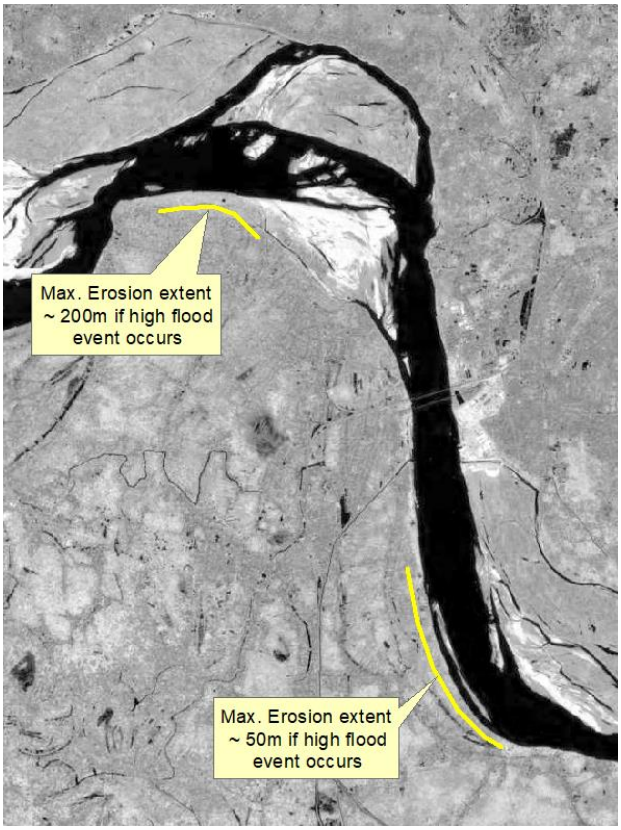


Figure 5.31 *Vulnerable Locations to Bank Erosion along the Ganges River within the study area "without project" condition*

5.4 Future Development within the Study Area

A qualitative prediction of possible future development or shifting of the river at and around the tentative crossing area for 20 years and a quantitative forecast for the next 2-3 years is provided in this section. It is mention worthy, as the upstream flow boundary of future condition is not known, the results do not exactly represent actual morphological process. Rather, it will suggest an indicative morphological process for a long period.

5.4.1 Long Term Development (20 years)

To predict the possible future development (within the 20 years) near the study area of Ganges and Jamuna River, a composite two-dimensional morphological model that was developed by IWM in connection with another project named " Technical Assistance Project in Connection with Flood Management Planning in Bangladesh: Cooperation on Mathematical Model of Hydrology and Sediment" (IWM 2019) has retrieved again.

The model bathymetry has been updated using the recent bathymetry of Ganges (October 2020) and Jamuna (January 2020) River. The proposed transmission lines are also incorporated and simulated to observe its impact on the river. This composite model is hydrodynamically and morphologically calibrated against the year of 2011. Finally, the 20-year long flood hydrograph (shown in **Figure 5.32**) has been applied to the model to observe the possible future development for "with project" condition. The simulated bed level for "with project" condition at the end of each five years along with initial bathymetry is shown in Figure 5.25 and Figure 5.26 for Ganges and Jamuna River, respectively.

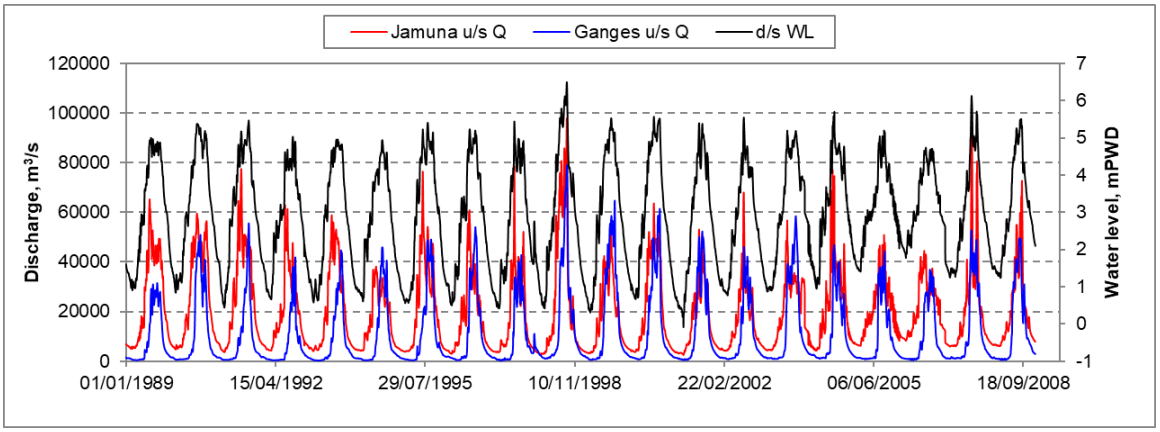


Figure 5.32 *Model u/s flow and d/s water level boundaries applied to 2D model of "with- and without-project" condition*

Planform Development

Figure 5.33 and **Figure 5.34** shows the change in simulated riverbed level from the present (2020) to after 5, 10, 15 and 20-years for 'with project' condition for Ganges and Jamuna River, respectively. The model results for "without project' condition and comparison for these two conditions will be updated in Final Report. As explained before, these simulated values do not mean the prediction of riverbed levels since the simulated values give the accumulation of morphological developments within the monsoon period only and those for the pre- or post-monsoon period are not taken into consideration.
In Ganges River, the main channel passes along the left bank near HB and hit the right bank at the d/s of HB after 5 years of morphological development. However, at the end of 20 years, a char is developed along that right bank. As the channel is confined at the HB, location, a single channel is always dominate the area. In case of Jamuna River, the main channel exists along the WGB after the next 5, 10, 15 and 20 years of simulation.

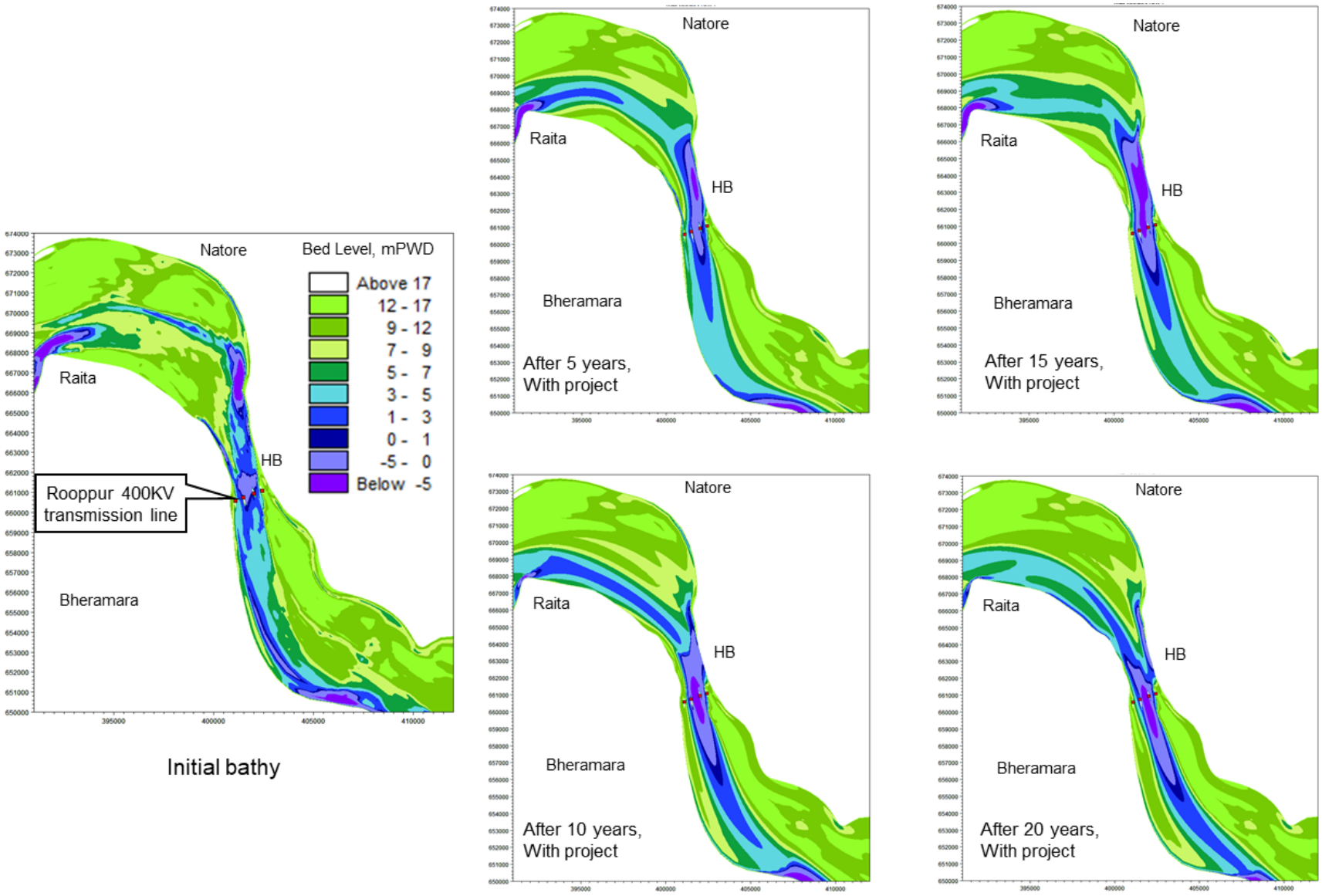


Figure 5.33 *Long Term Simulation for 20 years showing the Simulated Bed Level Contour in Ganges River in "with project" Condition*

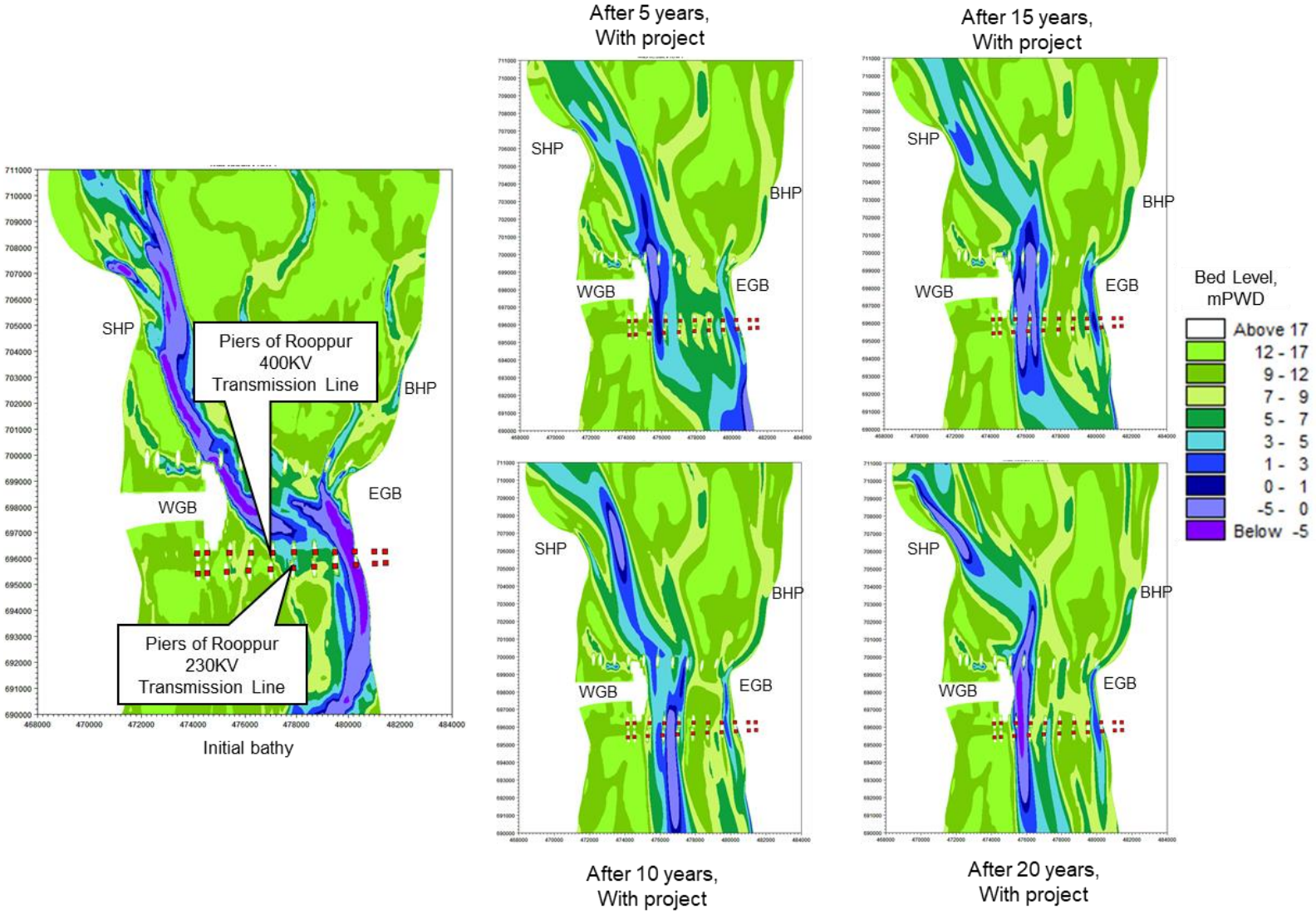


Figure 5.34 *Long Term Simulation for 20 years showing the Simulated Bed Level Contour in Jamuna River in "with project" Condition*

Bank Erosion / Shifting

The bank erosion that have been extracted from the long simulation is plotted in **Figure 5.35.** It is found that on the right bank, noticeable bank erosion of around 120m after 20 years might be occurred along the proposed Rooppur 400KV transmission line on Ganges River. Hence, the proposed anchor tower/ pier of transmission line parallel to the Ganges River along right bank should be shifted at least 100-150m away from the bank. In case of Jamuna River, similar tendency are also observed on the right bank of Jamuna River along the proposed Rooppur 400KV transmission line (TL-1) and Rooppur 230KV transmission line (TL-2) with an erosion of some 200 m after 20 years. Erosion along left bank was not significant in case of Ganges and Jamuna River.

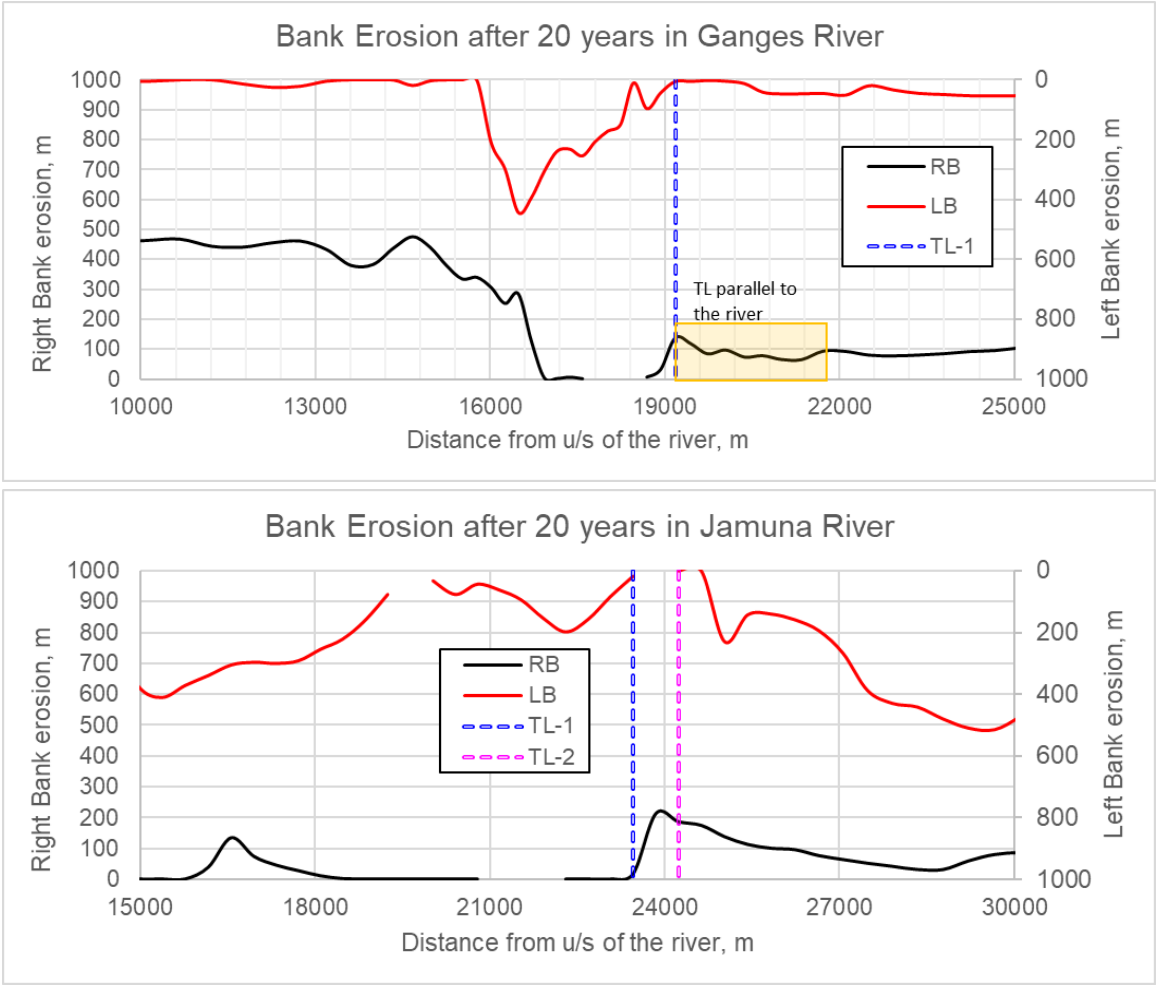


Figure 5.35 *Possible bank erosion/ shifting for the next 20 years in Ganges (top) and Jamuna (bottom) Rivers*

5.4.2 Short Term Development (2-3 years development)

A quantitative prediction for the next 2-3 years has been carried out to understand the probable scenario near the area of crossing lines over the Ganges and Jamuna River. Hence, to simulate the model, selection of boundary condition is one of the most critical decision. The performance of the river for average flood event and high flood event are already simulated for this model domain. Therefore, it has been decided that the boundary of recent 3 years i.e. 2017-2018-2019 will be selected as the boundary condition for short term development. In case of Ganges River, the boundary of 2017 and 2019 are reflect the return period of 1 in 2 year and 1 in 5 year, respectively. The boundaries of these simulation are shown in **Figure 5.36** and **5.37** for Ganges and Jamuna River, respectively.

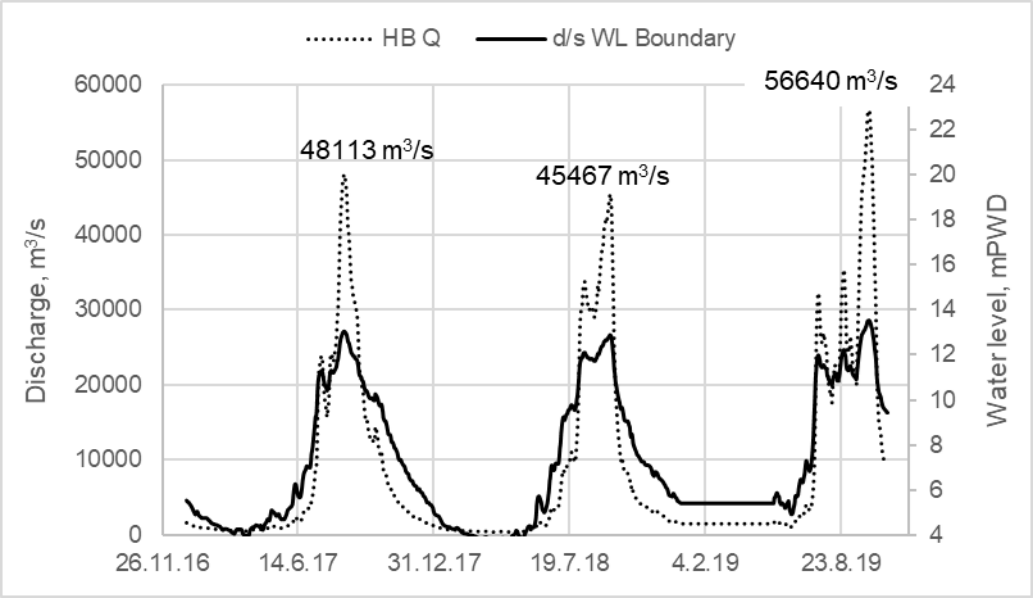


Figure 5.36 *Upstream and downstream boundary condition of 2017,2018 and 2019 year for the Ganges River*

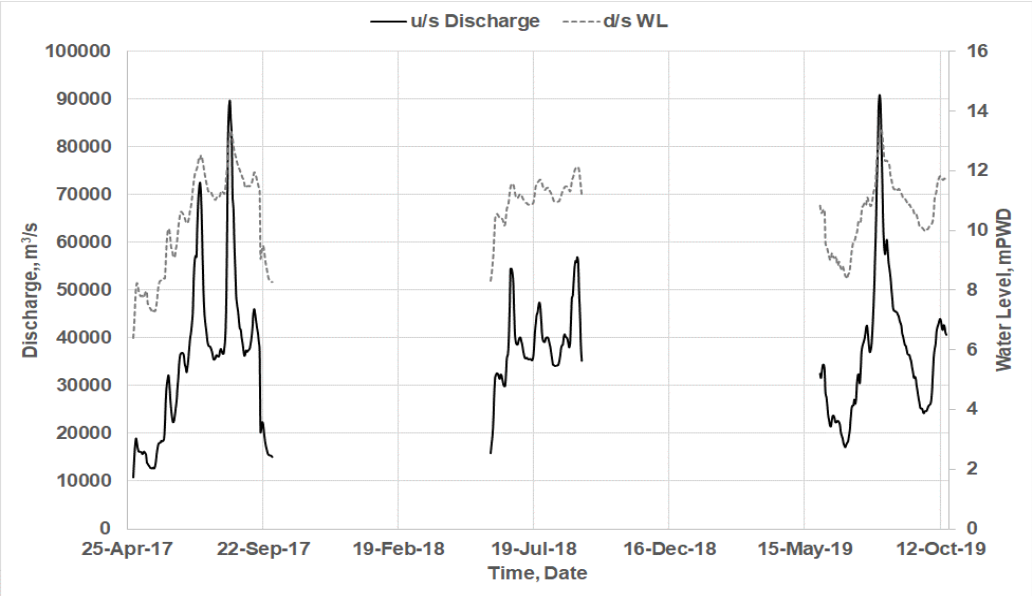


Figure 5.37 *Upstream and downstream boundary condition of 2017,2018 and 2019 year for the Jamuna River*

Planform Development

The probable river planform or bed level changes at the end of each year in Ganges and Jamuna River is shown in Figure 5.38 and Figure 5.39. The planform suggests that the main channel near crossing area is flowing along the left bank of Ganges River. The main channel is getting deeper and elongated at the end of 3rd year simulation. The cross-section profile along the transmission line over the Ganges River (Figure 5.40) shows that the main channel passes in between the pier no. 1 and 2 (counting from left bank at Rooppur powerplant site).

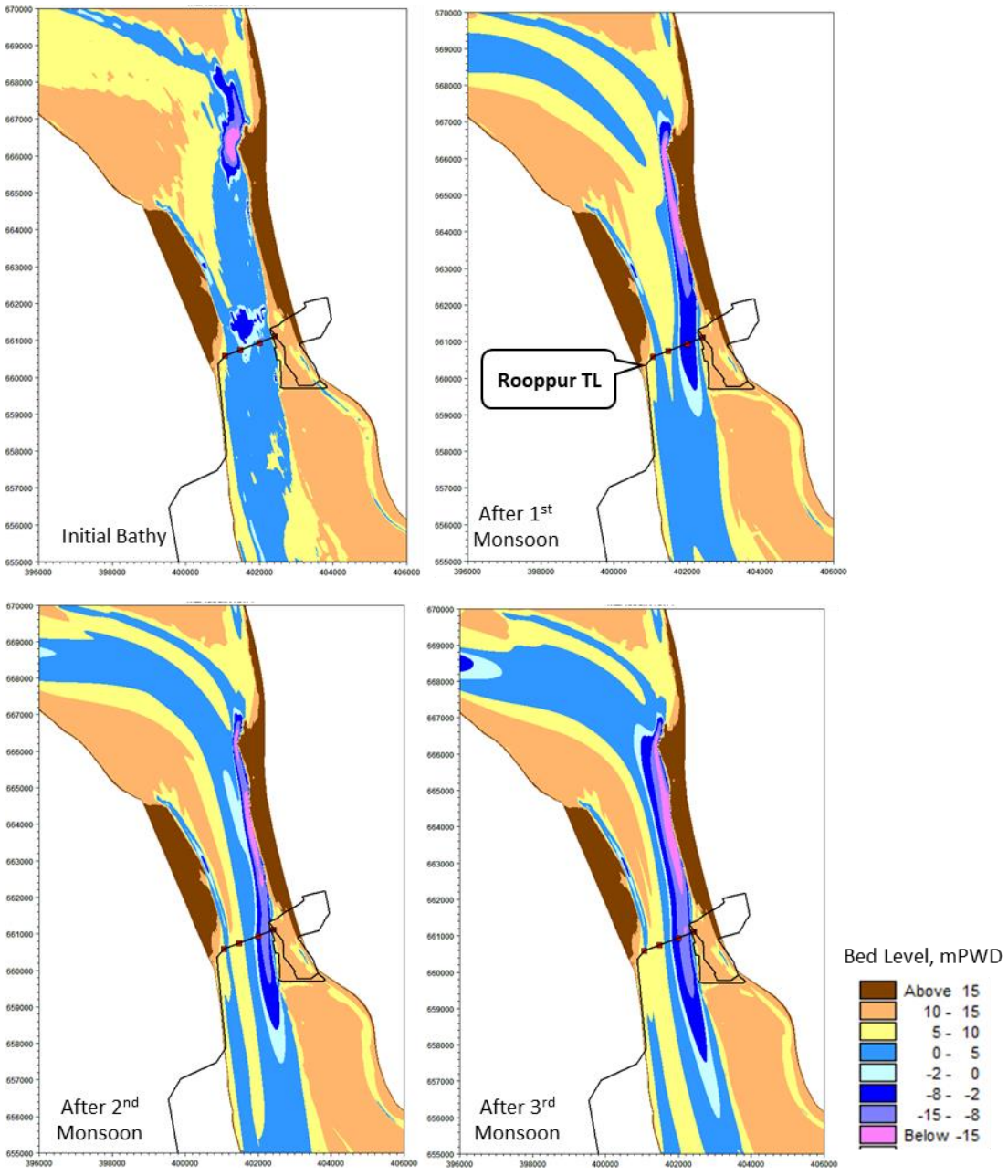


Figure 5.38 *Probable planform development in Ganges River at the end of each year*

In case of Jamuna River, the main channel was located initially along the left bank near both the transmission lines. After passing of first monsoon, the left channel (or west channel) is getting deeper around -31.47 mPWD (for TL-1) and -26.74 mPWD (for TL-2). However, in the following two years, the bed level remains unchanged along this bank. On the other hand, the right channel (or east channel) is getting deeper as more flow event has passed. The lowest bed level along east channel is found about -22.82 mPWD for TL-1 and –22.4 mPWD for TL-2.

The cross-section profile along both the transmission line over Jamuna River is presented in Figure 5.41 and Figure 5.42.

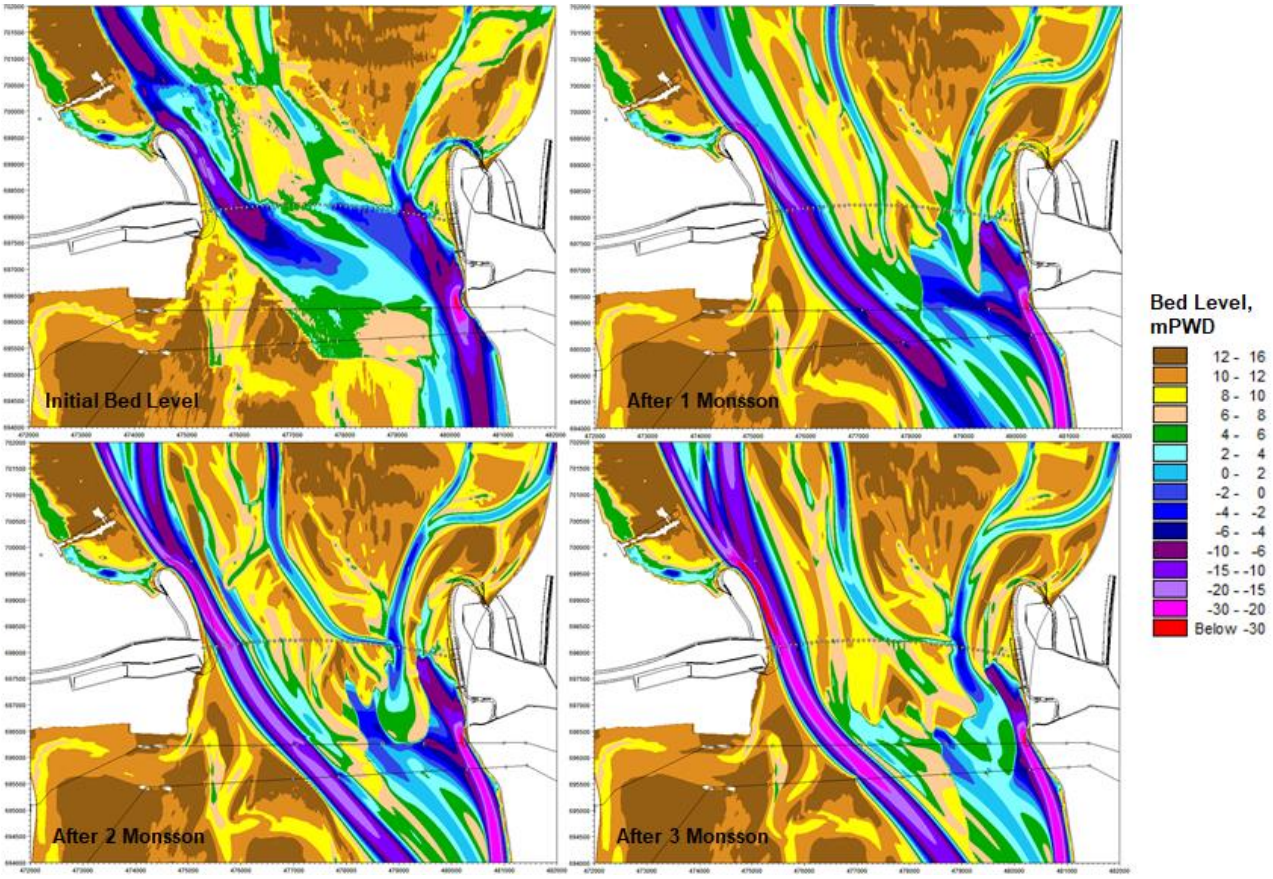


Figure 5.39 *Probable planform development in Jamuna River at the end of each year*

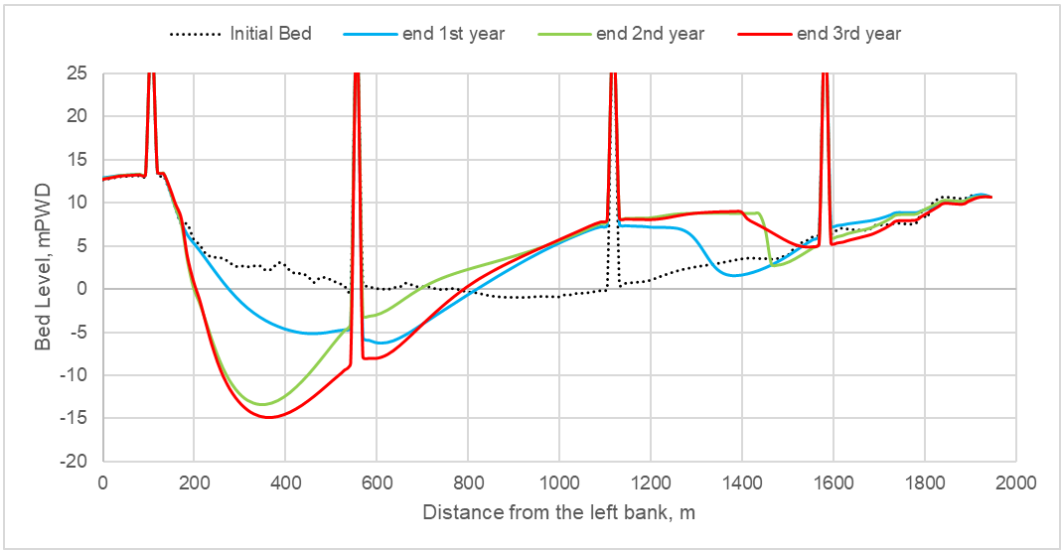


Figure 5.40 *Simulated cross-sections in Ganges River at the end of each year*

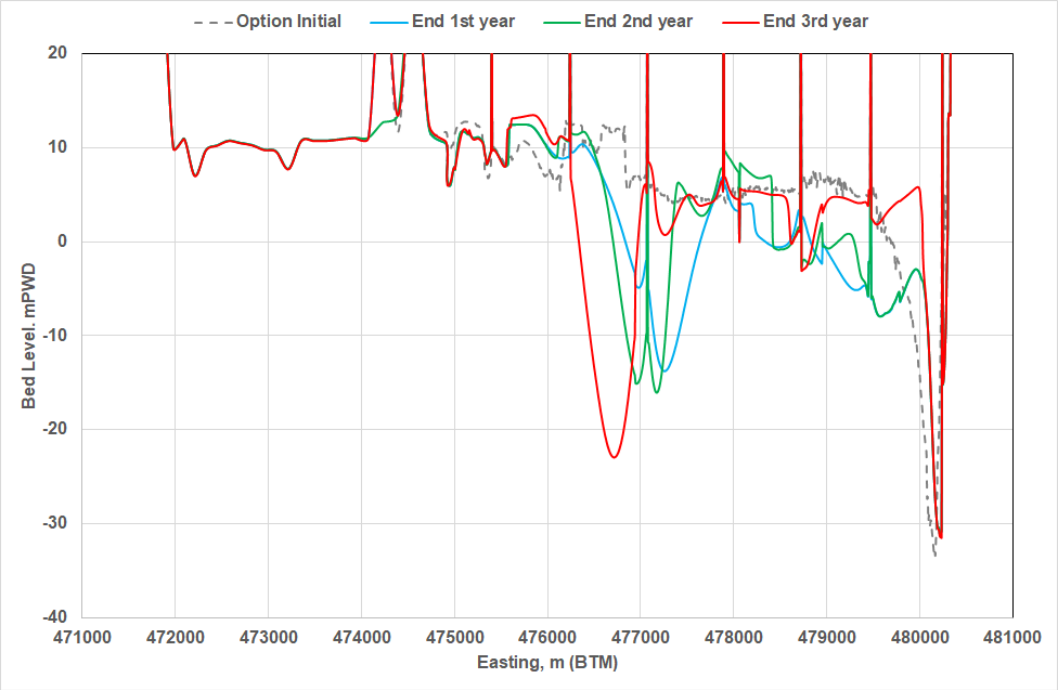


Figure 5.41 *Simulated cross-sections at Rooppur Transmission Line 1 in Jamuna River at the end of each year*

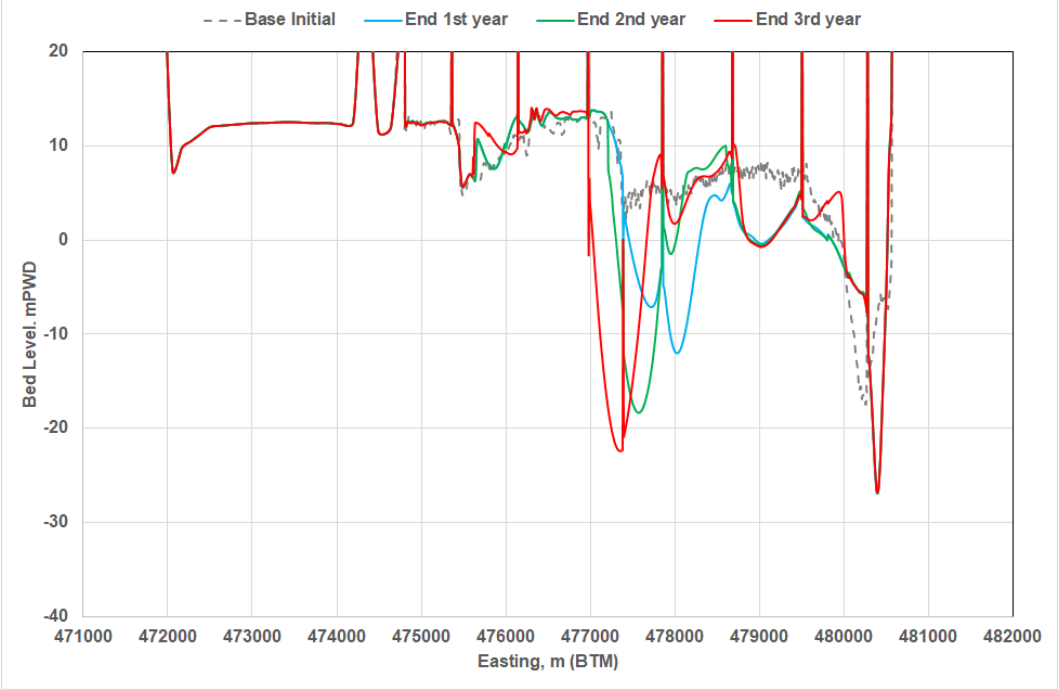


Figure 5.42 *Simulated cross-sections at Rooppur Transmission Line 2 in Jamuna River at the end of each year*

In Ganges River, the deepest scour is successively increased at the end of each year in between pier no. 1 and 2. The maximum depth of scour is found 17.2m at the end of 3rd year of simulation, which is lower than the design general scour (27.18m). On the other hand, the west channel is slightly aggraded, and the east channel is degraded along the TL-1(**Figure 5.41**). Again, in case of TL-2, the west channel is eroded approximately 10m after the end of 1st year. This bed erosion remains unchanged for the next two years. However, the bed erosion along the east channel is successively increased at the end of each year, **Figure 5.42**.

The depth of scour along the single transmission line over the Ganges River and two transmission lines over the Jamuna River is given in **Table 5.6**.

Table 5.6 Deepest Scour (m) along the transmission line at the end of each year in Ganges and Jamuna River

Transmission Line	River	Deepest Scour at the end of simulation		
		After 1st monsoon	After 2nd monsoon	After 3rd monsoon
Rooppur 400KV	Ganges	6.3	16.1	17.2
Rooppur 400KV	Jamuna	0	0	0
Rooppur 230KV	Jamuna	10	10	10

Flow Field near the Crossing Area

The flow field during the peak of monsoon at each year in the Ganges and Jamuna River within the study area is shown in **Figure 5.43** and **Figure 5.44**. It is found that the range of velocity near the crossing area persists above 3 m/s during the peak of every monsoon. The velocity vector or velocity attack towards the transmission piers of Ganges is also shown in **Figure 5.45**. The maximum velocity near the transmission line in Ganges River is about 3.46m/s, hit at the pier no. 2. The transmission line parallel to the river along the right bank also faces the velocity nearly 1.08m/s.

The maximum velocity in Jamuna River along both the transmission lines also persists above 3 m/s during the peak of every monsoon. The maximum velocity near the transmission line 1 and 2 over the Jamuna River is found about 3.62m/s and 4.19m/s, respectively, which hit the pier no. 5 of TL-1 and pier no. 6 of TL-2.

The maximum velocity at the immediate upstream of transmission lines in Ganges and Jamuna River during the peak of each year is tabulated in **Table 5.7**.

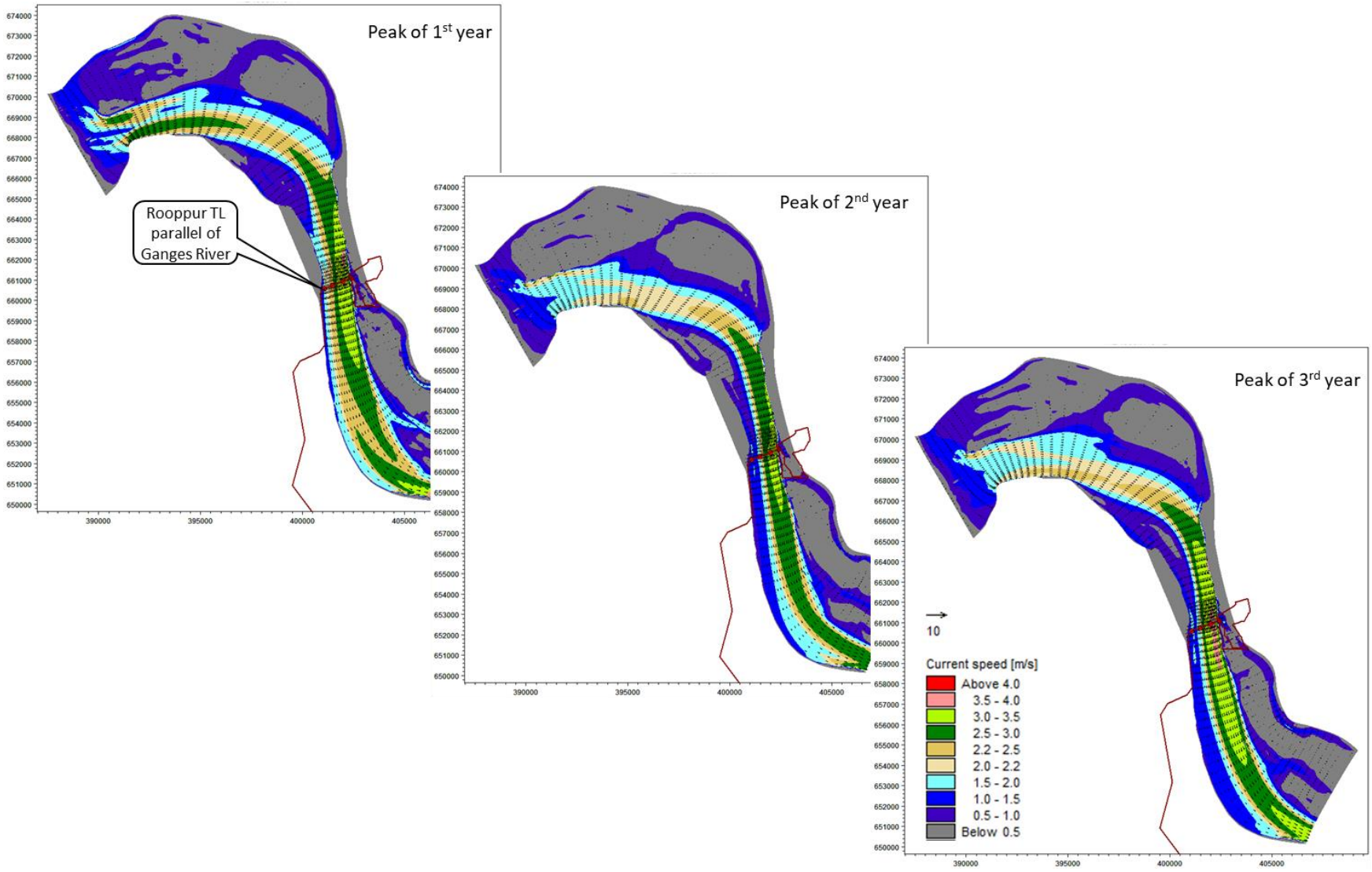


Figure 5.43 *Simulated peak velocity in Ganges River at each year of simulation*

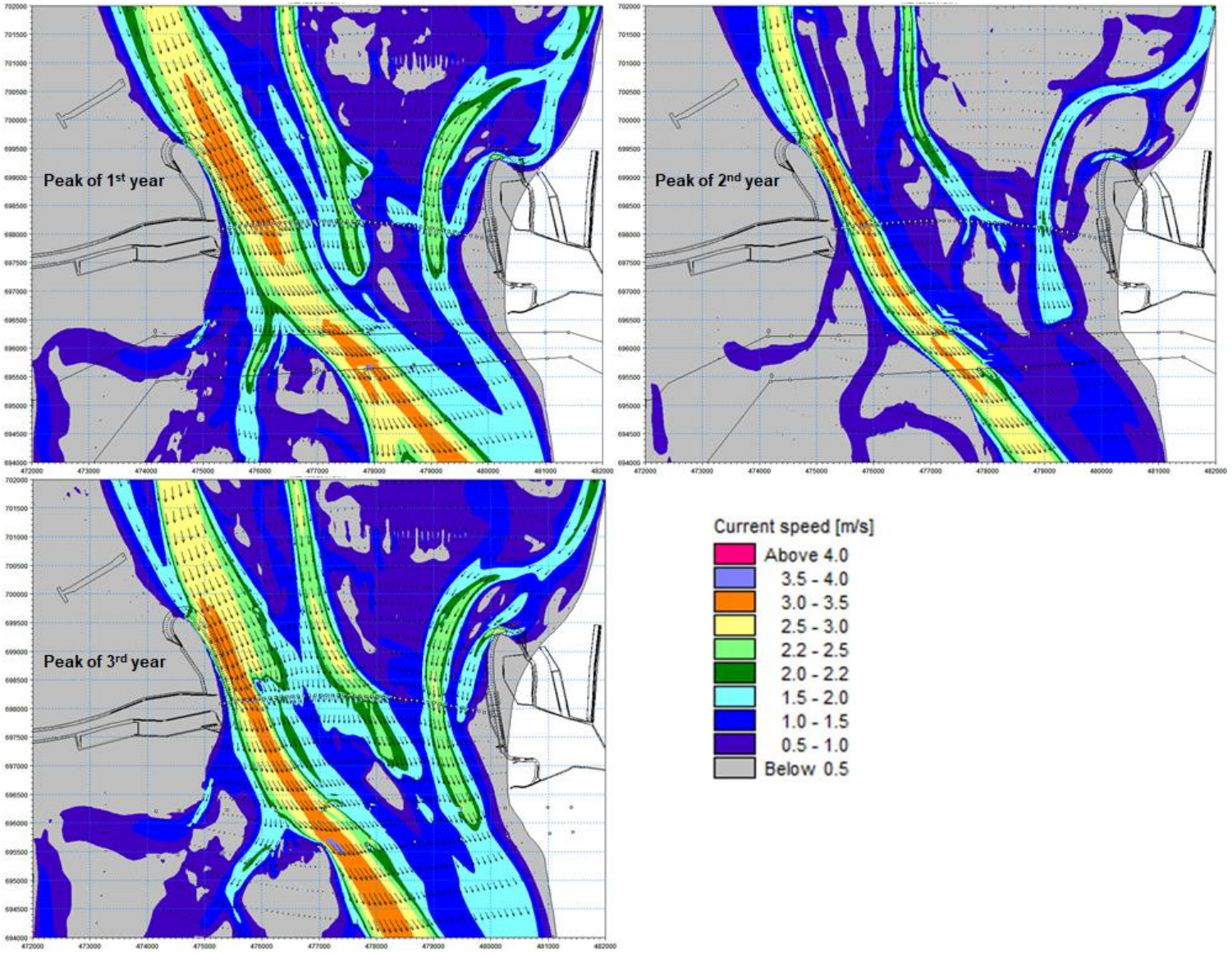


Figure 5.44 *Simulated peak velocity in Jamuna River at each year of simulation*

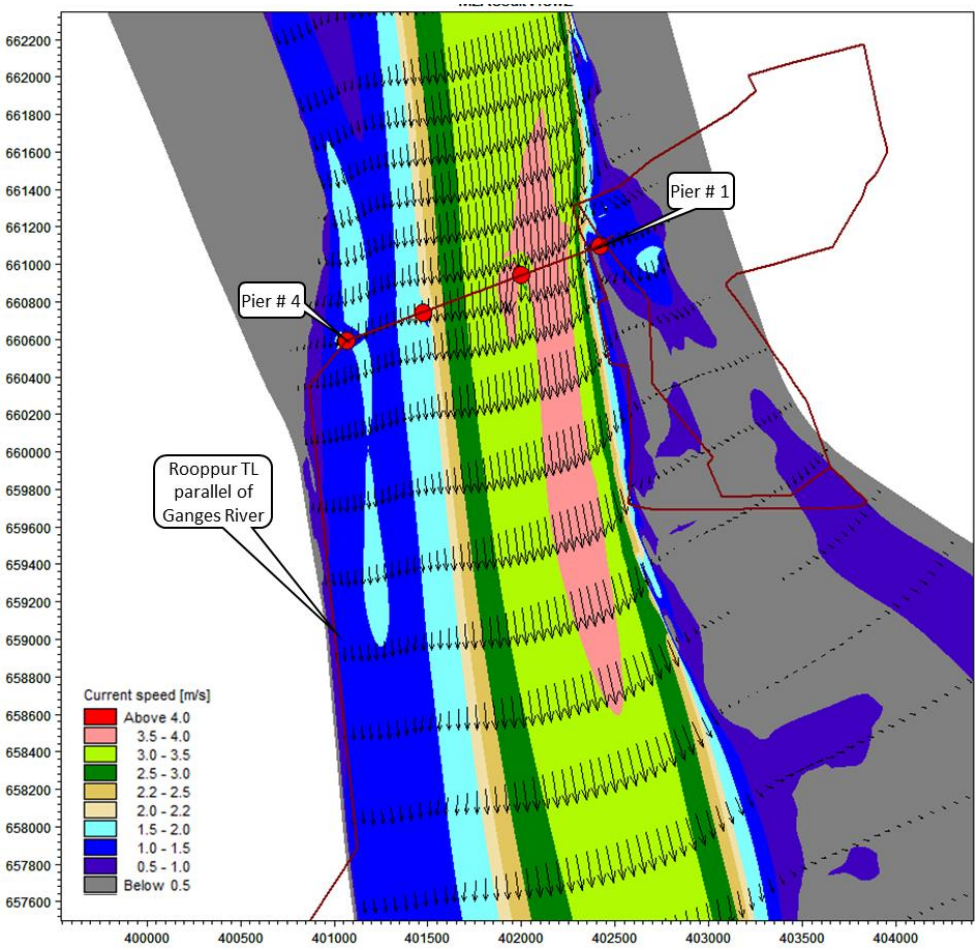


Figure 5.45 *Simulated bank erosion near the crossing line in Ganges River*

Table 5.7 Simulated Maximum Velocity at the immediate upstream of transmission pier of Ganges and Jamuna River

Transmission Line	River	Maximum Velocity at the peak of simulation		
		Peak of 1st year	Peak of 2nd year	Peak of 3rd year
Rooppur 400KV	Ganges	3.33	3.01	3.46
Rooppur 400KV	Jamuna	3.62	3.01	3.57
Rooppur 230KV	Jamuna	4.19	3.32	3.01

Bank Erosion near the Crossing Line

The simulated bank erosion at the end of each year is extracted from the model and plotted in **Figure 5.46** and **Figure 5.47** for Ganges and Jamuna River, respectively. The figure reveals that the right bank of Ganges is relatively vulnerable to bank erosion, approximately 40m. The transmission line parallel to Ganges along this bank is in a risk zone. Thus, it would be better if the anchor tower/ pier is moved about 100m away from the right bank.

There is no significant bank erosion along both the bank of Jamuna River near the transmission lines. However, the left bank shows around 200m of bank erosion along the transmission line 2.

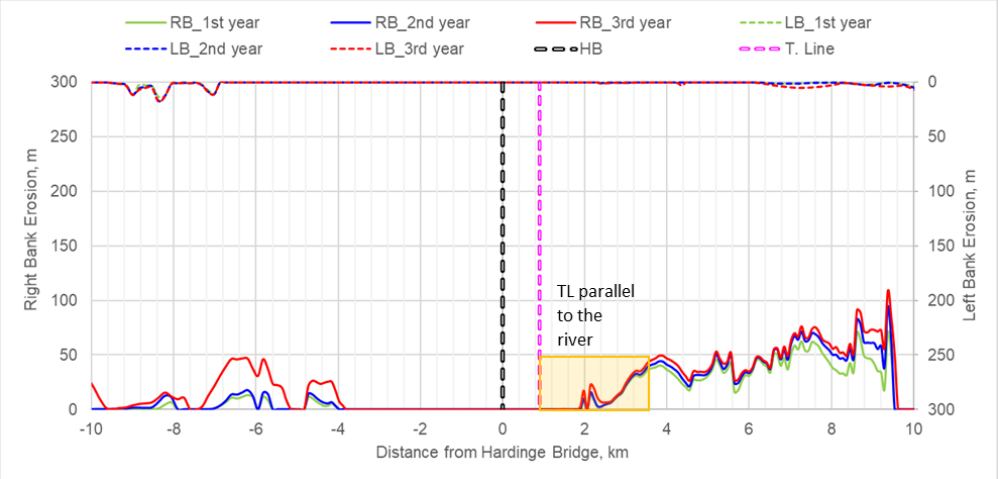


Figure 5.46 *Simulated bank erosion near the crossing line in Ganges River*

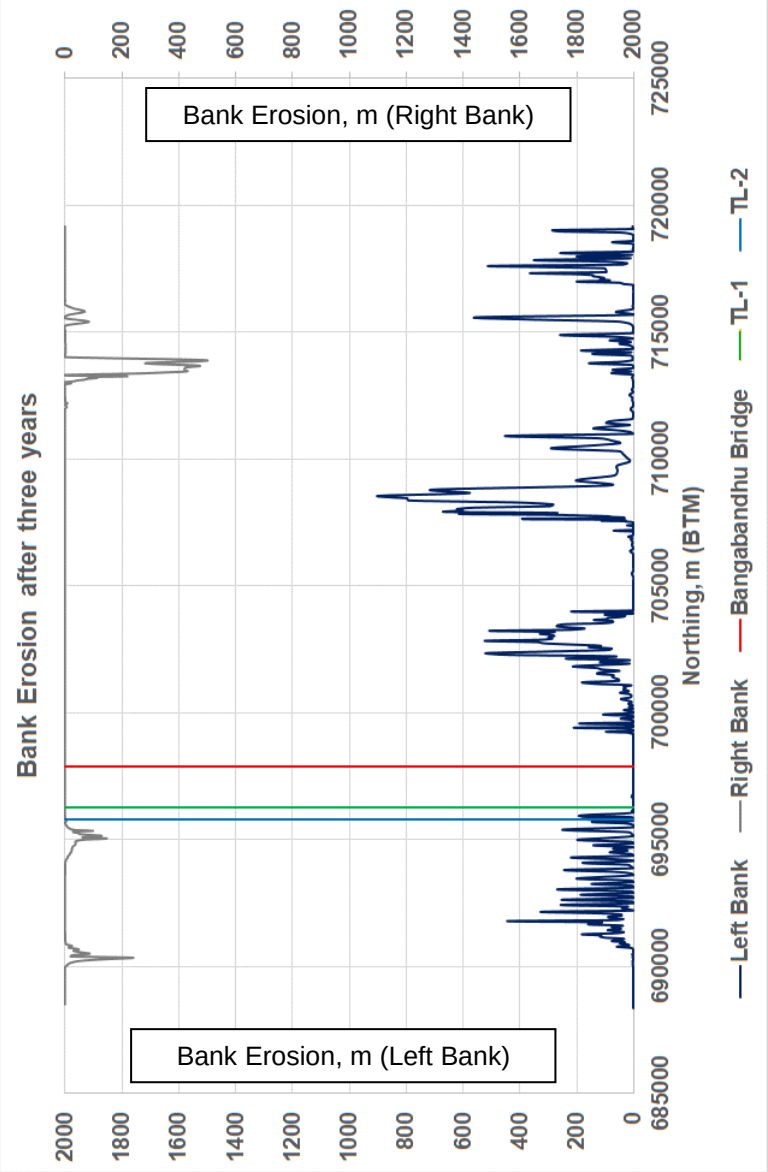


Figure 5.47 *Simulated bank erosion near the crossing line in Ganges River*

5.5 Impact of Transmission Line on nearby Existing Structures

If any kind of structure will be constructed on a river, it is necessary to identify whether there is any kind of hydrodynamic or morphological impact on the nearby existing structures of that river. In this regard, an analysis has been done in a tabular form to identify the impact of transmission line on the nearby structures. The proposed one transmission line over Ganges River is about 950m d/s of Hardinge Bridge and other two transmission lines over Jamuna River are about 2km and 2.6km d/s from the existing Bangabandhu Bridge. Hence, the significant nearby structures are mainly the Guide Bunds, bridges itself and other ancillary structures, like Sirajganj Hardpoint, Bhuapur Hardpoint, Cross-bars etc.

Table 5.8 and **Table 5.9** are showing the change of velocity and scour level for "with" and "without" project condition on nearby existing structures. It is clearly seen from the table that there are no significant changes due to construction of transmission lines over the river.

Table 5.8 Hydrodynamic and Morphological impact on nearby structures in Ganges River

Structures	Lowest Bed level, mPWD		Maximum Velocity, m/s	
	Without Project	With Project	Without Project	With Project
Left Guide Bund of Hardinge Bridge	-33.4	-33.4	4.22	4.63
Right Guide Bund of Hardinge Bridge	-0.068	-0.068	2.1	2.1
Hardinge Bridge	-21.36	-23.11	4.13	4.21
Lalon Shah Bridge	-21.39	-22.51	4.14	4.20

Table 5.9 Hydrodynamic and Morphological impact on nearby structures in Jamuna River

Structures	Lowest Bed level, mPWD		Maximum Velocity, m/s	
	Without Project	With Project	Without Project	With Project
East Guide Bund of Bangabandhu Bridge	0.48	-0.84	3.64	2.76
West Guide Bund of Bangabandhu Bridge	-33.76	-33.77	3.22	3.21
Sirajganj Hardpoint	-14.64	-14.69	2.2	1.53
Cross-bar 3	-0.57	-0.49	1.68	1.63
Cross-bar 4	-11.20	--11.24	0.79	0.84

6. SCOUR ASSESSMENT AND DESIGN PARAMETERS FOR PIER OF TRANSMISSION TOWER

6. SCOUR ASSESSMENT AND DESIGN PARAMETERS FOR PIER OF TRANSMISSION TOWER

6.1 General

Scour means lowering of river bed level by erosion or removal of river bed material by hydraulic action of flowing water. The depth of piers of Transmission Line Tower foundation should be well below the limit of this scour. Hydraulic study for this type of foundation, therefore, mainly evaluates the expected lowest bed level of river below which the foundation of piers has to be laid so that the Transmission Line Tower can withstand the effect of scour with no risk of failure.

6.2 Assessment of Scour around the Transmission Line/ Pier

Two types of pile dia are considered as per steel tubular pile drawings, provided by PGCB

Type-1: Steel Tubular 8 Piles with 2m Dia, and
Type-2: Steel Tubular 8 Piles with 3m Dia

6.2.1 Type of Scour and Computation Method

The total scour for design of foundation piers is comprised of following three components:

- General scour
- Constriction scour
- Local scour

General scour is the scour one has to anticipate in the long term irrespective of the construction of Pier Foundation. Constriction of flow encroaching onto the flood plain and/or into river is the most common cause of constriction scour. Local scour involves removal of material due to obstruction such as foundation piers, design discharge, waterways and river bed materials etc. It is caused by acceleration of flow and resulting vortices induced by the flow obstruction, and usually cyclic in nature.

General and Constriction Scour Assessment

The general and constriction scour have been assessed at site using the state-of-art of hydrodynamic and morphological technique and the values are given in **Table 6.1**.

The general and constriction scour were predicted as model generated output tabulated as below.

Table 6.1 Computation of General and Constriction Scour

TL/River Name	General Scour (m)	Constriction Scour (m)
TL-1 Ganges	27.18	3.28
TL-1 Jamuna	0.0	6.95
TL-2 Jamuna	17.88	5.17

Local and Total Scour Computation

The assessment of local scour has been carried out mainly based on empirical relations established considering explicit descriptions of the physical process involved in scour development. Therefore, results are given with some reservation due to the limitations and gaps of knowledge inherent in these empirical relations. Sound engineering judgment is,

therefore, necessary in the evaluation of results. Many different relations are available for determining the local scour of pier. As such FHWA Method, Laursen's Method, Breuser's and IRC:78 Methods are executed. Details of the methods of computation of local scours have been provided in Scour Computation Sheets as in **APPENDIX-A**

6.2.2 Hydraulic and Physical Parameters or Scour Computation

Hydraulic Parameters

The two most important hydraulic parameters for computation of local scour are depth of flow and velocity. These parameters have been computed from hydrodynamic model simulation based on a design event for proposed crossing line. It is anticipated that any pier could potentially be subjected to maximum depth of flow and average velocity derived from hydraulic model. Therefore, only one computation for one pier scour is conducted and assumed to apply for all the piers. The hydraulic design parameters of crossing sites are given in **Table 6.2** below:

Table 6.2 Related Hydraulic Design Parameters

TL/River Name	Design High Water Level (mPWD)	Design Low Water Level (mPWD)	Minimum Bed Level (mPWD)	Maximum Depth of Flow (m)	Average velocity (m/s)
TL-1 Ganges	15.22	4.20	-0.97	16.19	4.22
TL-1 Jamuna	14.00	5.29	-34.37	48.37	2.90
TL-2 Jamuna	13.89	5.25	-17.44	31.33	3.25

Physical Parameters

Type-1 (Pile Dia 2m, Total 8 piles @ 15.012m c/c)

Table 6.3 Physical Parameters of Piles/Equivalent pier, Pile/ Cap and Pile Foundation of all 4 legs

Parameters	Value
Piles cluster/equivalent width/dia of pier/pile support, 2mx 8 Nos. (m)	16.00
Nos. of Pier/Support Per Tower	8.00
Distance of Pier/support face from pile cap edge (m), below 450mm of HFL	1.00
Piles cluster/equivalent width of pile cap (m), 4.0mx3Nos	12.0
Piles cluster/equivalent Length of pile cap (m), 4.5mx3nos	12.0
Thickness of pile cap (m), below 450mm of HFL	9.50
Diameter of pile (m)	2.00
Spacing of pile transverse to flow (m)	15.01
Number of pile transverse to flow	3.00
Spacing of pile along flow (m)	15.01
Number of piles along flow	3.00

Type-2 (Pile Dia 3m, Total 8 piles @ 15.012m c/c)

Table 6.3 Physical Parameters of Piles/Equivalent pier, Pile/ Cap and Pile Foundation of all 4 legs

Parameters	Value
Piles cluster/equivalent width/dia of pier/pile supports, 3mx 8 Nos. (m)	24.00
Nos. of Pier/Support Per Tower	8.00
Distance of Pier/support face from pile cap edge (m), below 450mm of HFL	1.00
Piles cluster/equivalent width of pile cap (m), 5mx3	15.0
Piles cluster/equivalent Length of pile cap (m), 5mx3	15.0
Thickness of pile cap (m), below 450mm of HFL	9.50
Diameter of pile (m)	3.00
Spacing of pile transverse to flow (m)	15.01
Number of pile transverse to flow	3.00
Spacing of pile along flow (m)	15.01
Number of piles along flow	3.00

6.2.3 Computation of Local Scour and Design Scour Level of Pier

Governing Formula for Local scour around Pier

Many different relations are available for determining the local scour at foundation pier. Following empirical equations have been used to calculate local scour at pier. All formulae are depicted in Scour Computation Sheet as in **APPENDIX-A**.

a. FHWA Method

Hydraulic Engineering Circular (HEC) No. 18 of the US Federal Highway Administration (FHWA) publication (May 2005) refers to the method of scour calculations, supported by worked out examples. FHWA recommends the following Colorado State University (CSU) equation for calculation of the local scour depth, for pier as depicted in computational sheet as in **APPENDIX-A.**

b. Laursen's Method

Laursen (1960) proposed the following equation to compute local scour at foundation pier as depicted in computational sheet as in Appendix-A.

c. Breuser's Method

Breuser's (1965) proposed the following simple formula for live-bed scour at piers, Type I and Type II as depicted in computational sheet as in Appendix-A.

d. IRC:78 Method

IRC:78-2014 proposed the following simple equations with parameter like Design discharge, effective waterways, Type of Bed Materials etc. to compute local scour at foundation pier as depicted in computational sheet as in Appendix-A.

Local Scour computations for foundation pier have been done using available formulae, computed hydraulic parameters such as maximum depth of flow and average velocity and Typical Section with size of pier, pile cap and piles (Ref: Appendix-A Figure A-1 and Figure A-2). The details of scour computation are furnished and shown in Separate Sheets in APPENDIX-A.

The summery of computed local scour is shown below in **Table 6.4**.

Table 6.4 Summary of Computed Local Scour of Pier of Transmission Line Tower Foundation

Transmission Line with River Name	Methods/ Formulae of Local Scour in m						Calculated Maximum Local Scour (m)	Method of Maximum Local Scour
	FHWA	Laursen's	Breuser's Type-I	Breuser's Type-II	Richardson's	IIRC:78		
TL_Ganges	20.54	27.51	20.27	28.46	23.20	00.25	28.46	**Breuser's T-II**
TL-1 Jamuna	19.64	39.52	21.30	37.10	23.87	18.71	39.52	**Laursen's**
TL-2 Jamuna	22.45	37.27	22.23	38.85	24.19	18.60	38.85	**Breuser's T-II**

The anticipated total scour and design scour level are given below in **Table 6.5**. The bottom level of the pile foundation should be set well below this level.

Table 6.5 Design Scour Level at Pier of Transmission Line Foundation

Transmission Line (TL) with River Name	General Scour (m)	Constriction Scour (m)	Maximum Local Scour (m)	Maximum Total Scour Depth below River bed (m), MTSD	Minimum Bed Level (m PWD), MBL	Design Scour Level from Datum (m PWD). [-MTSD ± MBL]
TL_Ganges	27.18	3.28	28.46	58.92	-0.97	-59.89
TL-1 Jamuna	0.00	6.95	39.52	46.47	-34.37	-80.84
TL-2 Jamuna	17.88	5.17	38.85	61.90	-17.44	-79.34

6.3 Estimated Hydraulic Parameters for Designing Transmission Piers

The estimated hydraulic parameter for designing the transmission lines/ piers on Ganges and Jamuna River are tabulated in **Table 6.6**.

Table 6.6 Hydraulic Parameters for Designing Transmission Piers on Ganges and Jamuna River

Hydraulic Parameters	Unit	Values			Remarks
		Rooppur 400KV on Ganges River	Rooppur 400KV on Jamuna River	Rooppur 230KV on Jamuna River	
Design Discharge	m^3/s	79059	102436	102436	Model estimated
Design High Water Level (HFL)	mPWD	15.22	14.00	13.89	Model estimated
	MSL	*14.76*	*13.54*	*13.43*	
Design Low Water Level	mPWD	4.20	5.29	5.25	Observed data using slope analysis
	MSL	*3.74*	*4.83*	*4.79*	
Maximum average velocity	m/s	4.22	2.9	3.25	2D model estimated
Minimum Bed Level	mPWD	-0.97	-34.37	-17.44	surveyed
	MSL	*-1.43*	*-34.83*	*-17.9*	
General Scour	m	27.18	0	17.88	model estimated
Constriction Scour	m	3.28	6.95	5.17	model estimated
Maximum Local Scour	m	28.46	39.52	38.85	Calculated from equations
Total Scour	m	58.92	46.47	61.90	
Design Scour Level from Datum	mPWD	-59.89	-80.84	-79.34	
	MSL	*-60.35*	*-81.3*	*-79.80*	
Angle of attack, ~~Θ~~	°	-18.43	25.5	52.96	Calculated from model output
Mean Diameter, d_{50}	mm	0.15	0.18	0.18	
Max depth of flow	m	16.19	48.37	31.33	Calculated
Max span length or max distance between tower	m	557.2	848	874	

7. SHIP IMPACT LOAD, INPUT DATA REQUIRED TO CALCULATE VELOCITY ATTACK AND WAVE ATTACK

7. Ship Impact Load, Input data required to calculate Velocity attack and Wave attack

7.1 Ship Impact Load

For the protection of piers in the river, the head-on collision of a ship is important. For this purpose, the results of collision tests carried out in Germany under the direction of *Gerhard Woisin* were evaluated as well *Woisin* found a dynamic relationship between the impact forces over time, where the maximum force for about 0.1 to 0.2 seconds at the beginning of the collision increases up to double the value of the average collision force over several seconds. From *Woisin*'s test results the author concluded that equivalent static impact forces from a direct collision of a large ship against a rigid wall are, in a first approximation, proportional to the square root of the dead weight tonnage (DWT) dead weight tonnage of the ship, However, within this relationship a wide scatter of impact forces exists for ships with the same DWT due to their widely varying hull structures and collision speeds. The author thus proposed the formula for the impact forces with a scatter of ±50 %. (*Svensson*, 1981) P = 0.88 $\sqrt{DWT}$, where P is the equivalent average impact load in MN. This formula was published by the author in Germany in 1981, in the IABSE Periodica in 1982, and in the Proceedings of the IABSE Colloquium on Ship Collision with Pier in river held in Copenhagen in 1983.

The AASHTO specification uses the relationship

F = 1.11* 0.88 $\sqrt{DWT} * \frac{v}{8}$

= 0.122 $\sqrt{DWT} * v$

where F is the equivalent average impact load in MN and *v* is the ship impact speed in m/s.

Table 7.1 Ship Impact Load

Equivalent Average Impact Load	Dead Weight Tonnage	Impact Speed	Vessel Size Group	Remarks
F (MN)	**DWT (MN)**	**v (m/s)**		
109.59	75000	3.28	Aframax (Min)	Considering Max velocity at pier-5 for 400KV line
135.70	115000	3.28	Aframax (Max)	

7.2 Input data required to calculate Velocity attack

The necessary input data to velocity attack are given below:

Table 7.1 Velocity and its direction on Rooppur 400KV Transmission line over Ganges River

Anchor Nos.	Anchor Chainage (m)	X_UTM	Y_UTM	Velocity (m/s)	Direction (Deg)
1	90.00	707154.67	2662561.80	1.96	27.77
2	540.28	706736.68	2662394.36	4.07	19.10
3	1097.73	706219.19	2662187.08	1.29	21.89
4	1534.76	705813.50	2662024.57	1.42	27.02

Table 7.2 Velocity and its direction on Rooppur 400KV Transmission line over Jamuna River

Anchor Nos.	Anchor Chainage (m)	X_UTM	Y_UTM	Velocity (m/s)	Direction (Deg)
1	0.00	778164.53	2699234.15	0.35	86.38
2	400.39	778564.73	2699246.36	0.21	89.18
3	1242.79	779406.74	2699272.05	0.37	22.61
4	2090.21	780253.77	2699297.89	2.32	24.91
5	2920.84	781084.02	2699323.23	3.28	36.44
6	3746.62	781909.41	2699348.41	2.69	22.40
7	4575.50	782737.90	2699373.69	0.93	22.55
8	5324.61	783486.67	2699396.53	2.07	34.05
9	6101.20	784262.89	2699420.22	0.07	1.38
10	6853.32	785014.67	2699443.16	Main land	Main land
11	7264.02	785425.17	2699455.68	Main land	Main land

Table 7.3 Velocity and its direction on Rooppur 230KV Transmission line over Jamuna River

Anchor Nos.	Anchor Chainage (m)	X_UTM	Y_UTM	Velocity (m/s)	Direction (Deg)
1	0.00	778216.95	2698441.39	0.54	80.29
2	353.69	778569.51	2698469.53	0.31	56.51
3	1128.83	779342.20	2698531.19	0.47	51.12
4	1961.50	780172.23	2698597.43	1.89	13.78
5	2804.80	781012.87	2698664.52	3.12	55.96
6	3679.93	781885.22	2698734.14	1.54	34.13
7	4499.42	782702.11	2698799.33	1.55	28.31
8	5311.52	783511.63	2698863.93	2.21	29.99
9	6118.70	784316.26	2698928.15	0.64	20.89
10	6863.77	785058.97	2698987.42	Main land	Main land
11	7263.89	785457.82	2699019.25	Main land	Main land

7.3 Input data required to calculate Wave attack

7.3.1 Computation for Wave Height and Wave Runup

In the monsoon the flood plain completely gets inundated and merges with rivers, that creates open fetch where wind generated waves are formed. So adequate allowances above design water level need to be considered to fixing the formation level of the pier. Moreover, assessment of wave height and period is required for the protection of hydraulic action of waves erosion. A definition sketch showing the wave height (H) and wave runup (R) is shown in figure below.

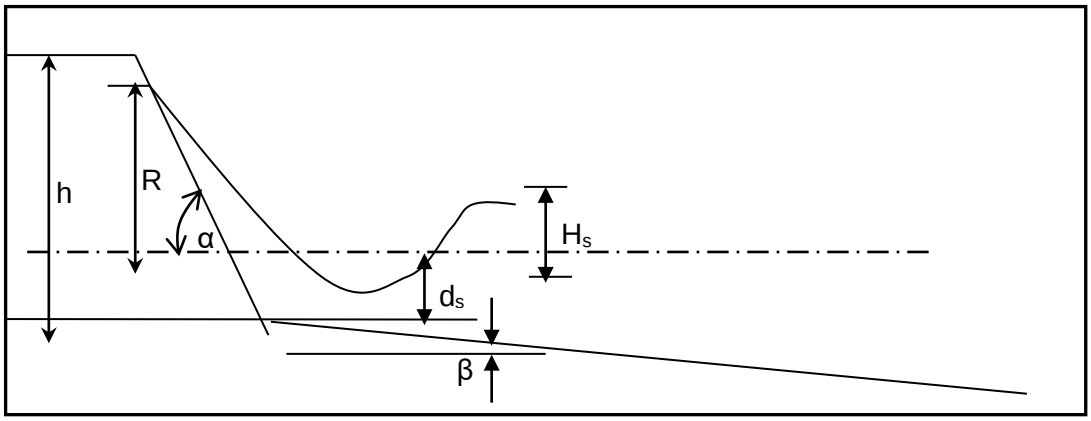


Figure 7.1 *Definition Sketch: Wave height and Wave runup*

d_s = depth of water

α = side slope

β = land slope

h = height of bank

R = wave runup

H = wave height

7.3.2 Wave Height Parameters

The three most important parameters required to compute wave height are: wind speed, fetch length and water depth. Maximum wave height is expected when wind will blow in between South-East direction (in the month of May) during monsoon period in the Tangail Station.

The fetch length depends upon wind field. For the present study the distance from the pier (crossing alignment) to the nearest char land/settlement has been taken as the fetch length. The fetch length has been measured as 13.6 km for Line-1 (400KV), 13.0 km for Line-2 (230KV) of the Jamuna River and 8.50 km of the Ganges River, respectively. The average depth of water of 6.0 m for Line-1 (400KV) 5.97m for Line-2 (230KV) of the Jamuna River and 9.98 m for the Ganges River is assessed considering 100 year return period high flood level and average ground level of the crossing alignment.

The wind speed data of Bangladesh Meteorological Department (BMD) station at Tangail and Ishwardi has been considered (**APPENDIX-C**). As the probability of occurrence of high wind speed with the occurrence of high-water level corresponding to 100-year return period is very minimum, a wind speed of 10.50 m/sec for Line-1 & Line-2 for the Jamuna River and 11.50 m/sec for the Ganges River [Wind Rose in the month of May (1987-2005)], i.e. 37.80 km/hour corresponding to 20 year return period of Tangail station and 41.4 km/hour for Ishwardi station has been used.

7.3.3 Wave Height and Period

Wave height has been computed using the formula for shallow water waves according to Shore Protection Manual (1984). Wave height and period for Line-1 & Line-2 for the Jamuna River and for the Padma River were computed using the following data.

- ***For (400KV) of the Ganges River:***

Data:

F- fetch length : 8,500 m
u- wind velocity : 11.5 m/sec
d- average depth of water : 9.98 m
g- acceleration due to gravity : 9.81 m/sec^2

Computation:

Wave height:

$$\frac{gH}{u^2} = 0.283\, tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right] tanh\frac{0.00565\left(\frac{gF}{u^2}\right)^{0.50}}{tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right]}$$

$$H = 0.283\, tanh\left[0.53\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.75}\right] tanh\frac{0.00565\left(\frac{9.81 * 13000}{10.5^2}\right)^{0.50}}{tanh\left[0.53\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.75}\right]} * \frac{10.5^2}{9.81}$$

= 0.53 m

Wave period:

$$\frac{gT}{u} = 7.54\tanh\left[0.833\left(\frac{gd}{u^2}\right)^{0.375}\right]\tanh\frac{0.0379\left(\frac{gF}{u^2}\right)^{0.33}}{\tanh\left[0.833\left(\frac{gd}{u^2}\right)^{0.375}\right]}$$

$$T = 7.54\, tanh\left[0.833\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.375}\right] tanh\frac{0.0379\left(\frac{9.81 * 13000}{10.5}\right)^{0.33}}{tanh\left[0.833\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.375}\right]} * \frac{10.5}{9.81}$$

= 2.50 sec

- ***For Line-1 (400KV) of the Jamuna River:***

Data:

F- fetch length : 13,600 m
u- wind velocity : 10.5 m/sec
d- average depth of water : 6.0 m
g- acceleration due to gravity : 9.81 m/sec^2

Computation:

Wave height:

$$\frac{gH}{u^2} = 0.283\, tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right] tanh\frac{0.00565\left(\frac{gF}{u^2}\right)^{0.50}}{tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right]}$$

$$H = 0.283\, tanh\left[0.53\left(\frac{9.81*6.0}{10.5^2}\right)^{0.75}\right] tanh\frac{0.00565\left(\frac{9.81*13600}{10.5^2}\right)^{0.50}}{tanh\left[0.53\left(\frac{9.81*6.0}{10.5^2}\right)^{0.75}\right]} * \frac{10.5^2}{9.81}$$

= 0.62 m

Wave period:

$$\frac{gT}{u} = 7.54\tanh\left[0.833\left(\frac{gd}{u^2}\right)^{0.375}\right]\tanh\frac{0.0379\left(\frac{gF}{u^2}\right)^{0.33}}{\tanh\left[0.833\left(\frac{gd}{u^2}\right)^{0.375}\right]}$$

$$T = 7.54\, tanh\left[0.833\left(\frac{9.81*6.0}{10.5^2}\right)^{0.375}\right] tanh\frac{0.0379\left(\frac{9.81*13600}{10.5}\right)^{0.33}}{tanh\left[0.833\left(\frac{9.81*6.0}{10.5^2}\right)^{0.375}\right]} * \frac{10.5}{9.81}$$

= 2.89 sec

- ***For Line-2 (230KV) of the Jamuna River:***

Data:

F- fetch length : 13,000 m
u- wind velocity : 10.5 m/sec
d- average depth of water : 5.97 m
g- acceleration due to gravity : 9.81 m/sec^2

Computation:

Wave height:

$$\frac{gH}{u^2} = 0.283\, tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right] tanh\frac{0.00565\left(\frac{gF}{u^2}\right)^{0.50}}{tanh\left[0.53\left(\frac{gd}{u^2}\right)^{0.75}\right]}$$

$$H = 0.283\, tanh\left[0.53\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.75}\right] tanh\frac{0.00565\left(\frac{9.81 * 13000}{10.5^2}\right)^{0.50}}{tanh\left[0.53\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.75}\right]} * \frac{10.5^2}{9.81}$$

= 0.60 m

Wave period:

$$\frac{gT}{u} = 7.54 \tanh\left[0.833\left(\frac{gd}{u^2}\right)^{0.375}\right] \tanh\frac{0.0379\left(\frac{gF}{u^2}\right)^{0.33}}{\tanh\left[0.833\left(\frac{gd}{u^2}\right)^{0.375}\right]}$$

$$T = 7.54\, tanh\left[0.833\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.375}\right] tanh\frac{0.0379\left(\frac{9.81 * 13000}{10.5}\right)^{0.33}}{tanh\left[0.833\left(\frac{9.81 * 5.97}{10.5^2}\right)^{0.375}\right]} * \frac{10.5}{9.81}$$

= 2.84 sec

8. SUMMARY FINDINGS AND RECOMMENDATIONS

8. SUMMARY FINDINGS AND RECOMMENDATIONS

8.1 Summary Findings

The findings of the study are described as follows:

Selection of Crossing Locations

From Rooppur Powerplant, one transmission line will be crossed over the Ganges River. These single crossing line over the Ganges River named as Rooppur-Gopalganj 400KV Transmission Line, which will start from Rooppur Nuclear Powerplant territory and crosses over Kushtia, Rajbari, Faridpur and ended at Muksupur upzilla of Gopalganj district. The proposed transmission line will be constructed at about 950 m downstream of Hardinge Bridge

In case of the Jamuna River, two transmission line will be crossed. These two crossing lines over the Jamuna River named as “Rooppur Nuclear Power Plant to Dhaka Double Circuit 400kV TL” as Transmission Line 1 and “Rooppur to Dhamrai SS Double Circuit 230kV TL” as Transmission Line 2. Both the transmission lines are started at Rooppur Nuclear Power Plant and ended at Dhamrai upzilla of Dhaka district.

Selection of Design Hydrological Event

Using observed flow data from 1934 to 2019 of the Ganges and 1956-2019 of the Jamuna River, frequency analysis has been carried out, in which 1 in 100 year return period flood event and average flood event have been considered for model simulation. For the Ganges River, the maximum flow of these two events are 79059m^3/s and 51000m^3/s for 100 year and average flood event, respectively. For the Jamuna River, the maximum flow of these two events are 105249m^3/s and 68565m^3/s for 100 year and average flood event, respectively.

Channel/ Bankline Shifting at and around the Crossing Location

There was a significant bankline shifting along both banks of Ganges River during 1976 to 2000, at the location of proposed transmission line. The lateral shifting was about 690m along the right bank and 610m along the left bank. However, in the last two decades there were no bankline shifting along the right bank. For the 6km transmission line parallel to the right bank of the Ganges River, it is clearly seen that the right bank was not always stable. After 1980, there was a massive erosion occurred along that bank. However, this bank is being quite stable after the year 2000.

In Jamuna River, the major bankline is shifted along the left bank at the immediate d/s of EGB. The maximum extent of erosion was about 720m with a rate of 40m/yr. Furthermore, this extent of erosion is found nearly 300m during the period from 2002 to 2020, along the transmission line 2. On the other hand, there was an accretion (maximum extent is about 1km) at the right bank just u/s of Belkuchi.

From model results, it is observed that there is no bank erosion along both the bank of transmission line in Ganges and Jamuna River. However, at 10km u/s and from 5km to 10km d/s of Hardinge Bridge, there might be bank erosion occurred along the right bank, if high flood event passed. In case of Jamuna River, there is no bank erosion at the right bank along the crossings. However, about 10m of erosion might be happened at the left bank of the Jamuna River along the crossing lines.

Hydraulic Design Parameters

For the Proposed Transmission Line on the Ganges River

Design Discharge	: 79059 m^3/s (model estimated)
Design High Water Level (HFL)	: 15.22 mPWD, 14.76 MSL (model estimated)
Standard High Water Level	: 14.87 mPWD, 14.41 MSL
Minimum Water Level	: 4.20 mPWD, 3.74 MSL (observed data using slope analysis)
Maximum average velocity	: 4.22 m/s (2D model estimated)
Minimum Bed Level	: -0.97mPWD, -1.43 MSL (surveyed)
General Scour	: 27.18 m (model estimated)
Constriction Scour	: 3.28 m (model estimated)
Local Scour	: 28.46 m
Total Scour	: 58.92 m
Scour Level	: -59.89 mPWD, -60.35 MSL
Minimum Vertical Navigation Clearance	: 5 m (according to BIWTA Guideline)
Minimum Horizontal Navigation Clearance	: 20 m (according to BIWTA Guideline)
Angle of attack, Θ	: 18.43˚
Mean Diameter, d_{50}	: 0.15 mm
Type of river bed material	: fine sand
Max depth of flow	:16.19 m
Max span length or max distance between tower	:557.2 m

For the Proposed Transmission Line 1 on the Jamuna River

Design Discharge	: 102436 m^3/s (model estimated)
Design High Water Level (HFL)	: 14.00 mPWD, 13.54 MSL (model estimated)
Standard High Water Level	: 14.083 mPWD, 13.623 MSL
Minimum Water Level	: 5.292 mPWD, 4.83 MSL (observed data using slope analysis)
Maximum average velocity	: 2.90 m/s (2D model estimated)
Minimum Bed Level	: -34.37mPWD, -34.83 MSL (surveyed)
General Scour	: 0 m (model estimated)
Constriction Scour	: 6.95 m (model estimated)
Local Scour	: 39.52 m
Total Scour	: 46.47 m
Scour Level	: -80.84 mPWD, -81.3 MSL
Minimum Vertical Navigation Clearance	: 7.62 m (according to BIWTA Guideline)
Minimum Horizontal Navigation Clearance	: 30.48 m (according to BIWTA Guideline)
Angle of attack, Θ	: 25.5˚
Mean Diameter, d_{50}	: 0.18 mm
Type of river bed material	: fine sand
Max depth of flow	: 48.37 m
Max span length or max distance between tower	: 848 m

For the Proposed Transmission Line 2 on the Jamuna River

Design Discharge	: 102436 m^3/s (model estimated)
Design High Water Level (HFL)	: 13.89 mPWD, 13.43 MSL (model estimated)
Standard High Water Level	: 14.048 mPWD, 13.588 MSL
Minimum Water Level	: 5.256 mPWD, 4.79 MSL (observed data using slope analysis)
Maximum average velocity	: 3.25 m/s (2D model estimated)

Minimum Bed Level	: -17.44 mPWD, -17.9 MSL (surveyed)
General Scour	: 17.88 m (model estimated)
Constriction Scour	: 5.17 m (model estimated)
Local Scour	: 38.85 m
Total Scour	: 61.9 m
Scour Level	: -79.34 mPWD, -79.8 MSL
Minimum Vertical Navigation Clearance	: 7.62 m (according to BIWTA Guideline)
Minimum Horizontal Navigation Clearance	: 30.48 m (according to BIWTA Guideline)
Angle of attack, Θ	: 52.64˚
Mean Diameter, d_{50}	: 0.18 mm
Type of river bed material	: fine sand
Max depth of flow	: 31.33 m
Max span length or max distance between tower	: 874 m

8.2 Recommendations

The following recommendations have been made based on the study results:

- As Ganges or Jamuna River are so dynamic in nature, the thalweg of the rivers may shift from one bank to another. So, every tower/ pier should be designed considering the maximum scour.
- Monitoring of hydro-morphological conditions of the river at upstream, downstream and along the crossings are suggested to arrest any unaccountable situation after construction of the crossings.
- To save the foundation cost at right bank of Ganges River, the 6km of transmission line (Rooppur-Gopalganj) parallel to the river can be shifted about 200m towards the country side (by observing the bank erosion from the long term simulation).

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9. REFERENCES

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APPENDIX-A: COMPUTATION OF LOCALSCOURS AND TYPICAL TRANSMISSION TOWER FOUNDATION LAYOUT

A.1 Computation of Local Scour for Transmission Line on the Ganges River

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

FHWA Method

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	15.27 m
Equv. Pier width, a_{pier} =	16 m
Number of pier, n=	8 nos
Length of Equv. pier, L=	16 m
Mean velocity of flow directly upstream of pier, V_1=	4.22 m/s
Angle of attack of the flow, Θ=	18.43 degree
Height of the pile cap above bed at beginning of computation, h_0 =	0 m
Acceleration due to gravity, g =	9.81 m/s^2
Thickness of pile cap, T=	9.5 m
Centre to centre spacing of piles, S=	15.012 m
Pile cap width, a_{pc} =	12 m
Distance between front edge of pile cap or footing and pier, f=	1 m

Pier Stem Component Computation

Height of the pier stem sbove the bed before scour, h_1=h_0+T	9.5 m
f/a_{pier} =	0.06
h_1/a_{pier} =	0.59
Coefficent of account for the height of the pier stem above the bed and the shielding effect by the pile cap overhang distance "f" in front of the pier stem $K_{h\ pier}$ =(.4075-.0669 f/a_{pier})-(.4271-.0778f/a_{pier})h_1/a_{pier}+(.1615-.0455f/a_{pier})$(h_1/a_{pier})^2$-(.0269-.012 f/a_{pier})$(h_1/a_{pier})^3$	0.203
Corrction factor for pier nose shape , K_1 =	1.00
Corrction factor for angle of attack , K_2= $(\cos\theta + L/a \sin\theta)^{.65}$	1.17
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed size , K_4=	1.00
a_{pier}/y_1	1.05
Froude number, $F_1 = V_1/(gy_1)^{.05}$	0.34

$$\frac{y_{spier}}{y_1} = K_{hpier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{V_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{spier}

y_{spier} = y_1 * K_{hpier} [2.0 $K_1.K_2.K_3.K_4$ *($\frac{a_{pier}}{y_1}$)$^{0.65}$ {$\frac{V_1}{(gy_1)^{0.5}}$}$^{0.43}$] 5.18 m

Design Data for pile cap

Pile cap width, a_{pc} =	12 m
Length of pile cap, L_{pc} =	12 m
Thickness of pile cap, T=	9.5 m

Pier cap Component Computation

$h_2=h_0+y_{spier}/2$	2.59 m
$y_2=y_1+y_{spier}/2$	17.86 m
$V_2=V_1(y_1/y_2)$	3.61 m/s^2
If, y_2 =3.5*a_{pc}>y_2 calculated than use y_2 calculated y_2 =3.5*a_{pc}=	42.00 m
so use y_2 =	17.86
h_2/y_2 =	0.15
T/y_2 =	0.53
a* pc /a_{pc} = exp{-2.705+0.51*Ln(T/y_2)-2.783(h_2/y_2)^3+1.751/exp(h_2/y_2)}	0.22
a* pc	2.62
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2= $(\cos\theta+L_{pc}/a_{pc}\sin\theta)^{0.65}$	1.17
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed materials size , K_4 =	1.00
If y_2 /a* pc >0.8,then Kw=1. y_2/a* pc=32.72, so use correction factor, Kw=	1.00
a* pc/y_2=	0.15
Froude number, $F_2 = V_2/(gy_2)^{.05}$	0.27

$$\frac{y_{spc}}{y_2} = 2.0K_1K_2K_3K_w\left(\frac{a^*_{pc}}{y_2}\right)^{0.65}\left(\frac{V_2}{\sqrt{gy_2}}\right)^{0.43}$$

Pile cap scour depth component,

y_{spc} = y_2 * [2.0. K_1.K_2.K_3.K_4 *($\frac{a^*_{pc}}{y_2}$)$^{0.65}$ { $\frac{V_2}{(gy_2)^{0.5}}$ }$^{0.43}$] 7.52 m

Design Data for Pile group

Diameter of pile, a_{pile} =	2.00 m
Number of pile transverse to flow, m=	3.00 nos
Number of pile along to flow n=	3.00 nos
Centre to centre spacing of piles, S=	15.01 m

Pier group Component Computation

Length of pile, L_{pile} =	6.00 m
$h_3=h_0+(y_{spier}+y_{spc})/2$	6.35 m
$y_3=y_1+(y_{spier}+y_{spc})/2$	21.62 m
$V_3=V_1(y_1/y_3)$	2.98 m/s^2
a_{pioj} = number of pile along flow, n x pile dia, a_{pile}	6.00 m
a_{pioj}/a =	3.00
Relative Centre to centre spacing of piles, S/a=	7.51
Coefficent for pile spacing K_{sp}=1-4/3(1-1/(a_{proj}/a))(1-(S/a)$^{-.6}$	0.38
Coefficent for number of aligned rows,Km=0.9+.1*m-.0714(m-1)(2.4-1.1(s/a)+.1(S/a)^2)	1.23
a * pg =K_{sp}*K_m*a_{proj}	2.78 m
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2 = $(\cos\theta + L/a \sin\theta)^{.65}$	1.52
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed material size , K_4 =	1.00
If y_3 max= 3.5xa* pg > y_3 calculated,then use y_3 calculated, other wise, y_3 =3.5*a*pg	9.73 m
So, use y_3 =	9.73 m
h_3/y_3 =	0.65
Pile group height adjustmen0t factor, K_{hpg} =(3.08(h_3/y_3)-5.23(h_3/y_3)^2+5.25(h_3/y_3)3-2.1(h_3/y_3)^4)$^{0.65}$	0.91
a * pg /y_3	0.29
Froude number, $F_3=V_3/(gy_3)^{0.5}$	0.31

$$\frac{Y_{spg}}{y_3} = K_{hpg}\left[2.0K_1K_3\left(\frac{a*_{pg}}{y_3}\right)^{0.65}\left(\frac{V_3}{\sqrt{gy_3}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{hpg} =

$$y_3*K_{hpg}[2.0K_1.K_2.K_3.K_4*(\frac{a*_{pg}}{y_3})^{0.65}\{\frac{V_3}{(gy_3)^{0.5}}\}^{0.43}] \quad 7.83 \text{ m}$$

Total Estimated Scour, $y_{spg}=y_{spir}+y_{spc}+y_{hpg}$ 20.54 m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Laursen's Method

Pier component

Width of equv. pier, b=	16.00 m
Length ofequv. pier, L=	16.00 m
Flow depth directly upstream of pier, y_1 =	15.27 m
Flow depth /Width of pier at stream bed, r= y_1/b	0.95
Angle of attack, θ=	18.43 degrees
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.17
Multiplying factors, s= $1.5\,r^{0.3}$	1.48
Shape cofficent, ks=	1.00
D_{s1} =C.s.b.ks	27.57 m

Pile cap cmponent

Pile cap width, b=	12.00 m
Length of pile cap ,L=	12.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.17
Flow depth /Width of pier, r= y_1/b	1.27
Multiplying factors, s= $1.5\,r^{0.3}$	1.61
Shape cofficent, ks=	1.10
D_{s2} =C.s.b.ks	24.80 m

Pile component

Pile dia, d=	2.00 m
No of pile transverse flow, m =	3.00
Pile width, b=md	6.00 m
No of pile along to flow, n=	3.00 nos
Length, L=nd	6.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.17
Flow depth /Width of pier. r= y_1/b	2.55
Multiplying factors, s= $1.5\,r^{0.3}$	1.99
Shape cofficent, ks=	1.00
D_{s3} =C.s.b.ks	13.88

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	6.69 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2 =	0.00 m
Maximum Depth of Flow (m)	16.19 m
Combined Scour Depth=	27.51 m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Breuser's Method : type-I

Pier Computation

Width of Equv. pier, b=		16.00 m
Length of equv. pier , L=		16.00 m
Angle of flow attack, Θ=		18.43 degree
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17
Flow depth directly upstream of pier, y_1=		15.27 m
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pier, d_{gp1}= 1.4xb		22.40

Pile cap Component

Pile cap width,b=		12.00 m
Length of pile cap , L=		12.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17
Correction factor for pier , K_s=		1.10
f(u/uc)= for (u/uc)>1.00		1.00
Using pile cap, d_{gp2}= 1.4xb		16.80 m

Pile Computation

pile dia, d=		2.00 m
Number of pile tranverse to flow,m=		3.00 nos
Pile width,b=		6.00 m
Number of pile along flow,n=		3.00 nos
Length of pile along , L=		6.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pile , d_{gp3}= 1.4xb		8.40

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1 =	6.69 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2=	0.00 m
Maximum Depth of Flow (m)	16.19 m

Combined Scour Depth = 20.27 m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Breuser's Method : type-II

Pier Computation

Width of equv. pier, b=	16.00	m
Length of equv. pier , L=	16.00	m
Angle of flow attack, Θ=	18.43	degree
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17	m
Flow depth directly upstream of pier, y_1=	15.27	m
Correction factor for pier , K_s=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pier, d_{gp1}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	27.65	

Pile cap Component

Pile cap width,b=	12.00	m
Length of pile cap , L=	12.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17	
Correction factor for pier , K_s=	1.10	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile cap, d_{gp2}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	26.28	m

Pile Computation

pile dia, d=	2.00	m
Number of pile tranverse to flow,m=	3.00	nos
Pile width,b=	6.00	m
Number of pile along flow,n=	3.00	nos
Length of pile along , L=	6.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17	
Correction factor for pier , K_s=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile , d_{gp3}=f(u/uc)*2*tanh(y_1/b)*$K_\Theta K_s$ *b	13.81	

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1

Height of pier obstructed by current, h_1=	6.69	m
Height of pile cap obstructed by current, T=	9.50	m
Height of pile obstructed by current, h_2=	0.00	m
Maximum Depth of Flow (m)	16.19	m
Combined Scour Depth =	28.46	m

Location Ganges River Transmission Line Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Rechardson's Method :

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	15.27	m
Equv. Pier width, a =	16	m
Number of pier, n=	8	nos
Length of Equv. pier, L=	16	m
Mean velocity of flow directly upstream of pier, V_1=	4.22	m/s
Angle of attack of the flow, Θ=	18.43	degree
Acceleration due to gravity, g =	9.81	m/s^2

Corrction factor for pier nose shape , =	1.00	
Corrction factor for angle of attack , = $(\cos\theta + \mathrm{L/a}\sin\theta)^{.65}$	1.17	
Corrction factor for bed condition, K_3 =	1.00	
Corrction factor for armouring of bed size , K_4=	1.00	
$\frac{a}{y_1}$	1.05	
Froude number, $Fr = V_1/(gy_1)^{.05}$	0.34	

Pier stem scour depth component,

y_a = $[2.0 * y_1 K_1.K_2.K_3.K_4 * (\frac{a}{y_1})^{0.65} \{ F_r \}^{0.43}]$ 23.20 m

Local Scour Computation TL-1 Ganges River

IRC 78 Method

Design Discharge	Dd		79059	m³/s
Min. Water Ways	Mww		14444	m
	D_b=	Dd/Mww	5.473484	m³/s/m
	K_{sl}=	$1.76\sqrt{d_m}$	0.699586	
	d_m	= Fine Sand	0.158	
Mean Scour Deoth =	d_m=1.34*$(\frac{D_b^2}{K_{sl}})^{.33}$		4.62979	m
Max. Depth of Scour is 2 times of	d_m=		9.259581	m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

FHWA Method

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	15.27 m
Equv. Pier width, a_{pier} =	24 m
Number of pier, n=	8 nos
Length of Equv. pier, L=	24 m
Mean velocity of flow directly upstream of pier, V_1=	4.22 m/s
Angle of attack of the flow, Θ=	18.43 degree
Height of the pile cap above bed at beginning of computation, h_0 =	0 m
Acceleration due to gravity, g =	9.81 m/s^2
Thickness of pile cap, T=	9.5 m
Centre to centre spacing of piles, S=	15.012 m
Pile cap width, a_{pc} =	15 m
Distance between front edge of pile cap or footing and pier, f=	1 m

Pier Stem Component Computation

Height of the pier stem sbove the bed before scour, h_1=h_0+T	9.5 m
f/a_{pier} =	0.04
h_1/a_{pier} =	0.40
Coefficent of account for the height of the pier stem above the bed and the shielding effect by the pile cap overhang distance "f" in front of the pier stem $K_{h\ pier}$ =(.4075-.0669 f/a_{pier})-(.4271-.0778f/a_{pier})h_1/a_{pier}+(.1615-.0455f/a_{pier})$(h_1/a_{pier})^2$-(.0269-.012 f/a_{pier})$(h_1/a_{pier})^3$	0.260
Corrction factor for pier nose shape , K_1 =	1.00
Corrction factor for angle of attack , K_2= $\boxed{(\cos\theta + L/a \sin\theta)^{.65}}$	1.17
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed size , K_4=	1.00
a_{pier}/y_1	1.57
Froude number, $\boxed{F_1 = V_1/(gy_1)^{.05}}$	0.34

$$\frac{y_{spier}}{y_1} = K_{hpier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{V_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{spier}

$$y_{spier} = y_1 * K_{hpier}\ [2.0\ K_1.K_2.K_3.K_4 *(\frac{a_{pier}}{y_1}\ )^{0.65}\ \{\frac{V_1}{(gy_1)^{0.5}}\ \}^{0.43}]$$ 8.65 m

Design Data for pile cap

Pile cap width, a_{pc} =	15 m
Length of pile cap, L_{pc} =	15 m
Thickness of pile cap, T=	9.5 m

Pier cap Component Computation

$h_2=h_0+y_{spier}/2$	4.32 m
$y_2=y_1+y_{spier}/2$	19.59 m
$V_2=V_1(y_1/y_2)$	3.29 m/s^2
If, y_2 =3.5*a_{pc}>y_2 calculated than use y_2 calculated y_2 =3.5*a_{pc}=	52.50 m
so use y_2 =	19.59
h_2/y_2 =	0.22
T/y_2 =	0.48
a* pc /a_{pc} = exp{-2.705+0.51*Ln(T/y_2)-2.783(h_2/y_2)^3+1.751/exp(h_2/y_2)}	0.18
a* pc	2.74
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2= $(\cos\theta+L_{pc}/a_{pc}\sin\theta)^{0.65}$	1.17
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed materials size , K_4 =	1.00
If y_2 /a* pc >0.8,then Kw=1. y_2/a* pc=32.72, so use correction factor, Kw=	1.00
a* pc/y_2=	0.14
Froude number, $F_2 = V_2/(gy_2)^{.05}$	0.24

$$\frac{y_{spc}}{y_2} = 2.0K_1K_2K_3K_w\left(\frac{a^*_{pc}}{y_2}\right)^{0.65}\left(\frac{V_2}{\sqrt{gy_2}}\right)^{0.43}$$

Pile cap scour depth component,

y_{spc} = y_2 * [2.0. K_1.K_2.K_3.K_4 *($\frac{a^*_{pc}}{y_2}$)$^{0.65}$ { $\frac{V_2}{(gy_2)^{0.5}}$ }$^{0.43}$] 7.53 m

Design Data for Pile group

Diameter of pile, a_{pile} =	3.00 m
Number of pile transverse to flow, m=	3.00 nos
Number of pile along to flow n=	3.00 nos
Centre to centre spacing of piles, S=	15.01 m

Pier group Component Computation

Length of pile, L_{pile} =	9.00 m
$h_3=h_0+(y_{spier}+y_{spc})/2$	8.09 m
$y_3=y_1+(y_{spier}+y_{spc})/2$	23.36 m
$V_3=V_1(y_1/y_3)$	2.76 m/s^2
a_{pioj} = number of pile along flow, n x pile dia, a_{pile}	9.00 m
a_{pioj}/a =	3.00
Relative Centre to centre spacing of piles, S/a=	5.00
Coefficent for pile spacing K_{sp}=1-4/3(1-1/(a_{proj}/a))(1-(S/a)$^{-.6}$	0.45
Coefficent for number of aligned rows,Km=0.9+.1*m-.0714(m-1)(2.4-1.1(s/a)+.1(S/a)^2)	1.29
a * $_{pg}$ =K_{sp}*K_m*a_{proj}	5.20 m
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,$K_2=(\cos\theta + L/a \sin\theta)^{.65}$	1.52
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed material size , K_4 =	1.00
If y_3 max= 3.5xa* $_{pg}$ > y_3 calculated,then use y_3 calculated, other wise, y_3 =3.5*a*$_{pg}$	18.20 m
So, use y_3 =	18.20 m
h_3/y_3 =	0.44
Pile group height adjustmen0t factor, K_{hpg} =(3.08(h_3/y_3)-5.23(h_3/y_3)^2+5.25(h_3/y_3)3-2.1(h_3/y_3)^4)$^{0.65}$	0.80
a * pg /y_3	0.29
Froude number, $F_3=V_3/(gy_3)^{0.5}$	0.21

$$\frac{Y_{spg}}{y_3} = K_{hpg}\left[2.0K_1K_3\left(\frac{a^*_{pg}}{y_3}\right)^{0.65}\left(\frac{V_3}{\sqrt{gy_3}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{hpg} =

$$y_3*K_{hpg}[2.0K_1.K_2.K_3.K_4*(\frac{a*pg}{y_3})^{0.65}\{\frac{V_3}{(gy_3)^{0.5}}\}^{0.43}]$$ 10.97 m

Total Estimated Scour, $y_{spg}=y_{spir}+y_{spc}+y_{hpg}$ 27.15 m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Laursen's Method

Pier component

Width of equv. pier, b=	24.00 m
Length ofequv. pier, L=	24.00 m
Flow depth directly upstream of pier, y_1 =	15.27 m
Flow depth /Width of pier at stream bed, r= y_1/b	0.64
Angle of attack, θ=	18.43 degrees
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.17
Multiplying factors, s= $1.5\,r^{0.3}$	1.31
Shape cofficent, ks=	1.00
D_{s1} =C.s.b.ks	36.62 m

Pile cap cmponent

Pile cap width, b=	15.00 m
Length of pile cap ,L=	15.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.17
Flow depth /Width of pier, r= y_1/b	1.02
Multiplying factors, s= $1.5\,r^{0.3}$	1.51
Shape cofficent, ks=	1.10
D_{s2} =C.s.b.ks	28.99 m

Pile component

Pile dia, d=	3.00 m
No of pile transverse flow, m =	3.00
Pile width, b=md	9.00 m
No of pile along to flow, n=	3.00 nos
Length, L=nd	9.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.17
Flow depth /Width of pier. r= y_1/b	1.70
Multiplying factors, s= $1.5\,r^{0.3}$	1.76
Shape cofficent, ks=	1.00
D_{s3} =C.s.b.ks	18.43

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	6.69 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2 =	0.00 m
Maximum Depth of Flow (m)	16.19 m
Combined Scour Depth=	34.08 m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur

(Type-02 Pile dia 3m, Total 8 pile @15.012m c/c)

Breuser's Method : type-I

Pier Computation

Width of Equv. pier, b=		24.00 m
Length of equv. pier , L=		24.00 m
Angle of flow attack, Θ=		18.43 degree
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17
Flow depth directly upstream of pier, y_1=		15.27 m
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pier, d_{gp1}= 1.4xb		33.60

Pile cap Component

Pile cap width,b=		15.00 m
Length of pile cap , L=		15.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17
Correction factor for pier , K_s=		1.10
f(u/uc)= for (u/uc)>1.00		1.00
Using pile cap, d_{gp2}= 1.4xb		21.00 m

Pile Computation

pile dia, d=		3.00 m
Number of pile tranverse to flow,m=		3.00 nos
Pile width,b=		9.00 m
Number of pile along flow,n=		3.00 nos
Length of pile along , L=		9.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pile , d_{gp3}= 1.4xb		12.60

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	6.69 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2=	0.00 m
Maximum Depth of Flow (m)	16.19 m
Combined Scour Depth =	27.79 m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Breuser's Method : type-II

Pier Computation

Width of equv. pier, b=	24.00	m
Length of equv. pier , L=	24.00	m
Angle of flow attack, Θ=	18.43	degree
Correction factor for angle of attack, KΘ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17	m
Flow depth directly upstream of pier, y_1=	15.27	m
Correction factor for pier ,Ks=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pier,d_{gp1}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	31.45	

Pile cap Component

Pile cap width,b=	15.00	m
Length of pile cap , L=	15.00	m
Correction factor for angle of attack, KΘ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17	
Correction factor for pier ,Ks=	1.10	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile cap,d_{gp2}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	29.57	m

Pile Computation

pile dia, d=	3.00	m
Number of pile tranverse to flow,m=	3.00	nos
Pile width,b=	9.00	m
Number of pile along flow,n=	3.00	nos
Length of pile along , L=	9.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.17	
Correction factor for pier ,Ks=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile ,d_{gp3}=f(u/uc)*2*tanh(y_1/b)*$K_\Theta K_s$ *b	19.61	

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1

Height of pier obstructed by current, h_1=	6.69	m
Height of pile cap obstructed by current, T=	9.50	m
Height of pile obstructed by current, h_2=	0.00	m
Maximum Depth of Flow (m)	16.19	m
Combined Scour Depth =	32.17	m

Computation of Local Scour at Foundation Pier

Location Ganges River Transmission Line Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Rechardson's Method :

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	15.27	m
Equv. Pier width, a =	24	m
Number of pier, n=	8	nos
Length of Equv. pier, L=	24	m
Mean velocity of flow directly upstream of pier, V_1=	4.22	m/s
Angle of attack of the flow, Θ=	18.43	degree
Acceleration due to gravity, g =	9.81	m/s^2

Corrction factor for pier nose shape , =	1.00	
Corrction factor for angle of attack , = $(\cos\theta + \mathrm{L/a}\sin\theta)^{.65}$	1.17	
Corrction factor for bed condition, K_3 =	1.00	
Corrction factor for armouring of bed size , K_4=	1.00	
$\frac{a}{y_1}$	1.57	
Froude number, $Fr = V_1/(gy_1)^{.05}$	0.34	

Pier stem scour depth component,

y_a = $[2.0 * y_1 K_1.K_2.K_3.K_4 * (\frac{a}{y_1})^{0.65} \{ F_r \}^{0.43}]$ 30.20 m

Local Scour Computation TL-1 Ganges River

IRC 78 Method

Design Discharge	Dd		79059	m³/s
Min. Water Ways	Mww		14444	m
	D_b=	Dd/Mww	5.473484	m³/s/m
	K_{sl}=	$1.76\sqrt{d_m}$	0.699586	
	d_m	= Fine Sand	0.158	

Mean Scour Deoth = d_m=$1.34*(\frac{D_b^2}{K_{sl}})^{.33}$ 4.62979 m

Max. Depth of Scour is 2 times of d_m= 9.259581 m

A.2 Computation of Local Scour for Transmission Line-1 on the Jamuna River

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-01 Pile dia 2m, Total 8 pile @15.012m c/c)

FHWA Method

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	48.62 m
Equv. Pier width, a_{pier} =	16 m
Number of pier, n=	8 nos
Length of Equv. pier, L=	16 m
Mean velocity of flow directly upstream of pier, V_1=	2.9 m/s
Angle of attack of the flow, Θ=	25.5 degree
Height of the pile cap above bed at beginning of computation, h_0 =	0 m
Acceleration due to gravity, g =	9.81 m/s^2
Thickness of pile cap, T=	9.5 m
Centre to centre spacing of piles, S=	15.012 m
Pile cap width, a_{pc} =	12 m
Distance between front edge of pile cap or footing and pier, f=	1 m

Pier Stem Component Computation

Height of the pier stem sbove the bed before scour, h_1=h_0+T	9.5 m
f/a_{pier} =	0.06
h_1/a_{pier} =	0.59
Coefficent of account for the height of the pier stem above the bed and the shielding effect by the pile cap overhang distance "f" in front of the pier stem $K_{h\ pier}$ =(.4075-.0669 f/a_{pier})-(.4271-.0778f/a_{pier})h_1/a_{pier}+(.1615-.0455f/a_{pier})$(h_1/a_{pier})^2$-(.0269-.012 f/a_{pier})$(h_1/a_{pier})^3$	0.203
Corrction factor for pier nose shape , K_1 =	1.00
Corrction factor for angle of attack , K_2= $(\cos\theta + \mathrm{L/a}\sin\theta)^{.65}$	1.21
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed size , K_4=	1.00
a_{pier}/y_1	0.33
Froude number, $F_1 = V_1/(gy_1)^{.05}$	0.13

$$\frac{y_{spier}}{y_1} = K_{hpier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{V_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{spier}

y_{spier} = y_1 * K_{hpier} [2.0 $K_1.K_2.K_3.K_4$ *($\frac{a_{pier}}{y_1}$)$^{0.65}$ {$\frac{V_1}{(gy_1)^{0.5}}$ }$^{0.43}$] 5.34 m

Pier cap Component Computation

$h_2=h_0+y_{spier}/2$	2.67 m
$y_2=y_1+y_{spier}/2$	51.29 m
$V_2=V_1(y_1/y_2)$	2.75 m/s^2
If, y_2 =3.5*a_{pc}>y_2 calculated than use y_2 calculated y_2 =3.5*a_{pc}=	42.00 m
so use y_2 =	42.00
h_2/y_2 =	0.06
T/y_2 =	0.23
a* pc /a_{pc} = exp{-2.705+0.51*Ln(T/y_2)-2.783(h_2/y_2)^3+1.751/exp(h_2/y_2)}	0.16
a* pc	1.94
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2= $(\cos\theta+L_{pc}/a_{pc}\sin\theta)^{0.65}$	1.21
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed materials size , K_4 =	1.00
If y_2 /a* pc >0.8,then Kw=1. y_2/a* pc=32.72, so use correction factor, Kw=	1.00
a* pc/y_2=	0.05
Froude number, $F_2 = V_2/(gy_2)^{.05}$	0.12

$$\frac{y_{spc}}{y_2} = 2.0K_1K_2K_3K_w\left(\frac{a^*_{pc}}{y_2}\right)^{0.65}\left(\frac{V_2}{\sqrt{gy_2}}\right)^{0.43}$$

Pile cap scour depth component,

y_{spc} = y_2 * [2.0. K_1.K_2.K_3.K_4 *($\frac{a^*_{pc}}{y_2}$)$^{0.65}$ { $\frac{V_2}{(gy_2)^{0.5}}$ }$^{0.43}$] 6.40 m

Design Data for Pile group

Diameter of pile, a_{pile} =	2.00 m
Number of pile transverse to flow, m=	3.00 nos
Number of pile along to flow n=	3.00 nos
Centre to centre spacing of piles, S=	15.01 m

Pier group Component Computation

Length of pile, L_{pile} =	6.00 m
$h_3=h_0+(y_{spier}+y_{spc})/2$	5.87 m
$y_3=y_1+(y_{spier}+y_{spc})/2$	54.49 m
$V_3=V_1(y_1/y_3)$	2.59 m/s^2
a_{pioj} = number of pile along flow, n x pile dia, a_{pile}	6.00 m
a_{pioj}/a =	3.00
Relative Centre to centre spacing of piles, S/a=	7.51
Coefficent for pile spacing K_{sp}=1-4/3(1-1/(a_{proj}/a))(1-(S/a)$^{-.6}$	0.38
Coefficent for number of aligned rows,Km=0.9+.1*m-.0714(m-1)(2.4-1.1(s/a)+.1(S/a)^2)	1.23
a * $_{pg}$ =K_{sp}*K_m*a_{proj}	2.78 m
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2 = $(\cos\theta + L/a \sin\theta)^{.65}$	1.67
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed material size , K_4 =	1.00
If y_3 max= 3.5xa* $_{pg}$ > y_3 calculated,then use y_3 calculated, other wise, y_3 =3.5*a*$_{pg}$	9.73 m
So, use y_3 =	9.73 m
h_3/y_3 =	0.60
Pile group height adjustmen0t factor, K_{hpg} =(3.08(h_3/y_3)-5.23(h_3/y_3)^2+5.25(h_3/y_3)3-2.1(h_3/y_3)^4)$^{0.65}$	0.89
a * pg /y_3	0.29
Froude number, F_3=V_3/(gy_3)$^{0.5}$	0.26

$$\frac{Y_{spg}}{y_3} = K_{hpg}\left[2.0K_1K_3\left(\frac{a^*_{pg}}{y_3}\right)^{0.65}\left(\frac{V_3}{\sqrt{gy_3}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{hpg} =

$$y_3 * K_{hpg}[2.0K_1.K_2.K_3.K_4*(\frac{a*pg}{y_3})^{0.65}\{\frac{V_3}{(gy_3)^{0.5}}\}^{0.43}]$$ 7.90 m

Total Estimated Scour, y_{spg}=y_{spir}+y_{spc}+y_{hpg} 19.64 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Laursen's Method

Pier component

Width of equv. pier, b=	16.00 m
Length ofequv. pier, L=	16.00 m
Flow depth directly upstream of pier, y_1 =	48.37 m
Flow depth /Width of pier at stream bed, r= y_1/b	3.02
Angle of attack, θ=	25.50 degrees
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.21
Multiplying factors, s= $1.5\,r^{0.3}$	2.09
Shape cofficent, ks=	1.00
D_{s1} =C.s.b.ks	40.32 m

Pile cap cmponent

Pile cap width, b=	12.00 m
Length of pile cap ,L=	12.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.21
Flow depth /Width of pier, r= y_1/b	4.03
Multiplying factors, s= $1.5\,r^{0.3}$	2.28
Shape cofficent, ks=	1.10
D_{s2} =C.s.b.ks	36.26 m

Pile component

Pile dia, d=	2.00 m
No of pile transverse flow, m =	3.00
Pile width, b=md	6.00 m
No of pile along to flow, n=	3.00 nos
Length, L=nd	6.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.21
Flow depth /Width of pier, r=y_1/b	8.06
Multiplying factors, s= $1.5\,r^{0.3}$	2.81
Shape cofficent, ks=	1.00
D_{s3} =C.s.b.ks	20.29

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	38.87 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2 =	0.00 m
Maximum Depth of Flow (m)	48.37 m
Combined Scour Depth=	39.52 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Breuser's Method : type-I

Pier Computation

Width of Equv. pier, b=		16.00 m
Length of equv. pier , L=		16.00 m
Angle of flow attack, Θ=		25.50 degree
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21
Flow depth directly upstream of pier, y_1=		48.37 m
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pier, d_{gp1}= 1.4xb		22.40

Pile cap Component

Pile cap width,b=		12.00 m
Length of pile cap , L=		12.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21
Correction factor for pier , K_s=		1.10
f(u/uc)= for (u/uc)>1.00		1.00
Using pile cap, d_{gp2}= 1.4xb		16.80 m

Pile Computation

pile dia, d=		2.00 m
Number of pile tranverse to flow,m=		3.00 nos
Pile width,b=		6.00 m
Number of pile along flow,n=		3.00 nos
Length of pile along , L=		6.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pile , d_{gp3}= 1.4xb		8.40

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1

Height of pier obstructed by current, h_1 =	38.87 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2=	0.00 m
Maximum Depth of Flow (m)	48.37 m

Combined Scour Depth = 21.30 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Breuser's Method : type-II

Pier Computation

Width of equv. pier, b=	16.00	m
Length of equv. pier , L=	16.00	m
Angle of flow attack, Θ=	25.50	degree
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21	m
Flow depth directly upstream of pier, y_1=	48.37	m
Correction factor for pier , K_s=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pier, d_{gp1}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	38.39	

Pile cap Component

Pile cap width,b=	12.00	m
Length of pile cap , L=	12.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21	
Correction factor for pier , K_s=	1.10	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile cap, d_{gp2}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	31.80	m

Pile Computation

pile dia, d=	2.00	m
Number of pile tranverse to flow,m=	3.00	nos
Pile width,b=	6.00	m
Number of pile along flow,n=	3.00	nos
Length of pile along , L=	6.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21	
Correction factor for pier , K_s=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile , d_{gp3}=f(u/uc)*2*tanh(y_1/b)*$K_\Theta K_s$ *b	14.47	

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1

Height of pier obstructed by current, h_1=	38.87	m
Height of pile cap obstructed by current, T=	9.50	m
Height of pile obstructed by current, h_2=	0.00	m
Maximum Depth of Flow (m)	48.37	m
Combined Scour Depth =	37.10	m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Rechardson's Method :

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	48.37	m
Equv. Pier width, a =	16	m
Number of pier, n=	8	nos
Length of Equv. pier, L=	16	m
Mean velocity of flow directly upstream of pier, V_1=	2.9	m/s
Angle of attack of the flow, Θ=	25.5	degree
Acceleration due to gravity, g =	9.81	m/s^2

Corrction factor for pier nose shape , =		1.00
Corrction factor for angle of attack , =	$(\cos\theta + \mathrm{L/a}\sin\theta)^{.65}$	1.21
Corrction factor for bed condition, K_3 =		1.00
Corrction factor for armouring of bed size , K_4=		1.00
$\frac{a}{y_1}$		0.33
Froude number,	$Fr = V_1/(gy_1)^{.05}$	0.13

Pier stem scour depth component,

y_a = $[2.0 * y_1 K_1 . K_2 . K_3 . K_4 * (\frac{a}{y_1})^{0.65} \{ F_r \}^{0.43}]$ 23.87 m

Local Scour Computation TL-1 Jamuna River

IRC 78 Method

Design Discharge	Dd		102436	m³/s
Min. Water Ways	Mww		6446	m
	D_b=	Dd/Mww	15.89141	m³/s/m
	K_{sl}=	$1.76\sqrt{d_m}$	0.699586	
	d_m	= Fine Sand	0.158	
Mean Scour Depth =	d_m=1.34*$(\frac{D_b^2}{K_{sl}})^{.33}$		9.355658	m
Max. Depth of Scour is 2.times of	d_m=		18.71132	m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

FHWA Method

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	48.37	m
Equv. Pier width, a_{pier} =	24	m
Number of pier, n=	8	nos
Length of Equv. pier, L=	24	m
Mean velocity of flow directly upstream of pier, V_1=	2.9	m/s
Angle of attack of the flow, Θ=	25.5	degree
Height of the pile cap above bed at beginning of computation, h_0 =	0	m
Acceleration due to gravity, g =	9.81	m/s^2
Thickness of pile cap, T=	9.5	m
Centre to centre spacing of piles, S=	15.012	m
Pile cap width, a_{pc} =	15	m
Distance between front edge of pile cap or footing and pier, f=	1	m

Pier Stem Component Computation

Height of the pier stem sbove the bed before scour, h_1=h_0+T	9.5	m
f/a_{pier} =	0.04	
h_1/a_{pier} =	0.40	
Coefficent of account for the height of the pier stem above the bed and the shielding effect by the pile cap overhang distance "f" in front of the pier stem $K_{h\ pier}$ =(.4075-.0669 f/a_{pier})-(.4271-.0778f/a_{pier})h_1/a_{pier}+(.1615-.0455f/a_{pier})$(h_1/a_{pier})^2$-(.0269-.012 f/a_{pier})$(h_1/a_{pier})^3$	0.260	
Corrction factor for pier nose shape , K_1 =	1.00	
Corrction factor for angle of attack , K_2= $(\cos\theta + L/a \sin\theta)^{.65}$	1.21	
Corrction factor for bed condition, K_3 =	1.10	
Corrction factor for armouring of bed size , K_4=	1.00	
a_{pier}/y_1	0.50	
Froude number, $F_1 = V_1/(gy_1)^{.05}$	0.13	

$$\frac{y_{spier}}{y_1} = K_{hpier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{V_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{spier}

y_{spier} = y_1 * K_{hpier} [2.0 $K_1.K_2.K_3.K_4$ *($\frac{a_{pier}}{y_1}$)$^{0.65}$ {$\frac{V_1}{(gy_1)^{0.5}}$}$^{0.43}$] 8.90 m

Design Data for pile cap

Pile cap width, a_{pc} =	15 m
Length of pile cap, L_{pc} =	15 m
Thickness of pile cap, T=	9.5 m

Pier cap Component Computation

$h_2=h_0+y_{spier}/2$	4.45 m
$y_2=y_1+y_{spier}/2$	52.82 m
$V_2=V_1(y_1/y_2)$	2.66 m/s^2
If, y_2 =3.5*a_{pc}>y_2 calculated than use y_2 calculated y_2 =3.5*a_{pc}=	52.50 m
so use y_2 =	52.50
h_2/y_2 =	0.08
T/y_2 =	0.18
a* pc /a_{pc} = exp{-2.705+0.51*Ln(T/y_2)-2.783(h_2/y_2)^3+1.751/exp(h_2/y_2)}	0.14
a* pc	2.09
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2= $(\cos\theta+L_{pc}/a_{pc}\sin\theta)^{0.65}$	1.21
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed materials size , K_4 =	1.00
If y_2 /a* pc >0.8,then Kw=1. y_2/a* pc=32.72, so use correction factor, Kw=	1.00
a* pc/y_2=	0.04
Froude number, $F_2 = V_2/(gy_2)^{.05}$	0.12

$$\frac{y_{spc}}{y_2} = 2.0K_1K_2K_3K_w\left(\frac{a^*_{pc}}{y_2}\right)^{0.65}\left(\frac{V_2}{\sqrt{gy_2}}\right)^{0.43}$$

Pile cap scour depth component,

y_{spc} = y_2 * [2.0. K_1.K_2.K_3.K_4 *($\frac{a^*pc}{y_2}$)$^{0.65}$ { $\frac{V_2}{(gy_2)^{0.5}}$ }$^{0.43}$] 6.81 m

Design Data for Pile group

Diameter of pile, a_{pile} =	3.00 m
Number of pile transverse to flow, m=	3.00 nos
Number of pile along to flow n=	3.00 nos
Centre to centre spacing of piles, S=	15.01 m

Pier group Component Computation

Length of pile, L_{pile} =	9.00 m
$h_3=h_0+(y_{spier}+y_{spc})/2$	7.86 m
$y_3=y_1+(y_{spier}+y_{spc})/2$	56.23 m
$V_3=V_1(y_1/y_3)$	2.49 m/s^2
a_{pioj} = number of pile along flow, n x pile dia, a_{pile}	9.00 m
a_{pioj}/a =	3.00
Relative Centre to centre spacing of piles, S/a=	5.00
Coefficent for pile spacing K_{sp}=1-4/3(1-1/(a_{proj}/a))(1-(S/a)$^{-.6}$	0.45
Coefficent for number of aligned rows,Km=0.9+.1*m-.0714(m-1)(2.4-1.1(s/a)+.1(S/a)^2)	1.29
a * $_{pg}$ =K_{sp}*K_m*a_{proj}	5.20 m
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2 = $(\cos\theta + L/a \sin\theta)^{.65}$	1.67
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed material size , K_4 =	1.00
If y_3 max= 3.5xa* $_{pg}$ > y_3 calculated,then use y_3 calculated, other wise, y_3 =3.5*a*$_{pg}$	18.20 m
So, use y_3 =	18.20 m
h_3/y_3 =	0.43
Pile group height adjustmen0t factor, K_{hpg} =(3.08(h_3/y_3)-5.23(h_3/y_3)^2+5.25(h_3/y_3)3-2.1(h_3/y_3)^4)$^{0.65}$	0.80
a * pg /y_3	0.29
Froude number, F_3=V_3/(gy_3)$^{0.5}$	0.19

$$\frac{Y_{spg}}{y_3} = K_{hpg}\left[2.0K_1K_3\left(\frac{a^*_{pg}}{y_3}\right)^{0.65}\left(\frac{V_3}{\sqrt{gy_3}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{hpg} =

$$y_3 * K_{hpg}[2.0K_1.K_2.K_3.K_4*(\frac{a*pg}{y_3})^{0.65}\{\frac{V_3}{(gy_3)^{0.5}}\}^{0.43}] \quad 11.44 \text{ m}$$

Total Estimated Scour, y_{spg}=y_{spir}+y_{spc}+y_{hpg} 27.15 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Laursen's Method

Pier component

Width of equv. pier, b=	24.00 m
Length ofequv. pier, L=	24.00 m
Flow depth directly upstream of pier, y_1 =	48.37 m
Flow depth /Width of pier at stream bed, r= y_1/b	2.02
Angle of attack, θ=	25.50 degrees
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.21
Multiplying factors, s= $1.5\,r^{0.3}$	1.85
Shape cofficent, ks=	1.00
D_{s1} =C.s.b.ks	53.55 m

Pile cap cmponent

Pile cap width, b=	15.00 m
Length of pile cap ,L=	15.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.21
Flow depth /Width of pier, r= y_1/b	3.22
Multiplying factors, s= $1.5\,r^{0.3}$	2.13
Shape cofficent, ks=	1.10
D_{s2} =C.s.b.ks	42.39 m

Pile component

Pile dia, d=	3.00 m
No of pile transverse flow, m =	3.00
Pile width, b=md	9.00 m
No of pile along to flow, n=	3.00 nos
Length, L=nd	9.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.21
Flow depth /Width of pier, r= y_1/b	5.37
Multiplying factors, s= $1.5\,r^{0.3}$	2.48
Shape cofficent, ks=	1.00
D_{s3} =C.s.b.ks	26.95

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	38.87 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2 =	0.00 m
Maximum Depth of Flow (m)	48.37 m
Combined Scour Depth=	51.36 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Breuser's Method : type-I

Pier Computation

Width of Equv. pier, b=		24.00 m
Length of equv. pier , L=		24.00 m
Angle of flow attack, Θ=		25.50 degree
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21
Flow depth directly upstream of pier, y_1=		48.37 m
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pier, d_{gp1}= 1.4xb		33.60

Pile cap Component

Pile cap width,b=		15.00 m
Length of pile cap , L=		15.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21
Correction factor for pier , K_s=		1.10
f(u/uc)= for (u/uc)>1.00		1.00
Using pile cap, d_{gp2}= 1.4xb		21.00 m

Pile Computation

pile dia, d=		3.00 m
Number of pile tranverse to flow,m=		3.00 nos
Pile width,b=		9.00 m
Number of pile along flow,n=		3.00 nos
Length of pile along , L=		9.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pile , d_{gp3}= 1.4xb		12.60

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	38.87 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2=	0.00 m
Maximum Depth of Flow (m)	48.37 m
Combined Scour Depth =	31.13 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Breuser's Method : type-II

Pier Computation

Width of equv. pier, b=	24.00	m
Length of equv. pier , L=	24.00	m
Angle of flow attack, Θ=	25.50	degree
Correction factor for angle of attack, KΘ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21	m
Flow depth directly upstream of pier, y_1=	48.37	m
Correction factor for pier ,Ks=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pier,d_{gp1}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	55.84	

Pile cap Component

Pile cap width,b=	15.00	m
Length of pile cap , L=	15.00	m
Correction factor for angle of attack, KΘ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21	
Correction factor for pier ,Ks=	1.10	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile cap,d_{gp2}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	39.66	m

Pile Computation

pile dia, d=	3.00	m
Number of pile tranverse to flow,m=	3.00	nos
Pile width,b=	9.00	m
Number of pile along flow,n=	3.00	nos
Length of pile along , L=	9.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.21	
Correction factor for pier ,Ks=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile ,d_{gp3}=f(u/uc)*2*tanh(y_1/b)*$K_\Theta K_s$ *b	21.70	

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1

Height of pier obstructed by current, h_1=	38.87	m
Height of pile cap obstructed by current, T=	9.50	m
Height of pile obstructed by current, h_2=	0.00	m
Maximum Depth of Flow (m)	48.37	m
Combined Scour Depth =	52.66	m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-1 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Rechardson's Method :

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	48.37	m
Equv. Pier width, a =	24	m
Number of pier, n=	8	nos
Length of Equv. pier, L=	24	m
Mean velocity of flow directly upstream of pier, V_1=	2.9	m/s
Angle of attack of the flow, Θ=	25.5	degree
Acceleration due to gravity, g =	9.81	m/s^2

Corrction factor for pier nose shape , =		1.00
Corrction factor for angle of attack , =	$(\cos\theta + L/a \sin\theta)^{.65}$	1.21
Corrction factor for bed condition, K_3 =		1.00
Corrction factor for armouring of bed size , K_4=		1.00
$\frac{a}{y_1}$		0.50
Froude number,	$Fr = V_1/(gy_1)^{.05}$	0.13

Pier stem scour depth component,

y_a = $[2.0 * y_1 K_1.K_2.K_3.K_4 * (\frac{a}{y_1})^{0.65} \{ F_r \}^{0.43}]$ 31.07 m

Local Scour Computation TL-1 Jamuna River

IRC 78 Method

Design Discharge	Dd		102436	m³/s
Min. Water Ways	Mww		6446	m
	D_b=	Dd/Mww	15.89141	m³/s/m
	K_{sl}=	$1.76\sqrt{d_m}$	0.699586	
	d_m	= Fine Sand	0.158	
Mean Scour Depth =	d_m=1.34*$(\frac{D_b^2}{K_{sl}})^{.33}$		9.355658	m
Max. Depth of Scour is 2.times of	d_m=		18.71132	m

A.3 Computation of Local Scour for Transmission Line-2 on the Jamuna River

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

FHWA Method

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	29.17 m
Equv. Pier width, a_{pier} =	16 m
Number of pier, n=	8 nos
Length of Equv. pier, L=	16 m
Mean velocity of flow directly upstream of pier, V_1=	3.25 m/s
Angle of attack of the flow, Θ=	52.64 degree
Height of the pile cap above bed at beginning of computation, h_0 =	0 m
Acceleration due to gravity, g =	9.81 m/s^2
Thickness of pile cap, T=	9.5 m
Centre to centre spacing of piles, S=	15.012 m
Pile cap width, a_{pc} =	12 m
Distance between front edge of pile cap or footing and pier, f=	1 m

Pier Stem Component Computation

Height of the pier stem sbove the bed before scour, h_1=h_0+T	9.5 m
f/a_{pier} =	0.06
h_1/a_{pier} =	0.59
Coefficent of account for the height of the pier stem above the bed and the shielding effect by the pile cap overhang distance "f" in front of the pier stem $K_{h\ pier}$ =(.4075-.0669 f/a_{pier})-(.4271-.0778f/a_{pier})h_1/a_{pier}+(.1615-.0455f/a_{pier})$(h_1/a_{pier})^2$-(.0269-.012 f/a_{pier})$(h_1/a_{pier})^3$	0.203
Corrction factor for pier nose shape , K_1 =	1.00
Corrction factor for angle of attack , K_2= $(\cos\theta + \mathrm{L/a}\sin\theta)^{.65}$	1.25
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed size , K_4=	1.00
a_{pier}/y_1	0.55
Froude number, $F_1 = V_1/(gy_1)^{.05}$	0.19

$$\frac{y_{spier}}{y_1} = K_{hpier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{V_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{spier}

y_{spier} = y_1 * K_{hpier} [2.0 $K_1.K_2.K_3.K_4$ *($\frac{a_{pier}}{y_1}$)$^{0.65}$ {$\frac{V_1}{(gy_1)^{0.5}}$ }$^{0.43}$] 5.40 m

Design Data for pile cap

Pile cap width, a_{pc} =	12 m
Length of pile cap, L_{pc} =	12 m
Thickness of pile cap, T=	9.5 m

Pier cap Component Computation

$h_2=h_0+y_{spier}/2$	2.70 m
$y_2=y_1+y_{spier}/2$	31.87 m
$V_2=V_1(y_1/y_2)$	2.97 m/s^2
If, y_2 =3.5*a_{pc}>y_2 calculated than use y_2 calculated y_2 =3.5*a_{pc}=	42.00 m
so use y_2 =	31.87
h_2/y_2 =	0.08
T/y_2 =	0.30
a* pc /a_{pc} = exp{-2.705+0.51*Ln(T/y_2)-2.783(h_2/y_2)^3+1.751/exp(h_2/y_2)}	0.18
a* pc	2.16
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2= $(\cos\theta+L_{pc}/a_{pc}\sin\theta)^{0.65}$	1.25
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed materials size , K_4 =	1.00
If y_2 /a* pc >0.8,then Kw=1. y_2/a* pc=32.72, so use correction factor, Kw=	1.00
a* pc/y_2=	0.07
Froude number, $F_2 = V_2/(gy_2)^{.05}$	0.17

$$\frac{y_{spc}}{y_2} = 2.0K_1K_2K_3K_w\left(\frac{a^*_{pc}}{y_2}\right)^{0.65}\left(\frac{V_2}{\sqrt{gy_2}}\right)^{0.43}$$

Pile cap scour depth component,

y_{spc} = y_2 * [2.0. K_1.K_2.K_3.K_4 *($\frac{a^*_{pc}}{y_2}$)$^{0.65}$ { $\frac{V_2}{(gy_2)^{0.5}}$ }$^{0.43}$] 7.05 m

Design Data for Pile group

Diameter of pile, a_{pile} =	2.00 m
Number of pile transverse to flow, m=	3.00 nos
Number of pile along to flow n=	3.00 nos
Centre to centre spacing of piles, S=	15.01 m

Pier group Component Computation

Length of pile, L_{pile} =	6.00 m
$h_3=h_0+(y_{spier}+y_{spc})/2$	6.23 m
$y_3=y_1+(y_{spier}+y_{spc})/2$	35.40 m
$V_3=V_1(y_1/y_3)$	2.68 m/s^2
a_{pioj} = number of pile along flow, n x pile dia, a_{pile}	6.00 m
a_{pioj}/a =	3.00
Relative Centre to centre spacing of piles, S/a=	7.51
Coefficent for pile spacing K_{sp}=1-4/3(1-1/(a_{proj}/a))(1-(S/a)$^{-.6}$	0.38
Coefficent for number of aligned rows,Km=0.9+.1*m-.0714(m-1)(2.4-1.1(s/a)+.1(S/a)^2)	1.23
a * $_{pg}$ =K_{sp}*K_m*a_{proj}	2.78 m
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2 = $(\cos\theta + L/a \sin\theta)^{.65}$	2.04
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed material size , K_4 =	1.00
If y_3 max= 3.5xa* $_{pg}$ > y_3 calculated,then use y_3 calculated, other wise, y_3 =3.5*a*$_{pg}$	9.73 m
So, use y_3 =	9.73 m
h_3/y_3 =	0.64
Pile group height adjustmen0t factor, K_{hpg} =(3.08(h_3/y_3)-5.23(h_3/y_3)^2+5.25(h_3/y_3)3-2.1(h_3/y_3)^4)$^{0.65}$	0.90
a * pg /y_3	0.29
Froude number, F_3=V_3/(gy_3)$^{0.5}$	0.27

$$\frac{Y_{spg}}{y_3} = K_{hpg}\left[2.0K_1K_3\left(\frac{a^*_{pg}}{y_3}\right)^{0.65}\left(\frac{V_3}{\sqrt{gy_3}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{hpg} =

$y_3*K_{hpg}[2.0K_1.K_2.K_3.K_4*(\frac{a*pg}{y_3})^{0.65}\{\frac{V_3}{(gy_3)^{0.5}}\}^{0.43}]$ 9.99 m

Total Estimated Scour, y_{spg}=y_{spir}+y_{spc}+y_{hpg} 22.45 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Laursen's Method

Pier component

Width of equv. pier, b=	16.00 m
Length ofequv. pier, L=	16.00 m
Flow depth directly upstream of pier, y_1 =	29.17 m
Flow depth /Width of pier at stream bed, r= y_1/b	1.82
Angle of attack, θ=	52.64 degrees
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.25
Multiplying factors, s= $1.5\,r^{0.3}$	1.80
Shape cofficent, ks=	1.00
D_{s1} =C.s.b.ks	35.79 m

Pile cap cmponent

Pile cap width, b=	12.00 m
Length of pile cap ,L=	12.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.25
Flow depth /Width of pier, r= y_1/b	2.43
Multiplying factors, s= $1.5\,r^{0.3}$	1.96
Shape cofficent, ks=	1.10
D_{s2} =C.s.b.ks	32.19 m

Pile component

Pile dia, d=	2.00 m
No of pile transverse flow, m =	3.00
Pile width, b=md	6.00 m
No of pile along to flow, n=	3.00 nos
Length, L=nd	6.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.25
Flow depth /Width of pier, r=y_1/b	4.86
Multiplying factors, s= $1.5\,r^{0.3}$	2.41
Shape cofficent, ks=	1.00
D_{s3} =C.s.b.ks	18.01

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	21.83 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2 =	0.00 m
Maximum Depth of Flow (m)	31.33 m
Combined Scour Depth=	37.27 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Breuser's Method : type-I

Pier Computation

Width of Equv. pier, b=		16.00 m
Length of equv. pier , L=		16.00 m
Angle of flow attack, Θ=		52.64 degree
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25
Flow depth directly upstream of pier, y_1=		29.17 m
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pier, d_{gp1}= 1.4xb		22.40

Pile cap Component

Pile cap width,b=		12.00 m
Length of pile cap , L=		12.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25
Correction factor for pier , K_s=		1.10
f(u/uc)= for (u/uc)>1.00		1.00
Using pile cap, d_{gp2}= 1.4xb		16.80 m

Pile Computation

pile dia, d=		2.00 m
Number of pile tranverse to flow,m=		3.00 nos
Pile width,b=		6.00 m
Number of pile along flow,n=		3.00 nos
Length of pile along , L=		6.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pile , d_{gp3}= 1.4xb		8.40

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	21.83 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2=	0.00 m
Maximum Depth of Flow (m)	31.33 m

Combined Scour Depth = 22.23 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Breuser's Method : type-II

Pier Computation

Width of equv. pier, b=	16.00	m
Length of equv. pier , L=	16.00	m
Angle of flow attack, Θ=	52.64	degree
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25	m
Flow depth directly upstream of pier, y_1=	29.17	m
Correction factor for pier , K_s=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pier, d_{gp1}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	37.83	

Pile cap Component

Pile cap width,b=	12.00	m
Length of pile cap , L=	12.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25	
Correction factor for pier , K_s=	1.10	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile cap, d_{gp2}=f(u/uc)*2*tanh(y1/b)*KΘKs*b	32.37	m

Pile Computation

pile dia, d=	2.00	m
Number of pile tranverse to flow,m=	3.00	nos
Pile width,b=	6.00	m
Number of pile along flow,n=	3.00	nos
Length of pile along , L=	6.00	m
Correction factor for angle of attack, K_Θ= $(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25	
Correction factor for pier , K_s=	1.00	
f(u/uc)= for (u/uc)>1.00	1.00	
Using pile , d_{gp3}=f(u/uc)*2*tanh(y_1/b)*$K_\Theta K_s$ *b	14.94	

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1

Height of pier obstructed by current, h_1=	21.83	m
Height of pile cap obstructed by current, T=	9.50	m
Height of pile obstructed by current, h_2=	0.00	m
Maximum Depth of Flow (m)	31.33	m
Combined Scour Depth =	38.85	m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-1 Pile dia 2m, Total 8 pile @15.012m c/c)

Rechardson's Method :

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	29.17	m
Equv. Pier width, a =	16	m
Number of pier, n=	8	nos
Length of Equv. pier, L=	16	m
Mean velocity of flow directly upstream of pier, V_1=	3.25	m/s
Angle of attack of the flow, Θ=	52.64	degree
Acceleration due to gravity, g =	9.81	m/s^2

Corrction factor for pier nose shape , =		1.00
Corrction factor for angle of attack , =	$(\cos\theta + L/a \sin\theta)^{.65}$	1.25
Corrction factor for bed condition, K_3 =		1.00
Corrction factor for armouring of bed size , K_4=		1.00
$\frac{a}{y_1}$		0.55
Froude number,	$Fr = V_1/(gy_1)^{.05}$	0.19

Pier stem scour depth component,

y_a = $[2.0 * y_1 {}^{K_1.K_2.K_3.K_4} * (\frac{a}{y_1})^{0.65} \{ F_r \}^{0.43}]$ 24.19 m

Local Scour Computation TL-2 Jamuna River

IRC 78 Method

Design Discharge	Dd		102436	m³/s
Min. Water Ways	Mww		6504	m
	D_b=	Dd/Mww	15.74969	m³/s/m
	K_{sl}=	$1.76\sqrt{d_m}$	0.699586	
	d_m	= Fine Sand	0.158	
Mean Scour Depth =	d_m=1.34*$(\frac{D_b{}^2}{K_{sl}})^{.33}$		9.30051	m
Max. Depth of Scour is 2 times of	d_m=		18.60102	m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

FHWA Method

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	29.17 m
Equv. Pier width, a_{pier} =	24 m
Number of pier, n=	8 nos
Length of Equv. pier, L=	24 m
Mean velocity of flow directly upstream of pier, V_1=	3.25 m/s
Angle of attack of the flow, Θ=	52.64 degree
Height of the pile cap above bed at beginning of computation, h_0 =	0 m
Acceleration due to gravity, g =	9.81 m/s^2
Thickness of pile cap, T=	9.5 m
Centre to centre spacing of piles, S=	15.012 m
Pile cap width, a_{pc} =	15 m
Distance between front edge of pile cap or footing and pier, f=	1 m

Pier Stem Component Computation

Height of the pier stem sbove the bed before scour, h_1=h_0+T	9.5 m
f/a_{pier} =	0.04
h_1/a_{pier} =	0.40
Coefficent of account for the height of the pier stem above the bed and the shielding effect by the pile cap overhang distance "f" in front of the pier stem $K_{h\ pier}$ =(.4075-.0669 f/a_{pier})-(.4271-.0778f/a_{pier})h_1/a_{pier}+(.1615-.0455f/a_{pier})$(h_1/a_{pier})^2$-(.0269-.012 f/a_{pier})$(h_1/a_{pier})^3$	0.260
Corrction factor for pier nose shape , K_1 =	1.00
Corrction factor for angle of attack , K_2= $(\cos\theta + L/a \sin\theta)^{.65}$	1.25
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed size , K_4=	1.00
a_{pier}/y_1	0.82
Froude number, $F_1 = V_1/(gy_1)^{.05}$	0.19

$$\frac{y_{spier}}{y_1} = K_{hpier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{V_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{spier}

y_{spier} = y_1 * K_{hpier} [2.0 $K_1.K_2.K_3.K_4$ *($\frac{a_{pier}}{y_1}$)$^{0.65}$ {$\frac{V_1}{(gy_1)^{0.5}}$}$^{0.43}$] 9.02 m

Design Data for pile cap

Pile cap width, a_{pc} =	15 m
Length of pile cap, L_{pc} =	15 m
Thickness of pile cap, T=	9.5 m

Pier cap Component Computation

$h_2=h_0+y_{spier}/2$	4.51 m
$y_2=y_1+y_{spier}/2$	33.68 m
$V_2=V_1(y_1/y_2)$	2.81 m/s^2
If, y_2 =3.5*a_{pc}>y_2 calculated than use y_2 calculated y_2 =3.5*a_{pc}=	52.50 m
so use y_2 =	33.68
h_2/y_2 =	0.13
T/y_2 =	0.28
a* pc /a_{pc} = exp{-2.705+0.51*Ln(T/y_2)-2.783(h_2/y_2)^3+1.751/exp(h_2/y_2)}	0.16
a* pc	2.42
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2= $(\cos\theta+L_{pc}/a_{pc}\sin\theta)^{0.65}$	1.25
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed materials size , K_4 =	1.00
If y_2 /a* pc >0.8,then Kw=1. y_2/a* pc=32.72, so use correction factor, Kw=	1.00
a* pc/y_2=	0.07
Froude number, $F_2 = V_2/(gy_2)^{.05}$	0.15

$$\frac{y_{spc}}{y_2} = 2.0K_1K_2K_3K_w\left(\frac{a^*_{pc}}{y_2}\right)^{0.65}\left(\frac{V_2}{\sqrt{gy_2}}\right)^{0.43}$$

Pile cap scour depth component,

y_{spc} = y_2 * [2.0. K_1.K_2.K_3.K_4 *($\frac{a^*pc}{y_2}$)$^{0.65}$ { $\frac{V_2}{(gy_2)^{0.5}}$ }$^{0.43}$] 7.47 m

Design Data for Pile group

Diameter of pile, a_{pile} =	3.00 m
Number of pile transverse to flow, m=	3.00 nos
Number of pile along to flow n=	3.00 nos
Centre to centre spacing of piles, S=	15.01 m

Pier group Component Computation

Length of pile, L_{pile} =	9.00 m
$h_3=h_0+(y_{spier}+y_{spc})/2$	8.24 m
$y_3=y_1+(y_{spier}+y_{spc})/2$	37.41 m
$V_3=V_1(y_1/y_3)$	2.53 m/s^2
a_{pioj} = number of pile along flow, n x pile dia, a_{pile}	9.00 m
a_{pioj}/a =	3.00
Relative Centre to centre spacing of piles, S/a=	5.00
Coefficent for pile spacing K_{sp}=1-4/3(1-1/(a_{proj}/a))(1-(S/a)$^{-.6}$	0.45
Coefficent for number of aligned rows,Km=0.9+.1*m-.0714(m-1)(2.4-1.1(s/a)+.1(S/a)^2)	1.29
a * $_{pg}$ =K_{sp}*K_m*a_{proj}	5.20 m
Corrction factor for pier nose shape ,K_1 =	1.00
Corrction factor for angle of attack ,K_2 = $(\cos\theta + L/a \sin\theta)^{.65}$	2.04
Corrction factor for bed condition, K_3 =	1.10
Corrction factor for armouring of bed material size , K_4 =	1.00
If y_3 max= 3.5xa* $_{pg}$ > y_3 calculated,then use y_3 calculated, other wise, y_3 =3.5*a*$_{pg}$	18.20 m
So, use y_3 =	18.20 m
h_3/y_3 =	0.45
Pile group height adjustmen0t factor, K_{hpg} =(3.08(h_3/y_3)-5.23(h_3/y_3)^2+5.25(h_3/y_3)3-2.1(h_3/y_3)^4)$^{0.65}$	0.81
a * pg /y_3	0.29
Froude number, F_3=V_3/(gy_3)$^{0.5}$	0.19

$$\frac{Y_{spg}}{y_3} = K_{hpg}\left[2.0K_1K_3\left(\frac{a^*_{pg}}{y_3}\right)^{0.65}\left(\frac{V_3}{\sqrt{gy_3}}\right)^{0.43}\right]$$

Pier stem scour depth component, y_{hpg} =

$$y_3 * K_{hpg}[2.0K_1.K_2.K_3.K_4*(\frac{a*pg}{y_3})^{0.65}\{\frac{V_3}{(gy_3)^{0.5}}\}^{0.43}] \quad 14.31 \text{ m}$$

Total Estimated Scour, y_{spg}=y_{spir}+y_{spc}+y_{hpg} 30.79 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Laursen's Method

Pier component

Width of equv. pier, b=	24.00 m
Length ofequv. pier, L=	24.00 m
Flow depth directly upstream of pier, y_1 =	29.17 m
Flow depth /Width of pier at stream bed, r= y_1/b	1.22
Angle of attack, θ=	52.64 degrees
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.25
Multiplying factors, s= $1.5\,r^{0.3}$	1.59
Shape cofficent, ks=	1.00
D_{s1} =C.s.b.ks	47.54 m

Pile cap cmponent

Pile cap width, b=	15.00 m
Length of pile cap ,L=	15.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.25
Flow depth /Width of pier, r= y_1/b	1.94
Multiplying factors, s= $1.5\,r^{0.3}$	1.83
Shape cofficent, ks=	1.10
D_{s2} =C.s.b.ks	37.63 m

Pile component

Pile dia, d=	3.00 m
No of pile transverse flow, m =	3.00
Pile width, b=md	9.00 m
No of pile along to flow, n=	3.00 nos
Length, L=nd	9.00 m
correction factor for angle of attack,C=($(\cos\theta + L/b\sin\theta)^{.65}$	1.25
Flow depth /Width of pier, r= y_1/b	3.24
Multiplying factors, s= $1.5\,r^{0.3}$	2.13
Shape cofficent, ks=	1.00
D_{s3} =C.s.b.ks	23.93

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	21.83 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2 =	0.00 m
Maximum Depth of Flow (m)	31.33 m
Combined Scour Depth=	47.83 m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Breuser's Method : type-I

Pier Computation

Width of Equv. pier, b=		24.00 m
Length of equv. pier , L=		24.00 m
Angle of flow attack, Θ=		52.64 degree
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25
Flow depth directly upstream of pier, y_1=		29.17 m
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pier, d_{gp1}= 1.4xb		33.60

Pile cap Component

Pile cap width,b=		15.00 m
Length of pile cap , L=		15.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25
Correction factor for pier , K_s=		1.10
f(u/uc)= for (u/uc)>1.00		1.00
Using pile cap, d_{gp2}= 1.4xb		21.00 m

Pile Computation

pile dia, d=		3.00 m
Number of pile tranverse to flow,m=		3.00 nos
Pile width,b=		9.00 m
Number of pile along flow,n=		3.00 nos
Length of pile along , L=		9.00 m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25
Correction factor for pier , K_s=		1.00
f(u/uc)= for (u/uc)>1.00		1.00
Using pile , d_{gp3}= 1.4xb		12.60

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

$D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1$

Height of pier obstructed by current, h_1=	21.83 m
Height of pile cap obstructed by current, T=	9.50 m
Height of pile obstructed by current, h_2=	0.00 m
Maximum Depth of Flow (m)	31.33 m

Combined Scour Depth = 31.98 m

Location Jamuna River Transmission Line-2 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Breuser's Method : type-II

Pier Computation

Width of equv. pier, b=		24.00	m
Length of equv. pier , L=		24.00	m
Angle of flow attack, Θ=		52.64	degree
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25	m
Flow depth directly upstream of pier, y_1=		29.17	m
Correction factor for pier ,K_s=		1.00	
f(u/uc)= for (u/uc)>1.00		1.00	
Using pier,d_{gp1}=f(u/uc)*2*tanh(y1/b)*KΘKs*b		50.11	

Pile cap Component

Pile cap width,b=		15.00	m
Length of pile cap , L=		15.00	m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25	
Correction factor for pier ,K_s=		1.10	
f(u/uc)= for (u/uc)>1.00		1.00	
Using pile cap,d_{gp2}=f(u/uc)*2*tanh(y1/b)*KΘKs*b		39.45	m

Pile Computation

pile dia, d=		3.00	m
Number of pile tranverse to flow,m=		3.00	nos
Pile width,b=		9.00	m
Number of pile along flow,n=		3.00	nos
Length of pile along , L=		9.00	m
Correction factor for angle of attack, K_{Θ}=	$(\cos\theta + L/b * \sin\theta)^{0.65}$	1.25	
Correction factor for pier ,K_s=		1.00	
f(u/uc)= for (u/uc)>1.00		1.00	
Using pile ,d_{gp3}=f(u/uc)*2*tanh(y_1/b)*$K_{\Theta}K_s$ *b		22.35	

Considering combinded Effect of depth of flow obstructing the pier, pile cap & pile:

D_s=(D_{s1}*h_1)/y_1+(D_{s2}*T)/y_1+(D_{s3}*h_2)/y_1

Height of pier obstructed by current, h_1=		21.83	m
Height of pile cap obstructed by current, T=		9.50	m
Height of pile obstructed by current, h_2=		0.00	m
Maximum Depth of Flow (m)		31.33	m
Combined Scour Depth =		50.35	m

Computation of Local Scour at Foundation Pier

Location Jamuna River Transmission Line-2 Rooppur (Type-2 Pile dia 3m, Total 8 pile @15.012m c/c)

Rechardson's Method :

Design Data for Pier stem

Flow depth directly upstream of pier, y_1=	29.17	m
Equv. Pier width, a =	24	m
Number of pier, n=	8	nos
Length of Equv. pier, L=	24	m
Mean velocity of flow directly upstream of pier, V_1=	3.25	m/s
Angle of attack of the flow, Θ=	52.64	degree
Acceleration due to gravity, g =	9.81	m/s^2

Corrction factor for pier nose shape , =	1.00	
Corrction factor for angle of attack , = $(\cos\theta + \mathrm{L/a}\sin\theta)^{.65}$	1.25	
Corrction factor for bed condition, K_3 =	1.00	
Corrction factor for armouring of bed size , K_4=	1.00	
$\frac{a}{y_1}$	0.82	
Froude number, $Fr = V_1/(gy_1)^{.05}$	0.19	

Pier stem scour depth component,

y_a = $[2.0 * y_1 K_1 . K_2 . K_3 . K_4 * (\frac{a}{y_1})^{0.65} \{ F_r \}^{0.43}]$ 31.49 m

Local Scour Computation TL-2 Jamuna River

IRC 78 Method

Design Discharge	Dd		102436	m³/s
Min. Water Ways	Mww		6504	m
	D_b=	Dd/Mww	15.74969	m³/s/m
	K_{sl}=	$1.76\sqrt{d_m}$	0.699586	
	d_m	= Fine Sand	0.158	
Mean Scour Depth =	d_m=1.34*$(\frac{D_b^2}{K_{sl}})^{.33}$		9.30051	m
Max. Depth of Scour is 2 times of	d_m=		18.60102	m

A.4 Typical Transmission Tower Foundation Layout

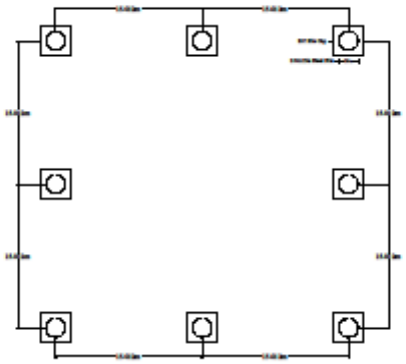


Figure-1
PILE LAYOUT PLAN
(BELOW TOP PLATFORM)

Type-1: Total 8 Nos. of Piles,
Each @ 2m Dia Tubular Steel Piles
Tower Top Platform is 450mm above HFL
RC Pile Cap Size 4mx4m. Hight 9.95m

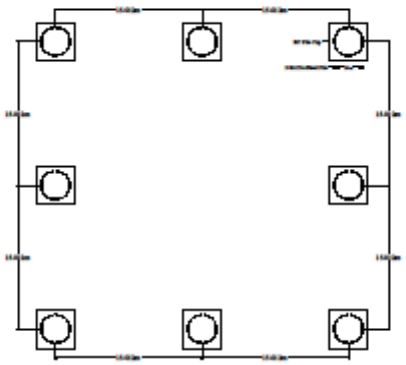


Figure-2
PILE LAYOUT PLAN
(BELOW TOP PLATFORM)

Type-2: Total 8 Nos. of Piles,
Each @ 3m Dia Tubular Steel Piles
Tower Top Platform is 450mm above HFL
RC Pile Cap Size 5mx5m. Hight 9.95m

Ref: Schematic drawings and opinions as provided by POCB

APPENDIX-B: TERMS OF REFERENCES (ToR)

Annexure-2

Section 6. Terms of Reference (TOR) (Revised)

Morphological Study of Different River Crossing (Padma River for one line and Jamuna River for two lines) for Infrastructure Development for Power Evacuation facilities of Roopur Nuclear Power Plant

6.1 OBJECTIVES OF THE STUDY

- Geological information of the area including geomorphology, geological structure, etc.
- Observations and data regarding historical channel and bank line movement/shifting for the river/ change of course of river
- Maximum design discharge, maximum velocity, scour depths, slit factor, etc., and history of flood details for mid-stream and river bank locations.
- One transmission line River Crossing at Padma
- Two Transmission line River Crossing at Jamuna

6.2 SCOPE OF THE STUDY

There is one river crossing of transmission line over the Padma river and two river crossings of transmission lines over the Jamuna river. In addition, there is about 6 kilometers of transmission line running parallel and close to the Padma river just after the crossing point. The scopes of study will be but not limited to the followings:

- Study area should cover at least 2(two) kilometers in upstream and 2 (two) kilometers in downstream stream from the proposed transmission line and portion of proposed transmission line running parallel to river.
- Collection and processing of historical data & maps, satellite images, hydrological data (water level, discharge), including the Highest Flood Level (HFL) of the rivers (within the study area) for at least past 20 years.
- Prediction about possible future development/shifting of the rivers within the study area (forecast for at least 50 years).
- Assessment of erosion-accretion over time and sedimentation processes of the rivers.
- Analysis and Identification of riverbank erosion vulnerable areas.
- Bathymetric survey shall be covered at least 0.5 kilometers in upstream and 0.5 kilometers in downstream stream from the proposed transmission line.
- Maximum design discharge, maximum water velocity, particle size of river bed, silt factor, width of rivers at crossing locations, depth of river bed, Highest & lowest water level at tower locations, Nature of river flow (perineal or non-perineal) and seasonal variations of the river (Discharge, Velocity, depth and width).
- Reduced Level (RL) of existing ground, highest water level and maximum scour depth for every finally proposed tower location shall be mentioned with respect to Mean Sea Level (MSL).
- Maximum scour depth shall be calculated: i) mathematically, following IRC: 78-2014 or updated guideline at each finally proposed tower location and ii) by modeling, following any standards and/or any

code & practices.

- Ship impact loads should be provided.
- Necessary input data required to calculate velocity attack and wave attack on the structures.
- Chemical analysis of water samples (Sulphate content, Calcium Content, Chloride content, Total Dissolved solids in water).
- Past observations and historical data, if available, for the area or for near other areas with soil profile, or with similar structures in the surrounding areas.
- Effect of river crossing transmission lines on nearby existing structures in the rivers.

Based on the study and analysis, Consultant should suggest any required shifting of the proposed line or part thereof or any tower location/locations to find a best possible suitable route and tower location for the river crossing section of the transmission line. In such case, the route proposed by the Consultant will be used for Construction of the river crossing portion of the transmission lines. Any other data/force (not mentioned here) which are necessary for river crossing tower foundation design (except sub-soil investigation) of transmission lines, shall be provided by the consultant.

6.3 Study Methodology

A sample methodology not mandatory for consultant is provided in this article. Consultant may propose his own methodology for carrying out the objectives.

6.3.1 Secondary data review

In order to get insight into the problem as well as understanding of the study areas and issues, an attempt would be made to review the available secondary documents. It included review of the project's documents and documents relating context and area profile. For the purpose of this review, following documents should be collected:

- Project documents e.g. proposal, logical framework analysis and other documents;
- Documents on socio economic features of study areas e.g. demography, settlement pattern and types, livelihood options, basic services, social protection, disaster awareness and practice, disaster situation and trend, disaster vulnerability, disaster coping, utilization of water resources, impact and consequences of water resource management etc.;
- Policy and planning documents
- Geographic information of study areas e.g. geographic location, physiographic features etc.;
- Secondary documents provided general overview on context and area, project activities, outputs and outcomes; also helped to formulate an appropriate questionnaire and check lists for primary data collection from the field.

6.3.2 Maps Collection and Processing:

Standard maps exhibiting administrative boundaries, geomorphic units would be collected from open source platforms. A land use and land cover map should be constructed using available satellite imagery through various GIS platforms.

6.3.3 Riverbank Erosion-Accretion Calculation:

The historical platform should be assessed using chronological Landsat imagery, focusing on delineation of bank lines, assessment of bank line shifting and assessment of erosion-accretion ratio in the case of Meghna River. The

analysis may be carried out using remote sensing services e: g: ERDAS Imagine, ENVI and various GIS platforms such as ArcGIS, QGIS etc.

6.3.4 Riverbank Erosion Assessment:

Through a combination of geo-informatics, hydrologic and geotechnical observations, riverbank erosion should be delineated. At the initial stage, remote sensing techniques (supervised and unsupervised classification, geo-rectification and other image processing techniques) should be implemented in the following: identification of crucial areas for navigation, barge capacity analysis for barge movements, projecting future development of river etc. For the subsoil structure and riverbank erosion management the electrical resistivity survey of the riverbank areas should be conducted. The combined approach should result in the outlined riverbank erosion management strategy for the study area.

6.3.5 Data Collection and review of available studies and reports:

At this stage, the information required for the hydrological analysis and design should be collected. The data should include all necessary maps to define the project location/extent and its relation to the existing infrastructure (roads, power lines, etc.). All software and methods to be utilized during the stud/ shall be presented and approved by the Client in advance.

6.3.6 Geological Analysis:

Reviewing available geological maps, previous geological studies, land use maps and satellite images, the characteristics of the land surface cover of the effective watersheds and loss coefficients of different catchments will be defined.

6.3.7 Site Visits:

Site visits shall be carried out for site reconnaissance and to collect all necessary information about site topography, land use, vegetative cover, soil type, hydrological features, etc. The site visit will help deciding actions and recommended priorities. Photographic records should be taken for existing conditions as well as natural obstacles.

6.3.8 Meteorological Analysis:

In order to determine the design storm rainfall values and intensity-duration-frequencies relations, the rainfall data collected from the representative meteorological stations would be statistically analyzed using the recommended statistical methods and models. A frequency analysis should be done to define the design storm for different return periods.

6.3.9 Hydrological Analysis:

Utilizing results obtained in the Meteorological analysis, the peak runoff (design) flow rates should be estimated for the effective catchments at their crossing locations with the borders of the project area. Hydrographs of surface runoff and sediment loads should be determined using rainfall-runoff models. A complete surface and groundwater quantity assessment shall form part of the hydrological analysis.

6.3.10 Catchment Hydraulics:

Utilizing all data/results above analysis the main catchments affecting proposed development sites should be studied for flood preserve. Flow paths will be identified based on topographical information obtained earlier in the study.

6.3.11 Scour Analysis

(in the event of a destructive flow determined with erodible soils):
The consultant should review of readily available existing soil information, historical geologic maps and reports, and previous geotechnical investigations of the proposed site or immediately adjacent areas. Based on the results of this analysis/review the flood flow limits, depths, and velocities the scour values will be estimated around the foundation locations proposed. Erosion effects due to scouring from floodwater and/or surface water drainage flow, especially in areas around array foundations and equipment pads must be estimated.

6.4 GEOTECHNICAL STUDIES

Detail sub-soil investigation work is not required for this study. Consultant should carry out the required field work necessary to calculate silt factor following IRC: 78-2014 or updated guideline at each finally proposed tower location.

6.5 Deliverables (Reports and Documents)

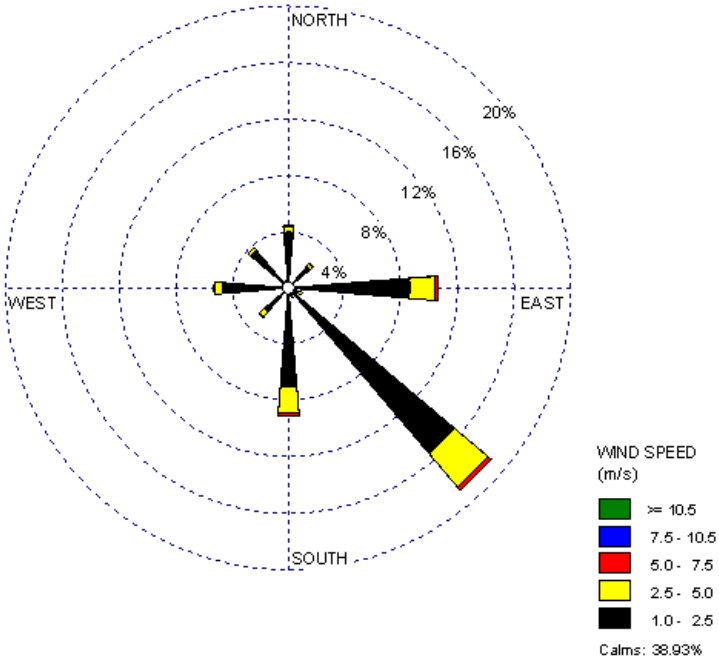
The team leader as a representative of the firm will communicate with and report only to the Employer's representative which is either Project Director or the person assigned by Project Director of the project. The Consultant shall prepare and submit reports and documents to PGCB as shown in Table -1. The Consultant shall also provide electronic copies. Relation between the Consultant, Project Director and Contractor is shown below:

Category	Type of Report	Timing	Contents	Copies
Periodical reporting	Inception Report	Within 7 days after commencement of services	Methodologies, schedule, organization etc.	5
	Monthly Progress Report and Progress Meeting MOM	Every 30 days	All activities / progress of previous month, works in next month	5
	Draft Report	Within 120 days after contract signing	Draft Study Report	5
	Final Report	Within 150 days after contract signing	Review, recast & finalized as per direction & comments of PGCB	5 hard copies along with 3 CDs'
Specific reporting requirements (reports)	Survey, primary & Secondary data Collection, Measurement & Analysis, Historical Data collection, several Modeling etc.	Within 100 days after contract signing	As required	5
Others	Technical Reports	As required	As required	
	Presentation	As required	As required	
	Report with recommendation	As required	As required	

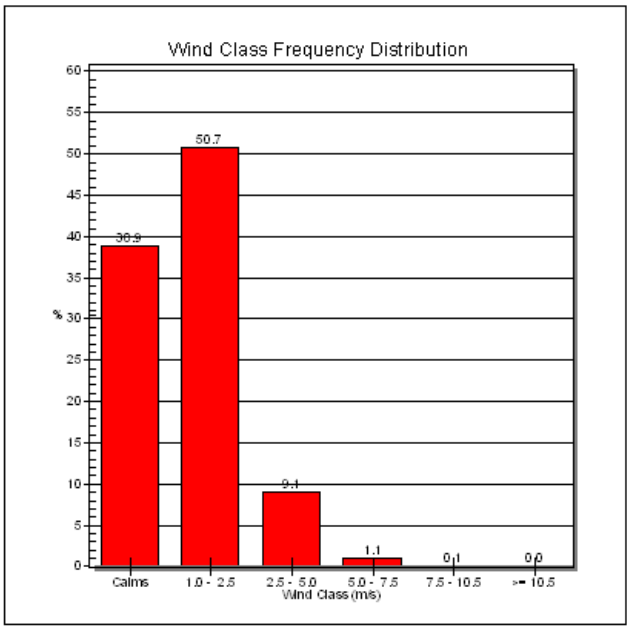
APPENDIX-C: WIND SPEED DATA

C.1 Wind Speed Data: Tangail 1987-2005

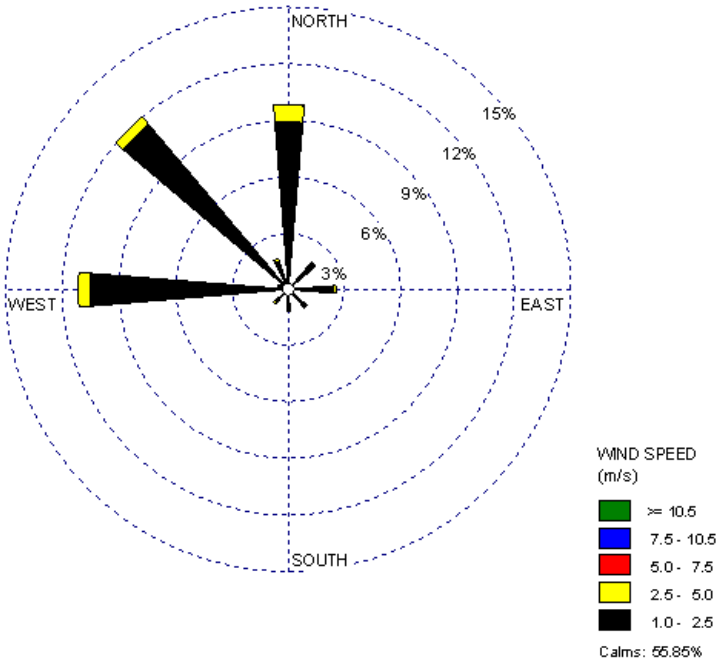
Wind Rose January - December



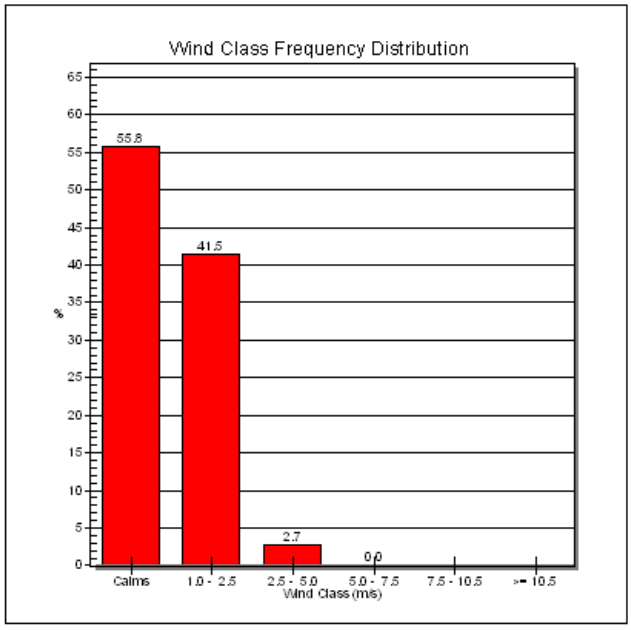
Wind Class January -December



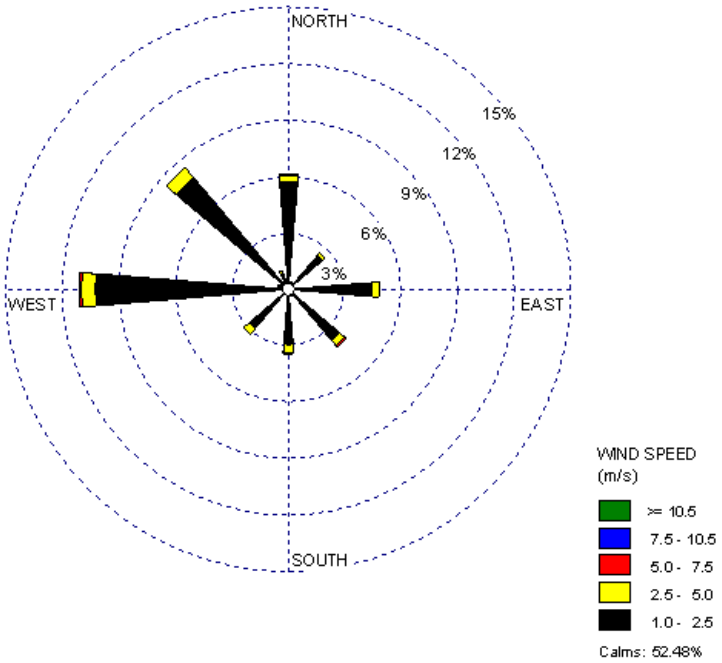
Wind Rose January



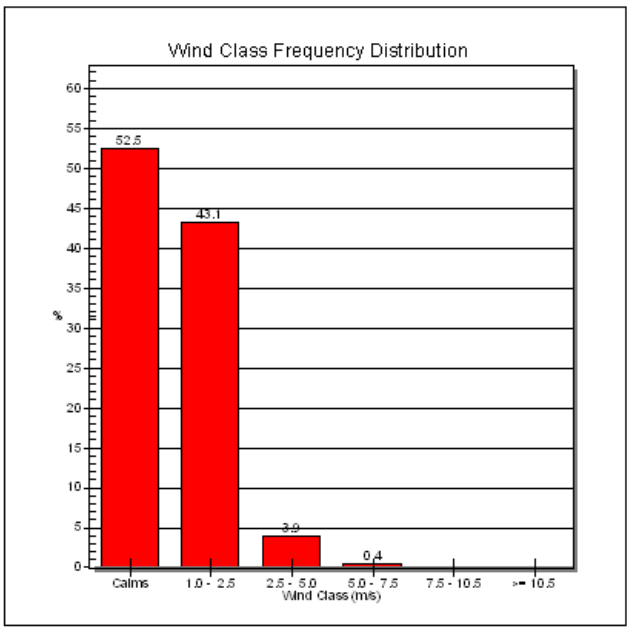
Wind Class January



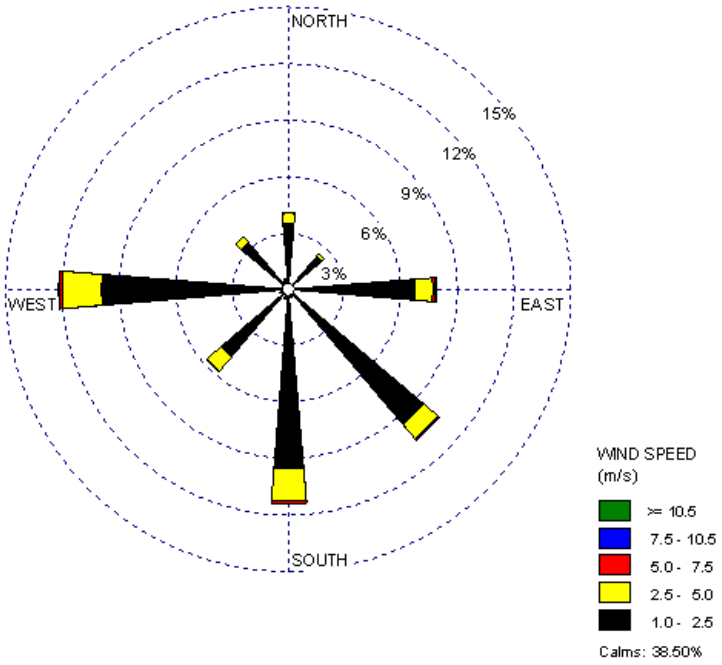
Wind Rose February



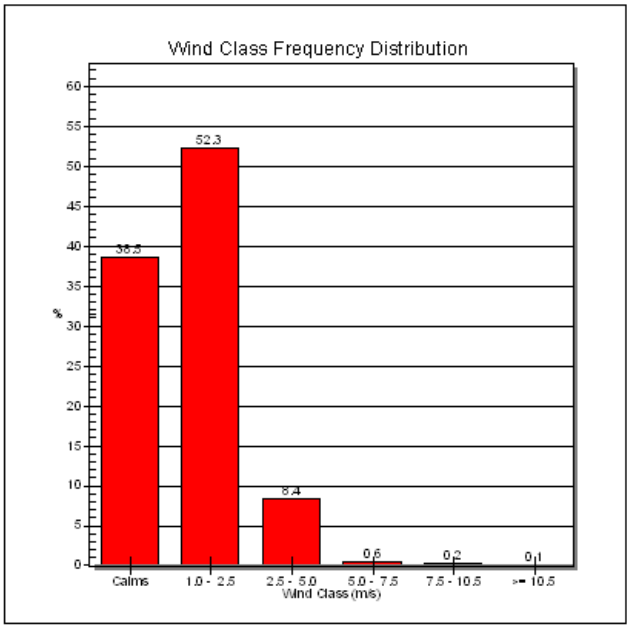
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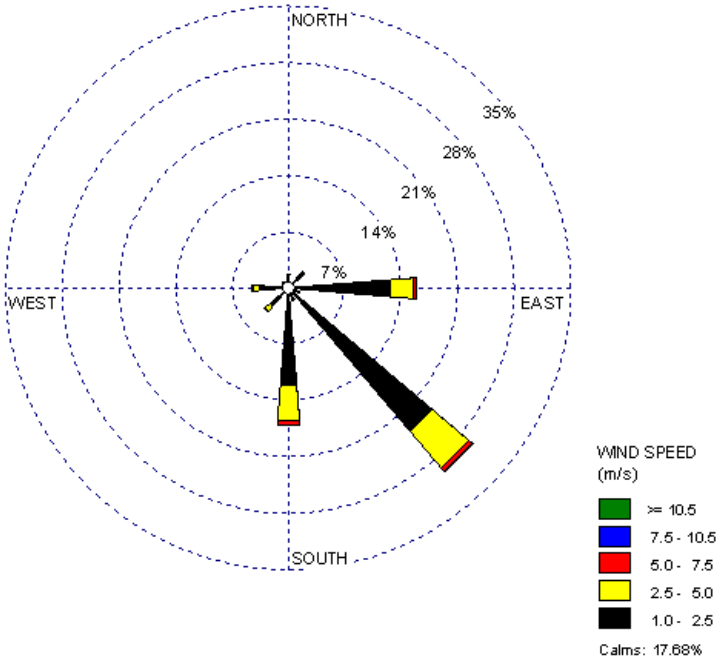
Wind Rose March



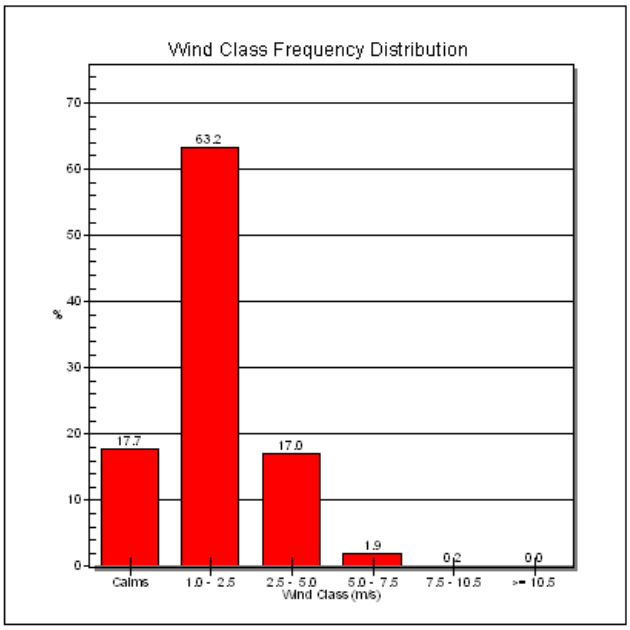
Wind Class March



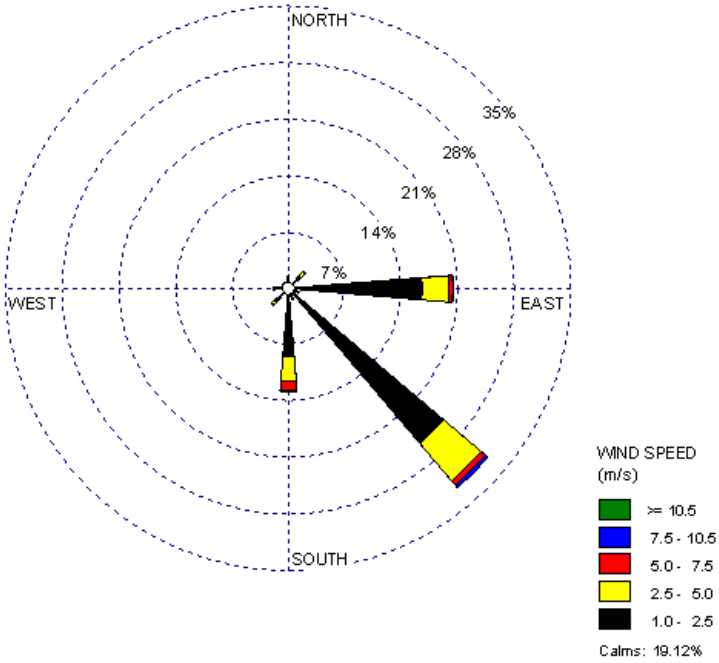
Wind Rose April



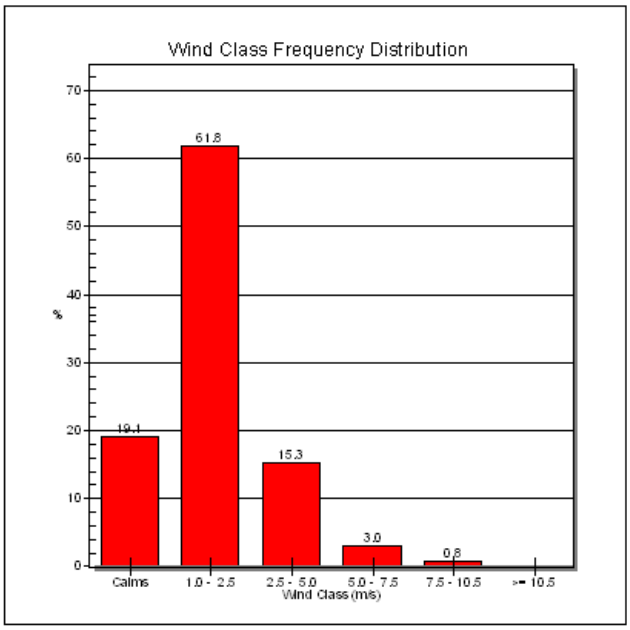
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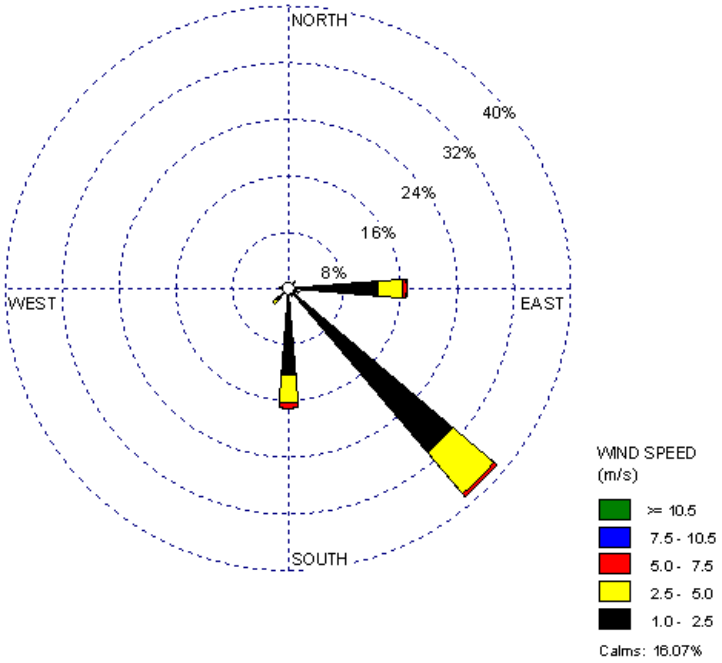
Wind Rose May



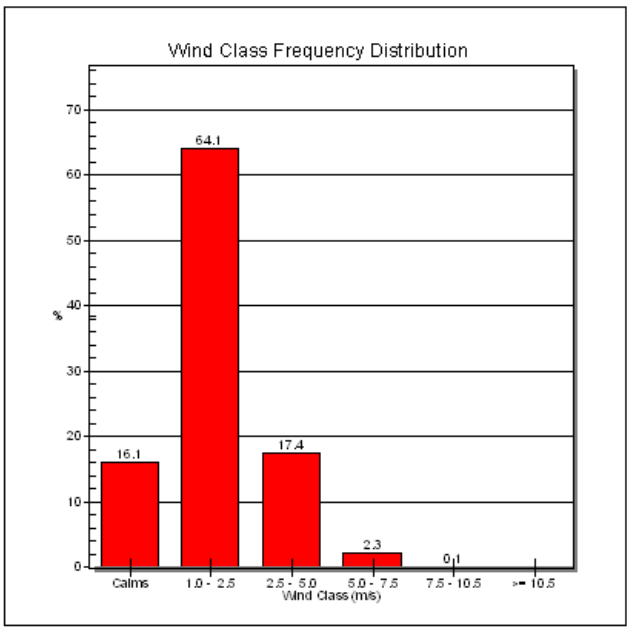
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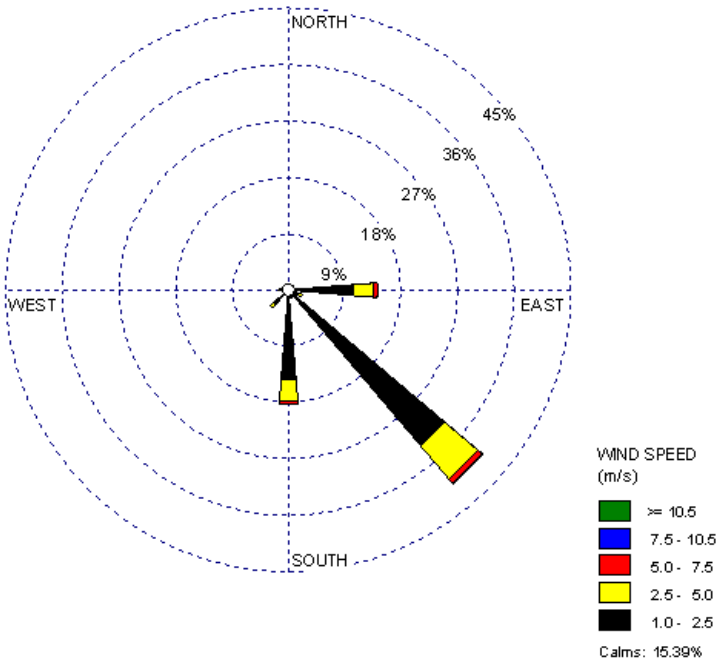
Wind Rose June



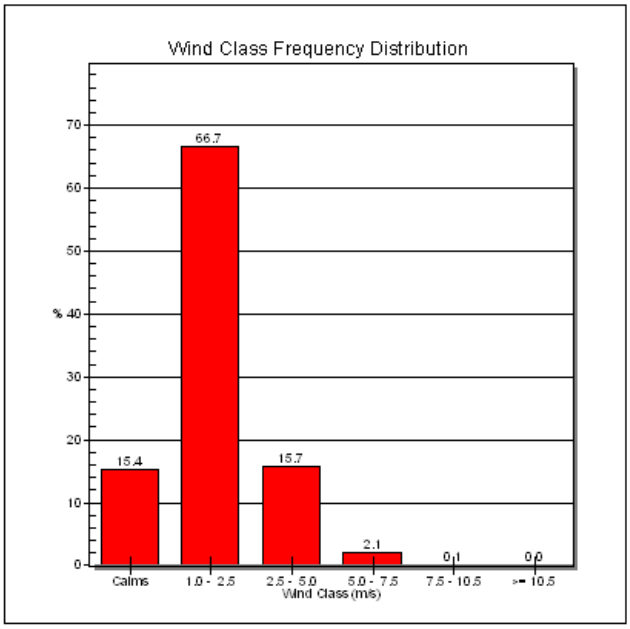
Wind Class June



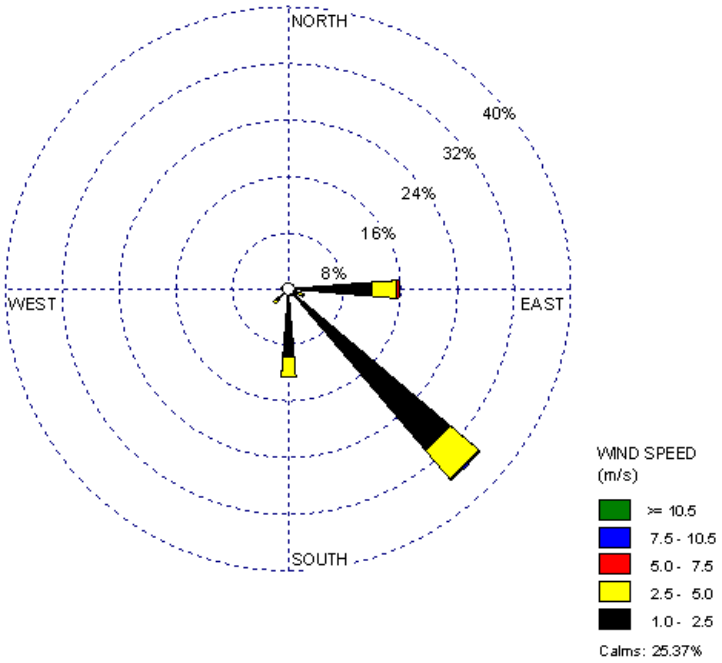
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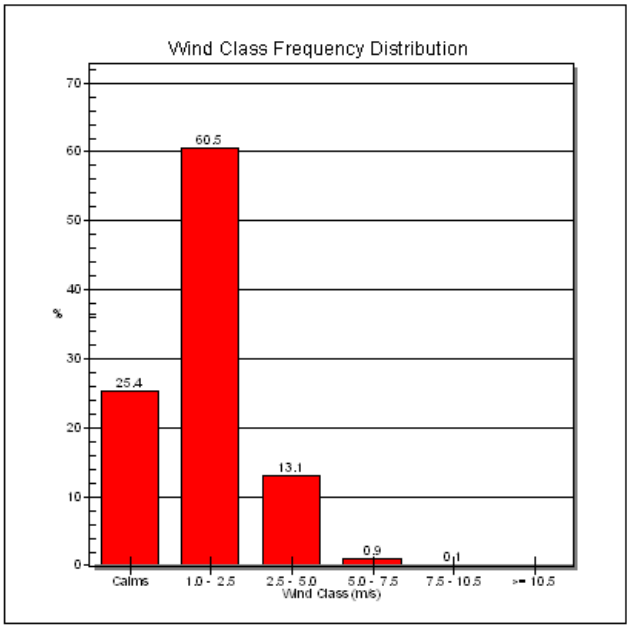
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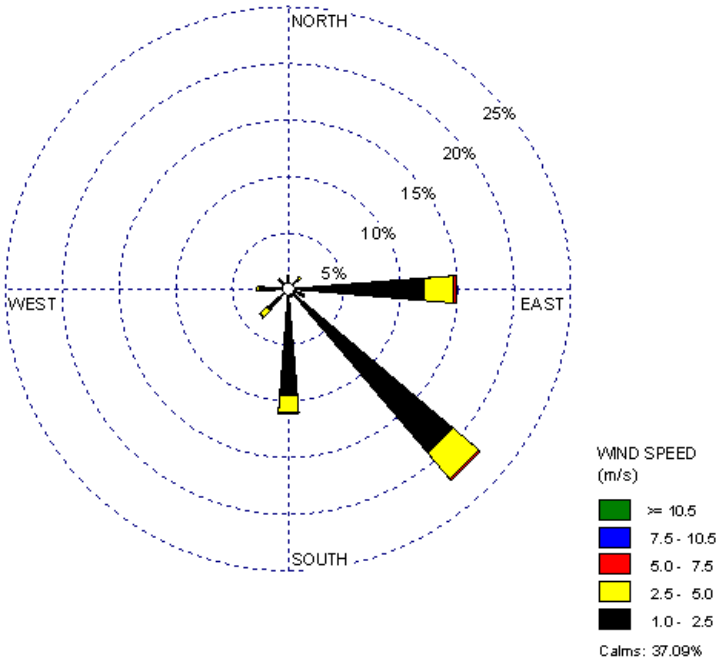
Wind Rose August



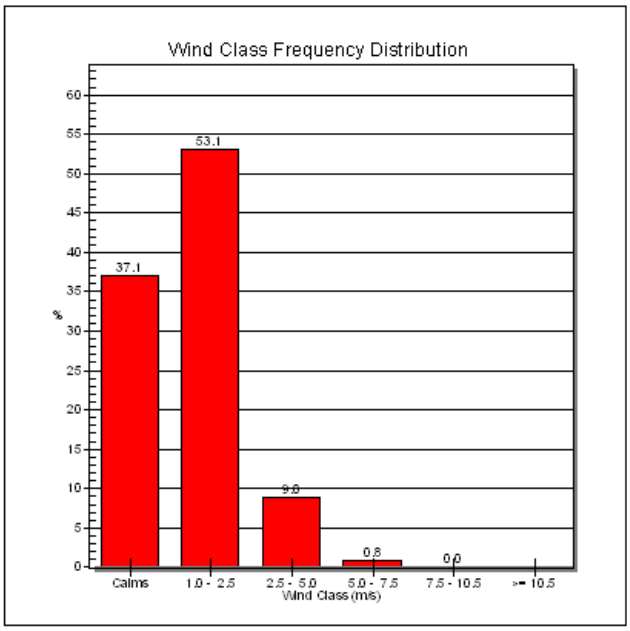
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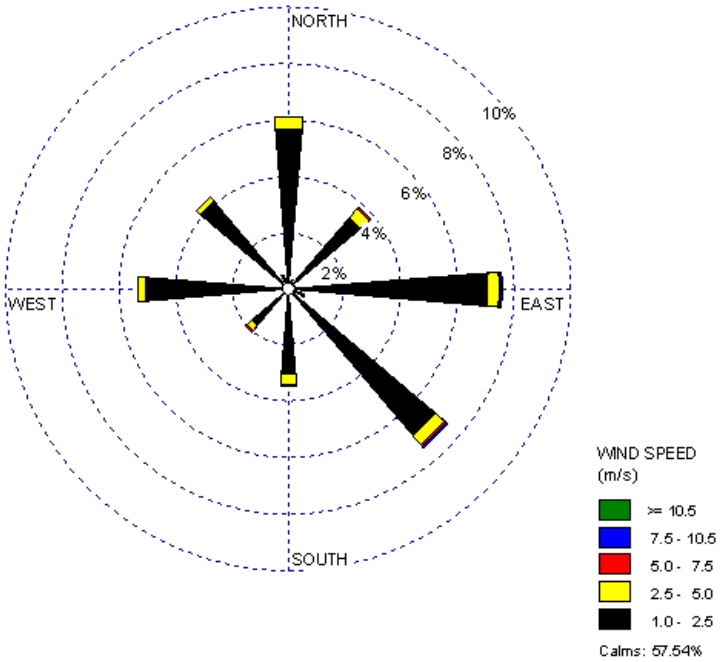
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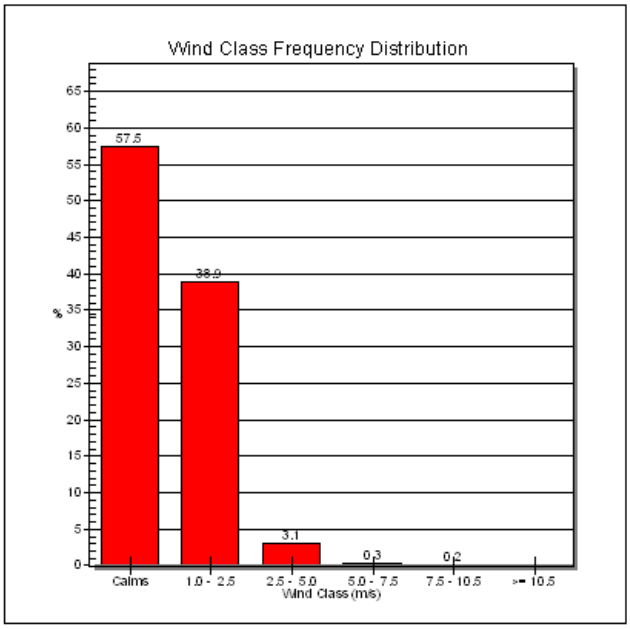
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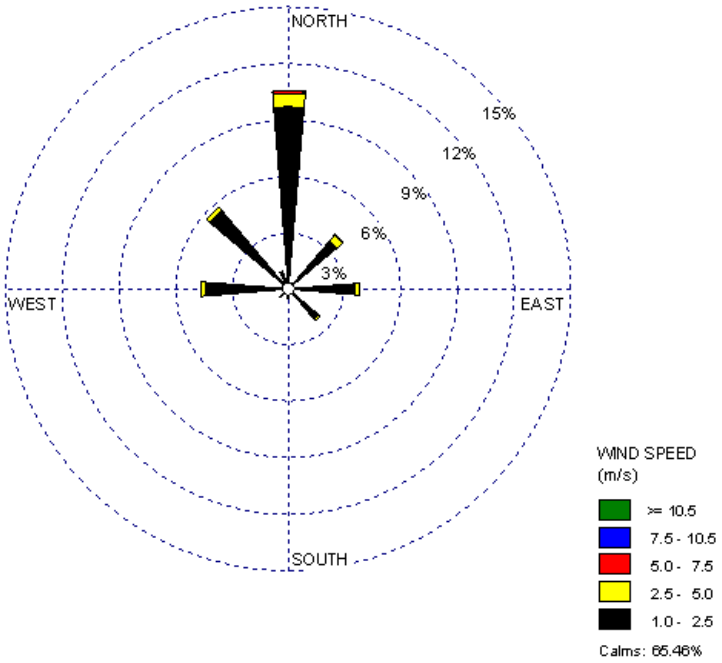
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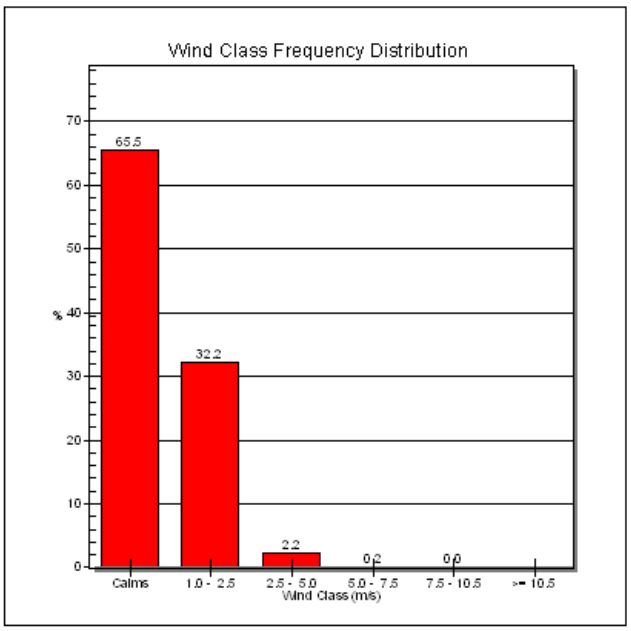
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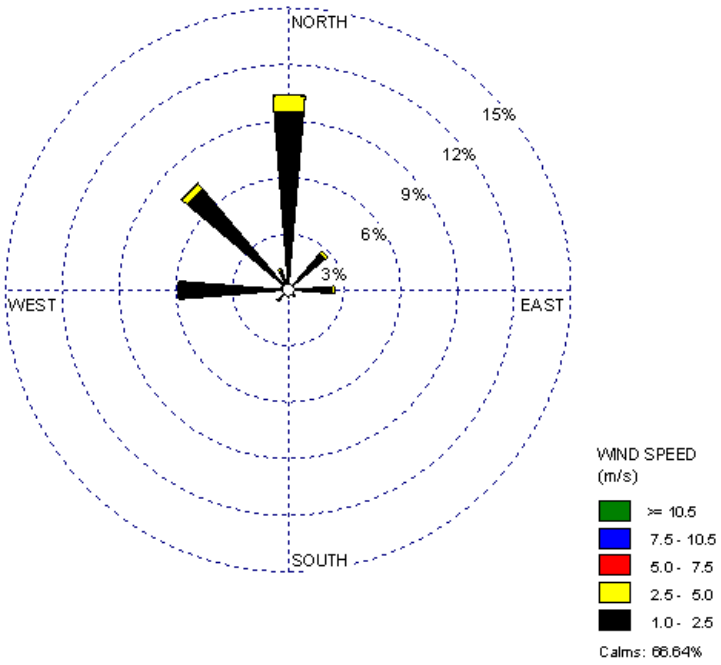
Wind Rose November



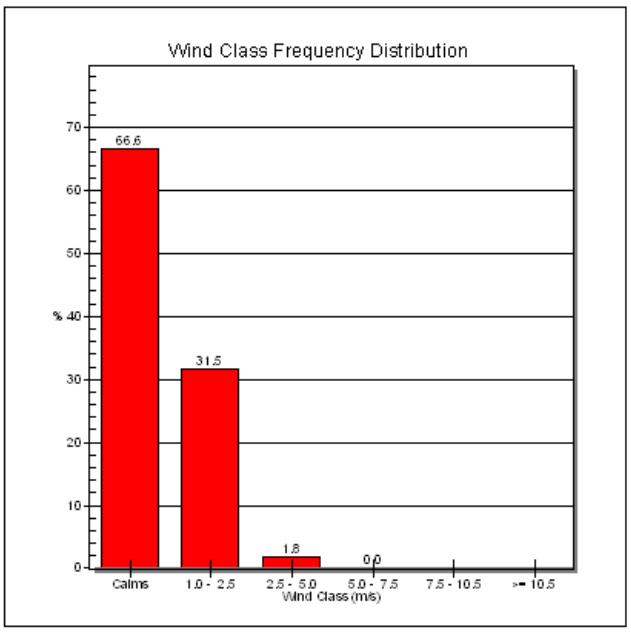
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Wind Rose December

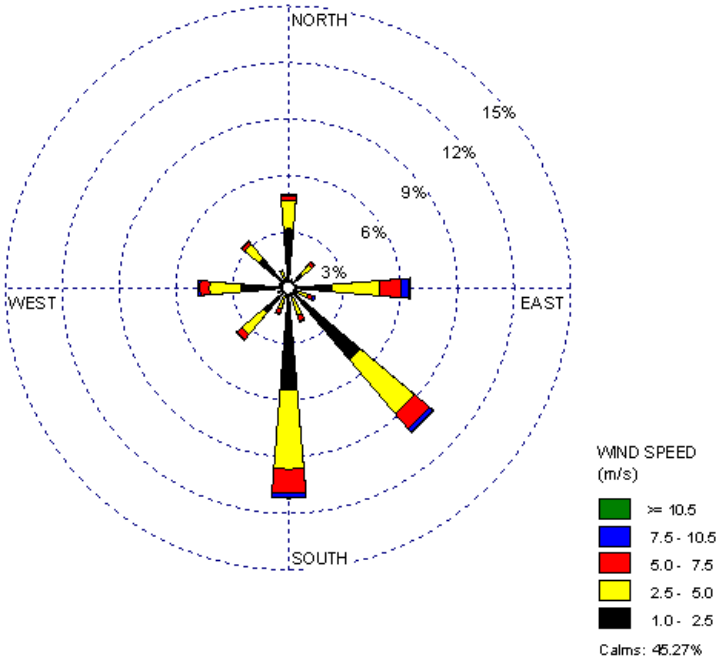


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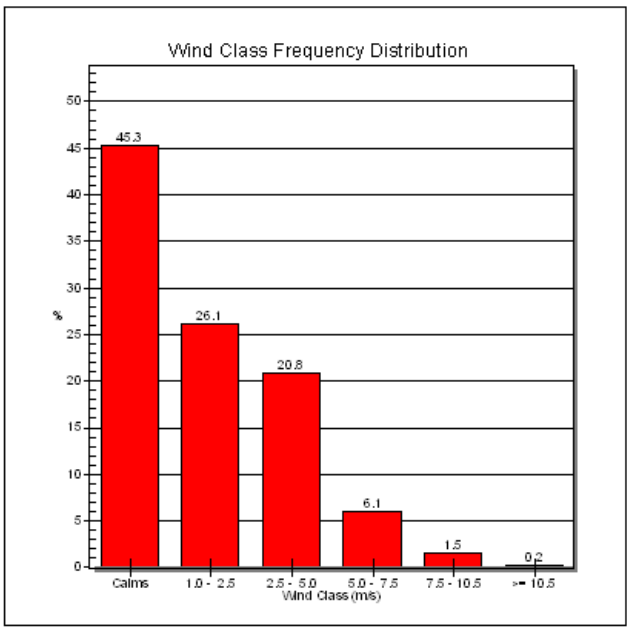


C.2 Wind Speed Data: Ishwardi 1961-2005

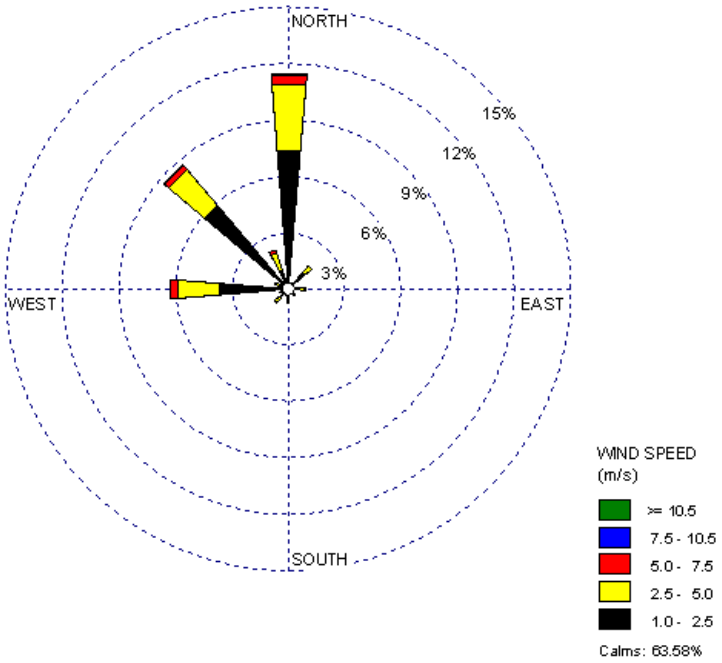
Wind Rose January - December



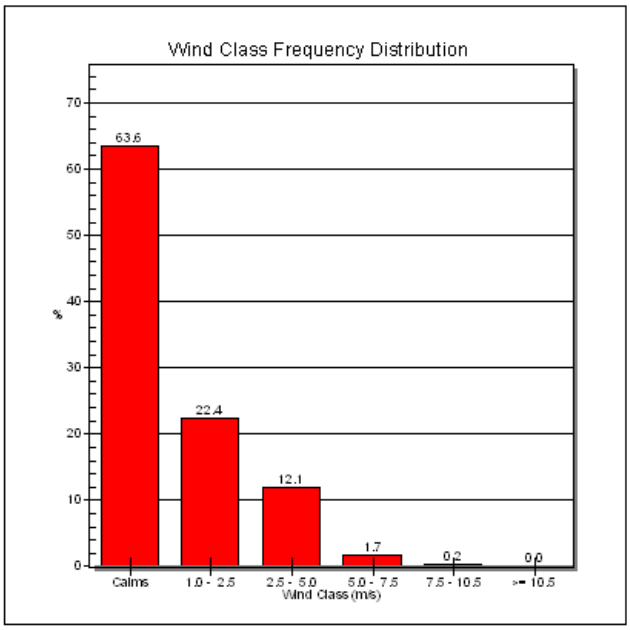
Wind Class January -December



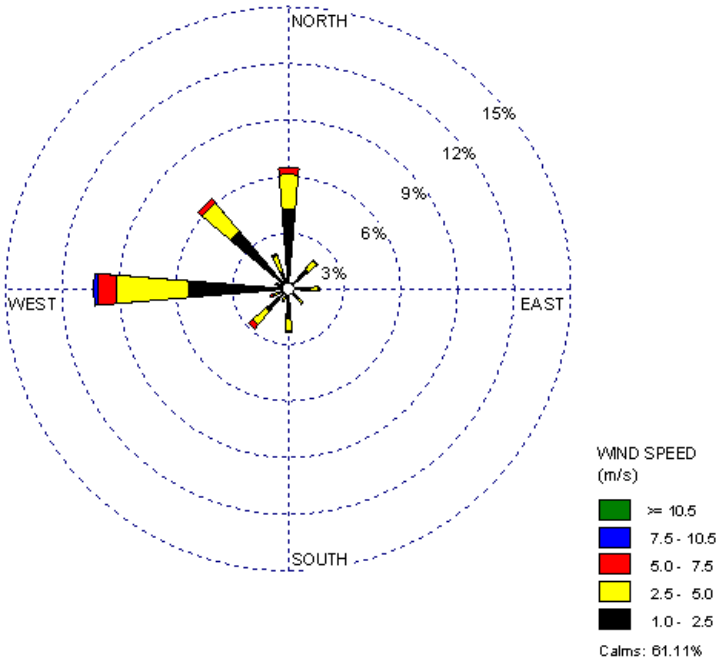
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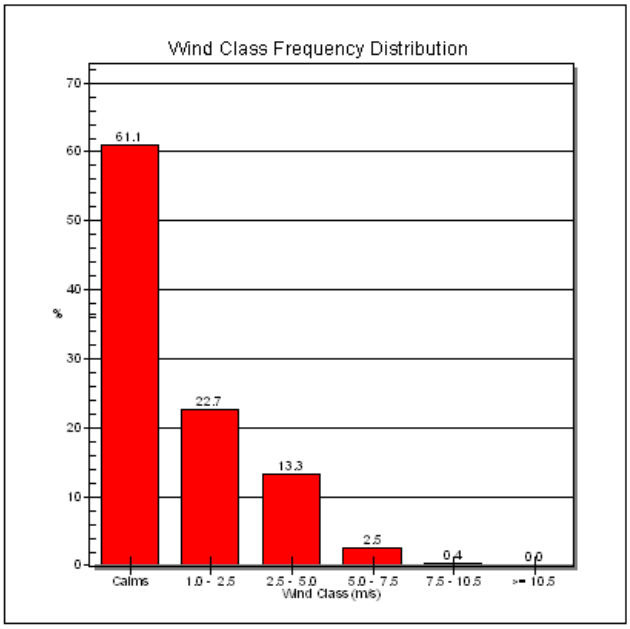
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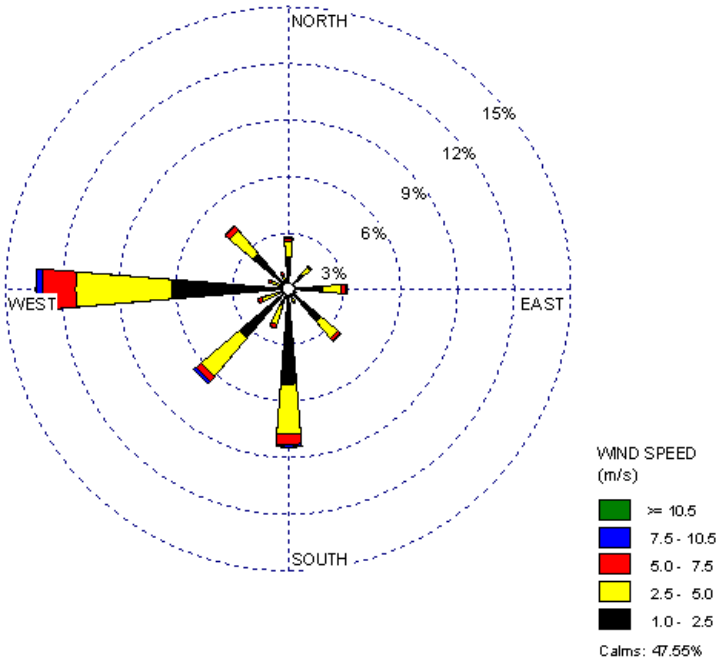
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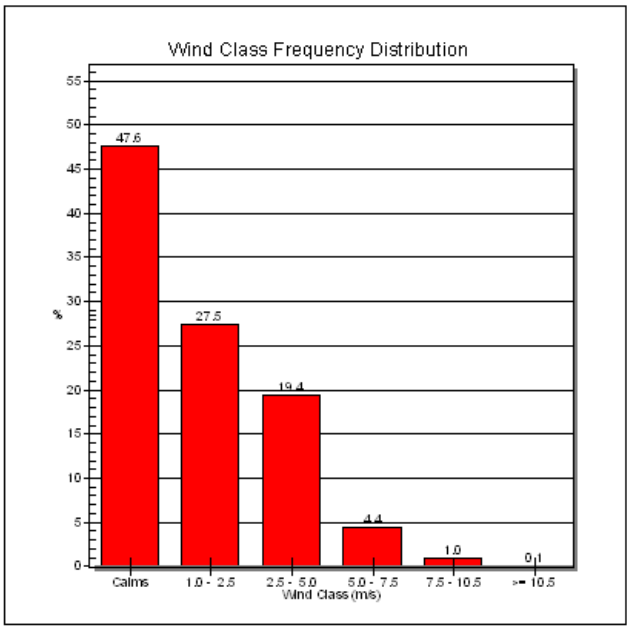
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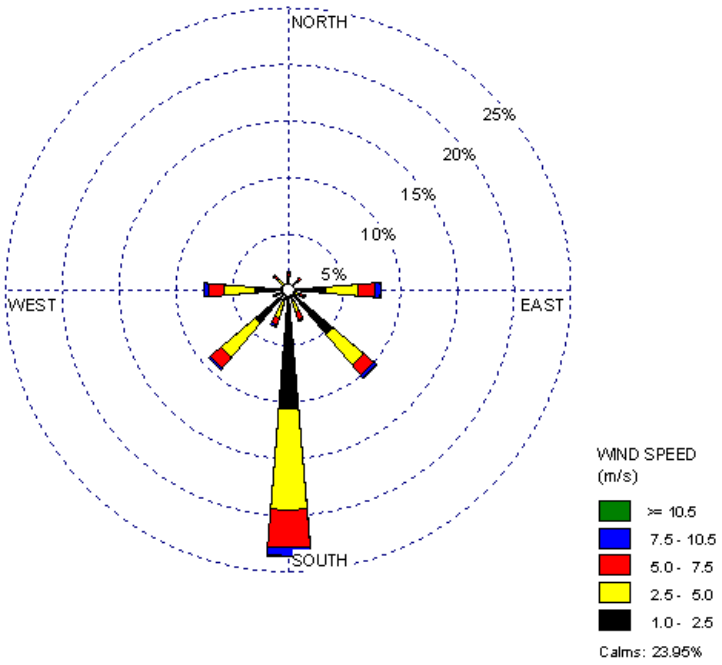
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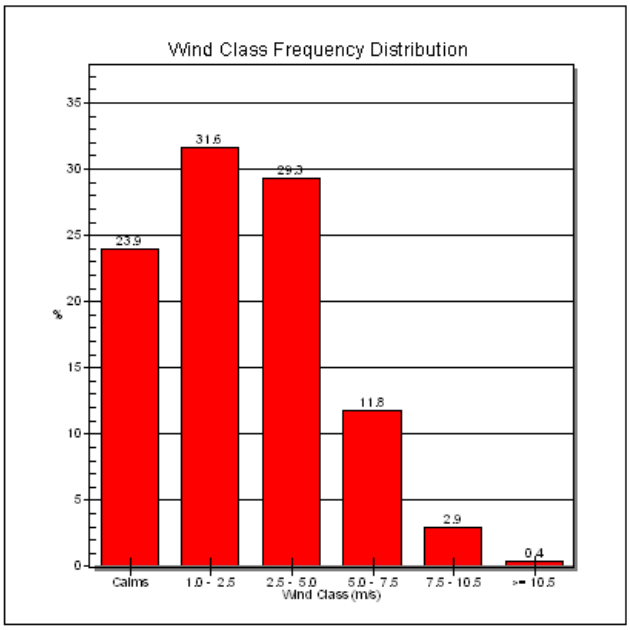
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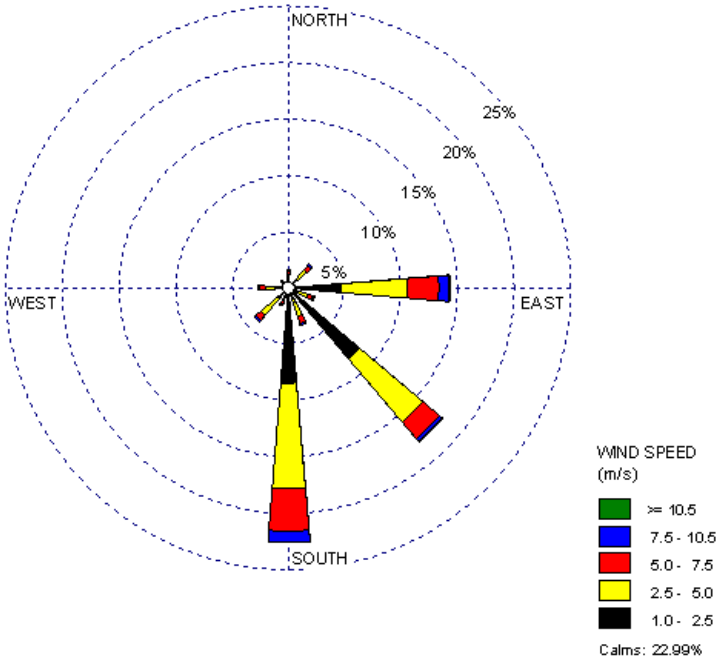
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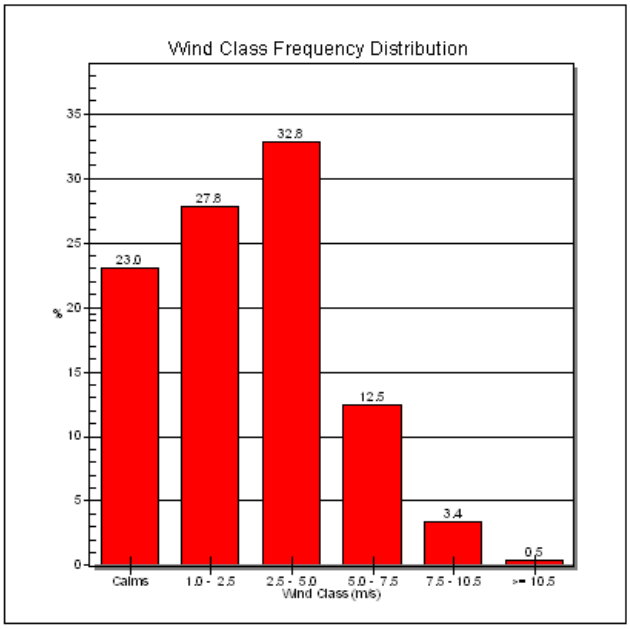
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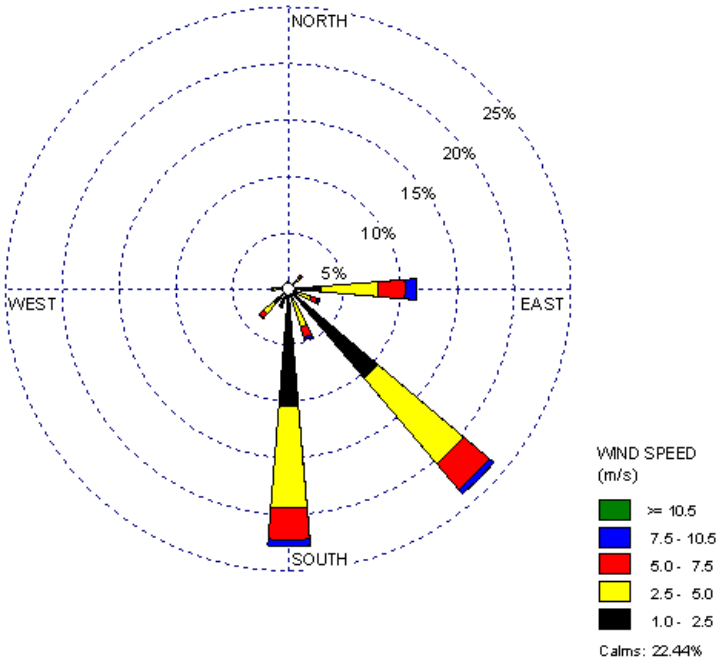
Wind Rose May



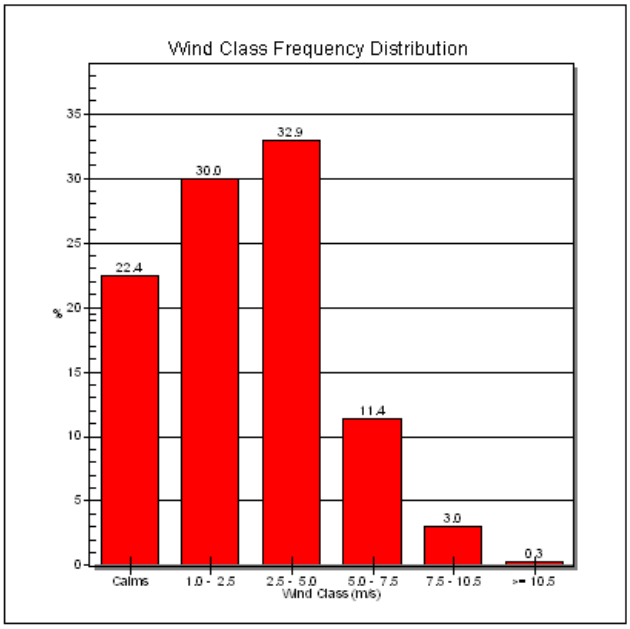
Wind Class May



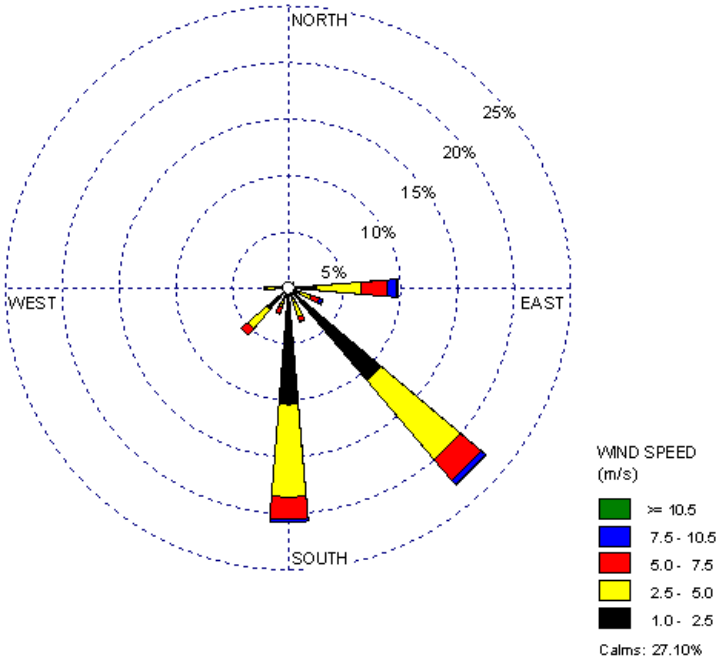
Wind Rose June



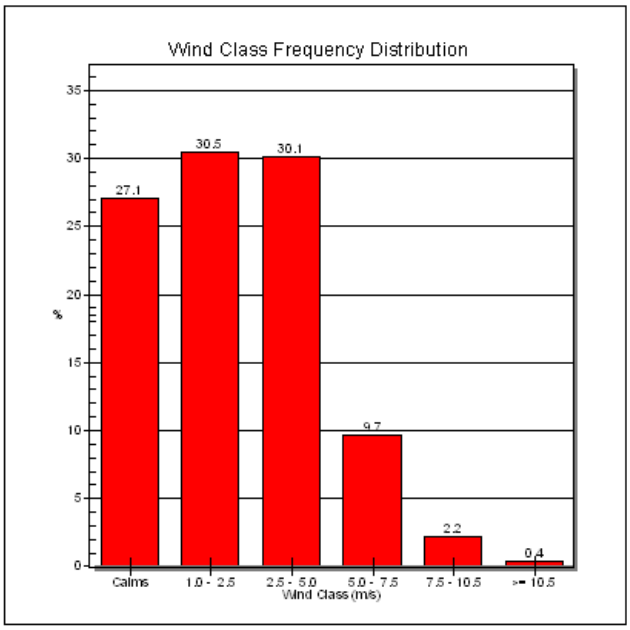
Wind Class June



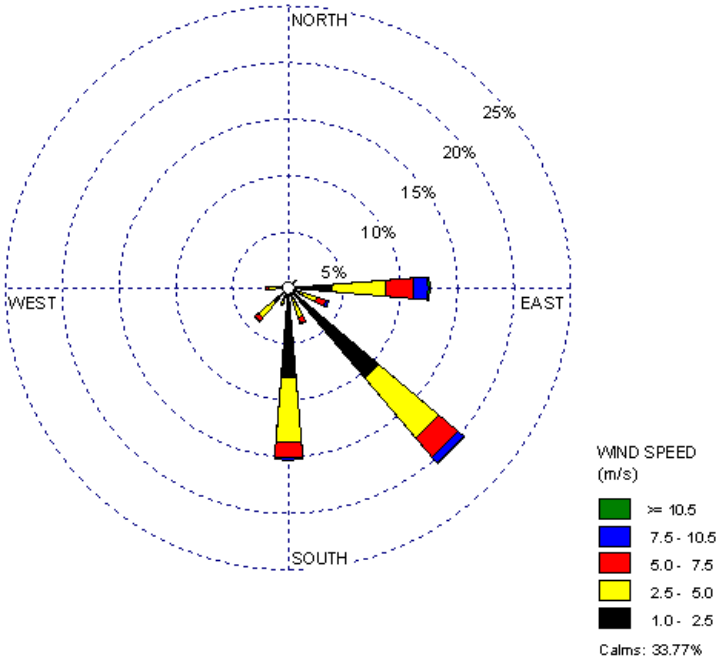
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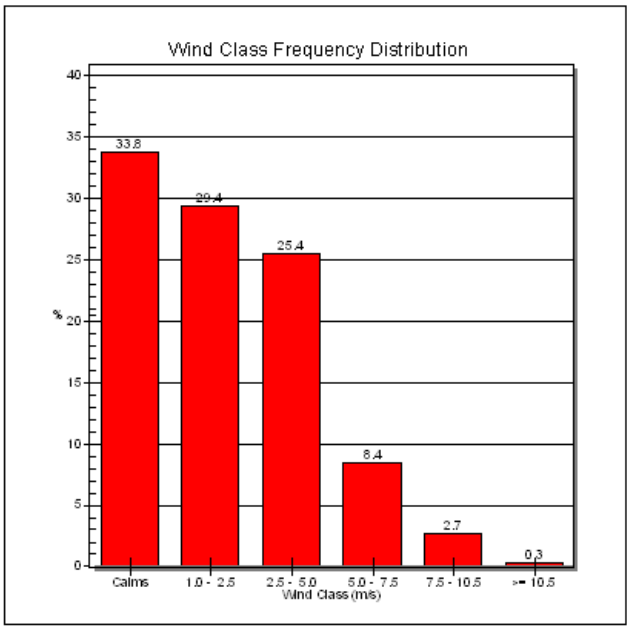
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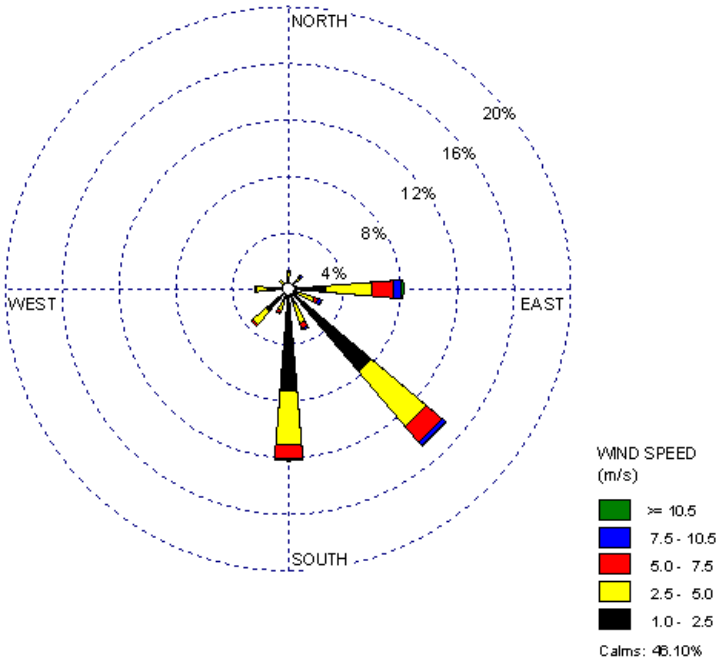
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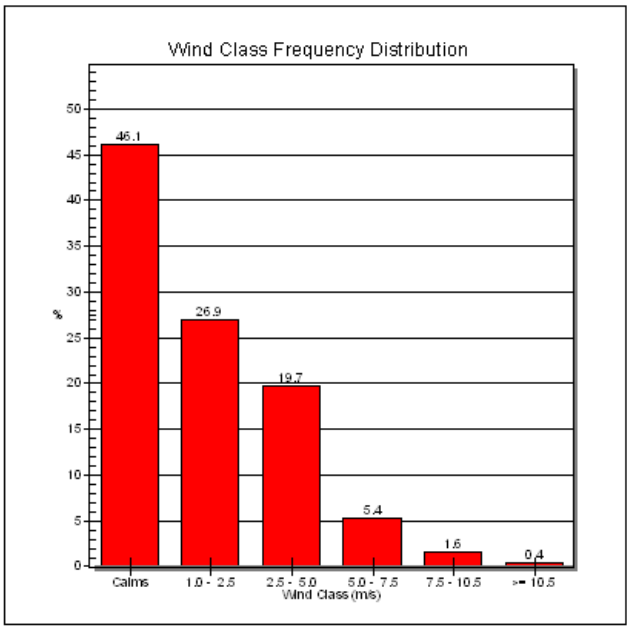
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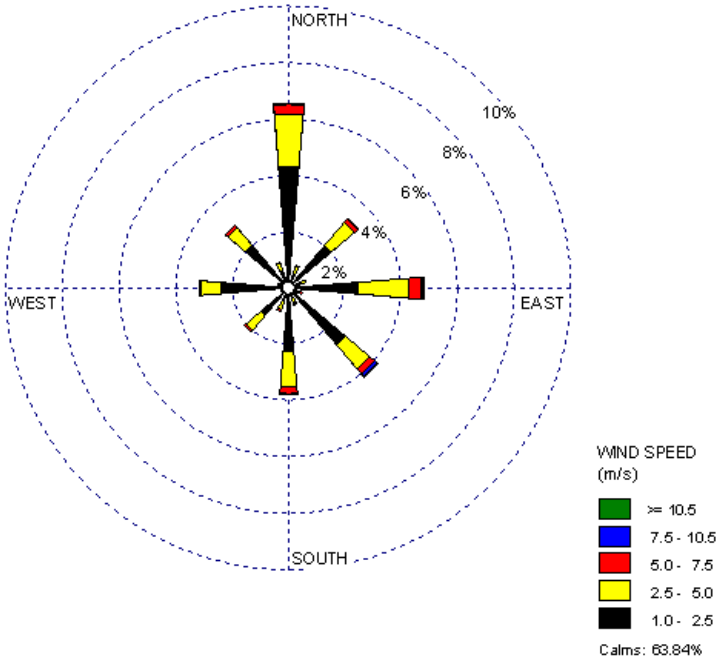
Wind Rose September



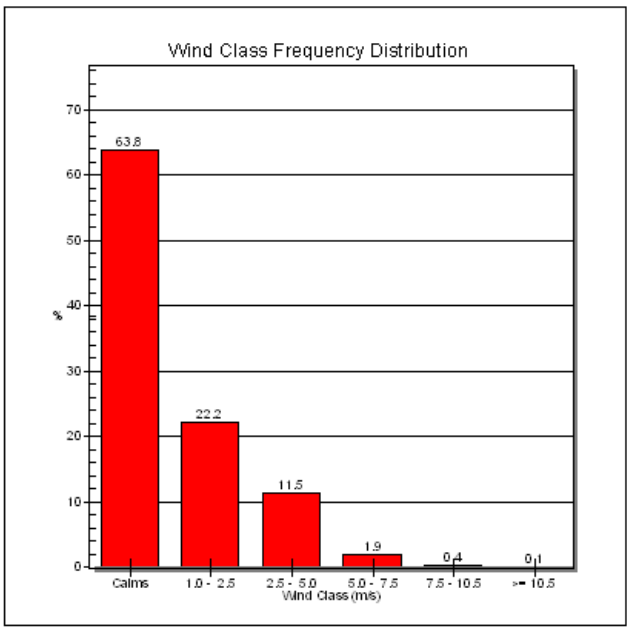
Wind Class September



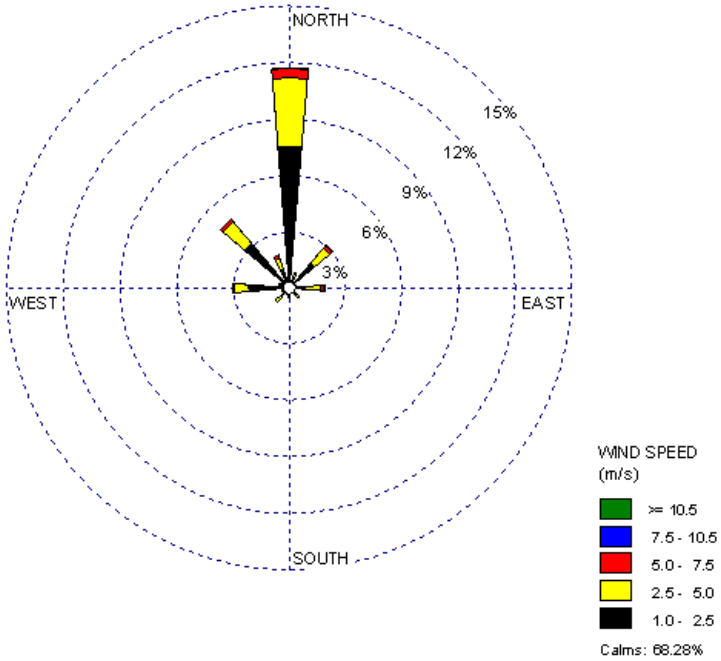
Wind Rose October



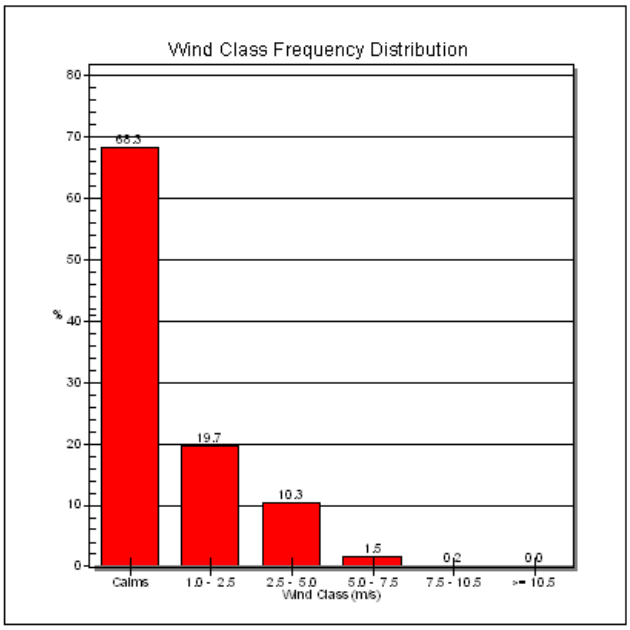
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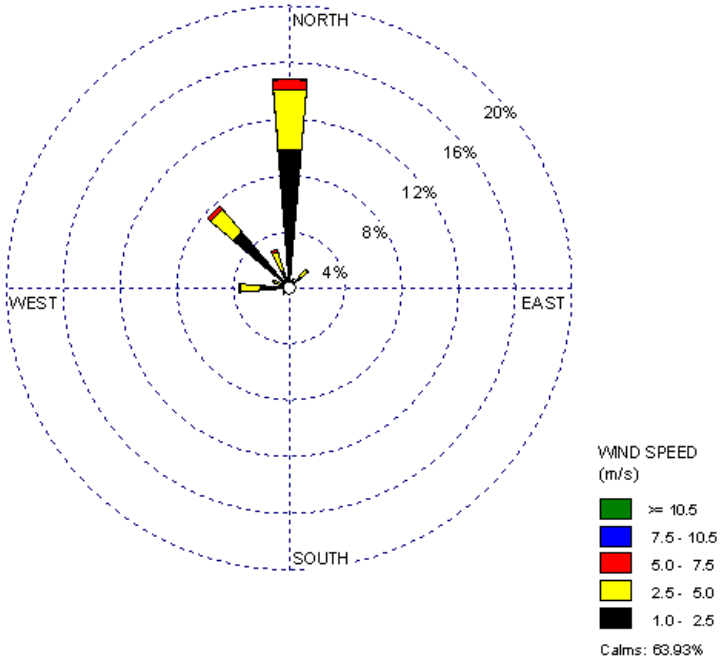
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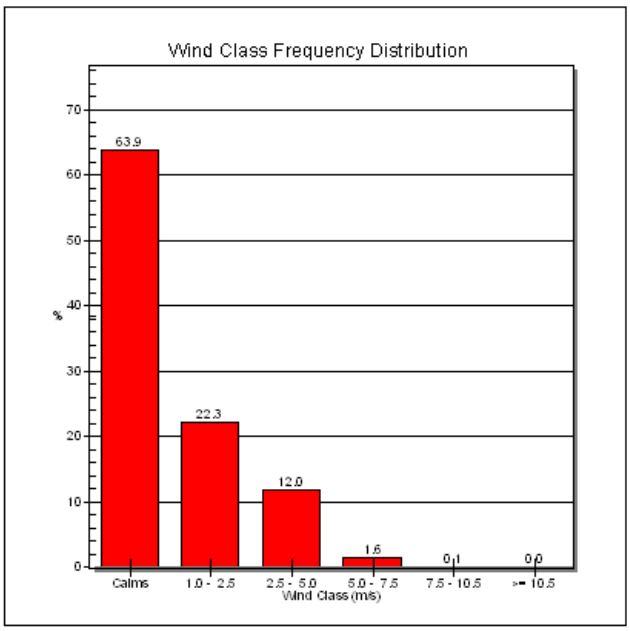
Wind Class November



Wind Rose December



Wind Class December



APPENDIX-D: RESPONSE ON DFR

Morphological Study of Different River Crossing (Padma River for One Line and Jamuna River for Two Lines) for Infrastructure Development for Power Evacuation Facilities of Rooppur Nuclear Power Plant

Comments on the Draft Final Report, and Response to the Comments of IWM

SL	Comments of PGCBL	IWM Responses	PGCB's reply	IWM Responses
1	Existing bed level/Reduced level of the proposed tower locations are not mentioned (page no 2-12,2-13). It would be beneficial for us if you provide these data.	Agreed and would be provided in the Final Report	Our construction bid was already floated last week. We need to provide morphological study with the bidding document. Please incorporate this in the Draft Final report and send as early as possible.	Existing bed level/Reduced level has been incorporated at page 2.12-2.13 of Chapter 2 in the Final Report
2	In page 3-5 Table 3.4, measured median grain size diameters (d_m) are shown. But for calculating local scour by IRC 78 method (Page A-7,A-14,A-21) different data have been used. As per IRC, dm should be taken up to the level of deepest scour (Attachment provided). Please explain.	As our type of bed material is fine sand, with reference to IRC-78, to calculate Scour Depth we used optimum mean diameter of fine sand d_m(tabulated)=0.158 mm as per Article 703.2.2.1 of IRC-78.vide page 10 (Row 2 and Column 2 for Table of Type of Bed Material and d_m) as against actual maximum value of d_m= 0.18mm-Surveyed, which is greater than tabulated value. Reasons behind is that, Depth of scour is inversely proportional to the value of d_m in millimeters. If the value of d_m is more, then Scour depth will be less. On the other hand, if the value of d_m is less, then Scour depth will be more. Towards determining Maximum Scour depth, as surveyed d_m is more than optimum experimental tabulated value (for ready reference and adoption) so, we have used this value as per Article 703.2.2.1 of IRC-78 as	Agreed with your original calculations.	-

		mentioned above. However even then to calculate Scour depth, if you intend to use actual surveyed value of d_m then we shall furnish revised calculations		
3	In page A-22, A-23 pile cap dimensions 6.08mX6.08m, Cap depth 1.62m, Pier dia 2m & height= flow depth, 8 nos of pile per leg has been considered. These dimensions are considered in local scour computation. This conditions may be ok for bank locations. But in our assumption, in flowing water/char areas steel tubular piles will be used for tower foundation. Number and diameters of piles per tower may be different for different locations. All the piles of a tower shall be connected with a common platform which will be located 450mm above HFL. Some schematic diagrams are attached here. Please calculate local scour for indicated 4 cases.	Agreed and revised calculation would be provided in Final Report. However, in this case, we need individual pier dimensions for each case.	Please consider the provided foundation drawing. You can consider the RC chimney as pier (1.5m dia, 2m height above platform level). However the whole platform shall be 450mm higher than HFL. Our construction bid was already floated last week. We need to provide morphological study with the bidding document. Please incorporate this in the Draft Final report and send as early as possible.	The calculation has been incorporated at APPENDIX A of the Final Report
4	Ship impact loads and Necessary input data required to calculate velocity attack and wave attack on the structures have not been provided.	Additional page explaining the calculation of ship impact load has been attached herewith and would also be provided in the Final Report	Our construction bid was already floated last week. We need to provide morphological study with the bidding document. Please incorporate this in the Draft Final report and send as early as possible.	Ship impact loads and Necessary input data required to calculate velocity attack and wave attack on the structures have been incorporated in Chapter 7 of the Final Report
5	In page ES-4 it is observed that from 5 to 10km d/s of Hardinge Bridge erosion may occur at the right bank under high flood event. In this region we have about 6km of transmission	Recommendation regarding this issue would be provided in Final Report.	Our construction bid was already floated last week. We need to provide morphological study with the bidding document. Please	To save the foundation cost at right bank of Ganges River, the 6km of transmission line (Rooppur-Gopalganj)

	line (Rooppur-Gopalganj) parallel to the river. We want to know if tower foundations in this region have to be designed considering total scour. If possible, can you suggest a safer route (shifted outside from current position) for which we do not need to consider scour for foundation design. It will save our foundation cost drastically.		incorporate this in the Draft Final report and send as early as possible.	parallel to the river can be shifted about 200m towards the country side (by observing the bank erosion from the long term simulation).
6	At the left bank (Rooppur power plant side) to the downstream of Hardinge Bridge we have 3 more transmission lines running 2/3km parallel of river (an autocad drawing is attached showing all the lines outgoing from Rooppur power plant). This was not in your TOR. But it is our earnest request if you could kindly provide any information about vulnerability of tower foundations on the left bank based on your current study.	Agreed and information about the probable vulnerability would be provided in the Final Report. Examination of vulnerability would be provided based on past data and satellite images.	Our construction bid was already floated last week. We need to provide morphological study with the bidding document. Please incorporate this in the Draft Final report and send as early as possible.	This has been incorporated at page 2.15-2.17 of Chapter 2 in the Final Report
7	In page 5-23, article 5.4.1 Long term development (20yrs) and article 5.4.2 Short term development (2-3yrs) of the rivers are shown. Can you please inform us about percentage of probabilities/accuracy of these predictions? Thanks.	Accuracy of the model prediction is generally expressed in terms of different parameters, for instance Nash–Sutcliffe efficiency coefficient (NSE), Percentage of bias (PBIAS),Co-efficient of determination (R2),RSR – ratio of RMSE to standard deviation of measured data, etc. These would be included in the Final Report.	Our construction bid was already floated last week. We need to provide morphological study with the bidding document. Please incorporate this in the Draft Final report and send as early as possible.	In case of long term simulation, if we want to calibrate the morphological model, first year the model would give us a better result with 80 % (for say) accuracy. In second year, it would give 64% accuracy and in third year it would give 51.2% accuracy as error introduce in bed level at the beginning of every hydrological year. In tenth

				year the accuracy would go to 10%. So, with this low accuracy any future prediction is quite impossible.

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Memo No. 42.07.016.06.05.2309.2021/0728 Date: 06.05.2021

The Chief Engineer
Project Monitoring
Power Grid Company of Bangladesh Ltd.
PGCB, Dhaka

Sub: Addendum of Final Report

Ref: Morphological Study of Different River Crossing (Padma River for One Line and Jamuna River for Two Lines) for Infrastructure Development for Power Evacuation Facilities of Rooppur Nuclear Power Plant

Dear Sir,

The Final Report of the mentioned Project has been submitted on February 4, 2021. At Chapter 7 under Section 7.1 Ship Impact Load Has been analyzed. This load has been calculated considering the international Dead Weight Tonnage of the Ships. Considering Bangladesh Inland Water Transport Authority's, guideline few additional calculation and guidelines are provided in this addendum under the same section.

Looking forward to continued cooperation,

Yours sincerely,

6/5/21

Sarwat Jahan
Director
River Engineering Division

Encl. As stated

CC: ED/ DED (Opn)/ PS, PL –P52309, IWM

7. Ship Impact Load, Input data required to calculate Velocity attack and Wave attack

7.1 Ship Impact Load

For the protection of piers in the river, the head-on collision of a ship is important. For this purpose, the results of collision tests carried out in Germany under the direction of *Gerhard Woisin* were evaluated as well *Woisin* found a dynamic relationship between the impact forces over time, where the maximum force for about 0.1 to 0.2 seconds at the beginning of the collision increases up to double the value of the average collision force over several seconds. From *Woisin*'s test results the author concluded that equivalent static impact forces from a direct collision of a large ship against a rigid wall are, in a first approximation,

proportional to the square root of the dead weight tonnage (DWT) dead weight tonnage of the ship, However, within this relationship a wide scatter of impact forces exists for ships with the same DWT due to their widely varying hull structures and collision speeds. The author thus proposed the formula for the impact forces with a scatter of ±50 %. (*Svensson*, 1981) P = 0.88 $\sqrt{DWT}$, where P is the equivalent average impact load in MN. This formula was published by the author in Germany in 1981, in the IABSE Periodica in 1982, and in the Proceedings of the IABSE Colloquium on Ship Collision with Pier in river held in Copenhagen in 1983.

The AASHTO specification uses the relationship

F = 1.11* 0.88 $\sqrt{DWT} * \frac{v}{8}$

= 0.122 $\sqrt{DWT} * v$

where F is the equivalent average impact load in MN and *v* is the ship impact speed in m/s.

Table 7.1 Ship Impact Load

River	Equivalent Average Impact Load, F (MN)	Dead Weight Tonnage, (DWT)	Impact Speed, v (m/s)	Vessel Size Group	Remarks
Jamuna River	108.59	75000	3.25	Aframax (Min)	DWT as per UNCTAD (2000) standard Vessel Size considering international importance as well as standard
	134.46	115000	3.25	Aframax (Max)	
Padma River	126.11	60000	4.22	Handy and Handymax	
Jamuna River	21.72	3000	3.25	Large Rhine vessels	DWT as per BIWTA and PIANC Guideline considering Bangladeshi route and vessel as well as international importance
Padma River	19.94	1500	4.22	Rhein-Herne-Canal standard vessel (R.H.K.)	

7.1.1 Ship Impact Load and it's Protective Measures

General

The protection of piers in the river against ship collision is becoming more and more important. The current state of the art for the two most important considerations in this regard, the determination of impact forces and the structural design of collision protection, in general, he following options are available for protecting Pier and other structures against ship collisions:

- Deflect ship by artificial islands or guide structures
- To Create guide Structures
- Make piers strong enough to withstand direct collisions

Examples of all these types of protection are given below.

Create artificial Island

If the water is too wide to be crossed without piers in a navigable channel, it should be investigated as to whether artificial islands are possible. The advantages of such islands are that they provide a high degree of safety and stop a ship gradually, thus limiting the extent of damage to the ship's hull. If protected against erosion, such islands are virtually maintenance-free and require only minor additional fill after a collision. Their use is often limited insofar as they may not reduce the flow cross-section such that the speed of the current is dangerously increased.

Create Guide Structure

Guide structures are designed to guide a ship away from the bridge piers or bridge superstructure. They are usually not designed for a head-on collision but instead for the glancing impact of a small or medium-sized vessel.

Making Strong Pier

Another way of protecting piers against ship collision in deep water is to make them strong enough to withstand the collision forces by themselves. The vertical loads on the foundations from the bridge weight assist considerably in designing the foundations to withstand horizontal impact loads (determined by the "Guide Specification and Commentary for Vessel Collision Design, AASHTO 1991)..For foundations on solid rock not too deep, this type of design can be more economical than designing independent protective structures without the benefit of the bridge's dead weight. Since these foundations are rigid, the ship's kinetic energy mainly has to be absorbed by the ship's hull and can therefore lead to more damage to the ship than to the sacrificial independent protection, which absorbs the ship's energy more gently through plastic deformations with large deflections but in general it is too costly.

Independent Structure

Where Protective islands not possible due to the great water depth, and the piers could not be made strong enough to withstand a collision due to poor soil conditions and cost-effective measures, therefore independent circular concrete dolphins are proposed with triangular platforms on top to withstand a collision or to guide ships away from the piers. The key to a dolphin's ability to absorb a major ship collision is to tie the top of the sheet piling rigidly to the concrete cap and to weld together the sheet steel pile interlocks.

DWT for Impact Load Calculation

***Reference-01:* Feasibility Study for construction of River Ports at Nagarbari, Chilmari, modernization of Baghabari River Port and construction and placement of special type terminal pontoons with allied facilities/structures, Final Feasibility Report, June 2017.**

Draft restrictions decided by BIWTA according to LAD do not allow a vessel having more than 3 meter draft to call at Nagarbari during high water period. As the water recedees vessels having more than 2-meter draft are not allowed to negotiate in the channel approaches to Nagarbari. But vessels those take load at anchorages at Chittagong and Mongla having draft of 3.5 to 4 meter have to off load goods at Daulatdia where mechanized boats take load from the deeper draft vessels. This also happens in case of those vessels take load of fertilizer and cement at plant jetty. Such constraints have increased the demand for non-standard mechanized boats to call at Nagarbari. According to size, vessels are categorized into following three groups:

Large vessels: Draft 3.5 to 4.00 meter. Beam 7.60 to 10.20 meter **LOA 44 to 55 meter**. In 2016; 556 vessels of this category called at Nagarbari, 7.55% of the total vessels.

Medium vessels: Draft 2.50 to 3.40 meter. Beam 6.00 to 7.50 meter. **LOA 25 to 40 meter**. 2068 (28.10%) of such vessels called at Nagarbari in 2016.

Small vessels: Draft less than 2.5 meter. Beam 4.80 to5.90 meter. **LOA less than 25 meter**. Such vessels made 4,736 (64.35%) calls in 2016.

Reference 02: Inland Waterways Ports, Waterways and Inland Navigation, Lectures Notes, 2012.

For classification of ships and waterways a world-wide classification is developed by PIANC (Permanent International Association of Navigation Congresses).

Table 2-2 Several ship types

Class	Ship type	Tonnage (t)	Length (m)	Beam (m)
I	Péniche Barge	250 - 400	38.50	5.05
II	Campine barge	400 - 650	50	6.60
III	Dortmund-Ems-Canal standard vessel (D.E.K.)	650 - 1000	67	8.20
IV	Rhein-Herne-Canal standard vessel (R.H.K.)	1000 - 1500	80	9.50
Va	Large Rhine vessels	1500 - 3000	95	11.40

Table 2-3 Classification of waterways by PIANC

Type of inland waterways		Classes of navigable waterways	**Motor vessels and barges**					Minimum height under bridges (m)
			Type of vessel: general characteristics					
			Designation	Length (m)	Beam (m)	Draught (m)	Tonnage (T)	
Of regional importance	To West of Elbe	I	Péniche barge	38.50	5.05	1.80-2.20	250-400	4.00
		II	Campine barge	50-55	6.60	2.50	400-650	4.00-5.00
		III	D.E.K.	67-80	8.20	2.50	650-1000	4.00-5.00
	To East of Elbe	I	Grosse Finow	41	4.70	1.40	180	3.00
		II	Barka Motorowa 500	57	7.50-9.00	1.60	500-630	3.00
		III		67-70	8.20-9.00	1.60-2.00	470-700	4.00
Of international importance		IV	R.H.K.	80-85	9.5	2.50	1000-1500	5.25 or 7.00
		Va	Large Rhine Vessels	95-110	11.40	2.50-2.80	1500-3000	5.25
		Vb						7.00 or 9.10
		VIa						7.00 or 9.10
		VIb		140	15.00	3.90		7.00 or 9.10
Type of inland waterways		Classes of navigable waterways	**Pushed convoys**					Minimum height under bridges (m)
			Type of convoy: general characteristics					
			Designation	Length (m)	Beam (m)	Draught (m)	Tonnage (T)	
Of regional importance		I						3.00
		II						3.00
		III		118-132	8.20-9.00	1.60-2.00	1000-1200	4.00
Of international importance		IV		85	9.5	2.50-2.80	1250-1450	5.25 or 7.00
		Va		95-110	11.40	2.50-4.50	1600-3000	5.25
		Vb		172-185	11.40	2.50-4.50	3200-6000	7.00 or 9.10
		VIa		95-110	22.80	2.50-4.50	3200-6000	7.00 or 9.10
		VIb		185-195	22.80	2.50-4.50	6400-12000	7.00 or 9.10
		VIc	6 barges, long 6 barges, wide	270-280 193-200	22.80 33.00-34.20	2.50-4.50 2.50-4.50	9600-18000 9600-18000	9.10
		VII		285 195	33.00-34.20	2.50-4.50	14500-27000	9.10

Reference 03: https://www.blue-growth.org/Climate_Warming_Action_Plans/Cargo_Container_Ships_Zero_Carbon_Emissions_Shipping/DWT_Deadweight_Tonnage_Tonnes_Ships_Versus_Displacement.htm

Deadweight tonnage was historically expressed in long tons but is now usually given internationally in tonnes (metric tons). In modern international shipping conventions such as the International Convention for the Safety of Life at Sea and the International Convention for the Prevention of Pollution From Ships, deadweight is explicitly defined as the difference in tonnes between the displacement of a ship in water of a specific gravity of 1.025 (corresponding to average density of sea water) at the draft corresponding to the assigned summer freeboard and the light displacement (lightweight) of the ship.

TYPE OF SHIP	CAPACITY (TEU)
SMALL FEEDER	Up to 1,000
FEEDER	**1,001 - 2,000**
FEEDERMAX	**2,001 - 3,000**
PANAMAX	3,001 - 5,100
POST PANAMAX	5,101 - 10,000
NEW PANAMAX	10,001 - 14,500
ULTRA LARGE CONTAINER VESSEL (ULCV)	14,501 - 23,500
MEGAMAX	Over 23,501



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শেখ হাসিনার উদ্যোগ ঘরে ঘরে বিদ্যুৎ

ISO 9001 : 2015 CERTIFIED

পাওয়ার গ্রিড কোম্পানি অব বাংলাদেশ লিঃ
POWER GRID COMPANY OF BANGLADESH LTD.
(An Enterprise of Bangladesh Power Development Board)

মুজিব শতবর্ষ MUJIB 100

Memo No.: 27.21.0000.414.14.001.22. 597 **Date:** January 12, 2022

Abu Saleh Khan
Executive Director (In charge)
Institute of Water Modeling (IWM)
House# 496, Road#32, New DOHS, Mohakahali
Dhaka-1215.

Attn: Ms. Sarwat Jahan (SRJ) , Director of REN, IWM.

Sub: Morphological Study of Different River Crossing (Padma River for one line and Jamuna River for two lines) **for Infrastructure Development for Power Evacuation Facilities of Rooppur Nuclear Power Plant.**
(RFP No: 27.21.2604.414.14.20.2134; Dated:11.03.2020)

- **Request for Elaboration of Provided Recommendations of Morphological Study.**

Your Ref No.: 42.07.016.06.05.2309.2021/0198; Dated: 04/2/2021

Dear Sir,
As per recommendation of your study (article 8.2) "Every tower/pier should be designed considering maximum scour."

We would like to request you to kindly elaborate on how "maximum scour" should be calculated. How will the value of general scour, constriction scour and local scour be calculated for each tower location. Please mention what should be the standard practice for design consideration of scour for this type of rivers.

Please add your recommendation for ship impact load. Whether your provided ship impact values can be directly used for tower foundation design or actual values should be collected from respective authority/organization.

Yours sincerely,

12/01/2022

(A.K.M Gause Mohiuddin Ahmed)
Chief Engineer (Project Monitoring)
PGCB, Dhaka

Copy to:

1. Executive Director (P&D), PGCB, Dhaka
2. Chief Engineer (P&D), PGCB, Dhaka
3. Superintending Engineer (Civil Design), PGCB, Dhaka.
4. Office copy

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Memo No. 42.07.014.06.05.2309.2022/2573 Date: 30.01.2022

The Chief Engineer
Project Monitoring
Power Grid Company of Bangladesh Ltd.
PGCB, Dhaka

Sub: Elaboration of Provided Recommendations in connection with the Project "Morphological Study of Different River Crossing (Padma River for One Line and Jamuna River for Two Lines) for Infrastructure Development for Power Evacuation Facilities of Rooppur Nuclear Power Plant"

Ref.: 27.21.0000.414.14.001.22.597 dated 12 January 2022

Dear Sir,

In response of you letter, an elaboration of the recommendations of the Final Report have been given below-

In general, the total scour is the summation of general scour, constriction or contraction scour and local scour. In this project, the existing bed level at TL-1 is found -34.37mPWD (**Figure 1**), which is itself the lowest bed level observed during the last four decades in Jamuna River along that section. The general scour has been calculated from model simulation after passing the 100 year flood event (design event), shows deposition trend in the main channel, which means no general scour is present in this section. However, incorporation of the Transmission Tower in the river made the river constricted a little bit. Thus, the constricted scour has been estimated by subtracting the bed level at the end of monsoon of "with Tower" condition from the end of monsoon of base condition. Based on this concept, the constricted scour is showing value 6.95m (at 4th transmission tower from left side) shown in **Figure 1**. Again, the calculated maximum local scour is found 39.52m (using Laursen method) for TL-1.

So, the Total scour for TL-1 = General scour + Constriction scour + Local scour
= 0 + 6.95 + 39.52
= 46.47 m

Similarly, the Total scour for TL-2, = General scour + Constriction scour + Local scour
= 17.88 + 5.17 + 38.85
= 61.9 m

Jamuna is a very dynamic river, and the thalweg of the channel may shift from one bank to another at the end of monsoon. For this reason, each transmission tower should be designed considering the maximum total scour found at any transmission pier in that section.

Institute of Water Modelling ★ Plot # 6, R # 3/C, Sector-15, Uttara ★ IWM Water Environment & Climate Dhaka

Jamuna and Ganges-Padma is very dynamic river, and the thalweg of the channel may shift from one bank to another at the end of monsoon. For this reason, each transmission tower should be designed considering the maximum total scour found at any transmission pier in that section.

Again, according to Bridge Manual (BUET-IWM 2008), the mathematical morphological modelling may also be employed to calculate the general and constriction scour. And these values can be used for scour calculation of any major or minor rivers.

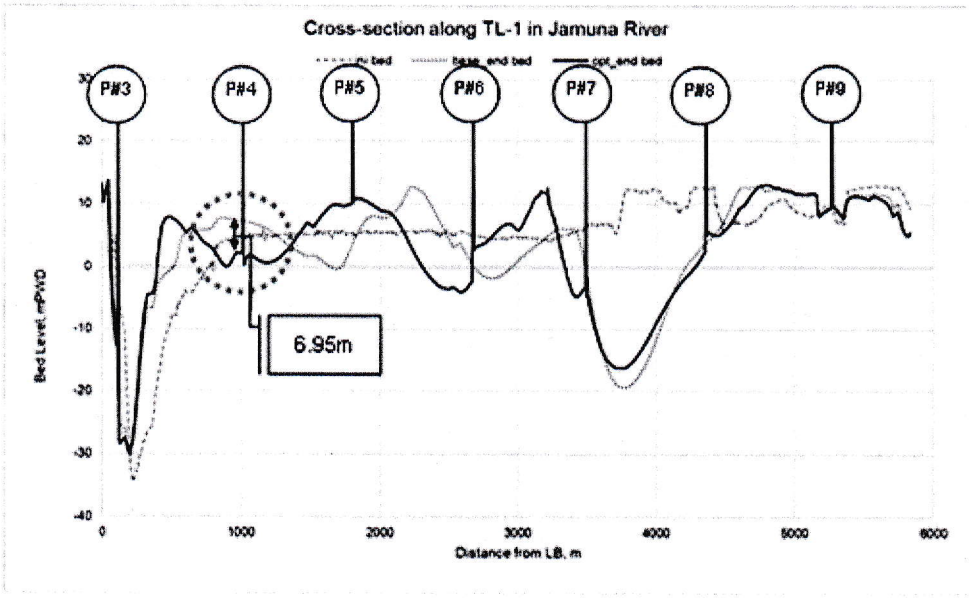


***Figure 1**: Simulated Cross-section in Jamuna River along Transmission Line 1*

Ship impact load provided in the morphological study is based on some similar data and assumptions. It should be taken as guideline purpose. Actual Ship impact load for the particular location/river is not available with IWM. You are advised to collect actual ship impact data for design of tower foundations.

Looking forward to continued cooperation,

Yours sincerely,

Abu Saleh Khan PEng.
Executive Director
Institute of Water Modelling

CC: DED (Opn)/ Director REN/ PS, PL-P52309, IWM